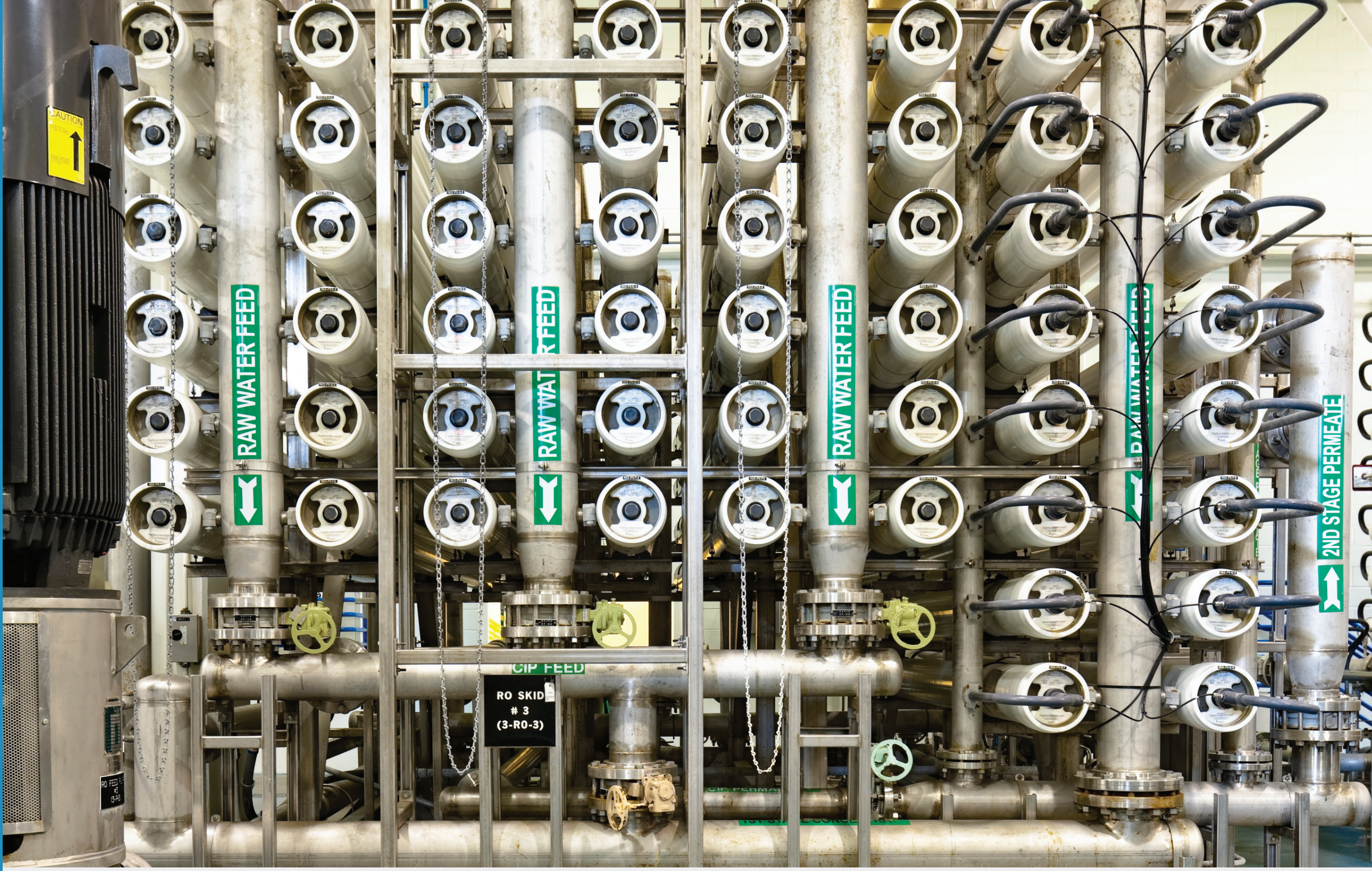

Antiscalant Technical Guide

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INTRODUCTION

As reverse osmosis (RO) recovery increases, the corresponding salt concentrations increase in the RO reject stream and exceed the saturated limits of the sparingly soluble salts. Over time, hard scale deposits will form on membrane surfaces and within the feed channel spacers. Scaling within RO systems is a serious matter, for not only does scaling drastically reduce system performance, but also the irreversible damage on the membranes can come from more than just scale deposition. If we are talking about strictly scaling, then the damage to the membrane can include telescoping, mechanical damage to the components, and also abrasion. Examples of some common sparingly soluble salts are calcium carbonate and the sulfates of calcium, barium, and strontium. Less common salts include calcium phosphate and calcium fluoride.

HISTORY

From 1970 to the mid-1980s, the only scale inhibitor available on the market was sodium hexametaphosphate (SHMP). Although primarily used for sulfate scale, SHMP has a number of drawbacks including lack of effectiveness against calcium carbonate, and its solutions were unstable, eventually reverting to orthophosphate. Orthophosphate not only lacks scale inhibition properties, but it may precipitate with calcium to form calcium phosphate scale. In the late 1960s Monsanto and Pfizer developed the first organic scale inhibitors. Initially, these were limited to several organic phosphonates and polyacrylic acid. The current generation of scale inhibitors includes a variety of different phosphonates and polymers, which are used either alone or in combination.

SCALE CONTROL METHODS

Over the years, the RO industry has developed methods of scale prevention. These methods fall into three categories:

- Acidification
- Ion exchange softening
- Scale inhibitor addition

ACIDIFICATION

Acidification shifts bicarbonate and carbonate alkalinity needed to produce calcium carbonate scale as illustrated by the following equations:

$$Ca^{+2} + HCO_3^{-} \rightarrow CaCO_3$$

$$Ca^{+2} + CO^{2-}_3 \rightarrow CaCO_3$$

While acidification prevents calcium carbonate scaling from occurring, it is not effective against the sulfate scales of calcium, barium, and strontium. Additional disadvantages of acidification include corrosivity of the acid, the cost of storage tanks, and the monitoring equipment required for proper acid dosing. Acidification also lowers permeate pH, requiring post-treatment pH adjustment or degassers to remove excess carbon dioxide.

The selection of the acid type for acidification is dependent on the feedwater quality. The two most common acids for feed pH adjustment are hydrochloric acid (HCl) and sulfuric acid (H_2SO_4. For waters containing elevated levels of barium, sulfuric acid would add additional sulfates that increase the potential for barium sulfate precipitation. Hydrochloric acid, on the other hand, will off-gas and is not operator friendly in terms of handling.

ION EXCHANGE SOFTENING

Ion exchange softening utilizes the sodium form of cation resin. In this process, hardness ions in the water exchange for sodium ions contained in the resin. The following equations illustrate these softening reactions. NaZ represents cation resin in the sodium form.

$$Ca^{+2} + 2NaZ \rightarrow 2Na^{+} + CaZ_2$$

$$Mg^{+2} + 2NaZ \rightarrow 2Na^{+} + MgZ_2$$

Regeneration of the resin is required following the replacement of all the sodium ions by calcium and magnesium.

There are anecdotal accounts of ion exchange softening reducing colloidal and particulate fouling of RO systems by increasing the electrostatic charge on the colloidal and particulate solids. However, to date there is no convincing evidence to support this claim. When compared to either acid or scale inhibitor addition, the main disadvantage of ion exchange softening is cost.

Table 1 gives a cost comparison between softening and scale inhibitor treatment for different levels of hardness. The basis for this example is an RO system designed to produce 75 gpm of permeate at 75 percent recovery. Using a present worth analysis, there is no level of hardness in which ion exchange softening competes economically with scale inhibitor addition.

The comparison does not include disposal costs for spent softener regenerate, which are significant in some areas.

DOSED COST

Dosed cost is the cost of scale inhibitor treatment per unit of time. The following equation calculates dosed cost in dollars per day.

Dosed cost, \$/day = 0.012 x C x Qf x D

Where 0.012 is a unit conversion:
C is the cost of neat product, \$/lb
Qf is feed flow, gpm
D is the neat product dose, mg/l

SCALE INHIBITOR ADDITION

Scale inhibitors are surface-active substances that prevent precipitation of sparingly soluble salts by three different mechanisms.

- Threshold inhibition
- Crystal modification
- Dispersion

THRESHOLD INHIBITION

Threshold inhibition is the delaying of crystal formation by scale inhibitors at very low concentrations. Physical chemists call this delay an induction period. Prior to crystallization, crystal nuclei begin to assemble on a sub-microscopic scale. Scale inhibitors act as structure breakers by associating with cations present in the assembling nuclei. Eventually crystal nuclei greatly outnumber inhibitor molecules, and crystallization of the sparingly soluble salt begins.

CRYSTAL MODIFICATION

Scale inhibitors incorporate into growing crystal structures and distort their shape. Crystals thus modified are slower to grow on membrane surfaces. Figure 1 illustrates the incorporation of inhibitor molecules into the crystal structure by association of the crystal cations with negative functional groups present on the inhibitor. R represents the inhibitor molecule.

TABLE 1. COST ANALYSIS OF SOFTENING VS. ANTISCALANT ADDITION

SOFTENING

HARDNESS, ppm	EQUIPMENT COSTS	SALT, cost per year	PRESENT WORTH
10	\$20,000	\$1,906	-\$43,825
20	\$20,000	\$3,812	-\$67,650
50	\$40,000	\$9,530	-\$159,125
100	\$40,000	\$23,825	-\$337,813
250	\$40,000	\$47,600	-\$635,000

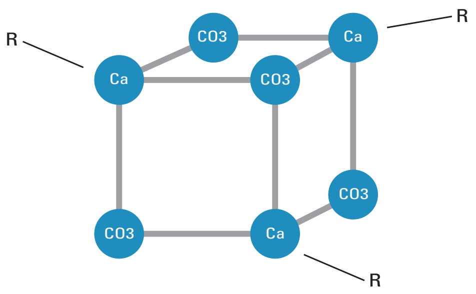
ANTISCALANT ADDITION

HARDNESS, ppm	EQUIPMENT COSTS	ANTISCALANT, cost per year	PRESENT WORTH
10	\$2,000	\$1,300	-\$5,750
20	\$2,000	\$1,300	-\$5,750
50	\$2,000	\$1,300	-\$5,750
100	\$2,000	\$1,300	-\$5,750
250	\$2,000	\$1,600	-\$5,750

NOTES

- Assumes skid-mounted softeners containing 40 ft^3 of resin each. For 50 ppm of hardness and above, two softeners are employed, with one as a standby.
- Klin-dried rock salt for softener regeneration costs \$0.17 per pound.
- Antiscalant equipment consists of feed and pump.
- Antiscalant dosages range from 2 to 5 ppm.
- Amortization period for present worth calculations is 5 years at 8% interest.
- These calculations are an example only and may not apply to all systems. Site-specific calculations are recommended.

FIGURE 1. CRYSTAL MODIFICATION



The greater negative electrostatic charge coupled with steric hindrance, created by the adsorbed inhibitor, increases the repulsion between the colloids and particulates, again delaying crystal growth on membrane surfaces.

Figure 2 illustrates the delay in crystallization caused by the addition of 2.4 mg/l of a neat scale inhibitor to supersaturated solutions of calcium carbonate. Sudden increases in turbidity signal the onset of crystallization.

PERFORMANCE REQUIREMENTS

Current generation scale inhibitors are capable of inhibiting the precipitation of a variety of different sparingly soluble salts, silica, and minerals.

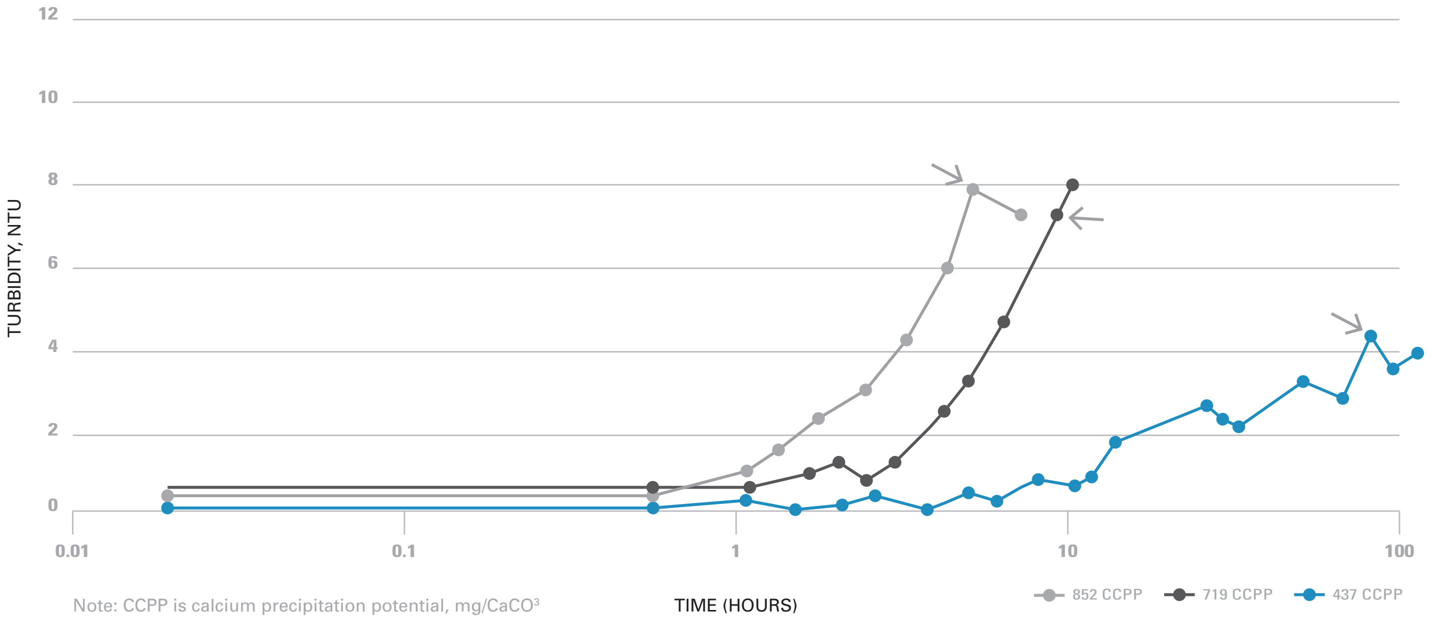
In addition to their ability to inhibit the precipitation of sparingly soluble salts, other desirable scale inhibitor traits include:

- Effective over a wide pH range.
- Neat product solutions are stable for long periods.
- Compatible with all major RO and nanofiltration membranes and element construction materials.
- Approved for potable water use.
- No environmental discharge hazard.

PROJECTION SOFTWARE

Chemical projection software provides options for the most appropriate inhibitor and calculates its dosage based upon the feedwater mineral analysis and system design and operating parameters.

FIGURE 2. TIME-TURBIDITY PLOTS FOR SATURATED CALCIUM CARBONATE SOLUTIONS WITH 2.4 PPM ADDED SCALE INHIBITOR



Note: CCPP is calcium precipitation potential, mg/CaCO^3

Other laboratories may do the calculations internally, simply reporting alkalinity as bicarbonate and carbonate, either as the ions or as calcium carbonate.

SYSTEM PARAMETERS

Required system and operating parameters:

- Element manufacturer and model
- System recovery
- Feedwater temperature
- Use of a quaternary amine coagulant upstream
- For well water, does the water contain air?

REFERENCE

Water and Waste Treatment Data Book by the Permutit Company

Please consult your sales and technical consultant.

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