

## Cleaning Spiral Wound Membrane Elements

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### INTRODUCTION

All pressure driven membrane separation systems foul over time. The symptoms of fouling include a decrease in normalized permeate flow, an increase in salt passage, and an increase in differential pressure. In addition to decreased system performance, severe fouling may irreversibly damage membrane elements and make effective cleanings difficult or impossible.

Indications that a system clean is required are: a 10 to 15 percent decline in normalized permeate flow; a 10 percent increase in salt passage; or a 15 percent increase in differential pressure.

Figure 1 illustrates the importance of cleaning effectively. The dotted lines illustrate cleanings that effectively restore flux to the original baseline value each time. By contrast, ineffective cleanings, represented by the solid lines, restore less and less of the original flow.

When cleanings are not effective, there is a need to clean much more frequently. This results in increased downtime, reduced element life, and higher operating costs. Ineffective cleanings result from the use of ineffective cleaners, poor cleaning procedures, and waiting too long to clean fouled elements.

The purpose of this bulletin is to describe procedures and products that will allow plant operators to achieve effective cleanings and more cost-effective system operation.

### FOULANTS

Foulants are divided into five different classes of material:

- |                       |              |
|-----------------------|--------------|
| (1) Metals            | (2) Scale    |
| (3) Silt              | (4) Organics |
| (5) Chemical foulants |              |

**Metals:** Metal foulants most frequently include iron, manganese, and aluminum. Less frequently, metals such as zinc, copper, and nickel are encountered. Iron and manganese commonly occur in groundwaters as soluble divalent ions. Should air or chlorine be introduced into these waters, iron and manganese may be oxidized and precipitate onto membrane surfaces as hydrous oxides.

Iron fouling may also be the result of corrosion processes that occur within well headers or feed piping. Another source of iron is carryover from flocculator/clarifiers or multimedia filters where iron salts are used sometimes as coagulants.

Fouling by hydrous aluminum oxide is also very common. The usual cause of

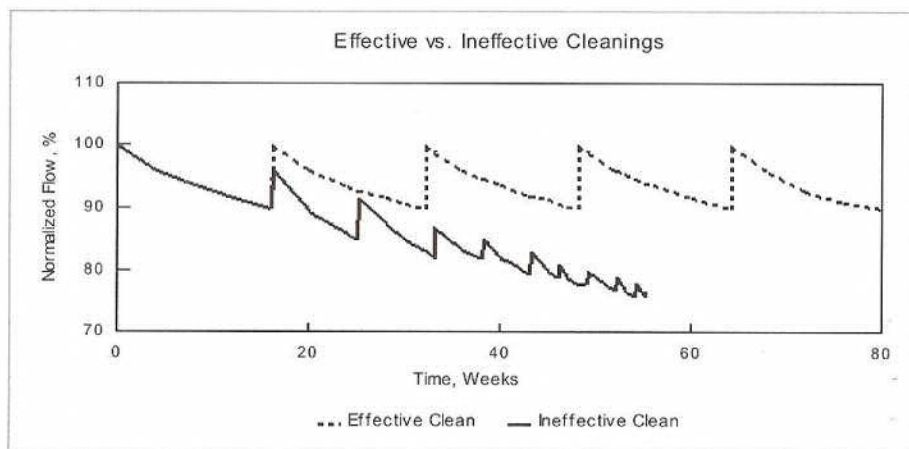


Figure 1 Cleaning Effectiveness and Subsequent Frequency



this type of fouling is carryover of flocculated solids from filtration processes that employ aluminum salts as coagulants.

**Scale:** Supersaturation of certain sparingly soluble salts can lead to scaling of membrane surfaces and feed spacers. The most common scale formers are calcium carbonate and the sulfates of calcium, barium, and strontium. Less common scales are silica and calcium fluoride. Silica scale, when it does occur, is very troublesome, as it is difficult to remove safely from membrane elements.

**Colloids and Silt:** Colloids and silt are the most common foulants and examples include clays, colloidal silica, and bacteria. Colloids are particles less than about one micron in diameter and do not settle from solution upon standing. Silt particles have diameters greater than one micron in diameter and will settle from solution.

**Organics:** Humic and fulvic acids result from the degradation of leaves and other vegetation and occur frequently in surface waters. These acids can cause serious membrane fouling depending upon their exact nature and the ionic composition of the feedwater and will foul polyamide to a greater extent than cellulose acetate membranes. Acids with higher molecular weights are more serious foulants than those with lower weights. Calcium and magnesium ions may contribute to humic and fulvic acid fouling by binding together anionic groups of membranes and acids.

Biologically derived organic foulants include the slime exuded from bacteria and filamentous fungi as well as the microorganisms themselves. Slime contains both polysaccharide and protein components. Slime may originate in the feedwater and be carried downstream to the membrane separation systems, but more frequently it forms insitu through the growth of microorganisms on membrane surfaces.

**Chemical Foulants:** Chemical fouling generally results from feeding two or more incompatible chemicals ahead of membrane separation systems. The most common example is the precipitation of polymeric antiscalants by organic coagulants.

#### **PACKAGED VS. GENERIC CLEANERS**

Plant operators have the choice of cleaning membrane systems with generic chemicals or commercial cleaning formulations. Generic cleaners, such as citric acid and trisodium phosphate, have an arguable cost advantage. However, this contrasts with the greater effectiveness of many commercial cleaners, the time required to mix generic cleaners, and the chance that generics may damage membrane element components (high or low pH excursions).

In general, good commercial cleaners are more effective than generic chemicals because they contain a "team" of ingredients that work together to remove foulants. Typical Avista Technologies cleaners contain the following categories of ingredients.

**Buffers:** maintain the cleaning solution pH in the range necessary for the other ingredients to work at their maximum efficiency. Buffers also maintain the pH in a range that is compatible with membranes and other element components.

**Surfactants:** wet surfaces and enable the other cleaner components to penetrate foulant layers.

**Builders:** complex divalent ions such as calcium and magnesium that may render surfactants inactive.

**Chelants:** sequester heavy metals such as iron and manganese as well as the components of many scales.

**Dispersants:** disperse colloids and silt components that are not capable of being dissolved by the cleaner.

Dispersants and surfactants work in concert.

**Hydrotropes:** are organic substances added to some of the Avista products to dissolve targeted organic foulant components such as bacterial slime.

**Redox Controllers:** Several of the Avista products contain ingredients that raise or lower the oxidation potential of the cleaning solution. Reducing agents help dissolve iron and manganese. Mild oxidizing agents help remove organic foulants.

***Iron fouling may also be the result of corrosion processes that occur within well headers or feed piping.***

#### **CLEANING EQUIPMENT**

Figure 2 shows the equipment needed for cleaning. The cleaning tank, made of non-corrosive materials such as reinforced plastic, should be sized to hold a volume equal to the total volume of water contained in first stage pressure vessels, cleaning system hoses, and cartridge filter holder. Fit the tank with a cover, heating units, temperature and level controls. If the cleaning tank is not in a well-ventilated area, provide it with an exhaust fan.

Use a 316 stainless steel cleaning pump and size it according to the guidelines set forth in the next section. A centrifugal pump is most suitable for flexibility. When hoses connect the cleaning skid with the RO system, they must be of an adequate pressure rating and located in a way that kinking does not occur. Locate return line below the water line to reduce splashing and foaming.

Locate a 5 micron filter after the cleaning pump to remove dislodged solids that could plug element feed passages. Locate a safety strainer upstream of the cleaning pump.

Provide appropriate valves to control system pressure and permit drainage and flushing of tank and lines. A flow meter is necessary to establish the proper rates through the pressure vessels. Locate a by-pass line around the cleaning tank to help control flowrate and to mix or dissolve cleaners.

## CLEANING PROCEDURES

Good cleaning procedures are essential to achieving effective cleanings. This section of the cleaning bulletin outlines these procedures. For custom cleaning instructions, please feel free to contact the Avista Technologies customer service department.

**Flow and Pressures:** Clean one stage at a time. Recirculate cleaning solution through each stage for a minimum of one hour. Flow at the maximum rate recommended by the element manufacturer. Use the guidelines listed in Table 1 if this rate is not known.

Clean at the minimum pressure needed to achieve the desired flow of cleaning solution through the pressure vessels. Low pressure minimizes permeation and reduces the convective force that holds foulants to membrane surfaces. In general, do not exceed 60 PSIG.

**Dilution Water:** Prepare cleaning solutions from either RO permeate or DI water.

**Flushing:** Flush the system with RO permeate or DI water prior to and after cleaning. If two cleaners are used sequentially, flush the system with RO permeate or DI water between the cleanings.

**Temperature:** Clean at the maximum temperature allowed by the element manufacturer. For thinfilm polyamide elements, 50°C (122°F) is both safe and effective. When cleaning cellulose acetate elements, do not exceed 35°C.

**Cleaner Quantity:** The total volume of water in the cleaning loop must be determined before the amount of

cleaner required is calculated. This volume includes water contained in the cleaning tank, pressure vessels, hoses, and cartridge filter housing. Volume estimates for pressure vessels (containing elements) and hoses are listed in tables 2 and 3, respectively. Cartridge filter housing volumes may be determined by contacting the manufacturer.

Table 4 illustrates the calculation of total system volume for a system designed in a 4:2 array with six 8-inch by 40-inch elements per vessel. There are 200 feet of 3-inch diameter hose used to connect the cleaning skid with the RO system. The cartridge filter housing contains 15 gallons of water. Cleaning tank volume is set to equal the volume of water contained in the hoses, pressure vessels, and cartridge filter holder.

Summation of these volumes gives a total of 466 gallons of water needed to perform a first stage clean. Cleaning of the second stage requires a minimum volume of 322 gallons.

Avista Technologies recommends a one weight percent cleaner concentration for light fouling and a two percent concentration for moderate to severe fouling. To prepare a 1% solution, add 4.3 pounds of cleaner per 50 gallons of water. A 2 % solution requires 8.5 pounds of cleaner added to 50 gallons of water.

In the example, the quantity of cleaner needed to make a 2 % solution for a first stage clean is  $466/50 \times 8.5 = 79.2$  pounds. By a similar calculation, the quantity of cleaner required for the second stage is  $322/50 \times 8.5 = 54.7$  pounds. Following the cleaning of the first stage, the same cleaning solution may be used to clean the second stage provided that the pH is still in the recommended range, and the solution is not turbid.

## CHOOSING CLEANERS

Coupled with the need to employ proper cleaning procedures, the choice of the proper cleaner or cleaner combinations is essential. Factors include the nature of the foulant or

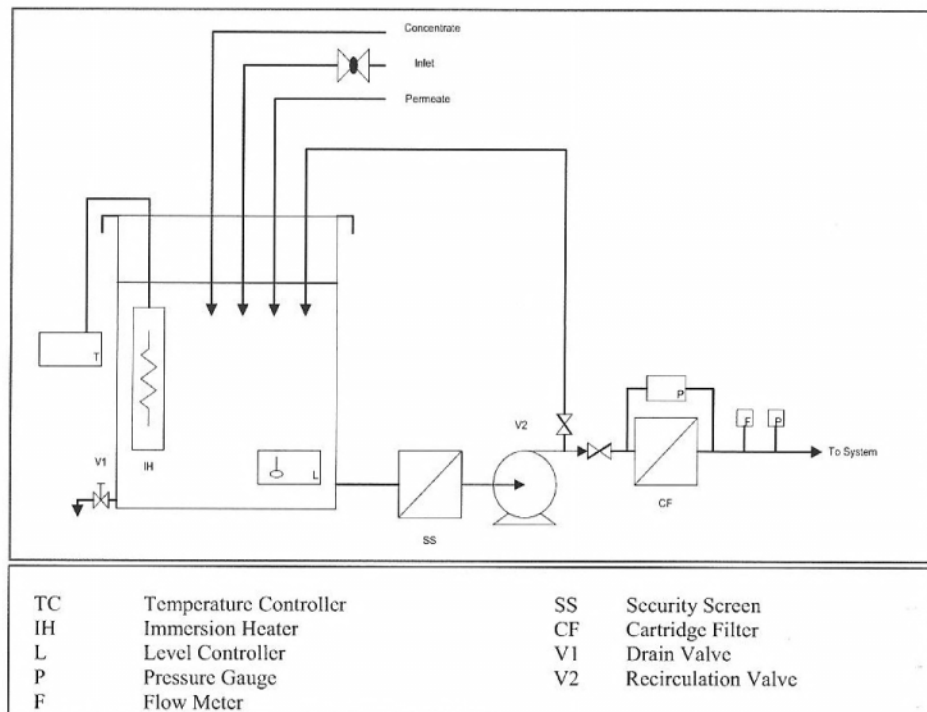


Figure 2 Cleaning Equipment



combinations of foulants present in the membrane elements.

When there have been prior problems obtaining an effective clean, Avista Technologies recommends a cleaner evaluation study. One element from the affected system is removed and fouled membrane samples chosen. These are then wet tested and cleaned with several candidate cleaners in our *RO Vision™* test cell apparatus. These test cells have a transparent top that allows one to observe the cleaning and collect membrane performance data. From the test cell results, the most effective cleaner is recommended. A foulant analysis may also be conducted as a knowledge of the chemical nature of the foulants may help to optimize pretreatment process operation.

Foulants tend to occur in combinations based upon the feed source and these are described below:

**Surface Water Supplies:** contain colloids, silt, natural organic matter, and sometimes iron. Added to this basic matrix can be aluminum (derived from filtration processes located upstream of the RO system) and biofouling. When all of these components are present in significant amounts, a combination cleaning is recommended.

For polyamide systems we recommend the following combinations of cleaners. RoClean L403 or P303 followed by RoClean P111 or L211. All four products are proven effective. For cellulose acetate systems, the following combinations of cleaners are recommended: RoClean L403 or P303 followed by RoClean L607 or P507

For heavy fouling, it is sometimes necessary to soak the system overnight in the appropriate cleaners. During the soaking period, it is helpful to occasionally "bump" the cleaning pump to agitate the cleaning solution within the membrane elements. When

aluminum is absent, a single cleaning may be sufficient.

**Ground Waters:** often contain significant concentrations of iron and manganese. If air enters the feedstream, these metals can precipitate within the RO system. Heavy iron fouling may also result from the corrosion of steel feed piping.

**Iron or manganese:** Clean with RoClean P703. For heavy fouling, an overnight soak may be necessary.

Scale can occur in systems operating on either ground or surface waters:

**Calcium carbonate scale:** Clean with either RoClean L403 or RoClean P303.

**Sulfate scale:** Use RoClean L811 on Polyamide elements. Cellulose acetate elements benefit from RoClean L607. For moderate to severe fouling, an overnight soak is recommended.

**Silica Scale:** Acid ammonium bifluoride solutions dissolve silica scale. However these solutions are very dangerous as they can cause severe burns on contact with skin and the subsequent wound heals slowly.

The pH of RoClean L211 can be raised to 12 with sodium hydroxide to dissolve small amounts of silica scale. Try this procedure before discarding silica scaled elements.

*The picture on page 1 shows two membranes, one heavily fouled and the other physically damaged during a generic cleaning process where high pressures and the use of unbuffered chemicals resulted in pH levels outside of the recommended ranges.*

VESSEL FLOW RATES TABLE 1	
Element Diameter, Inches	Flowrate per Vessel, GPM (LPM)
4	10 (38)
6	23 (87)
8	40 (151)

ESTIMATION OF HOSE VOLUMES TABLE 2	
Hose Diameter, Inches	Volume, Gallons per Foot
2	0.16
3	0.37
4	0.65

ESTIMATION OF PRESSURE VESSEL VOLUME TABLE 3	
Element Dimensions	Volume, Gallons per Element
4" x 40"	2
6" x 40"	3.5
8" x 40"	6

ESTIMATING TOTAL SYSTEM VOLUME TABLE 4		
Vessel	Volume in Gallons	
	Stage 1	Stage 2
Pressure Vessels	4 x 6 x 6 = 144	2 x 6 x 6 = 72
Cleaning Tank	233	161
Hoses	200 x 0.37 = 74	74
Filter Holder	15	15
Total Volume	466	322