Versaflex® Si silica dispersant

Reduce cooling water system damage

Nouryon

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Prevent the formation of hard-to-remove silica and silicate scales and reduce cooling water system damage.

Designed for use with today's cooling water systems

Significant changes to the chemical treatment of cooling water systems have occurred over the past 30 to 40 years. Higher population densities and the conservation of limited freshwater supplies drive process water users to work on maximizing water reuse and minimizing waste stream generation, objectives that can be achieved by increasing cooling water cycles.

However, naturally occurring salts that normally dissolve in fresh water become more concentrated as water evaporates during each recirculation cycle. This is especially true with salts that have relatively low solubilities, such as calcium carbonate, calcium phosphate, calcium sulfate, and silica/silicates. When this occurs, the minerals soon reach their maximum levels of solubility and can begin to settle out as scale on equipment surfaces. This leads to fouling in the cooling systems, decreasing their efficiency.

Preventative measures have been developed by water treatment chemical suppliers to keep such salts in solution at concentrations well beyond their normal solubility levels. This allows process water to be recirculated at higher cycles than could normally be achieved without fouling.

Some well-established technologies for the control of calcium carbonate, calcium phosphate, and calcium sulfate are listed in the table below.

Mineral salt	Chemical treatment
$CaCO_3$	Phosphonates, acrylic or maleic polymers
$Ca(PO_4)_2$	Sulfonated copolymers
$CaSO_4$	Acrylic or maleic copolymers

Silica/silicate is, unquestionably, the most difficult scale to remove because it

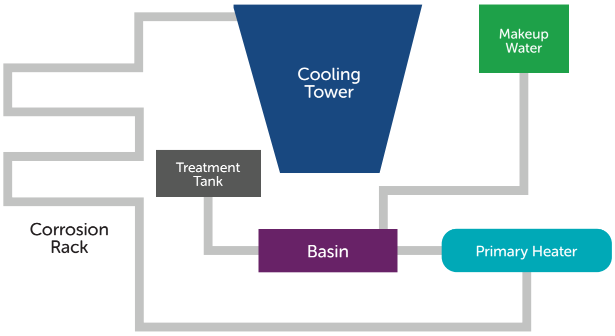
- Forms the hardest of all scales, causing the most damage to the cooling system
- Can occur throughout the entire system, even in difficult-to-reach places
- Cannot be removed by traditional acid cleaning methods because it is relatively inert

Nonetheless, effective, economical technologies for silica/silicate scale control have not been available, making hydrofluoric acid (HF) the only option. An especially aggressive and hazardous chemical to handle, HF requires labor-intensive mechanical cleaning that is time-consuming and physically damaging to the cooling system.

Pilot plant testing

The performance of our Versaflex® Si silica dispersant was evaluated in a laboratory scale pilot plant cooling tower with a PVC apparatus and standard honeycomb fill, as normally used in commercial cooling towers. A schematic diagram of the pilot plant cooling tower is shown in Figure 1.

Figure 1: Pilot plant cooling tower schematic



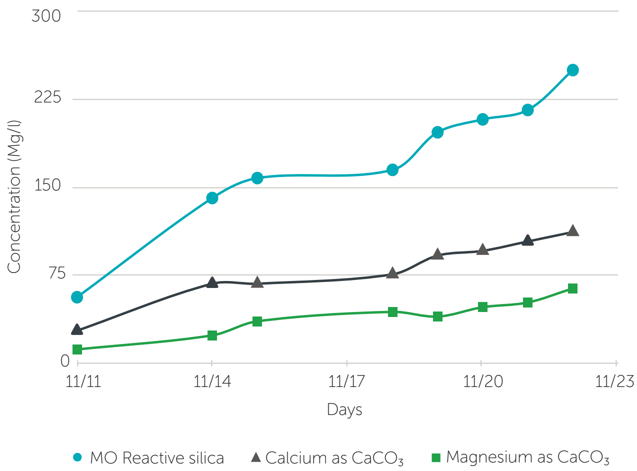
During preliminary pilot cooling tower testing using hard water as makeup, calcium hardness levels reached the break point and calcite precipitation began to occur. Upon reaching a level of 250 ppm silicon dioxide (SiO_2) in the tower water, this caused apparent co-precipitation of silica. When using partially softened water as makeup to avoid potential calcite interference, however, no calcite or silica scale formation was observed throughout the test period.

Silica can exist in more than eleven different forms and reduce the accuracy of test scenarios for silica dispersants with laboratory-spiked sodium silicate.

Because of this, naturally occurring water from the city of Madera in Southern California, where silica/silicate scaling is generally problematic, was used as makeup to gradually concentrate silica in the evaporative cooling system under simulated conditions.

During the pilot cooling tower test, samples were taken every two days and tested for molybdate-reactive silica levels as well as calcium and magnesium hardness. The results, shown in Figure 2, demonstrate the ability of our Versaflex® Si silica dispersant to significantly increase the solubility of silica in cooling water systems.

Figure 2: Results of pilot cooling tower test



Since pilot cooling tower tests indicated the superior effectiveness of our Versaflex® Si silica dispersant under simulated conditions, field trials were run to demonstrate its performance under real-world conditions.

Field trial testing

Molecular modeling studies, pilot plant cooling tower tests, and exhaustive field trials have all demonstrated that the Versaflex® Si silica dispersant can increase silica solubility by more than 2.5 times, allowing cooling systems to run at higher cycles of concentration without experiencing troublesome silica fouling.

Because silica exists in so many different forms, it is highly recommended that a program of actual field trials be implemented to determine the optimum concentrations and system conditions for use of our Versaflex® Si silica dispersant.

Two US locations were chosen to conduct field trials of our Versaflex® Si silica dispersant under real-world conditions: a comfort cooling system in the Northwest (Spokane, Washington) and a process cooling system in the Southwest (Southern Arizona).

Field trial #1

Makeup water chemical composition

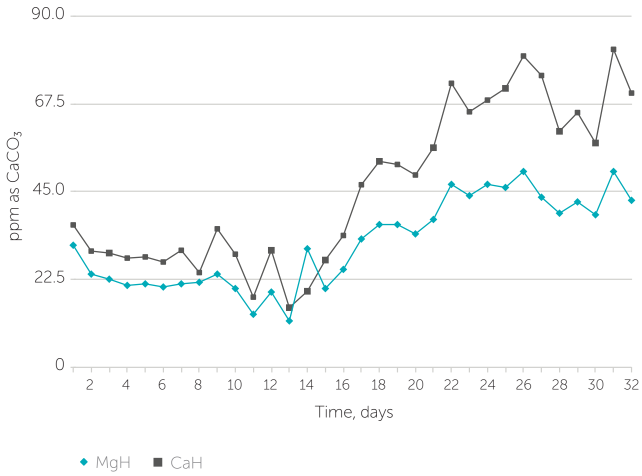
Calcium hardness	12 ppm as $CaCO_3$
Magnesium hardness	8 ppm as $CaCO_3$
Silica	48.5 ppm as SiO_2
Total alkalinity	128 ppm as $CaCO_3$
Chloride	34 ppm as Cl^-
Iron	0.16 ppm as Fe
Specific conductance	240 mmhos
pH	7.8

Treatment and test conditions

HEDP	6.0 ppm active
TTA	2.0 ppm active
PAA	5.0 ppm active
Versaflex® Si silica dispersant	20 ppm active
Biocide	150 ppm 1.5% Isothiazoline slug dosed every 2 days
Temperature	80°F
ΔT	10°F
Circulation rate	720 gpm
Evaporation rate	1008 gpd

The trial schedule was set at seven weeks, with recirculation cycles increasing from 3.0 to 6.0 cycles at the rate of 0.5 cycles per week throughout the trial period. As expected, the hardness of the tower water increased with each recirculation cycle as magnesium and calcium salts (calculated as $CaCO_3$) became more concentrated as shown in Figure 3.

Figure 3: Field trial #1 – hardness



With each recirculation cycle, soluble salts became more concentrated and the tower water showed a rise in both conductivity (Figure 4) and total alkalinity (Figure 5).

Figure 4: Field trial #1 — conductivity

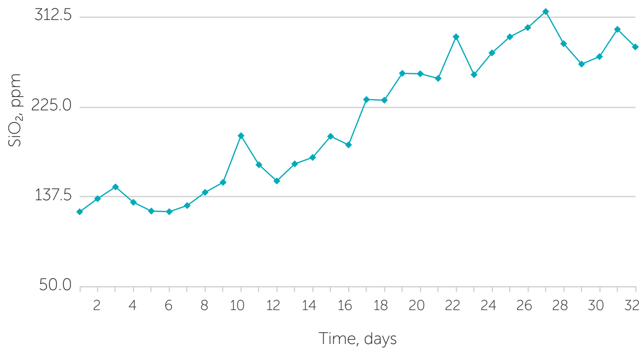
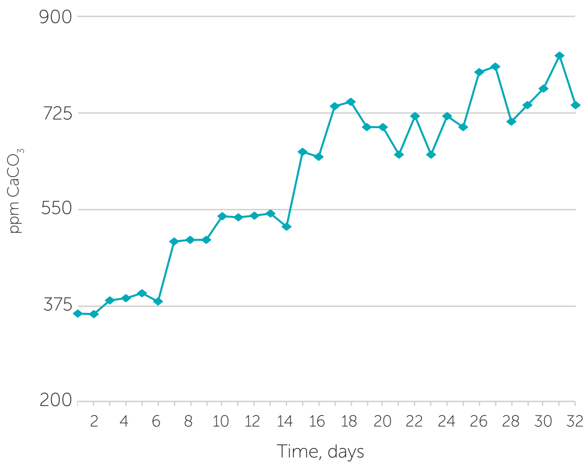
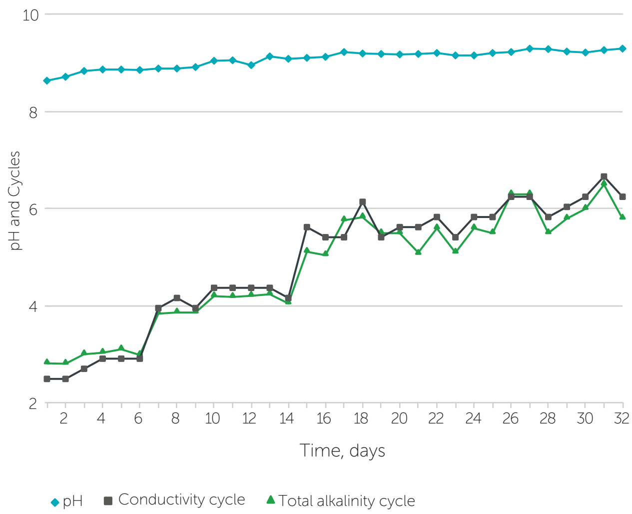


Figure 5: Field trial #1 — total alkalinity



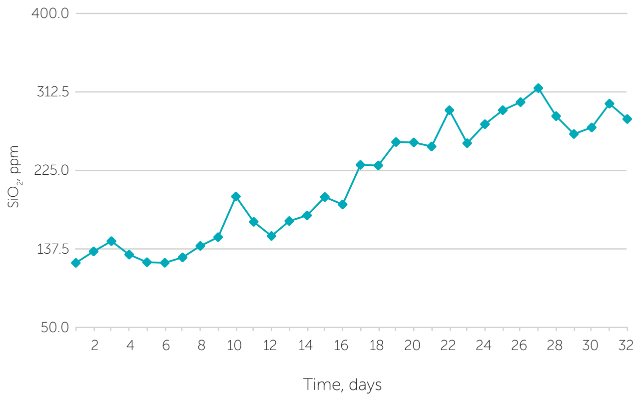
As both conductivity and total alkalinity increased significantly, however, the pH of the tower water increased only slightly as shown in Figure 6.

Figure 6: Field trial #1 – pH vs conductivity/ alkalinity cycles



At the same time, the presence of Versaflex® Si silica dispersant allowed an increase in silica levels in the cooling tower water from 132 ppm to >300 ppm SiO_2 without scale formation as shown in Figure 7.

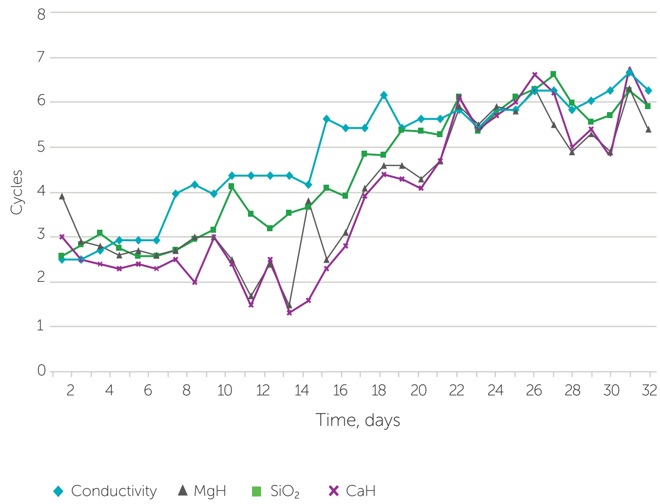
Figure 7: Field trial #1 — silica



This represents an increase in cycles of concentration from 2.8 to 6.5 with 100% silica retention, far exceeding the target performance the project was designed to demonstrate.

In fact, it was observed during the course of the field trial that because of the presence of our Versaflex® Si silica dispersant, the limiting factor of the cooling water began to shift from silica to calcium hardness during severe water conditions as shown in Figure 8.

Figure 8: Field trial #1 — cycles of concentration



This field trial revealed direct cost savings for the system, calculated as follows:

- Makeup water demand reduced by 24%
- Blowdown water (waste water) reduced by 68%
- Treatment usage reduced by 58%

Field trial #2

The second field trial was conducted at a power plant cooling tower plagued with silica fouling problems even though the makeup water contained only 22 ppm SiO_2 and the cooling water was running at 4 cycles of concentration.

Makeup water chemical composition

Calcium hardness	160 ppm as $CaCO_3$
Magnesium hardness	80 ppm as $CaCO_3$
Silica	22 ppm as SiO_2
Total alkalinity	192 ppm as $CaCO_3$
Chloride	112 ppm as Cl^-
Iron	0.01 ppm as Fe
Specific conductance	520 mmhos
pH	6.8

Treatment and test conditions

Equipment	On-site evaporative deposition test rig with automatic acid feed, inhibitor feed and blowdown
Heat exchanger	Copper nickel tube, 145° F skin temperature
Treatment program	Proprietary formula + Versaflex® Si silica dispersant
pH control	7.3–7.8
Test duration	30–90 days

Before the primary test was conducted, an evaporative deposition test was conducted on a side stream using competitive silica dispersant at 25 ppm active, which still produced silica fouling at 4 recirculation cycles. X-ray analysis of the deposit showed its identity and composition to be similar to that of the main plant heat exchanger deposit—i.e., Al, Si, Ca and Fe. This suggested that the deposit was, in fact, aluminum silicate, consistent with airborne dust/dirt/silt caused by frequent dust storms in the desert.

During the primary test, when the system was switched to Versaflex® Si silica dispersant at only 9 ppm active, no apparent deposits occurred either during or after the dust storms. The heat exchanger remained clean even when recirculation was increased from 4 to >6 cycles with half the water velocity over the heated tube. Dispersion of silt at high-dust loadings was seen as a surprising benefit of the silica dispersant.

This field trial exhibited the strength of our Versaflex® Si silica dispersant to:

- Disperse fully any deposits, during and after dust storms
- Require a 60% lower dosage than the competitor
- Maintain a clean system, even at 4 to 6 recirculation cycles

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