Aquatreat® AR-980

Maleic Copolymer

Nouryon

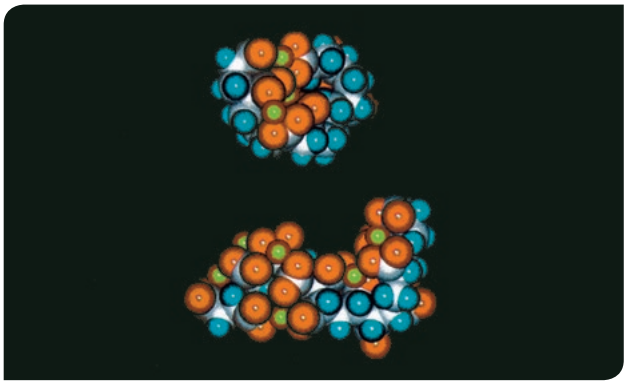
Aquatreat AR-980 maleic copolymer

AQUATREAT AR-980 has been demonstrated to be an effective tool for controlling deposits such as calcium carbonate, calcium sulfate, barium sulfate, silt and silicate salts. The following pages detail the use of AQUATREAT AR-980 for effective deposit control in industrial water systems.

Why should I use a maleic copolymer?

Maleic homopolymers and maleic copolymers are utilized in "stressed" conditions because of their inherent tolerance and continued efficacy in these environments. In high-alkalinity, high-hardness, and/or high-electrolyte environments, polymers such as polyacrylic acids lose functionality. The loss of functionality can be attributed to the polymer "coiling" or "balling." In this configuration, the carboxyl groups on the polymer tend to orient themselves towards the center of the ball. This configuration, in turn, largely leaves the hydrocarbon backbone of the polymer exposed to the surrounding aqueous solvent. The result in the application is a possible loss of the polymer due to precipitation and certain loss of functionality of the polymer. The molecular models (Figure 1) show the effect. The top molecule is a polyacrylic acid homopolymer in the presence of calcium. The bottom molecule is a maleic copolymer in the presence of calcium. It can be seen that the maleic copolymer maintains a more linear configuration. Also, the carboxyl groups are substantially oriented outward. Molecular modeling, applications testing and field use of AQUATREAT AR-980 has demonstrated its ability to maintain functionality in stressed conditions.

Figure 1: The top molecule is a polyacrylic acid homopolymer in the presence of calcium. The bottom molecule is a maleic copolymer in the presence of calcium. It can be seen that the maleic copolymer maintains a more linear configuration.



How does AQUATREAT AR-980 function?

Most low-molecular-weight polymers that are commonly used for cooling and boiler water treatment exhibit functionality for scale and deposit control by three basic mechanisms:

- Threshold inhibition
- Crystal modification
- Particulate dispersion

Threshold inhibition

Threshold inhibition is the ability of a material to maintain the solubility of an otherwise insoluble salt beyond its normal limits. Threshold inhibition differs from chelation because it normally occurs at a sub-stoichiometric level. The following graphs demonstrate the functionality of AQUATREAT AR-980 as a threshold inhibitor for common scales.

Calcium carbonate inhibition

The stressed calcium carbonate test differentiates maleic-containing polymers from polyacrylate homopolymers. This type of evaluation quantitates the amount of inhibited calcium carbonate, dispersed calcium carbonate and adherent calcium carbonate. The data show that polyacrylate homopolymers completely lose efficacy as threshold inhibitors (Figure 2). Both the maleic homopolymer and AQUATREAT AR-980 maintain their ability to act as inhibitors. AQUATREAT AR-980 severely limits the amount of adherent calcium carbonate in the test samples.

Calcium sulfate inhibition

AQUATREAT AR-980 is an excellent choice for systems where calcium sulfate control is required. Figure 3 demonstrates the ability of AQUATREAT AR-980 to inhibit calcium sulfate. Surprisingly, some other maleic copolymers and homopolymers do not exhibit threshold inhibition properties.

Barium sulfate inhibition

AQUATREAT AR-980 was evaluated in a standard laboratory barium sulfate inhibition test at pH 4.5. Results demonstrate that AQUATREAT AR-980 shows good efficacy as an inhibitor. Again, the competitive material does not show efficacy as an inhibitor (Figure 4).

Figure 2: Results of the stressed calcium carbonate evaluation

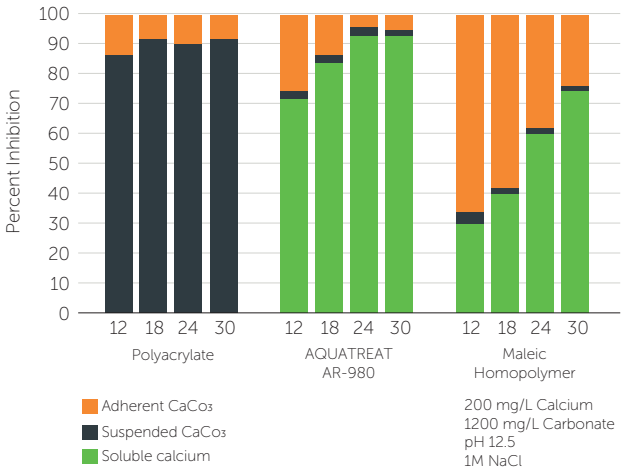


Figure 3: This graph demonstrates the ability of AQUATREAT AR-980 to inhibit calcium sulfate.

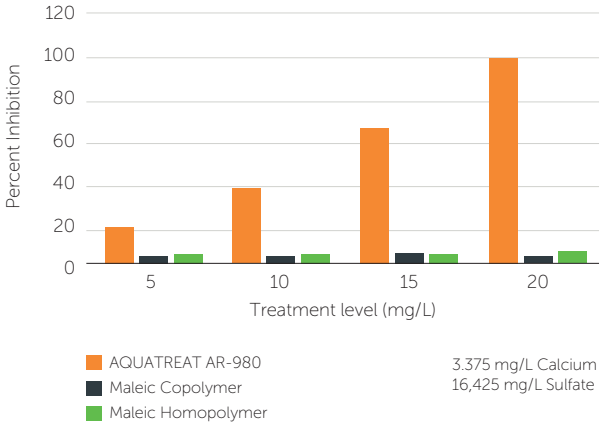
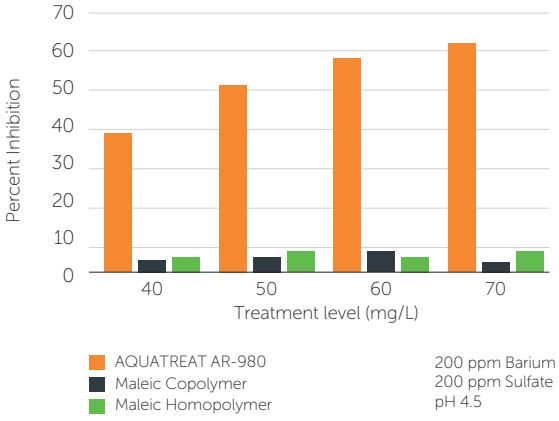


Figure 4: This graph demonstrates the ability of AQUATREAT AR-980 to inhibit barium sulfate.



Crystal modification

The importance of crystal modification is the limitation of adherent and/or agglomerated precipitate. AQUATREAT AR-980 severely modifies calcium carbonate crystal habit. The micrographs to the right are a representation of how polymers can modify crystal morphology to limit adherent deposition. On the top (Figure 5), cubic calcium carbonate (calcite) exhibits a maximum surface area for attachment to other forming crystals or a surface such as a heat exchanger tube. The micrograph in the center (Figure 6) represents calcium carbonate precipitation in the presence of polymer. As shown, the polymer modifies the crystal such that a limited surface area for attachment is available. In particular, calcium carbonate precipitated in the presence of AQUATREAT AR-980 has been shown to form fan- or ribbon-like crystals that emanate from a focal point (Figure 7).

Dispersion

Because of its molecular weight and composition, AQUATREAT AR-980 demonstrates much higher efficacy than common maleic homopolymers for particulate dispersion. AQUATREAT AR-980 is manufactured using a process developed by Nouryon to prepare high maleic-containing polymers using an aqueous route. This process allows the manufacture of much higher molecular-weight maleic products than have been traditionally available.

Figure 5: Calcium carbonate crystals without AQUATREAT

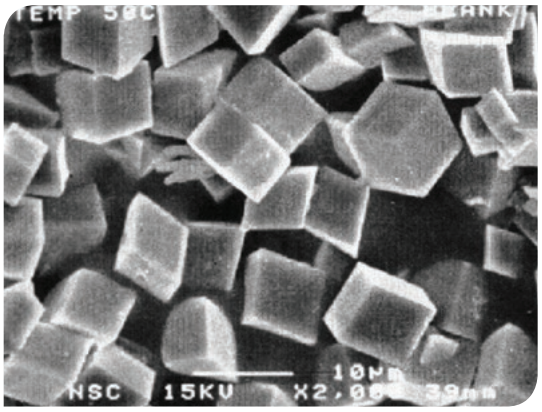


Figure 6: Calcium carbonate crystals treated with AQUATREAT AR-900A

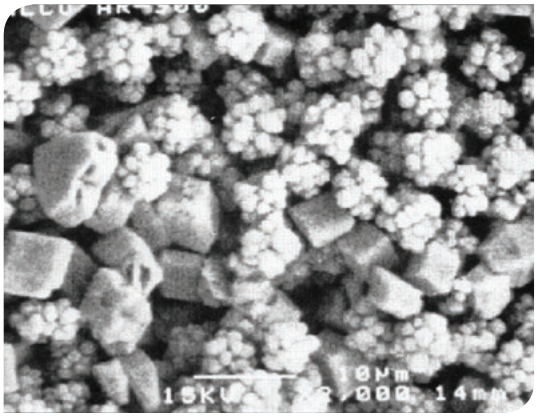
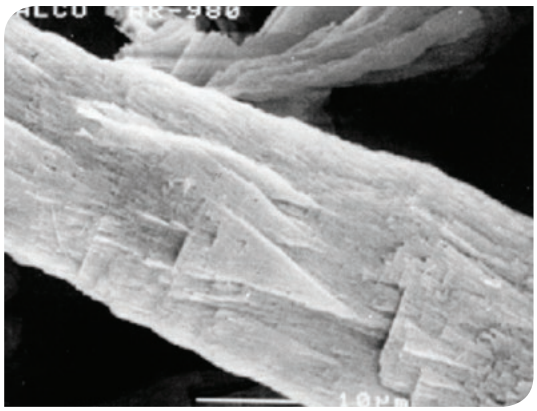


Figure 7: Calcium carbonate crystals treated with AQUATREAT AR-980



AQUATREAT AR-980 maleic copolymer dynamic test results

AQUATREAT AR-980 has been evaluated in a cooling-water treatment program with phosphono-butane tri-carboxylic acid (PBTC) in Nouryon's modern dynamic testing laboratory. The results of the studies demonstrate that a combination of AQUATREAT AR-980 and PBTC is a powerful tool for calcium carbonate control in high-cycle cooling.

In the past decade, PBTC has been established as an excellent product for calcium carbonate threshold inhibition in systems operating at high pH, high hardness or high dissolved solids. In many cases the use of HEDP or AMP are precluded due to characteristics of the water being treated. PBTC maintains stability and high-threshold functionality in many of these systems. AQUATREAT AR-980 is a maleic copolymer that is stable and highly functional in "stressed" or "severe service" applications. In numerous use patterns, AQUATREAT AR-980 has demonstrated an unequaled ability to limit or prevent adherent scale deposition.

The following pages detail a study comparing the use of AQUATREAT AR-980 and PBTC to a commercially available maleic homopolymer under high-cycle conditions.

Test conditions

A blend of AQUATREAT AR-980 and PBTC was compared to a commercially available maleic homopolymer and PBTC alone using Nouryon's non-evaporative dynamic test equipment. The purpose of the experiment was to examine the ability of the treatments to prevent calcium carbonate scaling under severe conditions. The experiment was designed to synthetically cycle the system until treatment failure was observed. The operating conditions were as follows:

Operating conditions

Flow rate	3 gpm
Velocity	3 ft/sec
Heat flux	10,000 BTU/hr/ft^2
Bulk water temperature	90° F
Skin temperature	120° F (estimated)

Water conditions (maximum in feed water)

Calcium	1000 ppm (as $CaCO_3$)
Magnesium	120 ppm (as Mg)
Alkalinity	800 ppm (Total as $CaCO_3$)
Sulfate	200 ppm (as SO_4)
Silica	10 ppm (as SiO_2)
Molybdate	3 ppm (as Mo)
pH	8.6–9.0

Treatment conditions

Treatment #1	10 mg/L (solids) maleic homopolymer
Treatment #2	10 mg/L (solids) AQUATREAT AR-980 3 mg/L (solids) PBTC
Treatment #3	3 mg/L (solids) PBTC

Results

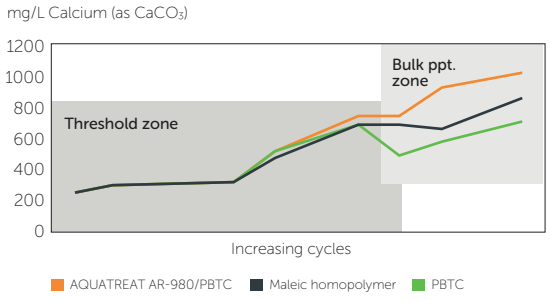
Results show that both the AQUATREAT AR-980/PBTC treatment and the maleic homopolymer treatment effectively prevent calcium carbonate precipitation up to 750 ppm calcium (as $CaCO_3$) at a pH of 8.6–9.0 (LSI + 2.6–2.9). The PBTC-only treatment allowed bulk precipitation to occur below 700 ppm calcium (as $CaCO_3$).

Above 750 ppm, calcium bulk precipitation occurred with each treatment. When bulk precipitation occurred, the AQUATREAT AR-980/PBTC blend prevented adherent deposition of calcium carbonate. Bulk precipitation in the presence of the maleic homopolymer treatment and PBTC-only treatment was extremely adherent to heat exchange, tubing and basin surfaces.

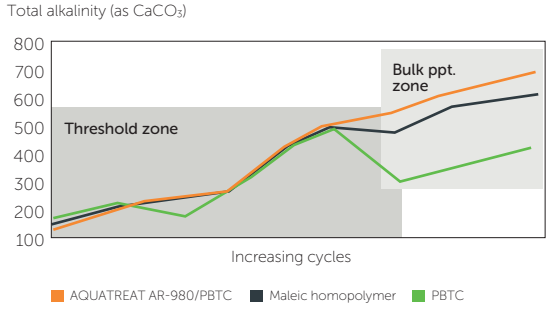
This data confirms previous studies using AQUATREAT AR-980 that demonstrate its ability to severely limit adherent scale in a variety of end uses that require high functionality under extreme conditions.

Figures 9 & 10: These figures show the superior functionality of AQUATREAT AR-980 in severe conditions.

Calcium hardness
pH 8.6-9.0



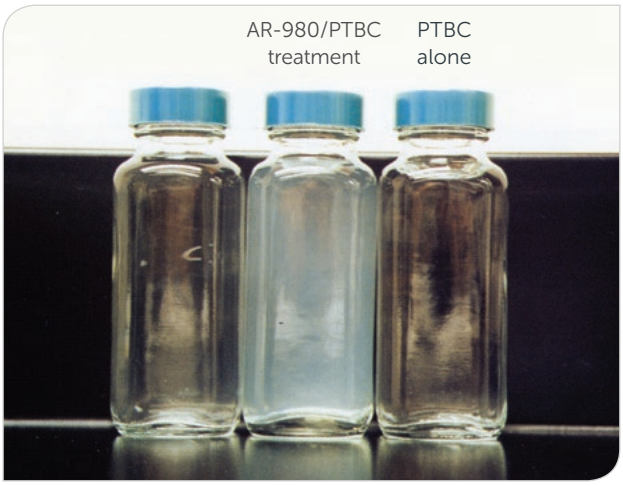
Total alkalinity
pH 8.6-9.0



Turbidity study

Samples of the bulk water were taken from each dynamic test unit when feedwater contained 1000 ppm calcium (as $CaCO_3$). Each unit contained bulk precipitation. However, substantially different results were observed.

Figure 11: Samples from each of the three test units containing separate treatments



The photo above shows samples from each of the three test units containing separate treatments. The bottle on the left contains water from the system treated with a maleic homopolymer. Although the solution in the bottle is relatively clear, substantial bulk precipitation of calcium carbonate had occurred. This precipitate was deposited throughout the system.

The middle bottle contains water from the system treated with AQUATREAT AR-980 and PBTC. It is obvious that there is a significant amount of suspended or dispersed calcium carbonate. Moreover, this treatment eliminated adherent deposits from surfaces in the system.

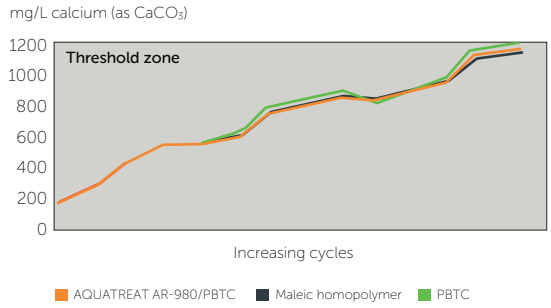
The third bottle contains water from the system treated with PBTC alone. Again, the sample is essentially clear with no visible precipitate. However, the result is the same as the water treated with maleic homopolymer. A substantial amount of adherent calcium carbonate deposition was present throughout the dynamic test unit.

Dynamic testing at lower pH

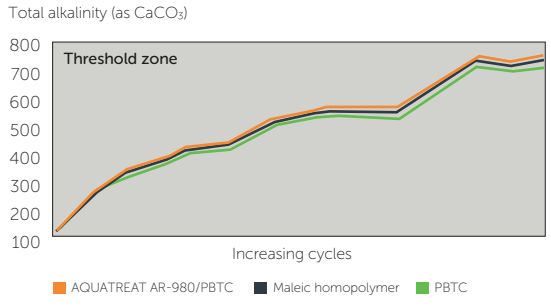
The same treatments were evaluated at a lower pH to determine the ability of each to maintain solubility of calcium carbonate. In this evaluation, all treatments maintained calcium carbonate up to 1250 ppm calcium (as $CaCO_3$) or an approximate LSI of 2.5.

Figures 12 & 13: These graphs show the same treatments being evaluated at a lower pH level to determine the ability of each to maintain solubility of calcium carbonate.

Calcium hardness
pH 8.3



Total alkalinity
pH 8.3



Summary of dynamic testing

AQUATREAT AR-980 and PBTC in "stressed" cooling water

- Effective control of calcium carbonate under high-cycle/high-LSI conditions
- Possible elimination of acid feed
- Operation at very high cycles when using acid feed
- Protection from adherent deposition when acid feed temporarily lost
- Scale control via threshold inhibition, crystal modification and dispersion
- Cost-effective treatment versus existing formulations

Storage and handling

AQUATREAT products are available in bulk, intermediate bulk and 55-gallon drums. The standard drum is fiber with 525 pounds net. Plastic drums are also available. AQUATREAT polymers have very low toxicity. Consult product MSDS for further information. Contact with the skin or eyes should be avoided. If an AQUATREAT product contacts the eyes, flush with water. If redness or sensitivity occurs and persists, consult a physician. AQUATREAT polymers should be shipped and stored in 304 stainless steel or better, fiberglass or plastic tanks. Certain phenolic linings are acceptable for use in drums and storage tanks. Mild steel, copper, brass and aluminum should not be used. The above materials of construction also apply to all pipes, valves and pumps used in the application or transport of AQUATREAT polymers.

Contact us directly for detailed product information and sample requests.

USA and Canada
Chicago, USA
T +1 800 906 9977

South America
Itupeva, Brazil
T +55 11 4591 8938

Central America and Caribbean
Mexico City, Mexico
T +52 55 5261 7895

China
Shanghai, China
T +86 21 2220 5000

South East Asia
Singapore
T +65 6635 5183

India
Mumbai, India
T +91 22 6842 6700

Europe
Stenungsund, Sweden
T +46 303 850 00

Middle East
Dubai, United Arab Emirates
T +971 (0) 4 2471500

Russia
Moscow, Russia
T +7 495 766 1606

About Nouryon

We are a global specialty chemicals leader. Markets worldwide rely on our essential chemistry in the manufacture of everyday products such as paper, plastics, building materials, food, pharmaceuticals, and personal care items. Building on our nearly 400-year history, the dedication of our 10,000 employees, and our shared commitment to business growth, strong financial performance, safety, sustainability, and innovation, we have established a world-class business and built strong partnerships with our customers. We operate in over 80 countries around the world and our portfolio of industry-leading brands includes Eka, Dissolvine, Trigonox, and Berol.

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