

Dow  
Liquid Separations

# **FILMTEC**

## **Membranes**

### **Understanding RO Element Salt Rejection Specifications**

# Understanding RO element salt rejection specifications

---

## Understanding RO element salt rejection specifications

There is a great deal of discussion these days about membrane salt rejection specifications for reverse osmosis (RO) brackish water elements. Some membrane element suppliers have recently upgraded their specifications to reflect higher salt rejection. These suppliers have made their salt rejection specifications a primary point of differentiation from competitive elements including FILMTEC® elements.

Focusing on a manufacturer's published salt rejection specifications ignores other important factors that have an impact on RO element performance. And, it does not take into account a fundamental truth: The actual long-term salt rejection performance of RO elements under your system conditions is far more important than the performance of individual elements in initial factory tests.

Now, you might wonder, aren't manufacturers' published salt rejection specs an indication of the performance you can expect in actual service? The fact is, it depends on how well the test conditions approximate your system conditions. Given the widely varying feedwater compositions RO elements can face in actual service—and differences in other system conditions including temperature, pressure, and pH—no factory test will ever be a perfect match for your system.

In addition, the way suppliers manufacture their elements, prepare them for testing, and establish test conditions can greatly influence test results, making useful, apples-to-apples comparisons of published salt rejection specifications difficult if not impossible.

Does this mean salt rejection specifications should be ignored when choosing an element? Not at all. But it does mean that the importance of salt rejection should be kept in perspective relative to the other important measures you'll use to gauge the performance of your system. And, it means that you'll

want to understand how various manufacturers establish their specs and how closely those printed numbers are likely to resemble what you will actually experience in your system.

Let's start with a review of what salt rejection is and why it is helpful in measuring RO element performance.

## What is salt rejection?

Reverse osmosis membranes are designed to remove dissolved salts from water. While water passes readily through the RO membrane, dissolved salt passes through very slowly. Under natural conditions of osmosis, water will diffuse through a semipermeable membrane toward a region of higher salt concentration in order to equalize solution strength on both sides of the membrane. In order to overcome and reverse this osmotic tendency, pressure is applied to the feedwater, thereby producing a purified permeate stream.

Salt rejection is a measure of how well a membrane element rejects the passage of dissolved ions. Although an RO element may be called upon to reject many different ions, sodium chloride (NaCl) is used as a measurement standard. With few exceptions RO membranes reject divalent ions better than monovalent ions such as sodium and chloride. Therefore, if a membrane exhibits excellent rejection of NaCl, the membrane can be expected to perform even better in rejecting the passage of such divalent ions as iron, calcium, magnesium, and sulfate. Thus NaCl (salt) rejection has been universally accepted as the standard for measuring a membrane element's ionic rejection performance.

It is important to remember that, while we are focusing here on rejection of ionic contaminants, membranes are also called upon to remove, or at least tolerate, other impurities in feedwaters, including organics, silica, and gases. Your evaluation of RO elements should also include analysis of their ability to remove or tolerate these non-ionic contaminants.

## Keeping salt rejection in perspective

It is also important to bear in mind that evaluation of long-term RO element performance involves consideration of more than salt rejection. Membrane flux, element flow capacity, system pressure requirements, membrane fouling rates, membrane response to cleaning operations and tolerance of cleaning procedures, and the durability of the element all can be important factors in choosing an element. Each can affect the overall productivity of your water treatment system and the capital and operating costs associated with it.

## How is salt rejection measured?

Actual salt flow through the membrane is measured in terms of mass per unit of volume. Available instruments measure the specific conductance (or conductivity) of the permeate stream and this information is easily translated into the number of milligrams of salt that pass through the membrane in each liter of permeate. Salt rejection is then expressed as a percentage derived from the following equation:

$$\text{Rejection (\%)} = \frac{\text{Conc}_f - \text{Conc}_p}{\text{Conc}_f} \times 100$$

$$\begin{aligned} \text{Conc}_f &= \text{Log mean Average Salt Concentration} \\ &= \text{Feed Concentration} \times \frac{\ln [1/(1-Y)]}{Y} \end{aligned}$$

Y = recovery

Conc<sub>p</sub> = Salt Concentration of Product

## Differences in test methods lead to differences in specifications

The most obvious problem with the current emphasis on manufacturers' published specifications is that these artificial tests on individual elements do not take into account specific field conditions. These field conditions determine how an RO element will actually perform in long-term service as part of an overall water treatment system. But there is another, less

obvious problem with using manufacturers' salt rejection specifications to choose an RO element.

A careful review of test methodology reveals that the test methods used by membrane manufacturers can vary, resulting in noncomparable specifications and misleading interpretations of published salt rejection data. This point is illustrated Table 1, which is a comparison of test conditions used by three leading RO element manufacturers.

Clearly, there are no "standard" test conditions for salt rejection. Yet, the salt rejection (and also the product flow rate) calculated during salt challenge tests is a function of the test conditions. If a test is conducted with a lower feed concentration (Brand "Y") or a lower recovery (Brand "X"), the data are not comparable to those of elements tested at higher values. FilmTec's test conditions are the most stringent of any used in the RO industry.

In addition, the duration of salt rejection tests has a significant impact on the results. This is because RO membrane elements provide peak salt rejection performance when they reach a stabilized operating condition. The longer an element is tested, the closer it moves toward this stabilized, steady state.

Because manufacturers test differently, it is difficult, if not impossible, to compare the technical specifications for competing products on an "apples-to-apples" basis.

### How differences in element manufacturing processes confuse salt rejection test results

Differences in manufacturing processes have a fundamental impact on the salt rejection numbers various suppliers report for their elements. Some RO element manufacturers fabricate membrane elements using a direct dry process. Chemicals used in making the element are dried in during the manufacturing process and must be flushed out before the element can be put into service. These elements may be flushed for 24 hours or longer to remove all chemical residue. Then

**Table 1: Comparison of Salt Rejection Test Methods Used By Three RO Element Suppliers**

Test Parameter	FilmTec	Brand "X"	Brand "Y"
Temperature	25°C	25°C	25°C
pH	8	7.5	6.5-7.0
Recovery	15%	10%	15%
Feed Pressure	225 psig	225 psig	225 psig
Feed Concentration	2000 ppm	2000 ppm	1500 ppm
Test Time	20 minutes	30 minutes	30 minutes

they're tested.

Under the element production process used by FilmTec Corporation, there is no need for an extended rinse procedure to remove manufacturing chemicals. Chemicals are washed out of the membrane by a water bath before the membrane is dried. Instead of a 24-hour flushing rinse, only a brief element rinse is required prior to testing and shipment.

The difference in the FilmTec manufacturing process and others involving extended flushing rinses is important because all RO membrane elements tend to exhibit higher salt rejection after extended wetting. The 24-hour rinse some manufacturers must use to leach out chemical residues pre-conditions their elements to perform better in factory salt rejection tests.

### What do manufacturers' salt rejection specifications really mean?

Salt rejection specifications published by element manufacturers are actually based on data from plant quality assurance testing or from post-production testing some manufacturers use to classify the products they manufacture.

Quality assurance tests—Quality assurance (QA) testing is required in RO element manufacturing operations, as it is in any precision manufacturing environment, to ensure the integrity of the elements manufacturers produce. The QA or compliance test used by manufacturers is a "salt challenge test" which measures element salt rejection under specific test conditions before the element can be shipped from the plant. Element flow is also measured

during these tests.

Although these QA tests do not replicate actual service conditions and were not originally intended to produce field performance specifications, over the years some manufacturers have encouraged you to interpret the test results in that way.

Post-production element classification—The second way in which published salt rejection specifications are generated is during post-production tests that some manufacturers use to classify their products by level of performance. This type of testing is necessary when a manufacturer's production process lacks the precision to produce elements that consistently exhibit the same level of performance. The manufacturer must test all elements for salt rejection to properly assign the appropriate product designation and the particular performance specification under which the product will be sold.

FilmTec's precision fabrication process eliminates the need for this kind of post-production classification testing because elements produced in our advanced production facilities are more consistent and their performance is very predictable. In fact the FilmTec manufacturing process is so precise, the need for quality assurance salt rejection testing may eventually be eliminated altogether. This would result in a very significant advantage. If salt rejection testing is not required, there will be no need to wet the dry elements produced by our process in order to conduct the preshipment QA test. And this means elements could

---

be shipped from our plant in a dry state. The advantages of dry elements are significant:

- There is no need for microbiological protection during shipment and storage.
- The elements have a longer “shelf-life”.
- They are easier to handle.
- Shipping costs are lower due to the reduced dry element weight.
- And time-consuming flush-out procedures are not required to remove preservative chemicals from the elements before your water treatment system is brought on line.

FilmTec has been shipping dry elements since 1985. Today we offer dry products ranging from low pressure elements for use in home tapwater systems to 8” brackish water elements for large commercial, municipal and industrial systems.

### **Stabilized system salt rejection is more important than rejection in Q.A. tests**

As you can see, placing too much emphasis on published salt rejection data produced by manufacturers’ quality assurance tests can be dangerous. But these test numbers are also not very useful to you in assessing the actual performance you can expect from membrane elements in your system.

Because of the differences in the way membrane elements are made, element salt rejection can only be fairly compared after a week or more of actual “wet” service. Analysis of actual element performance exhibited in the field — with specific feedwater quality and system conditions — is the best indicator of long-term salt rejection because it eliminates the misleading effects of artificial test conditions, preliminary rinses, and other pretest element preparation.

Extensive field testing has shown, for example, that the salt rejection performance of FILMTEC elements exceeds the numbers generated by our Q.A. tests when the elements reach a stabilized condition, typically within a few hours of initial system startup (See Figure 1). In fact, many

operators have found that FILMTEC elements provide salt rejection well above the published minimum specification immediately at system startup. This reflects the effect of membrane immersion in a preservative solution during shipment and storage prior to installation.

The bottom line is, it is common for FILMTEC elements to provide stabilized salt rejection of 99.5% or even higher in actual water treatment service. Of course, as with any elements, system feedwater and operating conditions can be significant determinants of the actual salt rejection experienced in any particular system.

Does salt rejection improve for all elements after the initial hours of system operation? Not necessarily. Elements exposed to a 24-hour rinse prior to manufacturer salt rejection testing are often already at the peak of their salt rejection performance and may exhibit little if any improvement under system conditions over time.

Furthermore, if the elements were tested under artificially generous conditions of recovery, feed concentration, temperature, or pressure—or over an extended test period—their performance may actually decline from the published salt rejection level once they are installed. In contrast, long-term monitoring of the performance of FILMTEC elements in numerous field installations—over a broad spectrum of feedwaters and under a wide range of operating conditions—has shown that their salt rejection remains highly consistent.

### **So what good is a published salt rejection specification?**

Because they are derived from artificial test methods, manufacturers’ salt rejection specifications do not reflect stabilized rejection under actual system conditions. Because there is no standard test method, and because differences in manufacturing processes bias the results of factory tests, manufacturers’ salt rejection specifications cannot be fairly compared, one-to-the next.

Nevertheless, published specifications do show that a particular element is subject to a particular manufacturer’s quality assurance or product classification standard. These specifications also have some value as indicators of the minimum performance that can be expected from an element, provided that the specifications have been established conservatively and don’t overstate what you can expect long term.

In the case of FILMTEC elements, our minimum salt rejection specifications are set primarily for quality assurance purposes to ensure the integrity of our products. However, we have begun publishing a stabilized salt rejection specification of 99.5% as a supplement to our minimum specification. This specification is based on laboratory salt challenge tests conducted under the same basic conditions as our minimum salt rejection test except the duration of the test is extended to allow the membrane to reach a stabilized condition.

The FilmTec stabilized salt rejection specification more closely reflects the performance our elements typically provide in the field. Of course, even our extended laboratory tests cannot take into account the many system variables our elements may encounter in actual service. However, in combination with existing field data, both the minimum and stabilized salt rejection specifications help establish a starting point for projecting the actual performance of FILMTEC elements in your specific system.

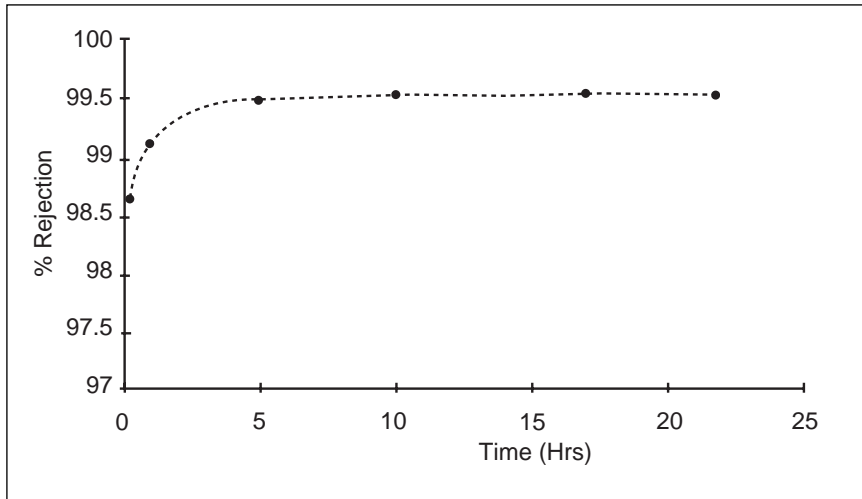
### **If not published salt rejection specs, what can you use to choose the best element?**

It’s a mistake to focus too much on estimating the performance of individual RO elements when projection of the total performance of your water treatment system is more productive and revealing.

The ROSA Reverse Osmosis System Analysis computer program was developed by the Liquid Separations group of The Dow.

---

**Figure 1—Typical salt rejection performance of FILMTEC elements after system startup**



Chemical Company to project the performance of water purification systems based on FILMTEC elements. Using specific information about your system, the program simulates the operation of the system to provide an accurate picture of what you can expect from FILMTEC elements under real-life conditions for the useful life of the elements.

The ROSA program focuses on the total system, taking into account...

- Feedwater content (including actual concentrations of sodium chloride, other ionic impurities, and silica).
- Operating conditions including pH, temperature, feed pressure, and recovery.
- Your specific water quality requirements.
- Length of service.

This program routinely projects salt rejection well above the minimum specification we publish for our elements. Field tests—coupled with the 15 years of on-line performance logged by FILMTEC elements—verify the accuracy of these projections, further evidence of the importance of stabilized salt rejection data versus numbers derived from artificial factory tests.

Of course, when you choose an RO element, you are also choosing an element supplier. It pays to evaluate not only the element you are offered but also the manufacturer's technical expertise and track record of success in installations similar to yours. FILMTEC elements are backed by a complete package of technical support that is unsurpassed in the industry. Innovations such as our advanced precision manufacturing capabilities, dry element technology, and the ROSA program show that FilmTec leads the way in advanced technology and technical support.

### **In conclusion..**

While it's true that some suppliers publish higher salt rejection specs than FilmTec does, these numbers distort more than enlighten. More significant than the reported differences in salt rejection between elements are the differences in element manufacturing techniques, testing methods, and test conditions that account for these disparities.

The fact is, by manipulating test conditions and other factors, element manufacturers can provide almost any salt rejection number they'd like to promote. But in our view, this is an unproductive use of resources that adds cost but no value to the product they deliver to you.

We hope that this paper encourages you to look beyond often misleading manufacturer specifications to more effectively assess the potential performance of RO elements in your actual system. We're confident that FILMTEC elements will continue to stand up to your most thorough analyses—and your toughest service requirements—just as they have in hundreds of installations globally since FilmTec Corporation was founded more than 15 years ago.

**Dow Liquid Separations Offices.**  
**For more information call Dow Liquid Separations:**

**Dow Europe**

Dow Information Centre  
Liquid Separations  
Schurenbergweg 5  
1105 AP Amsterdam Zuidoost  
P.O. Box 12121  
1100 AC Amsterdam  
The Netherlands  
Tel. +31-20-691-6268  
Fax +31-20-691-6418

**Dow Pacific**

Dow Chemical Japan Ltd.  
Liquid Separations  
Tennoz Central Tower  
2-24, Higashi Shinagawa 2-chome  
Shinagawa-ku, TOKYO 140-8617  
Japan  
Tel. (813) 5460 2100  
Fax (813) 5460 6246

**Dow Pacific**

Dow Chemical Australia Ltd.  
Liquid Separations  
26 Rodborough Road  
French's Forest  
New South Wales 2086  
Australia  
Tel. 61-2-9776-3226  
Fax 61-2-9776-3299

**Dow Latin America**

Dow Quimica S.A.  
Liquid Separations  
Rua Alexandre Dumas, 1671  
Sao Paulo - SP - Brazil  
CEP 04717-903  
Tel. 55-11-5188 9277  
Fax 55-11-5188 9919

**Dow North America**

The Dow Chemical Company  
Liquid Separations  
Customer Information Group  
P.O. Box 1206  
Midland, MI 48641-1206  
USA  
Tel. 1-800-447-4369  
Fax (517) 832-1465

**Internet**

<http://www.dow.com/liquidseps>

**Notice:** The use of this product in and of itself does not necessarily guarantee the removal of cysts and pathogens from water. Effective cyst and pathogen reduction is dependent on the complete system design and on the operation and maintenance of the system.

**Notice:** No freedom from any patent owned by Seller or others is to be inferred. Because use conditions and applicable laws may differ from one location to another and may change with time, Customer is responsible for determining whether products and the information in this document are appropriate for Customer's use and for ensuring that Customer's workplace and disposal practices are in compliance with applicable laws and other governmental enactments. Seller assumes no obligation or liability for the information in this document. **NO WARRANTIES ARE GIVEN; ALL IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE ARE EXPRESSLY EXCLUDED.**

Published February 1998.

