MICRODYN NADIR
ADVANCED SEPARATION TECHNOLOGIES

MICRODYN-NADIR

Sanitary Spiral-Wound Elements for Process & Specialty Applications

User Manual

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1 Introduction

MICRODYN-NADIR manufactures a wide variety of sanitary-style spiral membrane elements under the TRISEP®, TurboClean® and SPIRA-CEL® brands. These include many USDA-approved sanitary products that comply with 3-A Sanitary Standard 45-02 that are widely used in dairy and other process applications.

MICRODYN-NADIR offers custom-designed spirals, combining over 40 different membrane sheets from MF to RO, a dozen different feed spacers and many different combinations of permeate carriers and permeate tubes in different lengths and diameters.

For nearly 30 years, TRISEP membrane elements have been a leading brand for customized spiral elements for process and specialty applications. These products are MICRODYN-NADIR's "flagship" brand in these applications. TRISEP TurboClean elements feature a patented polypropylene shell which results in the best-performing sanitary element available.

MICRODYN-NADIR also offers SPIRA-CEL net-wrapped elements for process and specialty applications. SPIRA-CEL products have a long history of outstanding performance, and when combined with the TurboClean shell offer even better performance.

TurboClean elements are the strongest, most durable sanitary elements on the market. They deliver better system performance due to about 60% less bypass flow than net- or cage-wrapped sanitary elements. Lower bypass flow results in energy savings and/or higher flux rates as more of the feed flows across the membrane surface instead of around the outside of the element. Higher cross-flow velocity also results in the most effective membrane cleaning. TurboClean elements are stronger than net-wrapped sanitary elements and are able to withstand higher pressure drops. With the tightest outer diameter tolerance and optimal circularity, TurboClean elements are also the easiest elements to load and unload.

2 Membrane Products

MICRODYN-NADIR offers a full line of reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF) membranes for rolling spiral wound membrane elements and for use in plate & frame devices. TRISEP® and NADIR® membranes are used in a wide variety of process separations in addition to water purification. A general description of these membranes is presented below.

2.1 TRISEP® Reverse Osmosis (RO)

ACM1	Higher Rejection RO	NaCl	99.5%[1]
ACM2	"Standard" High Rejection RO	NaCl	99.5%[1]
ACM3	Higher Productivity RO	NaCl	99.3%[1]
ACM4	Low Energy RO	NaCl	99.3%[1]
ACMX™	Ultra-Low Pressure RO	NaCl	99.0%[2, 3]
X-20™	Low-Fouling RO	NaCl	99.5%[1]
SB20	High Rejection Cellulose Acetate	NaCl	98.0%[4]
SB50	Higher Productivity Cellulose Acetate	NaCl	96.0%[4]

[1] 2,000 mg/L NaCl @ 15.5 bar (225 psi), 25°C (77°F), pH 8
[2] 500 mg/L NaCl @ 7.0 bar (100 psi), 25°C (77°F), pH 8
[3] Two versions of ACMX™ membrane currently available
[4] 2,000 mg/L NaCl @ 29.0 bar (420 psi), 25°C (77°F), pH 8

2.2 TRISEP® Nanofiltration (NF)

TS80	Higher Rejection / "Softening" NF	$MgSO_4$ NaCl	99.0%[5] 80.0%[6]
TS50	Higher Rejection NF for Separations and Desalting	$MgSO_4$ NaCl	99.0%[5] 50.0%[6]
TS40	NF for Separations and Desalting	$MgSO_4$ NaCl	99.0%[5] 40.0%[6]
XN45	NF for Purification, Separation and Demineralization	$MgSO_4$ NaCl	96.0%[5] 20.0%[6]
UA60	Open NF for Purification, Separation and Demineralization	$MgSO_4$ NaCl	80.0%[5] 10.0%[6]
SB90	Cellulose Acetate NF for Low Pressure Water Purification	NaCl	85.0%[7]
SBNF	Cellulose Acetate for Color Removal	MWCO NaCl	2,000 Da 40 – 60%[8]

[5] 2,000 mg/L $MgSO_4$ @ 7.6 bar (110 psi), 25°C (77°F), pH 8
[6] Approximate rejection at 2,000 mg/L NaCl @ 7.6 bar (110 psi), 25°C (77°F), pH 8
[7] 2,000 mg/L NaCl @ 15.5 bar (225 psi), 25°C (77°F), pH 8
[8] Approximate rejection at 2,000 mg/L NaCl @ 9.7 bar (140 psi), 25°C (77°F), pH 8

2.3 TRISEP® Ultrafiltration (UF)

UF5	PES UF Membrane	MWCO	5,000 Da
UF5XT*	PES UF Membrane	MWCO	5,000 Da
UF10	PES UF Membrane	MWCO	10,000 Da
UF10XT*	PES UF Membrane	MWCO	10,000 Da
UE50	PES UF Membrane	MWCO	100,000 Da
UB50	PES UF Membrane	Pore Size	0.03 µm
UB70	PVDF UF Membrane	Pore Size	0.03 µm

* Available on polypropylene backing

2.4 TRISEP® Microfiltration (MF)

MF01	PES MF Membrane	Pore Size	0.1 µm
TM10	PVDF MF Membrane	Pore Size	0.2 µm

2.5 NADIR® Nanofiltration (NF)

NP030*	Acid/Caustic Stable PES NF Membrane	Na_2SO_4	80 – 95%[9]
NP010*	Acid/Caustic Stable PES NF Membrane	Na_2SO_4	35 – 75%[9]

* Available on polypropylene backing
[9] 5,000 mg/L Na_2SO_4 @ 40 bar (580 psi), 20°C (68°F)

2.6 NADIR® Ultrafiltration (UF)

UH004*	PESH UF for Protein Concentration	MWCO	4,000 Da
UP005*	PES UF for Protein Concentration	MWCO	5,000 Da
UP010*	PES UF for Protein Concentration	MWCO	10,000 Da
UP020*	PES UF for Protein Concentration	MWCO	20,000 Da
UH030*	PESH UF for Protein Separation	MWCO	30,000 Da
UH050*	PESH UF for Protein Concentration	MWCO	50,000 Da
US100*	PSH UF for Treatment of Fermentation Broth	MWCO	100,000 Da
UP150*	PES UF for MBR	MWCO	150,000 Da
UV150	PVDF UF Membrane for E-Coat Paint	MWCO	150,000 Da

* Available on polypropylene backing

2.7 NADIR® Microfiltration (MF)

MP005*	PES MF for Cell Separation	Pore Size	0.05 µm
MV020	PVDF MF for Particle Filtration	Pore Size	0.20 µm

* Available on polypropylene backing

3 Installation

3.1 Safety Equipment

Having proper equipment is essential for safely executing the following loading procedure. Appropriate gloves, shoes and safety glasses should be worn at all times. The following additional equipment for installation is recommended:

- Silicone
- Glycerin*
- Permeate quality water to flush vessel
- Sponge/swab, long stick or PVC pipe, and rope to clean vessel
- Spare o-rings to replace any damaged o-rings during loading
- Instructions and tools recommended by the pressure vessel manufacturer for removing and installing end cap assemblies

***Note:** When loading elements into a system, use a silicone based gel or glycerin to lubricate o-rings. Do not use oil, grease or petroleum based compounds as they may cause damage to the membrane or element.*

3.2 Installation Preparation

1. Check that all items (membrane elements, interconnectors, ATD's, o-rings and adapters) are present and in the correct quantities.
2. Carefully remove all dust, dirt and foreign matter from the pressure vessels before opening them.
3. Disassemble and wash all end cap parts with fresh water and keep parts clean for re-installation.
4. Flush permeate or fresh water through the open pressure vessels to remove any dust or debris present in the vessels. If additional cleaning is necessary, create a sponge/swab large enough to fill the inside diameter of the pressure vessel. Soak the sponge or swab in a 50-75% glycerin/water solution and move it back and forth through the pressure vessel with a piece of rope or long PVC pipe until the vessel is clean and lubricated. Be sure to avoid scraping the inside of the pressure vessel.

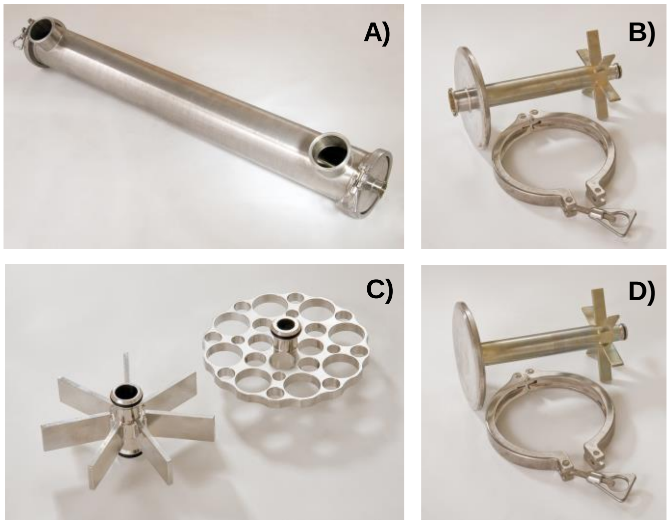

Figure 1. A) Sanitary, stainless steel pressure vessel, **B)** fixing clamp with permeate adaptor, **C)** sanitary interconnectors with ATD‘s, and **D)** fixing clamp with blank adaptor.

3.3 Element Loading

1. Stage the elements prior to loading and record each element's serial number by position so that each element location within the pressure vessel is known.
2. Open the element bag in a well-ventilated area and remove the element. Refer to the *Safety Equipment* section and minimize direct contact with the storage solution.

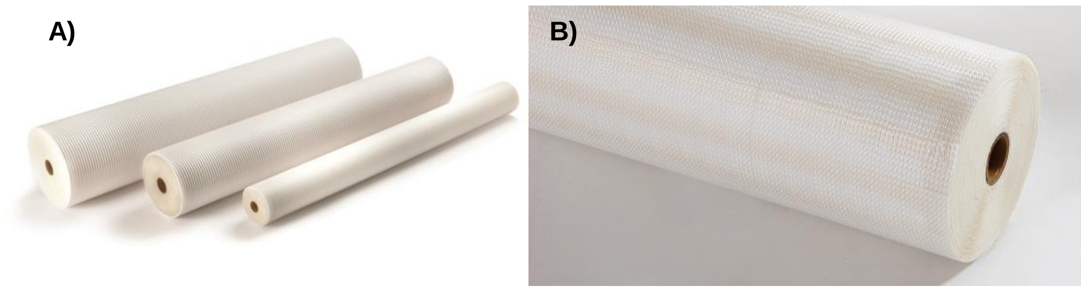

Figure 2. A) TurboClean® and **B)** SPIRA-CEL® elements for process & specialty applications.

3. Gently place the first element into the feed end of the first pressure vessel and slide the element in approximately one-half to three-quarters of the way (Figure 3).

Figure 3. Install element into pressure vessel.

4. To load elements, lubricate the o-ring seals on the interconnector and the inside of the permeate tube with a thin layer of lubricant and insert the interconnector into the permeate tube of the element (Figure 4).

   Note: When installing o-rings, expand them slightly, do not roll them into position.

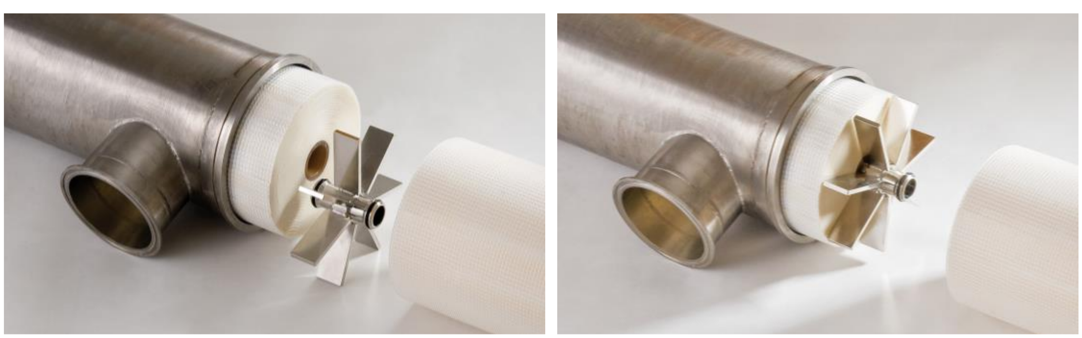

Figure 4. Insert the interconnector into the permeate tube of the installed element.

5. Lift the next element into position and install onto the interconnector in the previous element to connect elements (Figure 5). The ATD should be flush with the ends of both elements. Hold the next element with care so that the weight is not supported by the interconnector, and push the element into the pressure vessel until about one-half to one-quarter of the element extends outside the vessel.

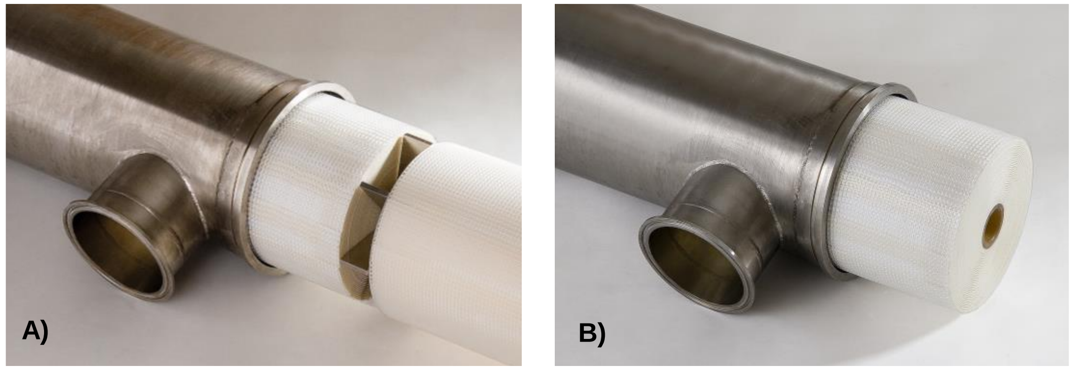

Figure 5. A) Install the next element into the pressure vessel and **B)** push connected elements into the pressure vessel.

6. Repeat steps 2 through 5 until all elements are loaded into the pressure vessels.
7. After all the elements have been loaded, install the downstream end cap assembly on the end of the pressure vessel (Figure 6). Carefully position the downstream end cap assembly in the vessel and push the end cap assembly as a unit squarely into the end of the element. Avoid pinching or rolling of the o-rings when seating the o-ring seal on the adapter. Rotate the end cap assembly to ensure proper alignment with the connecting piping.
8. Gently push the element stack from the feed end (upstream) towards the downstream end.
9. Continue steps 7 – 8 for each pressure vessel in the train or system.
10. Re-install the feed end cap assembly on each of the pressure vessels (Figure 6). Close each pressure vessel with the clean parts from Step 4 in *Installation Preparation*.

Figure 6. Install the downstream and feed end cap assemblies of the pressure vessels.

4 Operation

The following is intended to provide information on system start-up with TRISEP® TurboClean® and SPIRA-CEL® sanitary reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF) elements.

4.1 System Start-Up

Safety Equipment

Having proper equipment is essential for safely executing the following start-up procedure. Appropriate gloves, shoes and safety glasses should be worn at all times. Additional equipment may be necessary depending on specific system design.

Mechanical Inspection

A mechanical inspection of the system is recommended prior to start-up. This inspection should ensure that valves are positioned correctly, lines are free of air, safety precautions are functioning, instrumentation is calibrated, pumps are lubricated and have proper rotation and all pretreatment is operating properly.

Install Elements

Please refer to *Installation* (Chapter 3).

Purge Air

After the elements have been installed, it is recommended to perform a low pressure flush to purge air from the piping system, headers and vessels before engaging the high-pressure pump. Failure to purge air from the system can result in water hammer that can mechanically damage the newly installed elements. This can be avoided through the use of a soft-start mechanism or a variable frequency drive. The rate of pressurization (and depressurization) should not exceed 0.7 bar/second (10 psi/second) and the feed pressure should be gradually increased until the desired operating feed flow is achieved.

Flush System

Please refer to one of the following chapters for system flushing procedures:

Chapter 4.2: *RO & NF Process Element Start-Up Procedure*
Chapter 4.3: *UF & MF Process Element Start-Up Procedure*
Chapter 4.4: *Heat-Sanitizable Element Start-Up Procedure*

The system flush should be performed with high-quality water (see Table 1).

Table 1. Flush Water Quality Recommendations

Solute	Recommended Limit
Iron (Fe)	< 0.05 mg/L
Manganese (Mn)	< 0.02 mg/L
Aluminum (Al)	< 0.05 mg/L
Silica (SiO_2)	< 5.0 mg/L
Total Hardness as $CaCO_3$	< 50 mg/L as $CaCO_3$
Total Alkalinity as $CaCO_3$	< 50 mg/L as $CaCO_3$
Chlorine	0 mg/L*
Turbidity	< 0.5 NTU
Silt	< 1 SDI

*Chlorine must be undetectable for RO & NF membranes and may be ≥2 mg/L for UF & MF membranes.

Recommended flow rates for flushing vary based on the diameter of the elements (see Table 2).

Table 2. Recommended Flow Rates for Flushing

Membrane Diameter	Flow Rate per Vessel	Recommended Pressure
3.8”	2.7 – 3.2 m^3/hr (12 – 14 GPM)	1.5 – 4.0 bar (20 – 60 psi)
4.0”	2.7 – 3.2 m^3/hr (12 – 14 GPM)	1.5 – 4.0 bar (20 – 60 psi)
6.3”	3.6 – 4.5 m^3/hr (16 – 20 GPM)	1.5 – 4.0 bar (20 – 60 psi)
8.0”	7.0 – 9.1 m^3/hr (30 – 40 GPM)	1.5 – 4.0 bar (20 – 60 psi)
8.3”	8.0 – 10.2 m^3/hr (35 – 45 GPM)	1.5 – 4.0 bar (20 – 60 psi)

Initial Trial Run

After purging air from the system and flushing the system, an initial trial run at the design operating parameters is recommended. Check and adjust the following parameters to design value:

- Flow rates
- Recovery ratio
- Operating pressure

Prior to final evaluation of the trial run, operate the system for a minimum of two hours at the design operating conditions. All permeate and concentrate produced during the trial run should be discarded to drain.

Product Quality

Check the quality of the product and system performance as following:

- Check product quality for each vessel. If the product quality does not meet specification, check o-rings of the affected vessel. Log all data and corrective measures taken within the first 24 – 48 hours. Although membrane performance should stabilize after the first couple hours of operation, monitoring feed pressure, differential pressure, flows, recovery, and product quality will help indicate if the elements are performing as expected. This data may be used to normalize and track system performance.
- Recommended data to be logged:
  - Feed: feed pressure, temperature, feed quality, pH
  - Differential pressure across each vessel
  - Retentate: flow, retentate quality, pH
  - Permeate: flow, permeate quality of each vessel and total system.

4.2 RO & NF Process Element Start-Up Procedure

After the elements have been removed from their packaging and have been installed into their pressure vessels, a cleaning procedure must be performed prior to initial use of elements per FDA regulation. According to the Code of Federal Regulations (CFR) Title 21 Section 177.2550, "to assure their safe use, reverse osmosis membranes and their supports shall be thoroughly cleaned prior to their first use in accordance with current good manufacturing practice." The cleaning procedure below meets 21 CFR Section 177.2550 specifications and prepares membranes for start-up (Table 3).

Table 3. Start-up cleaning procedure for TRISEP® RO & NF elements used in process applications.

Step	Cycle	pH	Temperature	Duration (min)	Procedure
1	Flush	Neutral	30 – 40°C (86 – 104°F)	10	Flush system with high quality water (see Table 1) using a minimum of three times the system hold-up volume, sending concentrate and permeate to drain.
2	Alkaline	10.0 – 10.5	30 – 40°C (86 – 104°F)	20	Add high pH cleaner or sodium hydroxide to adjust pH. Circulate alkaline solution at recommended flow and pressure conditions listed in Table 2 for 20 minutes.
3	Flush	Neutral	30 – 40°C (86 – 104°F)	10	Flush system with high quality water using a minimum of three times the system hold-up volume, sending concentrate and permeate to drain.

4.3 UF & MF Process Element Start-Up Procedure

After the elements have been removed from their packaging and have been installed into their pressure vessels, the following cleaning procedure must be performed prior to initial use of elements. According to the Code of Federal Regulations (CFR) Title 21 Section 177.2550, dairy elements should be thoroughly cleaned prior to their first use in accordance with current good manufacturing practice. The cleaning procedure below meets 21 CFR Section 177.2550 specifications and prepares membranes for start-up (Table 4).

Table 4. Start-up cleaning procedure for TRISEP® and SPIRA-CEL® UF & MF elements used in process applications.

Step	Cycle	pH	Temperature	Duration (min)	Procedure
1	Flush	Neutral	30 – 40°C (86 – 104°F)	10	Flush system with high quality water (see Table 1) using a minimum of three times the system hold-up volume, sending concentrate and permeate to drain.
2	Alkaline / Chlorine	10.5 – 11.0	30 – 40°C (86 – 104°F)	15	Add high pH cleaner to adjust pH and then add 180-200 ppm total chlorine.* Circulate solution at recommended flow and pressure conditions listed in Table 2 for 15 minutes. **Note: Do not add chlorine until the pH has been adjusted to at least 10.5.*
3	Flush	Neutral	30 – 40°C (86 – 104°F)	10	Flush system with high quality water using a minimum of three times the system hold-up volume, sending concentrate and permeate to drain.

4.4 Heat-Sanitizable Element Start-Up Procedure

After the elements have been removed from their packaging and have been installed into their pressure vessels, the following heat-setting procedure must be performed prior to initial use of elements. The procedure below will remove residual storage solution and will prepare membranes for start-up (Table 5).

Table 5. Heat-setting (and heat-sanitizing) procedure for TRISEP® heat-sanitizable RO, NF, UF, and MF elements for high purity applications.

Step	Procedure
1	Flush system with high quality water for 30 min (see Tables 1 & 2).
2	Recirculate near-neutral (pH 6 – 8) water through the system at a temperature not exceeding 45°C (113°F) and a pressure not exceeding 1.7 bar (25 psi). Maximum pressure drop through a single element is 0.5 bar (7.3 psi).
3	Ramp temperature up at a rate no faster than 5°C/min until a temperature between 80 – 90°C (176 – 194°F) is achieved.
4	Maintain temperature between 80 – 90°C (176 – 194°F) for one hour.
5	Ramp temperature down at a rate no faster than 5°C/min until a temperature below 45°C (113°F) is achieved.
6	Flush system with high quality water (Table 1).

4.5 Operating Conditions

Although the MICRODYN-NADIR product specification sheets list the maximum operating pressures and temperatures, it is recommended to keep the following in mind when operating a membrane system:

- The permeate pressure must never exceed the feed or concentrate pressure.
- For operation outside the limits listed on the product specification sheet, consult MICRODYN-NADIR Technical Service.

4.5.1 Pilot Testing

Lab-scale element or pilot testing is performed in a test system to assess a membrane's ability to perform the required process separation. It allows for modifications to the feed pressure, flow and temperature in order to a better understand the membrane performance capabilities under different operating conditions. These systems typically use one or two smaller elements (i.e.1812, 3838 or 4040). Operation of a pilot test system allows for the determination of two important operating conditions: the operating flux and concentration factor (or recovery rate).

Pilot testing is also the most effective testing method to study the fouling effects over time and ensuring that an effective and economic cleaning regimen can be implemented to maintain membrane performance. This includes gathering pretreatment data, determining scaled-up operational characteristics and costs, testing cleaning regimens, ensuring stable operation over time with adequate product quality, familiarizing operators with the membrane technology, and demonstrating regulatory compliance.

5 Shutdown

5.1 Safety Equipment

Having proper equipment is essential for safely executing the following shutdown procedure. Appropriate gloves, shoes and safety glasses should be worn at all times. Additional equipment may be necessary depending on specific system design.

5.2 Shutting Down Procedure

1. Ensure that all chemical injections used for pretreatment have been stopped.
2. Flush the system at low pressure with permeate quality water (see Tables 1 and 2) to remove residual process fluid from the pressure vessels and until the retentate quality matches the feed quality.
3. After flushing the system, make sure all feed valves are completely closed.
4. If the retentate line ends into a drain below the level of the pressure vessels, employ an air break in the retentate line at a position higher than the highest pressure vessel to prevent a siphoning effect.
5. If the permeate line is pressurized during operation and the system is shut down, the membrane might become exposed to a static permeate backpressure, which may damage the membrane and void the warranty. Check valves or atmospheric drain valves in the permeate line can be used.
6. When the system is shut down for longer than 24 hours, be sure that the elements do not dry out. Dry elements will irreversibly lose flux. Please refer to *Shipping, Handling & Storage* (Chapter 6).

6 Shipping, Handling & Storage

- When not in operation, the membrane must be kept saturated with good quality feed water (see Table 1) at all times.
- The as-shipped elements must be kept sealed in their original oxygen-barrier bags, in a cool, dry place, out of direct sunlight, until required for installation.
- Please see refer to *Storage of Flat Sheet Membrane*, *Storage for Offline Elements*, and *Storage & Rewetting* (Chapters 6.1, 6.2 and 6.3) for more detailed recommendations.

6.1 Storage of Flat Sheet Membrane

Dry Membrane

Most of TRISEP® and NADIR® flat sheet membrane is shipped dry. Dry membrane is bagged and sealed in a plastic bag and does not require any preservation solution. It is recommended to keep the dry membrane in its sealed bag until its intended use.

For storage of dry flat sheet membrane, the following steps are recommended:

- Store membrane inside a cool building or warehouse and not in direct sunlight.
- TRISEP temperature limits for storage: -4°C to 35°C (22°F to 95°F).
- NADIR temperature limits for storage: 5°C to 30°C (41°F to 86°F).
- All new membrane being stored prior to use should remain in its original packaging.

Wet Membrane

Some of TRISEP flat sheet membrane is supplied wet, in a rolled format for shipment.

- Membranes must be kept away from direct sunlight and are best kept refrigerated at 4°C to 7°C (40°F to 45°F). This prevents biological growth and oxidation of the residual organic amines in the membrane.
- If membrane is kept in refrigerated storage, it should be used within 60-90 days of receipt. If membrane is not kept in refrigerated storage, it should be used within 30 days to avoid biological growth.

Handling Flat Sheet Membrane

When handling TRISEP and NADIR flat sheet, use butyl or nitrile gloves to prevent contact with residual organic amines as well as preventing oil from hands coming into contact with the membrane.

IMPORTANT: The first one to two (1 – 2) wraps of membrane may be damaged in shipment and should be inspected for damage or discarded.

6.2 Storage for Offline Elements

Short-Term Storage

For short-term storage of membrane elements in place within a system, the elements should be cleaned and then flushed daily with high-quality water.

The following steps to minimize biogrowth or scale formation are recommended:

1. When taking the membrane system offline, it is suggested that a full cleaning and flush of the system be performed. High-quality water is recommended for both cleaning and flush water.
2. During the storage period, it is recommended that the membrane system be flushed once daily with RO quality water to maintain an environment free from biological growth, oxidants and sparingly soluble salts that may scale the membrane.
3. Precautions should be taken to prevent exposing membranes to permeate backpressure when the high pressure pump is turned off (especially in cases where the permeate line is pressurized).
4. Precautions should also be taken to ensure the elements remain wet and are protected from temperature extremes during the shut-down period.

Long-Term Storage

If the system is not to be operated for over 5 days, long-term storage is recommended. For long-term storage of the membrane elements in place within a system, it is recommended that the elements be cleaned and then preserved using a solution of sodium metabisulfite.

The following steps are recommended:

1. When taking the membrane system offline, it is suggested that a full cleaning and flush of the system be performed. High-quality water meeting the recommended flush water quality should be used for both cleaning and flushing.
2. During the storage period, it is recommended that the membrane system be preserved using a 1% food-grade sodium metabisulfite (SMBS) solution to inhibit microbial growth. The SMBS solution should be recirculated through the membrane system for 30-60 minutes.
3. Vent air from the system and recirculate in a manner to minimize air in the system as oxygen will cause the SMBS to oxidize, dropping the pH and increasing the potential for microbial growth.
4. Following preservation, the feed, permeate and concentrate valves should be closed to isolate the system. During the storage period, the system should be periodically checked to insure that pH does not drop below 3. The recommended frequency of checks is every 30 days. If the pH should drop below 3 during storage, or if the preservative solution becomes discolored, the system should be flushed and the preservation process should be repeated.
5. Precautions should be taken to prevent exposing membranes to permeate backpressure when the high pressure pump is turned off (especially in cases where the permeate line is pressurized).
6. Precautions should also be taken to ensure the elements remain wet and protected from temperature extremes during the shut-down period.
7. When returning the membrane system to service, the preserved elements should be flushed to remove the SMBS solution prior to restart. Permeate from the first hour of operation should be discarded.

6.3 Storage & Re-wetting

Element Storage

TRISEP® and SPIRA-CEL® elements will maintain their flux/rejection characteristics for a minimum of 12 months upon arrival if stored in optimum conditions. The following are general guidelines for storage of TRISEP and SPIRA-CEL elements:

- Store elements inside a cool building or warehouse and not in direct sunlight.
- TRISEP temperature limits for storage: -4°C to 35°C (22°F to 95°F). Elements are stored in a preservative solution which may freeze in cold weather; however they will not be damaged. If freezing occurs, thaw the elements before loading.
- SPIRA-CEL temperature limits for storage: 5°C to 30°C (41°F to 86°F). Elements may not be exposed to freezing conditions.
- All new elements being stored prior to use should remain in their original packaging. These elements are packaged in a storage solution that both protects the membrane's performance and prevents biological growth.
- Elements that have been removed from their packaging should be re-bagged with a storage solution to prevent the elements from drying out and to maintain a sterile storage environment.

Re-wetting of Dried Out Membranes

Elements that have dried out after use may irreversibly lose water permeability. Although there aren't many published re-wetting procedures, customers have reported successful methods. Re-wetting may be successful with one of the following:

- Soak the elements in an alcohol solution. Though safety precautions should be taken, methanol may be most effective.
- Pressurize the element with the permeate port nearly closed.

7 Cleaning & Sanitization

During operation, the surface of a membrane is subject to fouling by mineral scale, biological matter, colloidal particles, and insoluble organic constituents. The term “fouling” includes the build-up of any type of material on the membrane surface, including mineral scaling. Membrane surface fouling results in lower permeate flow rate, increased pressure drop between the feed and concentrate, and/or higher solute passage.

Safety Precautions

When using the chemicals indicated below, please follow these accepted safety practices:

1. Always wear eye protection. In the case of handling corrosive chemicals, wear full-face masks and protective clothing. Consult the chemical manufacturer for detailed information about safety, handling, and disposal.
2. When preparing cleaning solutions, ensure that all chemicals are dissolved and well mixed before circulating the solutions to the elements.
3. High-quality water must be used for flushing, cleaning, and disinfecting TRISEP® and NADIR® membranes.
4. Cleaning chemicals will be present on both the permeate and concentrate sides of the membrane immediately after cleaning. Properly flush the system prior to operation with the feed stream and divert permeate and retentate to drain for at least 30 minutes or until the water is clear when starting up after cleaning.

Water Quality for Membrane Cleaning & Disinfecting

The quality of water used for CIP is important in order to avoid unwanted deposits on the membrane. RO quality water is recommended for flushing, cleaning, and disinfecting of TRISEP and NADIR membranes, but prefiltered water may be used. Table 6 outlines the quality of water suitable for the above cleaning procedure.

Table 6. Flush Water Quality Recommendations

Solute	Recommended Limit
Iron (Fe)	< 0.05 mg/L
Manganese (Mn)	< 0.02 mg/L
Aluminum (Al)	< 0.05 mg/L
Silica (SiO_2)	< 5.0 mg/L
Total Hardness as $CaCO_3$	< 50 mg/L as $CaCO_3$
Total Alkalinity as $CaCO_3$	< 50 mg/L as $CaCO_3$
Chlorine	0 mg/L
Turbidity	< 0.5 NTU
Silt	< 1 SDI

Flow Rates

High fluid flow rates improve the effectiveness of cleanings by flushing foulants removed during the process from the membrane system. Recommended flow rates vary based on the diameter of the membrane elements being cleaned. Table 7 summarizes the recommended flow rates and cleaning pressures. Please note that pressure drop during cleaning should not be allowed to exceed 3.5 bar (50 psi) across a pressure vessel or 1.0 bar (5 psi) per installed element within a vessel. Operate cleaning at as low a pressure as possible in order to clean the membrane most effectively and without pushing foulant into the membrane.

Table 7. Recommended Flow Rates for Flushing

Membrane Diameter	Flow Rate per Vessel	Recommended Pressure	Max. Pressure Drop
3.8”	1.8 – 2.3 m^3/hr (8 – 10 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)
4.0”	1.8 – 2.3 m^3/hr (8 – 10 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)
6.3”	3.6 – 4.5 m^3/hr (16 – 20 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)
8.0”	7.0 – 9.1 m^3/hr (30 – 40 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)
8.3”	7.9 – 10.2 m^3/hr (35 – 45 GPM)	1.5 – 4.0 bar (20 – 60 psi)	3.5 bar (50 psi)

A low flow rate should be used for the pre-soak recirculation. This flow rate would be about 50% less of what is shown in Table 7.

A high flow rate should be used for the post-soak recirculation. This flow rate would be about 50% more of what is shown in Table 7.

For extended soaks (10 – 15 hours), a very low flow may be used to maintain consistent temperature and pH throughout the duration of the soak. This flow rate would be about 10% of what is shown in Table 7.

7.1 RO & NF Process Element Cleaning & Sanitization

The following are general recommendations for cleaning sanitary TurboClean® and SPIRA-CEL® reverse osmosis (RO) and nanofiltration (NF) elements in process and specialty applications. More detailed procedures for cleaning membrane systems in process applications should be provided by the system supplier or the cleaning chemical supplier.

7.1.1 Cleaning Precautions

Certain chemicals and cleaning conditions may have an adverse effect on membrane performance. We recommend caution with the following:

- Aggressive alkaline cleanings at high temperature and pH may cause membrane degradation and lead to premature failure. Please follow the recommendations of the system supplier or the cleaning chemical supplier.
- Nitric acid solutions may have an oxidizing effect on the membranes, especially on nanofiltration, and therefore should be used with caution.
- Frequent disinfection with an oxidizing solution (such as hydrogen peroxide blend) more than 1-2 times per week may cause premature membrane oxidation.

7.1.2 Cleaning Method

The cleaning method described below is meant to be a general procedure. Between each step the system must be flushed with high-quality water; please refer to *Water Quality for Membrane Cleaning & Disinfecting* (Table 6) and *Flow Rates* (Table 7) for specific requirements.

1. Shut down the system to be cleaned. Be sure to follow all safety procedures for system shutdown.
2. Purge feed stream from the system.
3. Flush system with water. See *Water Quality for Membrane Cleaning & Disinfecting* and *Flow Rates* for specific requirements.
4. Alkaline wash, pH 11.0, 45°C (113°F), 30 minutes.
5. Flush system with water.
6. Acid wash, pH 2.0, 45°C (113°F), 30 minutes.
7. Flush system with water.
8. Enzyme wash, pH 9.5, 45°C (113°F), 45 minutes.
9. Flush system with water.
10. Clean water flux readings (see *Checking Cleaning Effectiveness*, Chapter 7.5).
11. Chemical soak, pH 3.6, no heat, 15 minutes if duration between production and CIP is over 2 hours.*
12. Flush system with water.

**Once per week, substitute a chemical sanitization with a hydrogen peroxide/peracetic acid blend (about 350 ppm active ingredient) at 20°C (68°F) for 15 minutes.*

7.1.3 Disinfection

In many food & dairy plants, cleaning is followed by a chemical disinfection. The frequency of disinfections is based on plant need, feed quality and membrane type. The procedure for a chemical disinfection is similar to the cleaning procedure (i.e. dosing and circulating the solution prior to flushing the system with water). It is important that chemical disinfection using peroxide be done only at or below 25°C (77°C) and in acidic conditions. It is also critical that all iron is removed from the membrane surface prior to disinfection. For more information, please refer to *Membrane Disinfection* (Chapter 7.4).

7.2 UF & MF Process Element Cleaning & Sanitization

The following are general recommendations for cleaning sanitary TurboClean® and SPIRA-CEL® ultrafiltration (UF) and microfiltration (MF) membranes with polyester backing in food & dairy applications. More detailed procedures for cleaning membrane systems in process applications should be provided by the system supplier or the cleaning chemical supplier. For TurboClean® Extreme element cleaning recommendations at high pH and high temperature, please refer to *Food & Dairy: TurboClean® Extreme (XT) Elements* (Chapter 7.3).

7.2.1 Cleaning Precautions

Certain chemicals and cleaning conditions may have an adverse effect on membrane performance. We recommend caution with the following:

- Aggressive alkaline cleanings at high temperature and pH may cause membrane degradation and lead to premature failure. Please follow the recommendations of the system supplier or the cleaning chemical supplier.
- Before adding chlorine, be sure that the pH has been adjusted to at least 10.5.

7.2.2 Cleaning Method

The cleaning method described below is meant to be a general procedure. Between each step the system must be flushed with high-quality water; please refer to *Water Quality for Membrane Cleaning & Disinfecting* (Table 6) and *Flow Rates* (Table 7) below for specific requirements.

1. Shut down the system to be cleaned. Be sure to follow all safety procedures for system shutdown.
2. Purge feed stream from the system.
3. Flush system with water. See *Water Quality for Membrane Cleaning & Disinfecting* and *Flow Rates* for specific requirements.
4. Alkaline wash with 180 ppm chlorine*, pH 11.0, 50°C (122°F), 30 minutes.
   **Note: Do not add chlorine until the pH has been adjusted to at least 10.5.*
5. Flush system with water.
6. Enzyme wash, pH 9.5, 50°C (122°F), 45 minutes.
7. Flush system with water.
8. Acid wash, pH 2.0, 50°C (122°F), 30 minutes.
9. Flush system with water.
10. Alkaline wash with 180 ppm chlorine*, pH 11.0, 50°C (122°F), 30 minutes.
    **Note: Do not add chlorine until the pH has been adjusted to at least 10.5.*
11. Flush system with water.
12. Clean water flux readings (see *Checking Cleaning Effectiveness*, Chapter 7.5).
13. Chemical soak, pH 3.6, no heat, 15 minutes if duration between production and CIP is over 2 hours.
14. Flush system with water.

7.3 TurboClean® Extreme Process Element Cleaning & Sanitization

The following are general recommendations for cleaning TRISEP® TurboClean® Extreme (XT) elements in food & dairy applications where extreme conditions (high pH and high temperature) are used. More detailed procedures for cleaning membrane systems in process applications should be provided by the system supplier or the cleaning chemical supplier.

7.3.1 Cleaning Method

The cleaning method described below is meant to be a general procedure. Between each step the system must be flushed with high-quality water; please refer to *Water Quality for Membrane Cleaning & Disinfecting* (Table 6) and *Flow Rates* (Table 7) for specific requirements.

1. Shut down the system to be cleaned. Be sure to follow all safety procedures for system shutdown.
2. Purge feed stream from the system.
3. Flush system with water. See *Water Quality for Membrane Cleaning & Disinfecting* and *Flow Rates* for specific requirements.
4. Alkaline wash, pH 13.0, 70°C (158°F), 30 minutes.
5. Flush system with water.
6. Acid wash, pH 2.0, 50°C (122°F), 30 minutes.
7. Flush system with water.
8. Enzyme wash, pH 9.5, 50°C (122°F), 40 minutes.
9. Flush system with water.
10. Alkaline wash, pH 13.0, 70°C (158°F), 30 minutes.
11. Flush system with water.
12. Clean water flux readings (see *Checking Cleaning Effectiveness*, Chapter 7.5).

7.3.2 Disinfection

In many food & dairy plants, cleaning is followed by a chemical disinfection. The frequency of disinfections is based on plant need, feed quality and membrane type. The procedure for a chemical disinfection is similar to the cleaning procedure (i.e. dosing and circulating the solution prior to flushing the system with water). It is important that chemical disinfection using peroxide be done only at or below 25°C (77°C) and in acidic conditions. It is also critical that all iron is removed from the membrane surface prior to disinfection. For more information, please refer to *Membrane Disinfection* (Chapter 7.4).

7.4 Membrane Disinfection

The following are general recommendations for disinfecting TRISEP® reverse osmosis (RO) and nanofiltration (NF) elements.

To maintain a sanitary system free of biological activity, a hydrogen peroxide solution, typically a mixture of hydrogen peroxide and peracetic acid, is a commonly used disinfectant in pharmaceutical and food & dairy systems.

Commercial hydrogen peroxide and peracetic acid solutions generally come in a concentrated form and are diluted with RO or NF permeate quality water (see *Water Quality for Membrane Cleaning & Disinfecting*, Table 6 for specifications) to obtain the appropriate concentration for disinfection. Please refer to the specific instructions of the chosen cleaning chemical supplier.

7.4.1 Precautions

Hydrogen peroxide is an effective disinfectant, but is also an oxidizing agent. It is important to take caution to prevent degradation of the membrane.

Temperature

The disinfecting solution should not exceed 25°C (77°F). Elevated temperatures catalyze the reaction between the disinfectant and membrane surface, which may lead to membrane degradation.

Iron (and Other Transition Metals)

The presence of iron or other transition metals with hydrogen peroxide solutions can also catalyze the reaction between the disinfectant and membrane surface. Continuous exposure to the combination of iron (or other transition metals) and hydrogen peroxide solutions may eventually damage the membrane. It is important to use water as specified below to avoid membrane degradation.

7.4.2 General Disinfection Procedure

For biologically contaminated systems, the following procedure using hydrogen peroxide solutions is recommended:

1. Before sanitizing, any deposits on the membrane or other parts of the system should be removed with an alkaline cleaner. Removing these deposits, microorganisms and bacteria, will maximize the effectiveness of the sanitization overall.
2. After the alkaline cleaning, flush the system with clean water. See *Water Quality for Membrane Cleaning & Disinfecting*.
3. Clean the system with acid to remove any iron from the membrane surface.
4. Flush the system with clean water.
5. Circulate a solution of hydrogen peroxide/peracetic acid blend diluted with RO quality water at a temperature below 25°C (77°F). Please see cleaning chemical supplier's instructions for more detail.

7.5 Check Cleaning Effectiveness

To verify that the cleaning procedure effectively cleaned the membranes, it is common to measure the clean water flux after cleaning. Water flux results can indicate whether surface foulants have been removed or if an additional cleaning step is needed. Clean water flux recorded over time can demonstrate cleaning effectiveness or lead to a cleaning or operating upset.

8 High Pressure and/or High Temperature Applications

There are a multitude of process and specialty applications that operate at higher feed pressures and/or higher temperatures than the standard membrane element is built to handle. Typically, such processes call for customized (high pressure/high temperature construction) elements that are capable of handling such harsh conditions. In order to select the proper element construction for these particular applications, it is important to understand the Wagner Unit. Coined by Jorgen Wagner, an engineer involved with membranes since the 1970's, Wagner Units help to consider the limits of different element construction.

8.1 Wagner Units

Figure 7 demonstrates what kind of construction is necessary at particular operating conditions. The Wagner Units are calculated by multiplying the operating temperature (in °C) and operating pressure (in bar). For Wagner Units below 1200, a standard element will generally meet the requirements. Seawater RO and most process elements are capable of up to 2,000 Wagner Units. When the Wagner Units for an application are above 2,000, special element construction is often required. MICRODYN-NADIR offers high temperature elements capable of continuous operation at up to 80°C (176°F) and ultra-high pressure elements capable of operating at pressure up to 100 bar (1,500 psi) to meet the demands of challenging applications.

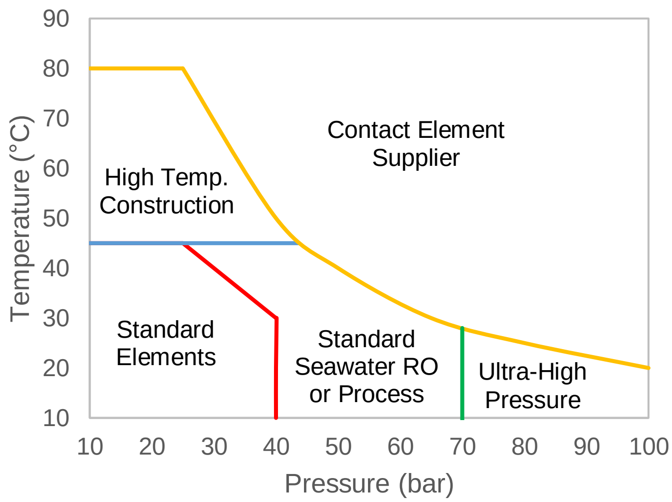

Figure 7.* Wagner Units are determined by multiplying the operating temperature (in °C) and operating pressure (in bar). The following guidelines are helpful in determining when a custom element is necessary for a particular application:

< 1,200:	Standard element applicable
1,200 – 2,000:	Seawater RO or process elements
> 2,000:	Custom solution

* *Diagram courtesy of Jorgen Wagner.*

8.2 Compaction & Intrusion

When standard elements are operated at higher pressures and/or temperatures than what they were originally designed for, compaction and/or intrusion may occur. Membrane compaction or intrusion may lead to low permeate flow. When exposed to high pressures and temperatures, the phenomena of compaction and intrusion are often times confused even though one involves the membrane itself while the other involves the element as a whole. The following is intended to clarify and distinguish the two. For additional information or questions, please contact MICRODYN-NADIR Technical Service.

8.2.1 Compaction

Membrane compaction refers to the physical compression of the membrane itself.

The effect of compaction is more significant in asymmetric cellulose acetate (CA) membranes than in thin-film composite membranes. When a CA membrane undergoes compaction, the asymmetric membrane itself becomes compressed. Thin-film membranes, on the other hand, have greater structural strength than CA membranes due to their microporous polysulfone substrate interlayer. This interlayer lies between the dense polyamide or piperazine barrier layer and the non-woven polyester support layer. This combination of the microporous polysulfone substrate and non-woven polyester support layer allows the barrier layer to withstand high operating pressures. So when a thin-film membrane undergoes compaction, the polysulfone substrate collapses rather than the membrane compressing as found with CA membranes.

Compaction typically occurs when the element is subjected to very high applied pressures. This compression results in a decrease in flux (and salt passage) and causes the membrane itself to lose efficiency. A compacted membrane will perform similarly to the element itself.

8.2.2 Intrusion

Intrusion generally occurs when the element is subjected to a combination of very high pressure and temperature. The term “intrusion” is based on the membrane being pushed (or intruded) into the channels of the permeate carrier. When this happens, the channels of the permeate carrier where the permeate flows to the permeate tube are partially blocked, hindering flow and creating a permeate-side pressure drop. This results in lower permeate flow, which is irreversible. Unlike compaction, intrusion causes the element as a whole to lose efficiency.

Because the polymeric components of a spiral-wound element tend to soften at elevated temperature, intrusion is far more common in applications where the feed temperature is above 35°C (95°F).

While compaction cannot be seen by the naked eye, one can clearly see concave scroll ends of elements that have experienced intrusion. When the membrane leaf gets pushed into the channels of the permeate carrier, the result is an element with concave scroll ends at both the lead and tail ends of the element (Figure 8A and 8C). This is not to be confused with an element that has experienced membrane telescoping, where the affected element’s lead end is concave and tail end is convex (Figure 8B). Membrane telescoping is usually the result of operation without a pressure vessel thrust ring.

Additionally, with intrusion, there may be some membrane damage from deformation of the membrane over the weaves of the permeate carrier. When membrane from an element affected by intrusion is removed and cell tested, it will typically have higher flux (and often higher salt passage) than the element.

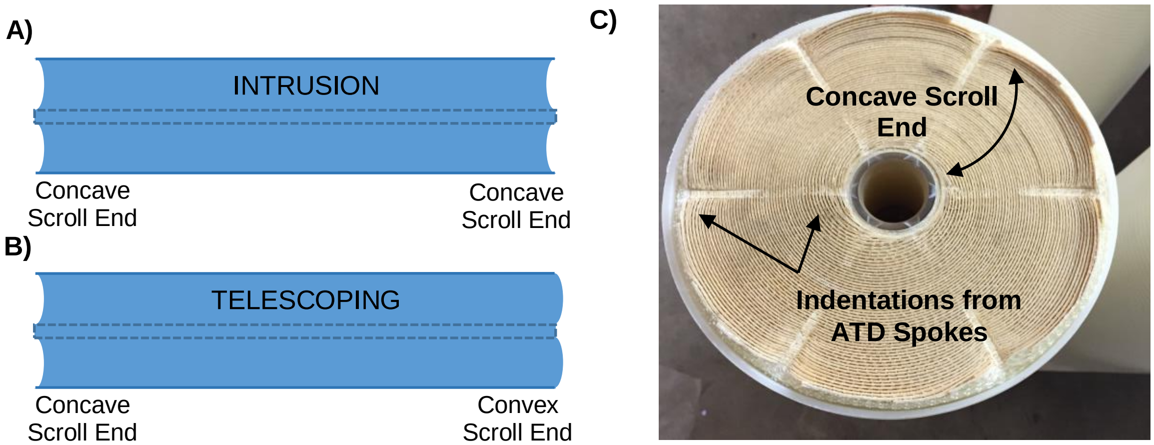

Figure 8. A) Elements that experience intrusion have concave scroll ends at both ends of the element. **B)** Elements that experience telescoping are usually concave at the lead end of the element and convex at the tail end of the element. **C)** An example of an element that has experienced intrusion. As depicted by the curved arrow, the scroll end towards the outer (near outerwrap) and inner (near permeate tube) perimeters of the element are level. The scroll end between the permeate tube and outerwrap, however, appear sunken. This can also be seen by the indentations on the scroll end by the ATD spokes. The indentations are more pronounced near the outerwrap as well as near the permeate tube, whereas the indentions are less pronounced otherwise.