Compaction & Intrusion

As referenced in **Troubleshooting – Low Permeability** (TSG-T-004), low permeate may be due to membrane compaction or intrusion. 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 guide is intended to clarify and distinguish the two. For additional information or questions, please contact DC Solutions Technical Service.

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 (explained in further detail **Membrane Chemistry – Cellulose Acetate vs. Thin-Film Composite** (TB-017)). 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.

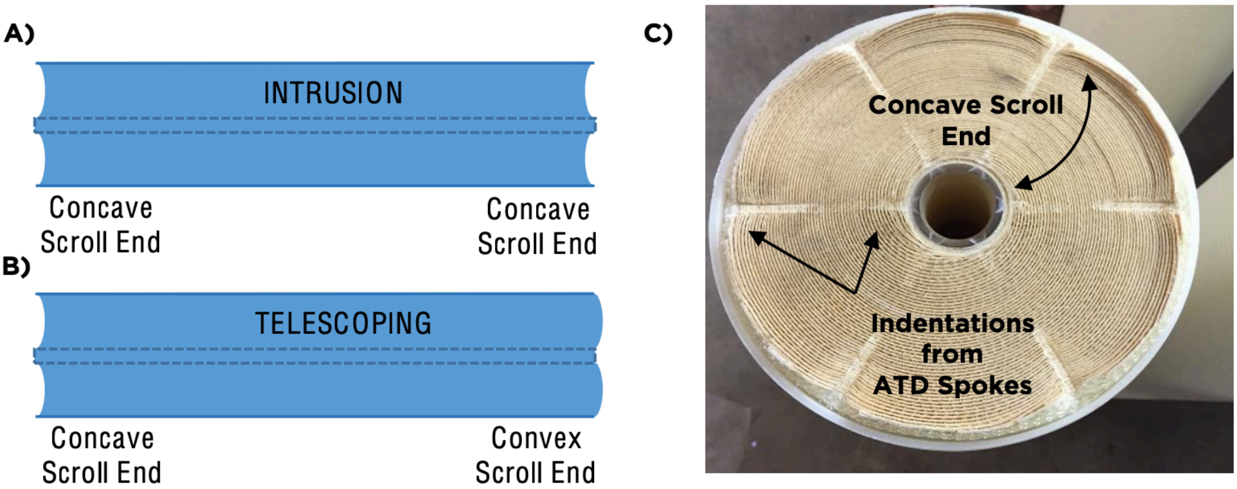

Figure 1. A) Elements that experience intrusion have concave scroll ends at both ends of the element. **B)** Elements that experience telescoping are usually concave at the lead end of the element and convex at the tail end of the element. **C)** An example of an element that has experienced intrusion. 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.

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 1A and 1C). This is not to be confused with an element that has experienced membrane telescoping, where the affected element's lead end is concave and tails

end is convex (Figure 1B). 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.

SPECIAL CONSTRUCTION

Because compaction and/or intrusion occur(s) at higher pressures and/or temperatures than the element was originally designed for, it is recommended to use elements that are capable of handling such harsh conditions. Typically, such processes call for customized (high pressure/high temperature construction) elements. 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.

Figure 2 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. DC Solutions 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.

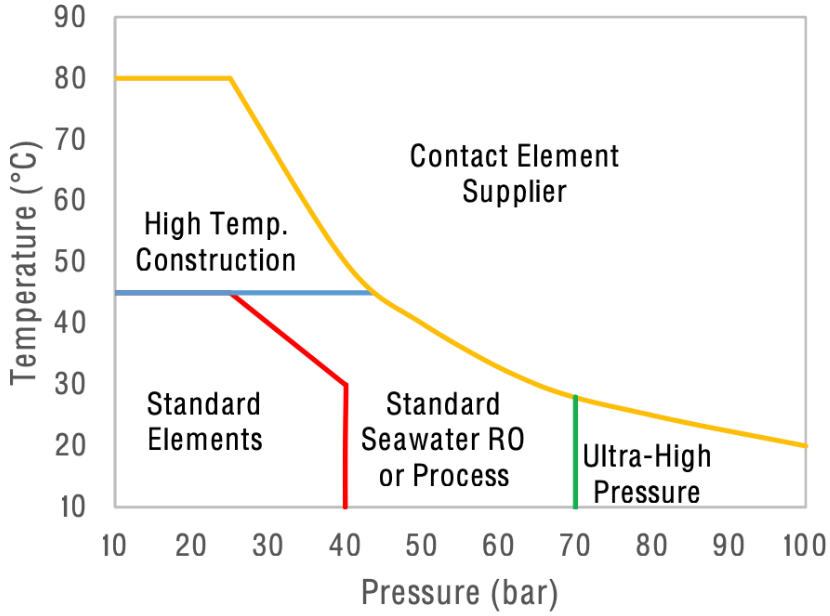

Figure 2. Wagner Units are determined by multiplying the operating temperature (in °C) and operating pressure (in bar). The following guidelines are helpful in determining when a custom element is necessary for a particular application:

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