ELECTROCHEMICAL WATER CONDITIONING

Operation of the Catalytic Water Conditioner

Technical Data

1.0 Introduction

1.1 Overview of Water Treatment Methods

Water treatment technologies in the United States and most other developed countries have evolved to their present levels of sophistication from their early beginnings on the basis of methodologies involving chemical additives that cause desirable reactions to occur in accordance with well-known classical textbook equations or involving ion-exchange and deionization techniques. These water technologies have provided, for the most part, satisfactory results in the industrial world when coupled with relatively complex and extensive maintenance and servicing programs. This success may be the main reason for the virtual absence of scientific research on alternate water treatment approaches.

Some research, however, has been accomplished on the magnetic treatment of water. The primary initial research in this area has been pursued mostly by European scientists (primarily in Russia) with the bulk of that research being done between 1950 and 1980. Users' field results with magnetic conditioners in Europe and the U.S. have been somewhat inconsistent although there have been many reports of outstanding effectiveness and cost savings. The magnetic treatment effects on water solutions are relatively transient, however, lasting for a maximum of about 72 hours. Water treatment with a patented metallic catalyst has been in successful use since the early 1950's but has only in the last few years been developed to its present state of effectiveness and efficiency.

The effects of catalytic alloy treatment are considerably more profound and longer lasting than the effects of magnetic water treatment although there appears to be some commonality in the chemical principles that are utilized by both of these methods. There are also effects produced by the catalytic method which are not claimed by manufacturers of the magnetic devices. The 'magnetic method' generates a magnetic field to electromagnetically induce ionic and molecular changes in the water solution. The catalytic alloy method applies the catalytic properties of several different metallic elements through reduction-oxidation reactions to produce electrochemical changes to the ions and molecules in the water through direct contact with these substances in the water solution.

1.2 Common Types of Scale in Plumbing Systems

The two most common forms of scale consist mainly of:

1. Calcium carbonate (CaCO3) and magnesium carbonate (MgCO3) (with binders). This forms in hot water heaters, boilers, valves, sinks, shower enclosures, etc.

2. Rust (in galvanized pipes) or corrosion (in/on copper, brass, aluminum, or chrome).

In order to understand the process by which the Catalytic Conditioner inhibits scale buildup (commonly called "lime" or "rust") and the way in which it breaks down and eliminates existing scale, it is necessary to understand the nature of scale and how it is formed.

2.0. The Nature of Calcium Carbonate and Magnesium Carbonate Scale (with Binders)

Calcium carbonate, CaCO3, exists in nature as limestone and marble. Silica (SiO2), alumina (Al2O3), and calcium sulfate (CaSO4) are principal impurities in limestone and function as binders (cementing agents). Large deposits of magnesium carbonate, MgCO3, exist in nature with calcium carbonate in the form of dolomite, CACO3 - MgCO3, or as magnesite, MgCO3. Limestone layers even in high Centralous regions such as the Grand Canyon in Arizona, which has a depth of over one mile, were each formed over millions of years from remains of sea creatures precipitated to the bottom of the ocean where the CaCo3 contained in these remains combined with silica (SiO2), alumina (A12O3), and/or clay (SiO2 - A1203 - 2 H2O), which serve as binders. In addition, limestone usually includes some MgCO3. In the case of the Grand Canyon, scientists have identified at least seven different limestone layers, each containing shells of marine animals, indicating that the region has been covered by at least seven different oceans in its geological history.

CaCO3 is only very slightly soluble in water, yet large amounts of calcium become dissolved in most water supplies by the action of rain water on limestone. Rain water is somewhat acidic because as it falls through the atmosphere, it encounters carbon dioxide (CO2) with which it reacts to form carbonic acid (H2CO3) as follows:

H2O +CO2 ------> H2CO3

When rain water contacts limestone in the earth, limestone material is dissolved and goes into solution as calcium bicarbonate as follows:

CaCO3 + H2CO3 -----> Ca++ + 2 HCO3-

The carbonic acid ionizes slightly:

H2CO3 <-----> H+ + HCO3-

Since the ionization constant of HCO_3^- is very small,

$$KI = \frac{[H^+] \times [CO_3^{--}]}{[HCO_3^-]}$$

The addition of H^+ ions from the carbonic acid reduces the concentration of CO_3^{--} (ions that go into solution in the water from the $CaCO_3$ solid) because the H^+ ion and the CO_3^{--} ion combine to form the slightly ionized bicarbonate ion, HCO_3^-. The reduction of the concentration of the CO_3^{--} ion in the solution causes more $CaCO_3$ to dissolve in the form of $Ca(^{++}) + 2\,HCO_3^-$ in an attempt to saturate the solution and produce a product of the concentrations of Ca^{++} and CO_3^{--} ions that equals the solubility product.

$[Ca^{++}] \times [CO_3^{--}] = K_{sp} = 1 \times 10^{-9}$ at 25_C.

Surface waters also dissolve carbon dioxide from soils where it is produced by the slow oxidation and decay of organic materials. As these waters contact limestone, the limestone gradually dissolves. Examples of this action are limestone caves and hard waters from wells.

The $Ca(^{++}) + 2\,HCO_3^-$ that is dissolved in water very readily converts into $CaCO_3$ when water is heated to boiling. The solubility of $CaCO_3$ decreases with increase in temperature and precipitates as $CaCO_3$ as follows:

Heat

$$Ca(^{++}) + 2\,HCO_3(^-) \longrightarrow CaC0_3 + H_2O + C0_2$$

This is the basic reaction that forms the bulk of the 'lime' in water heaters and boilers. This reaction also occurs when water containing $Ca(HCO_3)_2$ evaporates and leaves a $CaCO_3$ residue. The above mentioned reactions also apply to magnesium and its bicarbonates and carbonates.

For example:

$$MgCO_3 + H_2CO_3 \longrightarrow Mg(^{++}) + 2\,HCO_3^-$$

However, $MgCO_3$ is appreciably more soluble than $CaCO_3$.

$$[Mg^{++}] \times [CO_3^{--}] = K_{sp} = 1 \times 10^{-5} \text{ at25\_C}$$

Scientists and engineers who have investigated scale formation in various industrial systems have determined that although $CaCO_3$ and $MgCO_3$ form most of the mass of lime-type scale, they require silica (SiO_2), alumina (Al_2O_3), or calcium sulfate ($CaSO_4$) to act as a binder to hold them in place just as they do in nature.

$CaSO_4$ exists in ionized form when dissolved in water as the ions Ca^{++} and SO_4^{--}. The solubility of $CaSO_4$ increases with temperature up to about 100_F and then decreases with increasing temperature. Hence, precipitation of $CaSO_4$ also occurs in water heaters and boilers.

SiO_2 and Al_2O_3 are not ions but are relatively neutral colloidal residues that are slightly soluble in water. SiO_2 is found in fresh water in a range of 1 -100 mg/liter. At high concentrations (over 50 mg/liter), chemical precipitation appears to occur.

Colloids, including SiO_2, Al_2O_3, and clay (SiO_2 - Al_2O_3 - 2 H_2O), when suspended in water usually carry a negative charge. If these negative charges (extra electrons) are neutralized (extra electrons removed), the colloids coagulate, precipitate, and combine with (i.e., become absorbed by) $CaCO_3$, $MgCO_3$, and $CaSO_4$ to form typical lime scale. The denseness and hardness of the scale increases with increased concentrations of SiO_2, Al_2O_3, and/or $CaSO_4$.

Approximately 87 percent of the earth's solid crust consists of silicon compounds. Silica is one of the most abundant compounds of silicon. Aluminum is the most abundant metal and the third most abundant element. The most important ore of aluminum is bauxite, a mixture of hydrated aluminum oxide, Al_2O_3 + 3 H_2O, and iron oxide. Calcium is fifth in abundance of the metals in the earth's crust, of which it forms more than 3 percent.

3.0 How the Catalytic Water Conditioner Functions to Prevent Lime Scale Formation and to Dissolve Existing Scale

The Catalytic Water Conditioner consists of many semi-precious metals that form a special electrochemical catalyst. In addition, the core includes multiple venturis configured to prevent flow restriction while providing a high degree of turbulence and increased physical contact between: (1) the ions and molecules in the water; and (2) the core itself, thereby increasing catalytic efficiency.

3.1 Why the Catalytic Water Conditioner Core Acts as a Catalyst

All metals give up electrons in their outer atomic shells easily. For this reason, metals are good or excellent electrical conductors. Of all non-radioactive metals, cesium is the least electron acquisitive; it has an-electronegativity of 0.7 on the Electronegativity Scale of the Elements. Gold is the most electron-acquisitive of the metals and has an electronegativity of 2.4 on the Electro negativity Scale. The higher the electronegativity, the more acquisitive the element (atom) is concerning electrons for its outer shell to satisfy its own valence.

The most aggressive (electron-acquisitive) elements arc the following and arc all nonmetals.

ELEMENT	SYMBOL	ELECTRONEGATIVITY
Fluorine	F	4.0
Oxygen	O	3.5
Chlorine	Cl	3.0
Nitrogen	N	3.0
Bromine	Br	2.5
Carbon	C	2.5
Sulfur	S	2.5
Iodine	I	2.5
Selenium	Se	2.4
Hydrogen	H	2.1

The least aggressive (electron-acquisitive) elements are metals and include:

ELEMENT	SYMBOL	ELECTRONEGATIVITY
Gold	Au	2.4
Silver	Ag	1.9
Copper	Cu	1.9
Silicon	Si	1.9
Nickel	Ni	1.5
Cadmium	Cd	1.7
Zinc	Zn	1.6
Tantalum	Ta	1.5
Aluminum	Al	1.5
Manganese	Mn	1.5
Magnesium	Mg	1.2
Calcium	Ca	1.0
Strontium	Sr	1.0
Lithium	Li	1.0
Sodium	Na	0.9
Barium	Ba	0.9
Radium	Ra	0.9
Rubidium	Rb	0.5
Potassium	K	0.5
Cesium	Cs	0.7

Other common elements range in electronegativity between these high and low groups. The greater the separation of two elements on the Electronegativity Scale, the greater is the strength of the bond between these two elements.

3.2 Relative Electronegativities of the Catalytic Water Conditioner and the Water Solution

The electronegativity of the Catalytic Water Conditioner alloy is less than the overall electronegativity of the water solution. Therefore, the core loses (gives up) more electrons than it acquires to elements such as hydrogen (H+) ions which have an electronegativity of 2.1 and to ionic compounds (radicals) such as SO4-- and CO3-- which have higher electronegativities than the core alloy.

The relatively large distances between the nucleus and the electrons of atoms have been described as follows: If an atom were as large as a house, its nucleus (which is positively charged) would be about the size of the period at the end of this sentence, or a pin head, and its outer-shell electron orbits would be out where the walls of the house are.

The electrons (which are negatively charged) would be smaller than specks of dust that float in the air. When bonded with another atom(s), the outer orbital shell is pulled out into an egg shape even beyond the boundaries of the walls of the house because of the attraction of the other atom(s).

When water is in the form of ice, the molecules and ions in it are held in a relatively rigid pattern. But in the liquid state, this structure becomes a dynamic, whirling, chaotic dance in which groups of molecules and ions in the solution take turns whirling about one another, breaking their bonds, and finding new groups to find partners with. When water rushes through the Catalytic Water Conditioner, the pattern becomes even more frenzied; an electron orbits and associated bondings undergo increased perturbations and stresses, and additional electrons from the Catalytic Water Conditioner core are attracted into the water solution.

3.3 Verifiability of the Relative Electronegativities of the Catalytic Water Conditioner Core and the Water Solution

The loss of electrons by the Catalytic Water Conditioner to the water solution is easily verifiable by: (1) adapting a Catalytic Water Conditioner to a garden hose; (2) turning on the hose faucet; (3) connecting the positive lead of a multimeter to the Catalytic Water Conditioner case; (4) inserting the negative lead probe into the water stream; and (5) observing a voltage drop. (In this test do not jumper the Catalytic Water Conditioner to earth ground.) The fact that the Catalytic Water Conditioner goes positive with respect to the outlet water stream indicates that electrons are being removed from the Catalytic Water Conditioner by the water solution as it flows through the Catalytic Water Conditioner. Properly installed to service a water system, the Catalytic Water Conditioner has its case well grounded either by direct contact with the earth in an underground installation, via the connected copper pipe in above-ground installations, or by a grounding wire clamped to the Catalytic Water Conditioner and to an earth ground point for above-ground wire clamped to the Catalytic Water Conditioner and to an earth ground point for above-ground installations in plastic pipe or galvanized steel pipe (dielectrically isolated). This grounding is necessary to ensure that the Catalytic Water Conditioner has an adequate supply of electrons to transfer to the water solution. Waters with heavy electrolyte concentrations are able to provide sufficient conductivity to enable the

Catalytic Water Conditioner to function satisfactorily even when installed in a way in which it is dielectrically isolated from ground by plastic. However, grounding of the brass casing is recommended in all cases to ensure operation at peak efficiency because grounding will provide a more direct source of electrons with a minimum of electrical resistance.

3.4 The Electromotive Series

In Section 3.2, the electronegativities of various elements were listed to indicate their relative potentials or dispositions regarding electron acquisitiveness. Electron acquisitiveness can be regarded as "reduction potential." Reduction of an element occurs when its valence becomes more negative (or less positive); for example, in the reaction

$$e^- + C12 + H_2O \text{ ----->} HOCI^- + Cl^- + H^+$$

one atom of Cl_2 is reduced to Cl^-. Oxidation, which is the opposite of reduction, occurs to an element when its valence becomes more positive (or less negative); for example, in the reaction

$$2Cl(-) \text{ -----> } Cl_2 + 2e^-$$

2 Cl^- is oxidized to 2 Cl^0 to provide chlorine gas plus two electrons which are available (or can be made available) for reduction of another substance in the solution or circuit.

The Electromotive Series is a listing of elements and compounds rank-ordered according to their oxidation potentials or dispositions regarding electron relinquishment (or their tendency to lose electrons). The higher or more positive the oxidation potential of an element, the better the element is as a reducing agent. The following is a partial listing of the Electromotive Series.

OXIDATION POTENTIAL (VOLTS)
REACTION AT 1 MOLE CONCENTRATION
LiO -----> $Li^+ + e$-----> +3.05
$Ca\_$ -----> $Ca^{2+} + 2e$-----> +2.76
NaO -----> $Na^+ + e$-----> +2.71
MgO -----> $Mg2 + 2e$-----> +2.37
$Al0$ -----> $Al^{3+} + 3e$-----> +1.66
$Zn\_$ -----> $Zn^{2+}+2e$-----> +0.76
FeO -----> $Fe(++) + 2e$-----> +0.4 4

$H_2 + 2\ H_2O\_\ 2\ H_3O^+ + 2e$-----> 0

$Cu0$ ----->$Cu(++) + 2e$-----> -0.34

OXIDATION POTENTIAL (VOLTS)
REACTION AT 1 MOLE CONCENTRATION
2I- -----> I2 + 2e-----> -0.54
AgO -----> Ag+ + e-----> -0.80
HgO -----> Hg32++2e-----> -1.09

6 H2O -----> -----> O2 + 4 H3O+ + 4e-----> -1.23
2 Cl- -----> Cl2 + 2e-----> -1.36
2F- -----> F2+ 2e-----> -2.87

The Electromotive Series and the Electronegativity listings provide fundamental frames of reference and some insight into: (1) the many ways in which the elements can interact with each other; (2) why they interact as they do; (3) under what conditions changes or reactions will occur or will not occur; and (4) the reasons that metals can function as catalytic water conditioning agents.

3.5 The Addition of Electrons to the Water Solution and Their Effects on Scale

Electrons are drawn into the water solution because the solution contains ions that are more electronegative than the Catalytic Water Conditioner. Or in terms of the Electromotive Series, the Catalytic Water Conditioner contains elements which have higher oxidation >n potentials than ions in the water solution. As the water flows through the Catalytic Water Conditioner, some of the electrons drawn into the solution displace some already captured by ions such as CO3(--), HCO3(-), SO4(--), and OCI- during the turbulent orbitings of the various electrons. This allows the "displaced" electrons to become "free electrons" in the solution and these "free electrons" can be captured by ions or colloids with lesser electronegativities such as Ca++ and Mg++ to free themselves of CO3--, SO4--, and HCO3-, and assume their neutral atomic structures (Ca and Mg) and break away from their ionic bonds while in solution or from lattice scale bonds in cases where they are in solid, precipitated or scale form. The increased electron count in the water also inhibits the breakdown of the bicarbonate ion into H+ and CO3-- when heated in water heaters and boilers or when alkalinity reaches Levels above pH 8.4.

By acquiring or reacquiring a negative charge, colloidal substances such as silica, alumina, and rust particles remain in suspension instead of becoming absorbed onto calcium, magnesium, and iron ions; the acquisition of the negative charge also causes these colloidal substances to be repelled from these ions in the flowing water if they were already absorbed onto them. This separation inhibits the hardness effects of these three ions; hardness in water is always due to the presence of Ca++, Mg++, and/or Fe++ ions.

The silica and alumina are also able to escape from existing scale lattices to which they have been absorbed and for which they have been functioning as binders. Thus, the scale lattices are gradually broken down and eliminated by the escaping Ca and Mg elements and negatively charged SiO2(-) and A12O3(-) colloids.

The inhibiting effects of the Catalytic Water Conditioner on scale formation can be summarized as follows:

(1) Ca2+ + 2e-----> -----> Ca
(2) Mg2+ + 2e-----> -----> Mg
(3) xSiO2 + xe-----> -----> xSiO2(-)
(4) XAl2O3 +xe-----> -----> xAl2O3
(5) xFe2O3+ xe-----> -----> xFe2O3

6) 2 HCO3- + xe-----> Heat -----> 2 HCO ----> +

(inhibition of the CO3-- + H2O + CO2 reaction)
The inhibiting effects in heaters and boilers can be summarized as follows:
(7) Ca + 2 HCO3- Heat -----> Ca + H2O + 2CO2

(8) 2 CO3(--) + Heat -----> 2 CO2 + O2 + 4e

(9) 2 HCO3- + xe-----> Heat -----> 2 HCO +

(inhibition of break down to CO3(--) ----> + H2O + CO2)
(10) Al203 (----->) + SiO2(-) Heat -----> Al2O3 (----->) + Sl02(-)
(remain in suspension as colloids)

(11) Ca(++) + SO4-- + Heat -----> Ca(++) + S02(--) O2

(precipitation of CaSO4 is inhibited)

(12) Fe2O3(----->) Heat -----> Fe2O3(----->)

(Remains in suspension as a colloid)

The scale dissolving effects in water heaters, boilers, pipes, valves, and other plumbing or agricultural irrigation components are summarized by the following simplified equation:

(13) CaCO3 - CaSO4 - SIO2 - MgCO3 - A12O3 - Fe2O3 + 9e- .- 2 Ca_ + MgO + 2 CO32- + SO42- = SiO2(-) + Al2O3 ( ) + Fe2O3( )

+The acquisition of one or two electrons by a calcium ion (Ca++) will immediately cause other substances to bond with it. A typical reaction is:

(14) q Ca_ + r Ca(++) + s H2O -----> t Ca(OH)2 + u Ca(OH)+ + v H+,

where the H+ and OH- ions are derived from H2O molecules. The H+ ions are very useful in the breaking down of calcium carbonate.

If small or weak concentrations of the hydrogen ions are added to the water solution, carbonate ions are removed by the formation of bicarbonate ions.

(15) $H^+ + CO_3^{2-} \text{----->} HCO_3$

The bicarbonate ions are then decomposed by the hydrogen ions as follows:

(16) $H^+ + HCO_3^- \text{----->} H_2O + CO_2$

The $Ca(OH)^+$ formed in equation (14) will probably bond with an electronegative ion or radical, or with a colloid with a negative charge, but will probably remain in solution instead of forming part of a precipitate. The $Ca(OH)_2$ formed in equation (14) tends to precipitate but its solubility is approximately 40 times greater than that of $CaCO_3$. Hence, in view of the relatively slow rates at which the Ca_ and Ca(+) is formed, and the proportionally slow rates at which the $Ca(OH)_2$ are formed, it is highly unlikely the concentration of $Ca(OH)_2$ in water heaters and boilers (and even in cold water circuits) will reach levels where precipitation will occur.

The solubility of $Ca(OH)_2$ at 100° C is 0.77 gram per liter; for $CaCO_3$ it is 0.0190 gram per liter at 75° C. At 25° C the solubility of $Ca(OH)_2$ is 1.85 grams per liter; for $CaCO_3$ it is 0.0153 gram per liter at 25° C.

Conditioned water that has dried on surfaces exposed to air will leave water spots due to the minerals in the water just as soft water conditioners will leave sodium spots), but these spots are easily removed with a damp cloth and do not leave hard water stains. This is due to the neutralization of the scale binders and the calcium and magnesium as indicated in equations (1) through (5) above.

In zeolite water softeners, Ca^{++} and Mg^{++} ions in the water are exchanged for Na^+ ions (absorbed onto the zeolite) that are released and rush into the water solution as the water passes through the zeolite. Interestingly, zeolite consists of an aluminum-silicon-oxygen compound to which Ca and Mg are absorbed until flushed away during the recharging cycle while the Catalytic Water Conditioner supplies negative charges to SlO_2 and Al_2O_3 colloids in order to keep them in suspension and to keep them from becoming absorbed onto calcium and magnesium compounds and functioning as scale binders.

Ca and Mg readily oxidize in air to form CaO, MgO, Ca_3N_2, and Mg_3N_2, but these compounds are easily wiped off. The thin, waxy, shiny, protective, water-repellent finish that forms and is noticeable on chrome and mirrors after the Catalytic conditioned water is wiped off of these surfaces is a combination of various forms of calcium and magnesium compounds together with colloidal alumina and silica and is a welcome by-product of the Catalytic Water Conditioner.

3.6 The Insulating Effects of Water

Water (H_2O) molecules are excellent electrical insulators; and for this reason, at the low-voltage levels at which these catalytic actions and reactions occur, most of the electrons that are transferred from the Catalytic Water Conditioner to the ions and colloids in the water remain in the solution instead of escaping back to earth ground. Consequently, most of the additional electrons transferred from earth ground or transformer via the Catalytic Water Conditioner to the water solution stay in the solution and are able to provide the negative charges necessary for preventing scale from forming and for decomposing existing scale.

3.7 The Effects of the Negatively Charged Colloids on External Surfaces and Wash Water

Another important benefit resulting from the negative charging of the colloidal substances such as silica, alumina, and clay is that these substances form a negatively charged microscopic coating on surfaces such as glass, windows, chrome, porcelain, tile, enamel, lacquer, etc. This coating becomes very evident on surfaces such as mirrors and chrome faucets, on which residue from evaporated water is easily wiped off with a damp cloth, leaving a sparkling, wax-like, polished surface finish as mentioned in Section 3.5. Other examples of the effects of these negatively charged colloids is the way toilet bowls stay "ring free" and the way shower enclosures stay cleaner much longer.

In addition to these effects on external surfaces, the increased negativity provided to water solutions keeps soap scum particles in colloidal suspension in the water, inhibiting precipitation of soap scum and formation of "bathtub ring" when regular soap is used instead of detergent-type soap such as Zest. Detergents do not react with calcium to form soap scum but do leave residues with unconditioned waters. Scum and residue that do collect on bathtubs or other surfaces are very easily rinsed off with fresh water and also easily go back into colloidal suspension in the same water when the water is splashed on the scum or residue before it is allowed to dry.

4.0 The Wetter Water Effect

Another effect and benefit of the additional electrons in the water solution is the reduction in hydrogen bonding between H2O molecules. H2O molecules link up to each other because of the dipole nature of the individual H2O molecules. The additional negative charges in the solution reduce the bonding of the oxygen atoms of H2O molecules and the hydrogen atoms of other H2O molecules (i.e., hydrogen atoms other than those in their own molecules) by supplying the negative charges (electrons) that the oxygen atoms attract. As a result, there are less hydrogen bonds between the individual H2O molecules. This results in "wetter water," which in turn results in better cleaning water and better soil-leaching water. The breaking up of the H2O groupings into smaller groupings, because of the decrease in hydrogen bonding, enables soap and detergent to break up into smaller groupings and interface with the smaller H2O groupings. This results in a greatly increased surface area that can come in contact with grease, oil, dirt, and other contaminants in wash water. The surface area increases exponentially with decreases in the size of the groupings. Consequently, soap, detergents, and shampoos become more efficient and considerably less amounts are required when used with the conditioned water. Typically, people who require two shampooings with unconditioned water require only one shampooing with the conditioned water.

The wetter water also penetrates soil better and faster than unconditioned water. In addition, the increased wetness is supplemented by the salt and scale-dissolving properties of the electron rich water. This results in more effective breaking down and leaching away of the salts accumulated in the soil. Excessive salinity in the root zones in the soil is the primary cause of tip burn in plant and tree leaves. The excessive amounts of salts on and around the roots result in oxidation and reduction reactions that cause certain elements and compounds to be over-absorbed by plant roots and others that are required for normal health, to be under-absorbed or not absorbed at all.

5.0 Boiling Characteristics of Catalytic Conditioned Water Versus Non-conditioned Water

All other things being equal, the decrease in surface tension due to the decrease in hydrogen bonding of the water molecules reduces the boiling point of water. However, microwave oven tests conducted on equal amounts of conditioned and unconditioned water sometimes show that the boiling point of the conditioned water sample is higher than that of the unconditioned water sample. This apparent paradox can be explained when it is remembered that the gaseous content of the conditioned water is reduced by the Catalytic Water Conditioner. This can result in an increase in the molecular weight of the water for the given volume. According to the van der Waals Attraction Principle, which is used to explain differences in boiling points of different substances, normal molecular substances with larger molecular weight have higher boiling points than those with smaller molecular weight. However, after the unconditioned water is boiled and most of its gases are driven out by the heating, its boiling point will usually be higher because its hydrogen bonding is greater than that of the conditioned water. Results can also vary if the conditioned and the unconditioned water samples are drawn from different homes on the same street and have different amounts of dissolved solids, as when a Catalytic Water Conditioner has been installed and in use in a home for several weeks and has reduced the amount of solids in the water sample contributed by the scale in the plumbing in the house. In any event, Catalytic conditioned water characteristically boils in a steadier, smoother pattern with smaller, more uniform-sized bubbles than does unconditioned water, thereby demonstrating another effect that decreased hydrogen bonding has on water.

6.0 Removal of Chlorine and Other Gaseous Substances from Water

Every metal surface contains many small anodes and cathodes. These opposite-polarity sites are caused by: (1) surface irregularities resulting from forming, extruding, casting, or other fabrication processes; (2) stresses from welding, forming, or other operations; and/or (3) differences in the materials of which the metal or alloy is composed. Because the core alloy of the Catalytic Water Conditioner consists of 12 different metals specially proportioned and processed, and because the core is formed by casting and has relatively rough surfaces, the quantity and power of the anodic and cathodic points have been maximized by the above-mentioned causes (1) and (3). The Catalytic Water Conditioner core contains thousands of cathodes which supply electrons to positively charged ions in the water (such as H+) but also contains thousands of anodes that remove electrons from negative ions such as Cl-, allowing them to gather together as neutral gases such as Cl2. However, more electrons are supplied by the core to the water solution than are removed from the solution because the core, being metallic, is more electropositive than is the water solution. For this reason, the Catalytic Water Conditioner requires a good electrical path to earth ground or transformer in order to have an abundant supply of electrons to add to the solution.

The anodes and cathodes on certain metal surfaces also cause anodic and cathodic reactions that result in typical rusting or corrosion of these surfaces in plumbing systems. However, the Catalytic Water Conditioner core alloy is nonferrous and highly resistant to rusting and corrosion. But in order to render the core even more resistant to corrosion in corrosive waters, the core has been dielectrically isolated from the brass casing; in this configuration, the core's supply of electrons comes from the casing via the electrolytes in the water solution.

The turbulence resulting from the water rushing through the Catalytic Water Conditioner core facilitates the removal of gases by increasing the probabilities of gaseous elements such as Cl0 and N0 contacting other like elements and forming Cl2 gas and N2 gas, respectively. It should be noted that Cl2 (chlorine gas) is 2.49 times as heavy as air, however, and therefore will not rise up into the air at ordinary temperatures. For this reason, chlorine can more easily be smelled in a container only partly filled with chlorinated water conditioned by a Catalytic Water Conditioner than in the case where the container is filled with the water to overflowing.

7.0 How Rust and Corrosion are Inhibited and Dissolved by the Catalytic Water Conditioner. Rust is a type of corrosion involving the special case of iron. Rust formation requires three electrochemical steps.

1. Loss of metal occurs at the anodic area (anode) of the surface. In the case of iron, iron (Fe) is lost to the water solution and becomes oxidized to Fe++ ion.

2. As a result of the formation of Fe++, two electrons are released from the Fe atom and flow through the steel to a cathodic area (cathode).

3. Oxygen (O2) in the water solution moves to the cathode and completes the electric circuit by using the two electrons that moved to the cathode to form hydroxyl ions (OH-) at the cathode area. The reactions are as follows:

(1) Anodic reaction: FeO- > Fe(++) + 2e
(2) Cathodic reaction(s): 1/2 O2 + H2O + 2e-----> -----> 2(0H-)
(3) or-----> + H+ -----> HO-

If oxygen is absent, hydrogen ions (H+) participate in the reaction (equation (3) at the cathode instead of oxygen and completes the electrical circuit).

The Fe(++) and OH- ions combine to form ferrous hydroxide as follows:

(4) Fe(++) + 2 OH- -----> Fe(OH)2

Rust is formed when Fe(OH)2 is oxidized:

(5) 2 Fe(OH)2 + 1/2 O2 -----> Fe2O3 - 2 H2O

Corrosion is inhibited if the iron is made more negative compared to its surroundings, forcing the anode areas to act as cathodes. This is accomplished by the attraction of some of the extra electrons in the water solution (supplied by the Catalytic Water Conditioner) onto the anodic areas, thereby preventing the ionization of the Fe atoms. The additional electrons also dissolve rust by breaking it into fine colloidal particles (as indicated in equation (5) of Section 3.5) that go into suspension.

In a similar manner, corrosion is also inhibited and dissolved for metals other than iron such as brass and aluminum.

It is interesting to note that the addition of electrons to anodic areas in order to prevent corrosion has been accomplished by other means in industry. This method has been called "cathodic protection." Zinc plating is one example of this method of cathodic protection since zinc has a higher oxidation potential than iron and forces electrons onto the iron. Cathodic protection has also been obtained by driving stakes of magnesium or zinc into the ground and connecting them to pipelines or standpipes to be protected.

Water scientists have found that in addition to rust formed simply by corrosion, rust can be formed and deposited by iron-depositing bacteria in the water such as Sphaerotilus and Gallionella. Iron-depositing bacteria prefer water high in ferrous iron, which they convert to insoluble ferric hydroxide, Fe(OH)3, which becomes part of the mucilaginous sheath around the cell. These deposit on galvanized steel pipes and accelerate corrosion rates, which produce additional soluble iron, further increasing the population of iron-depositing bacteria in the system. The cycle sometimes continues until the whole system is plugged with oxidized iron deposits or until a pipe becomes rusted all the way through its walls. The cathodizing function of the Catalytic Water Conditioner also causes the Fe(OH)3 to break up into fine colloidal particles and go into suspension.

8.0 Effects of the Catalytic Water Conditioner on Algae and Fungus/Mildew Growth

Catalytic conditioned water has been found to have noticeable inhibiting effects on algae and fungus/mildew growth. In addition, it has been observed that chlorine stays in swimming pool water longer and does not have to be replenished as often.

Chlorine gas dissolved in water hydrolyzes readily according to the following equation:

(1) C12 + H2O -----> H+ + Cl- + HOCl

Hypochlorous acid (HOCl) is the active microbiocidal ingredient formed by this reaction. This weak acid tends to undergo partial disassociation as follows:

(2) HOCI -----> H+ + OCl-

This produces a hydrogen ion and hypochlorite ion. When the pH exceeds 9.5 in unconditioned water, HOCI completely dissociates into H+ + OCl-.

The toxicity of chlorine is thought to be derived not from the chlorine itself or its release of nascent oxygen, but rather from the reaction of the HOCl on the enzyme system of the cell. The superiority of HOC1 over OCl- appears to be due to the small molecular size and the electrical neutrality of HOCI, which allow it to pass through the cell membrane.

The Catalytic Water Conditioner decreases the dissociation of HOCl equation (2) by providing additional electrons to the water solution which has the net effect of inhibiting the rise in the phi of swimming pool water. This is due to inhibition of the following reaction which occurs at alkalinity levels above pH 8.4.

(3) HCO3 (-) -----> H+ + CO3--

where H+ breaks away from CO3--. These inhibiting effects appear to be due to the net decrease in oxidation reactions that take place in the conditioned water as compared to the amount that takes place in nonconditioned water. Oxidation reactions involve the removal of electrons from elements low on the Electronegativity Scale and high on the Electromotive Series by elements or radicals at the opposite polarity. By supplying electrons to the water solution, the oxidation reactions appear to be inhibited to a significant extent.

Another result of the inhibiting of the dissociation of OCl- from HOCl is that the chlorine concentration in swimming pools in preserved for longer periods of time because OCl- is more easily broken down by sunlight than is HOCl.

The ability of the Catalytic Water Conditioner to reduce the gaseous content of the water solution probably also contributes to inhibition of algae growth. Algae requires nitrogen as well as phosphorous and sunlight for growth. By reducing the nitrogen content of the water, the Catalytic Water Conditioner reduces the nutrient supply of algae.

The reduction of mildew and fungus growth commonly reported by users of the Catalytic Water Conditioner can be explained by: (1) the increased "sheeting" action of the conditioned water resulting in faster drying of shower enclosures and sprinkled plant leaves; (2) reduction of N2 in the water required for fungus and mildew growth; and (3) a slight increase in cupric sulfate (CuSO4) content in the water resulting from a decrease of calcium sulfate (CaSO4). The conversion of Ca++ ions into Ca allows more SO4-- ions to bond ionically with Cu2+ ions in the water to form CuSO4 which acts as a fungicide.

9.0 Summary

The potable water supplied to us is basically electron-deficient and not in optimum states of equilibrium. In accordance with the electronegativities of chemical elements and the oxidation potentials of the elements as listed in the Electronegativity Scale and the Electromotive Series, respectively, the Catalytic Water Conditioner provides electrons to the water solution in a non-sacrificial catalytic manner to reduce electron deficiencies In the water. This enables electrochemical changes to occur that: (1) inhibit scale and corrosion formation; (2) dissolve existing scale and corrosion; (3) increase the wetness and cleaning power of water; (4) decrease the gaseous content of water; (5) break down and leach away excessive salts from soil; and (6) inhibit algae, fungus, and mildew growth. Because of the dipolar (cathodic and anodic) nature of all formed metals, the Catalytic Water Conditioner also removes electrons from some negative ions. However, the Catalytic Water Conditioner provides a significant net increase of electrons for the ions and colloids in the water solution, resulting in: (1) inhibition of undesirable oxidation reactions; (2) an increase of beneficial reduction reactions; and (3) keeping/putting of scale-binding particles and rust/corrosion particles in colloidal suspension by providing them with negative charges.

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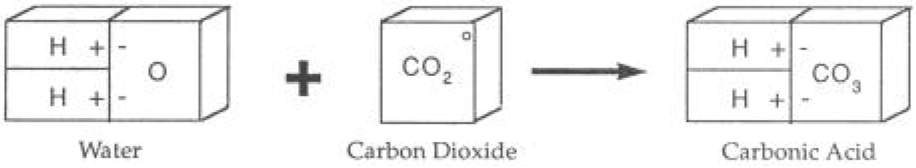
The Scale Problem

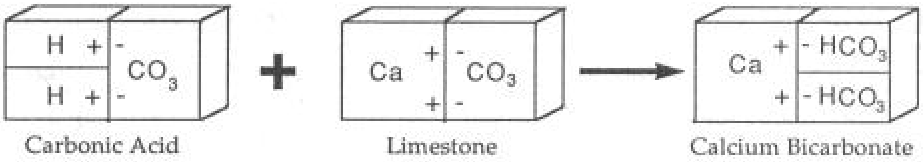
Scale occurs when dissolved minerals and salts (particles of hardness) precipitate out of solution. This precipitation is activated by heat or evaporation.

How Water dissolves and Redeposits Rock

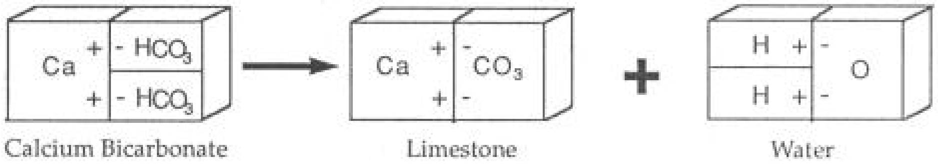
Rain Water Combines With Gases in Air and Becomes Slightly Acidic



The Slightly Acid Water Dissolves Rock and Forms Soluble Hardness

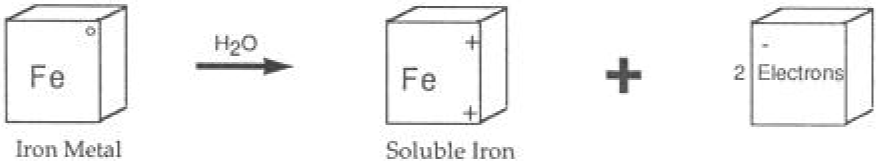


Upon Heating, Soluble Hardness Reverts to Lime Scale

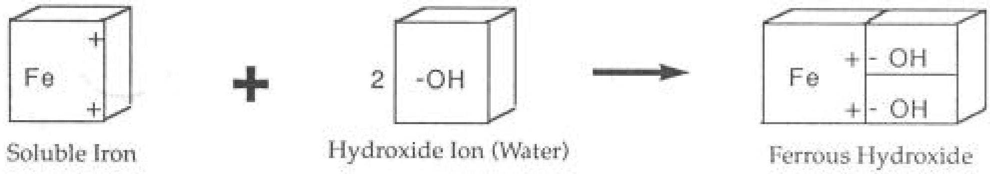


Corrosion Reactions
The Rusting of Iron

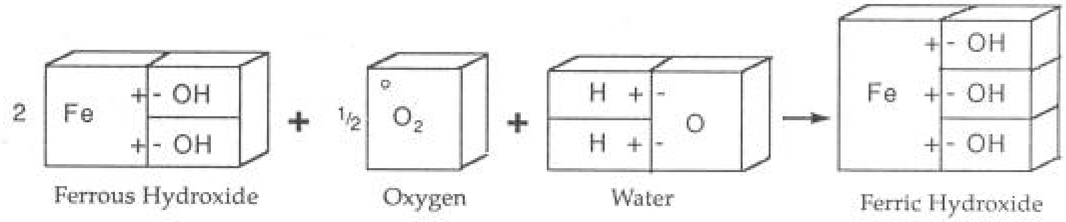
When Water Contacts Iron, Some Metal Goes Into Solution.



Water and Oxygen Act on Soluble Iron to Precipitate It



Action of Excess Oxygen Produces a Gelatinous Brown Sludge



When the Iron Sludge Dries It Forms Common Rust