White Paper

A Reliable Alternative to Conventional Scale Control

FlowScience

FlowScience represents the most advanced physical water treatment system available. It is the result of continued research to better understand the science and practice of physical water treatment. There are many physical water treatment devices on the market today. Some work quite well, while others seem to work some of the time and still others are outright fraudulent. In nearly all cases, the explanations given for how these systems work are not supported by actual science or true research. This misinformation has been the cause of industry mistrust as well as leading manufacturers of these devices to misapply their products.

The following information is a factual accounting of how FlowScience can be of benefit in controlling scale.

Understanding Calcium Carbonate

Calcium carbonate is found in nature as limestone, marble and sea shells. Calcium carbonate is largely responsible for the formation of pipe scale. In order to fully understand how FlowScience can control calcium carbonate scale, one must first have a basic understanding of how calcium carbonate behaves in water. Calcium carbonate ($CaCO_3$) is an inverse solubility salt, meaning that less of it will dissolve in hot water than in cold water. This is not what one would normally expect to see when dissolving something in water.

> Take table salt (sodium chloride – NaCl) and dissolve as much as you can in cold water. This is now called a saturated salt solution. Now heat that same water over the stove and you will be able to dissolve much more salt. If one now takes the hot, saturated salt solution and cools it on ice, the solution will first become supersaturated and then one will see a large number of small salt crystals forming and falling out of solution (this process is called precipitation).

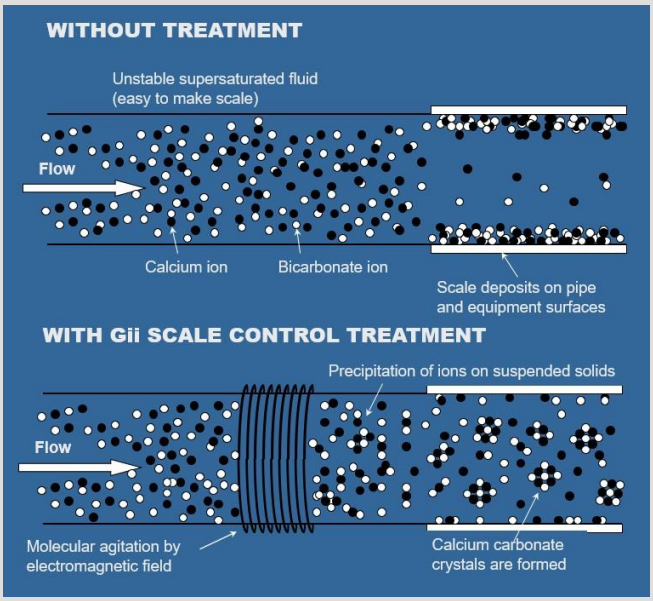
The inverse solubility of calcium carbonate is what makes it most troublesome. The calcium carbonate will precipitate and scale the warmest spots in the system where heat transfer is taking place. Problems occurring with scaling of tubing, pipes, boilers, coils, cooling towers, heat exchangers, or wherever industry is forced to use heated hard water, cost billions of dollars every year in excess energy usage.

At a Glance

Controls the Formation of Scale

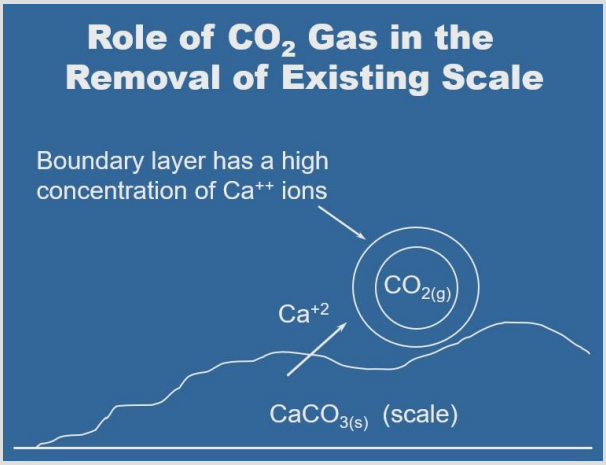
The FlowScience system uses advanced signal generating technology applied to water via proprietary web induction treatment pads that are attached to piping, pumps or custom designed reaction chambers. This technology produces an electrically generated surface active catalytic effect in water that neutralizes the natural charge of suspended solids.

The technology, in effect, creates billions of available nucleation sites out of the suspended solids in the water that were previously unavailable due to their natural charge. When nucleation occurs, the dissolved calcium carbonate follows a path of least resistance by precipitating as microscopic seed crystals onto the suspended solids that are in solution with it and travelling at the same rate, rather than onto static piping or equipment surfaces.



Dissolves and Eliminates Existing Scale

In addition to controlling the formation of new scale, the FlowScience system provides two functions that allow existing mineral scale deposits to be gradually softened and removed:



1. The precipitation reaction previously outlined above transforms the previously supersaturate solution into a lesser or undersaturated solution that has greater ability to dissolve existing calcium carbonate scale and carry it in solution.

2. Descaling can also be attributed to the liberation of dissolved CO_2 from leachate solution as CO_2 nanobubbles. These nanobubbles have a localized low pH in the range of 4 to 4.5. Physical contact of the acidic bubbles with existing scale promotes a carbonic acid affect that softens existing deposits. These bubbles have little affect on the bulk pH solution.

The Carbon Dioxide Key

Calcium carbonate is so insoluble (does not dissolve) in pure water that only about 0.6 ppb (0.0006 ppm) will go into solution [ppb = part per billion, ppm = part per million]. If that is the case, how can we have hard water with over 171 ppm (10 grains per gallon) calcium carbonate? The secret lays in the roll carbon dioxide gas (CO2) plays. Some of the carbon dioxide that is in the air dissolves into the water that falls as rain. This dissolved carbon dioxide makes a very unstable acid called carbonic acid (the same acid found in carbonated water and soft drinks).

CO_2 (dissolved) + $H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow 2\ H^+ + CO_3^{2-}$

carbon dioxide	water	carbonic acid	hydrogen ion	bicarbonate ion	carbonate ion

NOTE: double arrows {↔} indicate the reaction can go in either direction.

Carbonic acid instantly dissociates in water to form the negative bicarbonate (HCO_3^-) and carbonate ions (CO_3^-). The forming of carbonic acid when carbon dioxide in the air dissolves in water is the key to dissolving calcium carbonate. It is also the key to why water solutions of calcium bicarbonate will cause scale to form when heated instead of dissolving additional calcium carbonate. In summary, the combination of limestone, water and carbon dioxide results in significant quantities of calcium ions in solution.

The complex process of dissolving of calcium carbonate in limestone is summarized in the simplified reaction shown below.

$CaCO_3 + CO_2 + + H_2O \leftrightarrow Ca^{2+}_{(aq)} + 2HCO_3^-{}_{(aq)}$

calcium carbonate limestone	dissolved carbon dioxide	water	calcium ion	bicarbonate ion

While calcium carbonate is extremely insoluble, calcium bicarbonate is extremely soluble and will easily dissolve in water. The hydrogen ions (H+) produced by dissolving carbon dioxide react with the carbonate of calcium carbonate forming the very soluble calcium bicarbonate and thus the limestone dissolves. Because this reaction can be easily reversed, the dissolved limestone can be deposited in other places as scale deposits.

Bicarbonate Ion Decomposition

The bicarbonate ion is destroyed by heat. Heat causes increased molecular agitation and provides increased chances for two bicarbonate ions to react releasing carbon dioxide gas, water and forming the carbonate ion (see equations below). The carbonate ion will immediately combine with any calcium ions present to form solid calcium carbonate. This is why scale forms easiest on heated surfaces and in hot water pipes.

$$2HCO_{3\,(aq)} \xrightarrow{\Delta(\text{heat})} CO_2\uparrow + CO_3^-$$

bicarbonate ion	carbon dioxide (g)	carbonate ion

$$Ca^{2+}_{(aq)} + CO_3^{2-} \rightarrow CaCO_3\downarrow$$

calcium carbonate (s)

Treatment with FlowScience

Electronically Generated Seed Crystals

Another way to cause the same decomposition of bicarbonate and form solid calcium carbonate is to use electrical energy instead of heat energy. As in the case of heat, a pulsing electrical field of the correct frequency and amplitude can agitate the bicarbonate ions increasing the likelihood of reacting as illustrated above. In addition, the electrical field neutralizes some of the static charge which naturally occurs on suspended solids (dirt) making these particles preferential sites for precipitation of dissolved minerals. The result is that microscopic seed crystals are formed in the flowing water instead of directly on surfaces as scale. The seed crystals do not attach to the areas of localized high energy, because, unlike the case of a hot surface, by the time the seed crystal is formed the energy is no longer present to attract more ions to continue the process.

Crystal Seeding Prevents Scale Formation

The microscopic seed crystals formed by the FlowScience electrical fields flow with the water throughout the system. As the seed crystals enter areas of heat, high pH or turbulence (nucleation sites) where calcium carbonate will normally form scale, the precipitating calcium carbonate will preferentially attach itself to the existing seed crystals instead. In this way the seed crystals flow along with the water instead of attaching to surfaces. This mineral material is now a suspended solid not a dissolved solid and may settle and collect in quiescent areas such as sumps or pits. It is advisable to remove this loose sludge like material via filtration or some other physical means. If left to accumulate in large quantity it can impact and harden which will make removal more difficult.

Removal of Existing Scale

When the bicarbonate ion is decomposed by the intense localized electric fields produced by FlowScience, microscopic bubbles of carbon dioxide gas are transported downstream along with the seed crystals produced. Some of the microscopic bubbles will come in contact with existing scale and react with it to form the very soluble calcium bicarbonate. This material is gradually stripped away by the water flow.

Advantages of FlowScience Systems

In summation, we wish to present a listing of some of the many advantages to using FlowScience LSC treatment system instead of normal chemical-based systems:

- Eliminate the need for mechanical or acid cleaning
- Requires less frequent inspections
- Less on-site chemical analysis required
- No MSDS sheets and hazardous waste paperwork to maintain
- No chemical movement or storage requirements (especially nice for roof top installations)
- No spills of hazardous materials to report
- Less chance to injure employees or guests
- No complex injection pumps to maintain
- Provides a cost-effective solution to water treatment that results in a significant payback