

The application of acid free antiscalant to mitigate scaling in reverse osmosis membranes

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Abstract

This study evaluated alternatives to the traditional sulfuric acid/sodium hexametaphosphate (SHMP) chemical treatment program for use in reverse osmosis (RO) permeators. The aim was to find a simpler, safer (no acid), and more economical scale inhibition program. The study was conducted by using a pilot plant reverse osmosis skid. Three 4-inch B-9 hollow fine fiber (HFF) membranes were used in each test. These were arranged in a 2:1 array, whereby the supply water was fed into two parallel modules and the brine reject from these modules was combined and fed to a third module. Three different commercial antiscalants were evaluated. The paper discusses in some detail the fiber bundle autopsies of the membranes treated with different antiscalants. It also discusses the chemical analyses carried out and the detailed identification of the foulants found.

Keywords: SHMP (sodium hexametaphosphate); RO (reverse osmosis); Antiscalant

1. Introduction

The principal cause of reverse osmosis system failure is membrane scaling, which results from the accumulation of water-formed or water-borne deposits that impede the flow of fluid and increase the pressure differential across the membrane [1]. Antiscalant chemicals have been used for many years in RO membranes to prevent scaling and improve RO plant

performance. The conventional method for controlling scale formation on membranes involves addition of sulfuric acid and a scale inhibitor to the feed water [2]. The aim of this study was to evaluate a chemical treatment program that is simpler, safer (no acid), and more economical than the acid/scale inhibitor program. Antiscalant chemicals were evaluated and optimization of dosing rates was conducted under RO plant conditions.

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Saudi Aramco operates a brackish water reverse osmosis plant, which produces over one million gallons of drinking water per day. The plant uses sulfuric acid and sodium hexametaphosphate (SHMP) to minimize scaling in the DuPont B-9 membranes. Although polyphosphates exhibit excellent threshold inhibition for certain scale forms, they hydrolyze in short periods of time to form orthophosphate, which is inactive as an antiscalant. Consequently, their use leads to the formation of insoluble calcium phosphate scale deposits. Sulfuric acid is hazardous and corrosive and many plants are trying to eliminate acid injection. The disadvantages in the use of acid and SHMP led to the evaluation of new polymeric antiscalant chemicals. The development of specific synthetic polymers offers the ability to control scaling and fouling in RO membranes without the use of acid and SHMP.

The supersaturating conditions of calcium carbonate, calcium sulfate, and other low solubility constituents test the effectiveness of any treatment program's ability to inhibit scaling. The failure of an inhibitor program by chemical or thermal decomposition, ineffective performance, or improper treatment application, can result in severe scaling and fouling of RO membranes in a relatively short period of time.

This study outlines a comparative test regime used to evaluate three different acid free scale inhibitors. Each antiscalant trial lasted for two months. Upon completion of the antiscalant trials, the membranes were subjected to an autopsy investigation. Out of the three acid free antiscalant chemicals which were evaluated, only one showed excellent scale inhibition.

2. Types of chemicals used for trials

As mentioned earlier, there were three types of chemicals involved in these trials. Each chemical will be referred to by a letter. These chemicals are:

C-chemical. This chemical is an aqueous solution of organic phosphonate and acrylic polymer with a specific gravity of 1.22–1.26 and pH of 3.7–4.7. It contains 18% of sodium salt of phosphono-methylated diamine.

M-chemical. This chemical is non flammable and is phosphino-carboxylate based with a specific gravity of 1.135–1.140 and pH of 6.8–7.5.

H-chemical. This chemical is a phosphonate based with a specific gravity of 1.35 and a pH of 11.0.

3. Feed water chemical analyses

Table 1 shows the typical water analysis in the plant area.

Table 1
Typical water analysis in the plant area.

Calcium, ppm	233
Magnesium, ppm	81
Total hardness, ppm	920
Sodium, ppm	582
Potassium, ppm	36
Strontium, ppm	5.5
Aluminum, ppm	0.1
Iron, ppm	0.1
Manganese, ppm	0.04
Barium, ppm	0.05
Copper, ppm	0.005
Lead, ppm	0.005
Carbon dioxide, ppm	20
Silicon, ppm	12.6
Chloride, ppm	1190
Bicarbonate, ppm	214
Nitrate, ppm	10.5
Nitrite, ppm	0.1
Sulfate ppm	462
Specific gravity @ 60°F	1.0023
Conductivity, micromohs	4492
Boron, ppm	0.6
Arsenic	<0.01
Selenium	<0.01
pH	7.8
TDS	2833

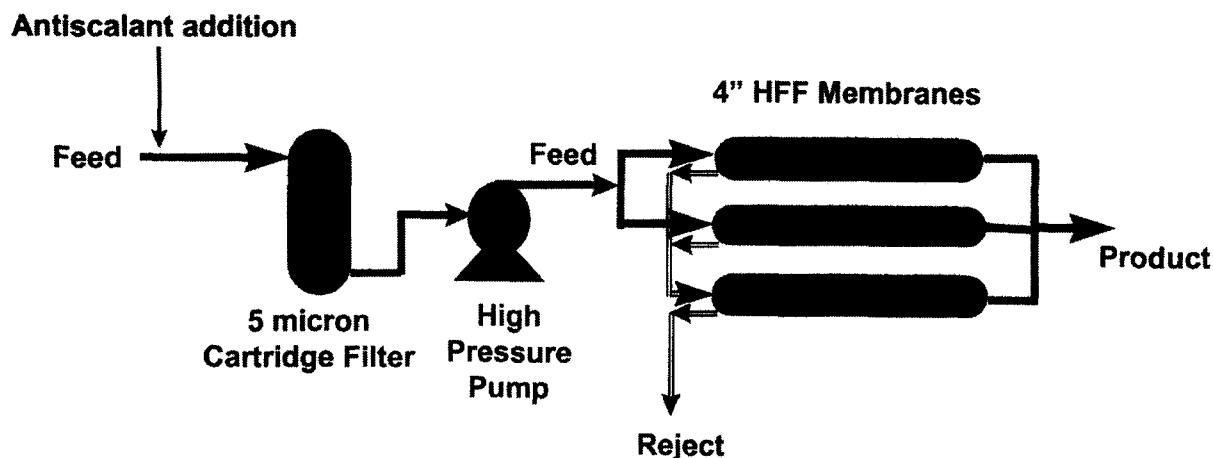


Fig. 1. Test skid configuration.

3.1. Test skid configuration

The membranes on the test skid were arranged in a 2:1 array configuration (see Fig. 1). Operational parameters were as follows:

- Feed flow: 11–12 gpm
- Product flow: 8–9 gpm
- Reject flow: 3–4 gpm
- Recovery: 75%
- Feed pressure: 350–400 psi
- First stage delta P: 30–40 psi
- Reject pressure: 300–330 psi
- Second stage delta P: 5–10 psi
- Feed temperature: 30–34°C
- Feed TDS: 2800 ppm
- Product TDS: 300–400 ppm
- Reject TDS: 5000–6500 ppm

4. Results and discussion

4.1. Visual examination from autopsy analyses

C-chemical. There were signs of solid accumulation on the innermost fibers and reemay surrounding the central distribution feed tube while cutting through the layers of the first stage permeators. Brown particulate deposits were detected scattered within the hollow fine fiber bundles and on the reemay sheets. However, no

solid build up was detected on the fibers or reemay of the autopsied second-stage permeator.

M-chemical. During the autopsy, the membrane layers looked clean. There was no sign for scaling or solid build up.

H-chemical. During the autopsy, the first stage permeators showed brownish black deposits on the fibers and reemay of the deepest layers of the membranes at the product side. The second stage permeator fibers and reemay were mostly clean and no signs of scaling or solid build up were seen.

4.2. Chemical analysis

Elemental composition analyses were carried out on the solid deposits collected from the membrane fibers and reemay by using the SEM-EDS technique. The results represent solids obtained from the 1st stage permeators during C-chemical and H-chemical pretreatment programs. SEM-EDS results conducted on the solids from the deepest layers of the two permeators indicated that they were primarily similar in composition (C-chemical). The elements Si, P, Ca, Cr and Fe were detected in all solid samples. Sulfur, Ni and Al were occasionally detected in the deposits. High calcium peaks were associated with high

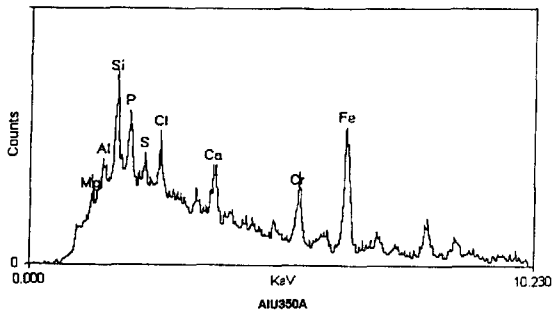


Fig. 2. SEM-EDS analysis for C-chemical trials.

carbon peaks, indicating calcite (CaCO_3) presence.

The observed Fe, Cr and Ni peaks are probably oxide/hydroxide corrosion products. The silica presence is probably due to dust particles and the phosphorus peak is probably due to the use of phosphate based scale inhibitor (see Figs. 2 and 3). Semi-quantitative analysis of the deposits collected from the last batch permeators (H-chemical) indicated that iron corrosion products were the predominant deposits. In addition, calcium, silicon and phosphorus were also present.

SEM-EDS analyses were not necessary for M-chemical because it did not show any scaling or build up of deposits. Based on the above analyses, M-chemical was selected to be the best of the three chemicals tested. Other parameters were also taken into account such as ease of use, safety, availability and cost factor.

5. Economics

In the conventional method of scale inhibition for the RO process by using sulfuric acid and SHMP, Saudi Aramco's daily consumption of sulfuric acid alone is 18 tons. This is equivalent to over \$3000 per day for all the Company's RO plants. Additional expense is also incurred from the use of SHMP and the lime that is needed down stream of the RO plant to elevate the pH.

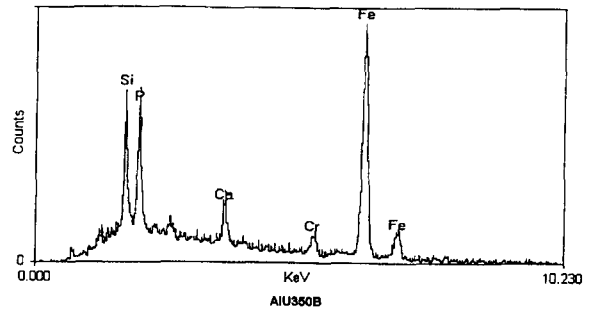


Fig. 3. SEM-EDS analysis for H-chemical trials.

M-chemical acid free antiscalant has proved to be much more cost effective than the traditional antiscalant SHMP and acid treatment. The daily consumption of M-chemical will be 120 gallons per day for all the Company's RO plants (based on an optimum dosage of 4 ppm M-chemical in the feed water). This will be equivalent to less than \$2500 per day.

Additional benefits of this chemical treatment program are:

- Ease of use (no solid/liquid mixing is needed)
- Higher stability (no hydrolysis)
- Superior dispersion of silt, clays and metal oxides
- Improvement of water quality due to less usage of chemicals
- Reduced soda ash consumption for pH elevation
- More accurate testing of the scale inhibitor, which means good quality control and monitoring of system and water
- Extension of the membrane useful life by reducing membrane chemical cleanings.

6. Conclusions

RO systems frequently experience operational problems due to scaling and fouling, which are the most common causes of lost production, reduced membrane life, and higher operating costs. Most RO pretreatment programs control

deposits by adding treatment chemicals to the feed water. Several co-polymer-based pretreatment programs provide superior performance over SHMP and sulfuric acid. Saudi Aramco RO Plant tried three different antiscalants and selected M-chemical to be the best with regard to the autopsy analysis as well as other important factors, such as safety, cost, operational practicality, and availability.

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