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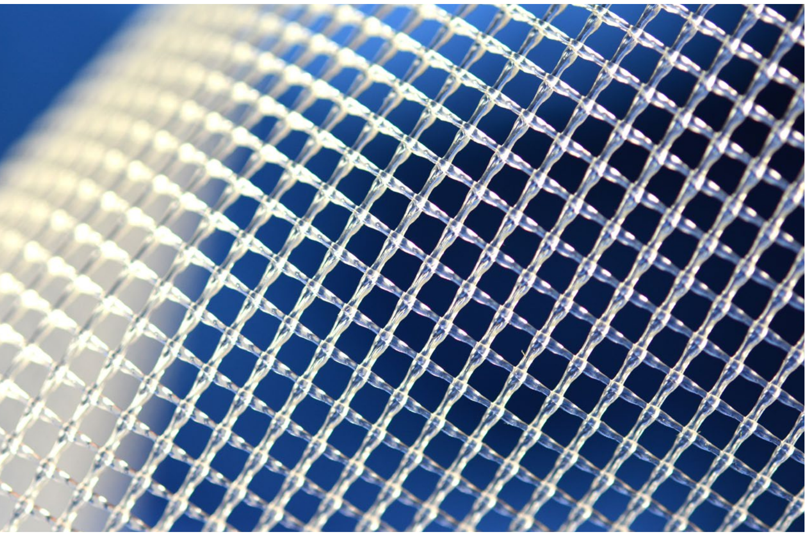

Effect of feed spacer on operation and performance of spiral wound reverse osmosis membrane elements.

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The RO process and operating conditions of spiral wound reverse osmosis elements.

The reverse osmosis (RO) process involves pressure application of dissolved species water solution against a float sheet semipermeable membrane. The water passes through the membrane as a permeate. All particulate species and majority of dissolved ions existent in the feed water, are rejected and flushed out to the drain as a concentrate stream. In order to function as a desalination device, the flat sheet membrane is configured as a spiral wound membrane element, schematically shown on Figure 1.

The spiral wound element consists of membrane envelopes (also called membrane leaves), wrapped around the central, perforated, permeate tube. As shown on Figure 1, the membrane element structure contains also a feed spacer that separates the surfaces of adjacent membrane envelopes. The feed spacer, configured as a net, keeps the feed channel open, allowing feed water to flow inside the feed channels, along the membrane element.

The feed water enters the feed channels from one side of the element (feed end) and flows parallel to the permeate tube to the concentrate end of the element. Along this feed flow path of approximately 1 m (3.3 ft), a typical element's length, about 5 – 15% of feed stream, passes through the membrane, to the inside of the membrane envelopes and then flows through the permeate channels, filled with permeate carrier, toward the central permeate tube.

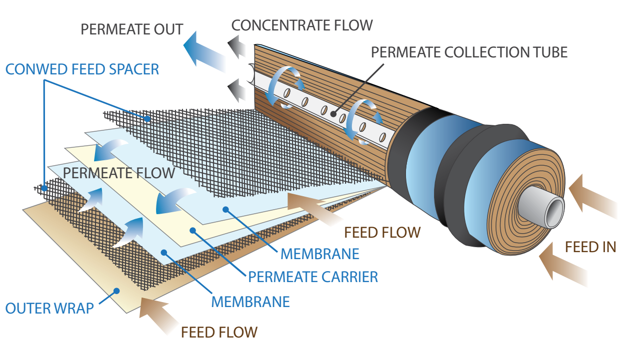

Figure 1. Schematic configuration of spiral wound membrane element

The configurations of feed channel and feed spacer net are shown schematically on Figure 2. The feed channel, shown here in unwrapped configuration, forms a rectangular opening of about 0.7 – 0.9 mm high.

Due to the presence of spacer filaments in the feed channel, the actual cross section area open to the feed flow is smaller than the geometric cross section.[1] The length of the feed channel is about 1 m (3.3 ft).

The feed spacer net, filling the feed channel, has filaments positioned biplanarly. This causes the feed stream to change flow direction as it flows above and below the subsequent filaments. The objective of the feed spacer, in addition to keeping the feed channel open, is to promote turbulence of the feed stream.

During operation of RO systems, the feed flow velocity in the feed channel is quite low, in the range of 1 – 3 cm/sec (0.4 – 1.2 inch/sec). This flow velocity falls into a laminar flow range and the required turbulence is facilitated by the presence of filaments of the feed spacer net.

The need for turbulence in the feed stream is related to the nature of the RO desalination process. The feed water and dissolve salts flow parallel to the membrane surface with fraction of the feed water passing through the membrane as a permeate, leaving the dissolved ions in the retained feed water stream. This process generates excess concentration of dissolved ions at the membrane surface, a phenomena known as concentration polarization.

The feed spacer induced turbulence reduces extend of concentrate polarization, thus improving performance of the RO membranes. However, the feed spacer induced turbulence increases friction in the feed channel, which is translated into pressure drop of the feed stream between element feed and exit points.[2, 3] If the feed channel is in clean condition, without particles that could block feed water flow, the pressure drop across a single element is about 0.1 – 0.2 bar (1.5 – 3 psi).

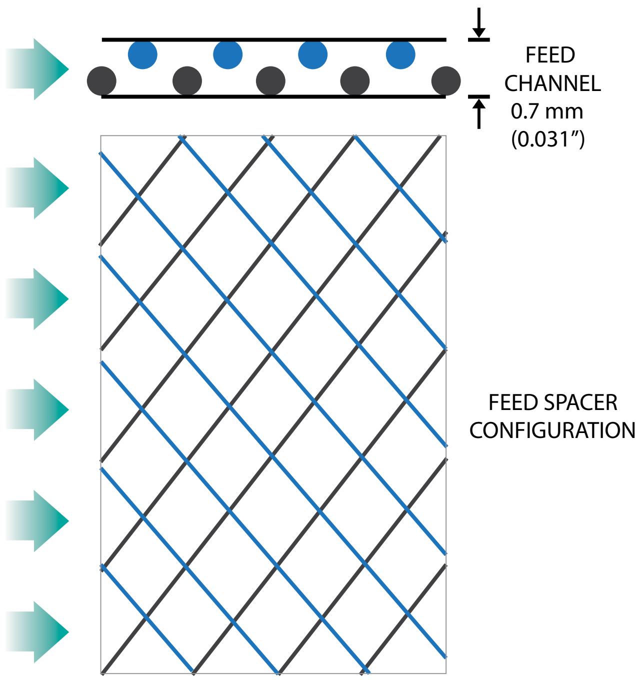

Figure 2. Configuration of a feed channel and a feed spacer net

In an RO system, membrane elements operate while enclosed in pressure vessel. A single pressure vessel usually contains 6 – 8 membrane elements, operating in series. Therefore, the combined pressure drop along a pressure vessel is in the range of 0.6 – 1.5 bar (9 – 22 psi). The required increase of RO system feed pressure, due to feed-concentrate pressure drop, is approximately equal to half of the pressure drop value. Therefore, the configuration of the feed spacer has to provide sufficient turbulence and mixing in the area adjacent to the membrane surface without significant increase of pressure drop in the feed channel.

Another important property required from the feed spacer is to minimize eddies and stagnant areas behind the spacer net filaments. Presence of stagnant areas in the feed channel will contribute to accumulation of colloidal matter and formation of conditions facilitating growth of biofilm.

Based on experimental results and hydraulic modeling, the configuration of feed spacers for RO applications evolved in to a biplanar net with square openings. The spacer is positioned in the feed channel with net filaments at an angle of about 45° to the direction of the feed flow (shown on Figure 2).

This configuration results in acceptable tradeoff of sufficient turbulence and mixing of the feed stream without excessive pressure drop. This orientation of the feed spacer net is applied in a vast majority of RO and NF membrane elements of spiral configuration.[4]

In addition to promoting turbulence, presence of the feed spacer prevents membrane sagging (nesting) into the feed channel, maintaining uniform feed channel height over the whole area of membrane leaf. The nodes of spacer filament net provide the support points for the membrane. The usual density of support points is in the range of above 10 support points per cm^2 of membrane area.

The pressure applied in the process of membrane element assembly and during field operation results, in some degree, of embossing of spacer net into the membrane. The spacer net has to be sufficiently firm to keep the feed channel open but configuration of the spacer-membrane support points should be smooth enough to avoid damage of membrane polyamide layer and loss of membrane barrier integrity.

The above orientation of feed spacers, relative to direction of the feed stream, and the presence of high density membrane support nodes, result in significant blockage of the flow path in the feed channel. Therefore, very clean feed water with low concentration of suspended matter is required for a stable operation of the membrane units.

The membrane fouling phenomena are in the form of particulate deposits, organic deposit, biofilms and/or scaling accumulating in the feed channel. The rate of fouling is a function of feed water quality and operating parameters of the membrane unit. Also, configuration of feed channel spacer could affect the fouling process and rate of pressure drop increase.[5, 6, 7]

Formation of fouling deposits on membrane surfaces and inside feed channels results in deterioration of membrane performance, reduction of water permeability of membranes and increase of pressure drop. The fouling phenomena translate into a need to apply higher feed pressure to maintain the water production rate. Excessive and prolonged membrane fouling conditions will lead to irreversible membrane element damage.

Therefore, foulant deposits have to be removed from the membrane unit. The only practical way to remove foulants from the membrane element feed channels is through dispersion and dissolution of foulants and subsequent flush out of membrane elements. Reduction of fouling deposits can be accomplished through application of cleaning chemicals, a process known as cleaning in place (CIP). It has been found that effectiveness of CIP foulants removal is improved by use of thicker feed spacers.

For this reason, there is a trend to construct spiral wound elements with thicker feed spacers, whenever practical. The current limit of feed spacer thickness is 0.86 mm (0.034”). Presently, the 0.86 mm thick feed spacer represents standard feed spacer thickness for 200 mm (8”) diameter membrane elements with 37.2 m^2 (400 ft^2) active membrane area. The 200 mm (8”) diameter membrane elements that have larger membrane area: 40.9 m^2 (440 ft^2), cannot utilize 0.86 mm (0.034”) spacer and had to apply somewhat thinner spacers, usually 0.71 – 0.78 mm (0.028 – 0.031”).

SUMMARY

I. Feed spacer is an essential part of the spiral wound element configuration. The feed spacer’s purpose is to maintain constant height of the feed channels and promote turbulence of the feed stream at the membrane surface.

II. Presence of spacer net filaments or strands in the feed channel constitutes obstruction to the feed flow inside the channel, which contributes to increase of pressure drop and creates areas of stagnant flow. Presence of areas of low cross flow could promote formation of foulant deposits.

III. Optimized configuration of feed spacer should result in effective mixing of the feed stream, maintaining low pressure drop during system operation, supporting membrane without excessive embossing and enabling effective removal of fouling fragments from the feed channels during the CIP procedure.

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