The Impact of pHairway® on Irrigation Piping Corrosion Rates

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Occasionally, we are asked questions about the effect of pHairway on irrigation piping. These questions arise from concerns regarding corrosion which are often the result of misinformation and a misunderstanding of the pH control application in general.

This purpose of this bulletin is to clarify the reactions which take place upon the addition of pHairway to irrigation water and its associated piping system and highlight other factors impacting corrosion.

To examine this issue thoroughly, we need to understand what pH means and what it influences. While it is true that metallurgies exposed to low pH water may have corrosion potentials, one must recognized that the potential for corrosion is not limited to pH alone.

We need to remember that water possesses several unique properties, one being its ability to dissolve to some degree every substance occurring on the earth's crust and in the atmosphere. Because of this solvent property, water typically contains a variety of impurities. These impurities are a source of potential trouble through deposition of the impurities in water lines.

Therefore, we should consider other prevalent factors which can accelerate corrosion. In addition to pH, other key considerations are:

- Dissolved Oxygen
- Temperature
- Solids
- Chemistry
- Water Velocity
- Metallurgies

WHAT IS pH?

The term pH was originally defined by Danish biochemist Søren Peter Lauritz Sørensen in 1909, is a measure of the concentration of hydrogen ions. The term pH was derived from the manner in which the hydrogen ion concentration is calculated, it is the negative logarithm of the hydrogen ion (H^+) concentration:

$$\mathbf{pH=log_{10}(a_{H+})}$$

Where log is a base-10 logarithm and a_H+ is the activity (related to concentration) of hydrogen ions. According to the Compact Oxford English Dictionary, the "p" stands for the German word for "power", *potenz*, so pH is an abbreviation for "power of hydrogen".

A higher pH means there are fewer free hydrogen ions, and that a change of one pH unit reflects a tenfold change in the concentrations of the hydrogen ion. For example, there are 10 times as many hydrogen ions available at a pH of 7 than at a pH of 8. The pH scale ranges from 0 to 14. A pH of 7 is considered to be neutral. Substances with pH of less that 7 are acidic and substances with pH greater than 7 are considered to be basic.

pH	Ion Concentration (gram equivalent per liter)	Type of Solution
0	1,0	Acid Solution - hydrogen ions - H^+
1	0,1	
2	0,01	
3	0,001	
4	0,0001	
5	0,00001	
6	0,000001	
7	0,0000001	Neutral Solution
8	0,000001	Basic (alkaline) Solution - Hydroxide ions H_3O^+
9	0,00001	
10	0,0001	
11	0,001	
12	0,01	
13	0,1	
14	1,0	

While pH can be viewed as an abbreviation for power of hydrogen a more accurate definition may be the power of the concentration of hydrogen ion.

The mathematical definition of pH is a bit less intuitive, but in general more useful. It says that the pH is equal to the **negative log of the hydrogen ion (H^+) concentration**, or **pH = -log [H^+]**.

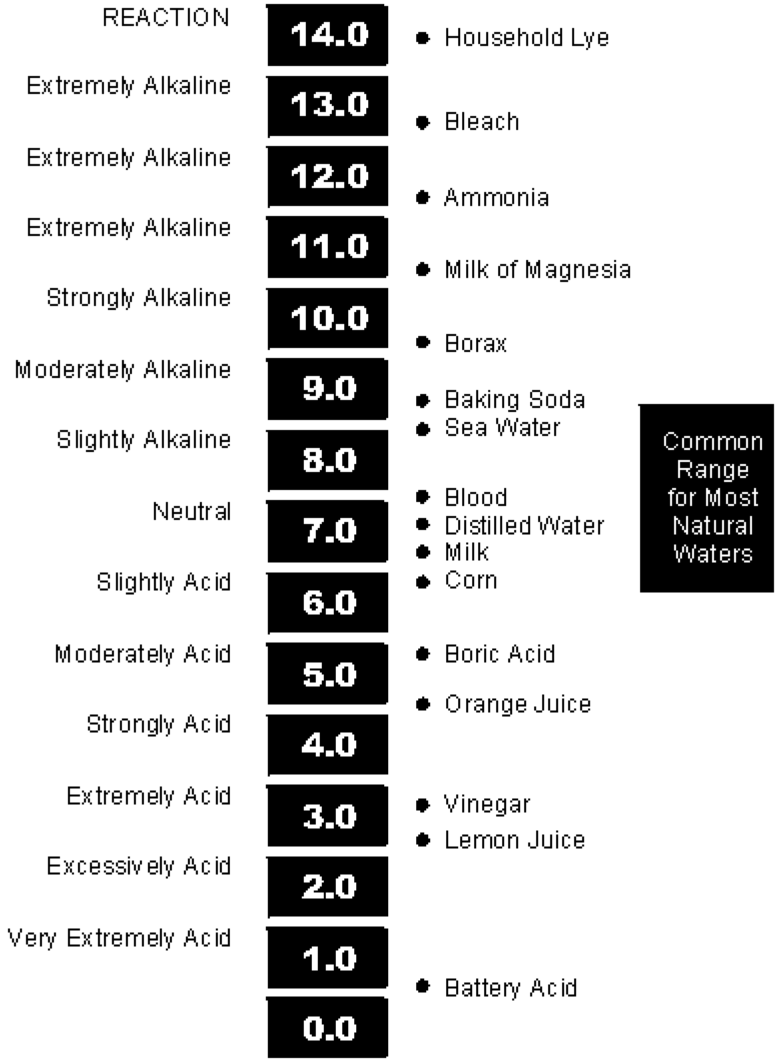
pH is alternatively defined mathematically as the **negative log of the Hydroxide ions (H_3O^+) concentration**. Using the Brønsted-Lowry approach that would be

pH = -log [H_3O^+]

pH values are calculated in powers of 10. The hydrogen ion concentration of a solution with a pH of 1.0 is 10 greater than a solution with a pH of 2.0. The greater the hydrogen ion concentration, the smaller the pH.

When the pH is **above 7**, the solution is **basic** (alkaline), and when it is **below 7**, the solution is **acidic**.

pH Scale



Effect of adding pHairway to Irrigation water

Acids are compounds which break into hydrogen (H^+) ions and another compound when placed in an aqueous solution. Bases are compounds which break up into Hydroxide (OH^-) ions and another compound when placed in an aqueous solution.

If you have an **IONIC** compound and you put it in water it will break apart into two ions. If one of those ions is **H^+**, the solution is acidic. If one of the ions is **OH^-**, the solution is basic.

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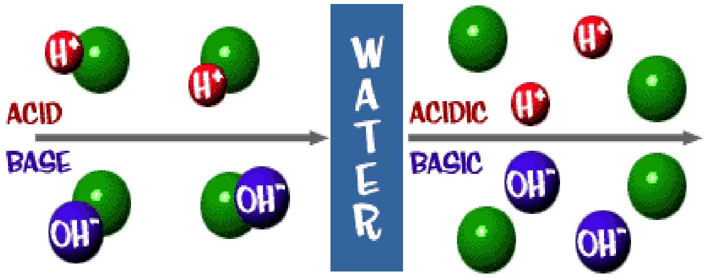
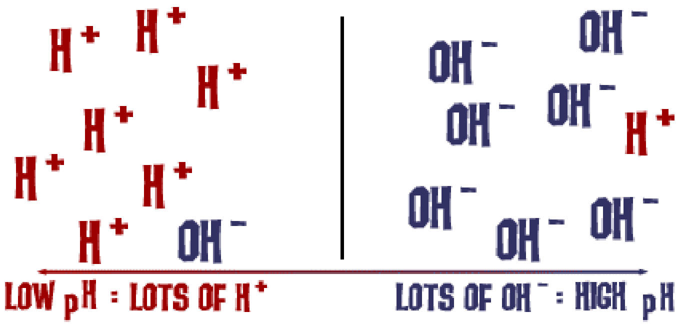
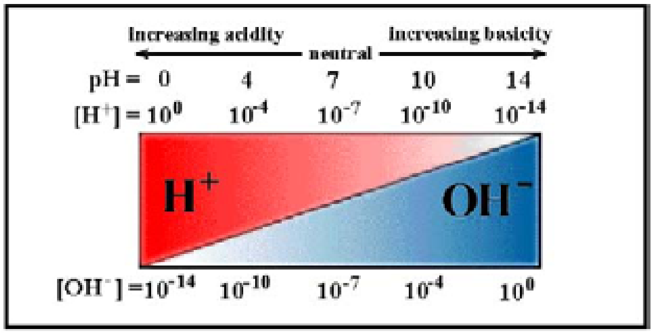


Remember that the **pH** scale is actually a measure of the number of $\mathbf{H^+}$ ions in a solution. If there are a lot of $\mathbf{H^+}$ ions, the pH is very low. If there are a lot of $\mathbf{OH^-}$ ions, that means the number of $\mathbf{H^+}$ ions is very low, so the pH is high.





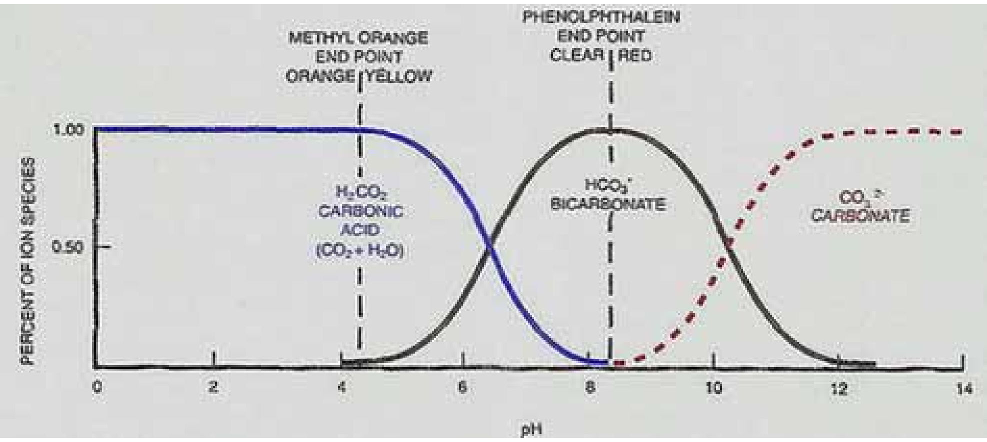
Relative relationship of Ion Distribution across the pH scale

The pHairway program is designed to safely lower the bicarbonate alkalinity of the irrigation water in order to improve infiltration and obtain the benefits of greater nutrient uptake. We use pH as our set point for control because there is a relatively linear relationship between alkalinity and pH.

It is important to recognize the sources of alkalinity in order to properly understand how to control it. Naturally present carbon dioxide dissolves in water as a gas. The dissolved carbon dioxide reacts with the water to form carbonic acid according to the following reaction:

$$\mathbf{CO_2 + H_20 \text{->} HCO_3}$$

Only a trace amount of carbonic acid is formed, but is acidic enough to to lower pH from the neutral point of 7.0. Carbonic acid is a weak acid, so it cannot lower the pH below 4.3. If the carbon dioxide levels are held constant (they are in most water sources we need to be concerned about) a gradual transformation towards the bicarbonate ion HCO3- occurs. This is shown on the graph below. The transformation is complete at pH 8.3. Furtherer elevation of pH forces another transformation into carbonate (CO3). The here species can be converted from one to another by adjusting pH. When we add pHairway, we are driving the bicarbonate level to the left in the graph. This is important because if there is carbonate available, limestone CACO3 will form and lock up the soil.



It is critically important to consider that when we add pHairway we are driving a complete chemical reaction as soon as the acid hits the water. This reaction is complete and changes the pH of the water immediately. The rate of reaction is measured in seconds. The notion that the acid "is carried to the turf" by the water is incorrect. It reacts with the water and alters the pH as shown here:

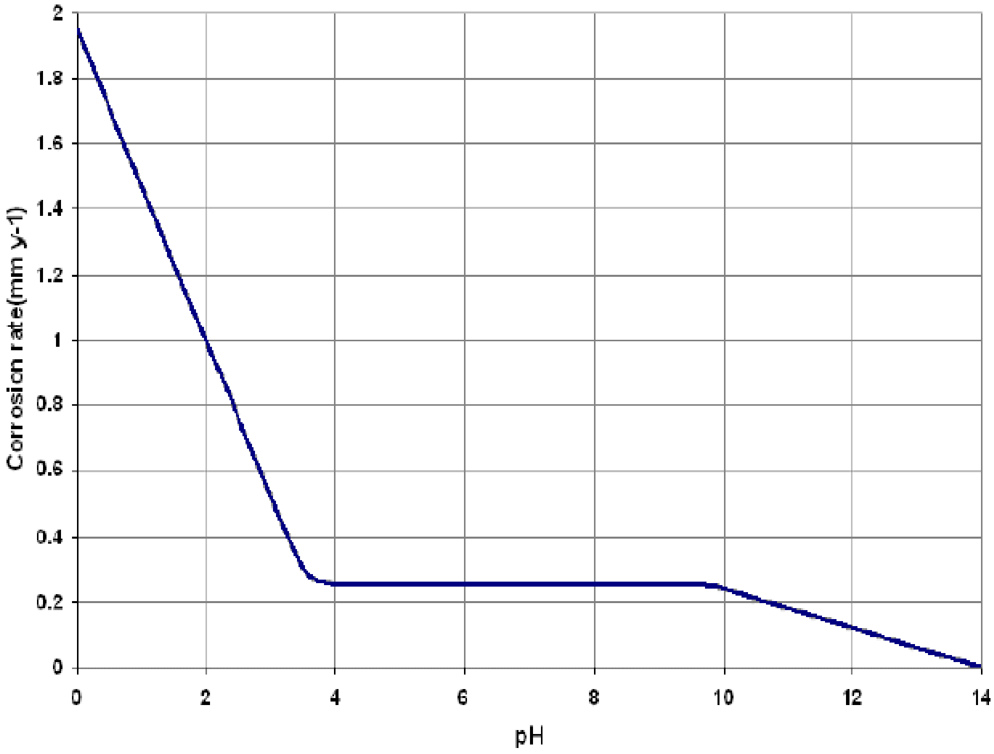
$$\underset{\text{ACID}}{H_2SO_4} + \underset{\text{BICARBONATE}}{2HCO_3-} = \underset{\text{SULFATE}}{SO_4} + \underset{\text{WATER}}{2H_20} + \underset{\text{CARBON DIOXIDE}}{CO_2}$$

While it is true that metallurgies exposed to low pH water may have corrosion potentials, one must recognized that the potential for corrosion at the pH ranges of our typical applications (6.0-6.5) is relatively low due to the proximity to the neutral pH of 7.0. Furthermore, this potential is not limited to pH alone.

Corrosion of Steel

The exposure of steel to aerated water at room temperature (aerated water will contain dissolved oxygen). The corrosion rate for iron as a function of pH is illustrated in the following figure.

Corrosion of steel as a function of water pH



In the range of pH 4 to pH 10, the corrosion rate of steel is relatively independent of the pH of the environment.

In this pH range, the corrosion rate is governed largely by the rate at which oxygen reacts with absorbed atomic hydrogen, thereby depolarizing the surface and allowing the reduction reaction to continue. For pH values below 4.0, ferrous oxide (FeO) is soluble. Thus, the oxide dissolves as it is formed rather than depositing on the metal surface to form a film. In the absence of the protective oxide film, the metal surface is in direct contact with the acid solution, and the corrosion reaction proceeds at a greater rate than it does at higher pH values.

It is also observed that hydrogen is produced in acid solutions below a pH of 4, indicating that the corrosion rate no longer depends entirely on depolarization by oxygen, but on a combination of the two factors (hydrogen evolution and depolarization). For pH values above about pH 10, the corrosion rate is observed to fall as pH is increased. This is believed to be due to an increase in the rate of the reaction of oxygen with $Fe(OH)_2$ (hydrated FeO) in the oxide layer to form the more protective Fe_2O_3 (note that this effect is not observed in deaerated water at high temperatures).

Other Factors Affecting Corrosion

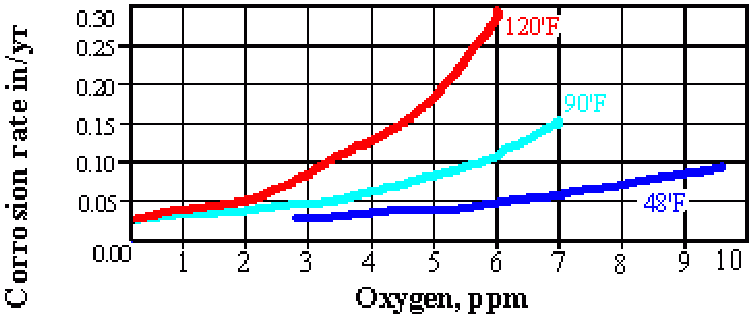
In a piping system there are a number of factors working alone or in combination that can affect the rate of corrosion occurring in pipe. Depending on the degree of these factors a new piping system can show signs of corrosive wear in as little as two years after installation.

The rate of corrosion on a piping system is related to basically these factors:

- the amount of oxygen in the water
- the chemical make up of the water
- the amount of galvanic corrosion from the use of dissimilar metals contained in or in contact with the piping system
- the temperature of the water
- the velocity/pressure of the water in the pipe

DISSOLVED OXYGEN

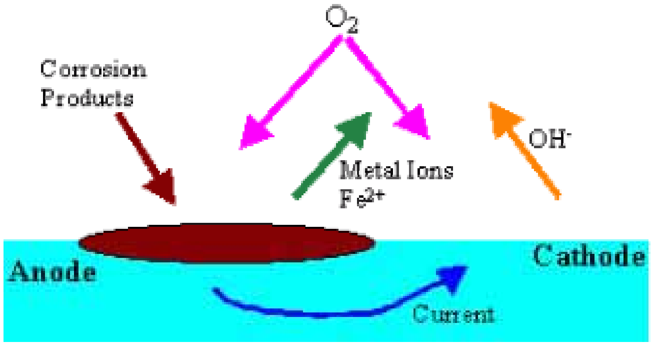
Dissolved oxygen**,** the principal gas present in water, is responsible for costly replacement of piping and equipment by corrosive attack on metals with which it comes in contact. The origin of all water supplies is moisture that has been evaporated from land masses and oceans and subsequently precipitated from the atmosphere. Depending on weather conditions, this may fall in the form of rain, snow, sleet or hail. As it falls, this precipitation contacts gases comprising the atmosphere and suspended particulates in the form of dust, industrial smoke and fumes, and volcanic dust and gases.



Dissolved oxygen (DO) refers to the volume of oxygen that is contained in water. Oxygen enters the water by photosynthesis of aquatic biota and by the transfer of oxygen across the air-water interface (Pond Aeration). The amount of oxygen that can be held by the water depends on the water temperature, salinity, and pressure. Gas solubility increases with decreasing temperature (colder water holds more oxygen). Gas solubility increases with decreasing salinity (freshwater holds more oxygen than does saltwater).

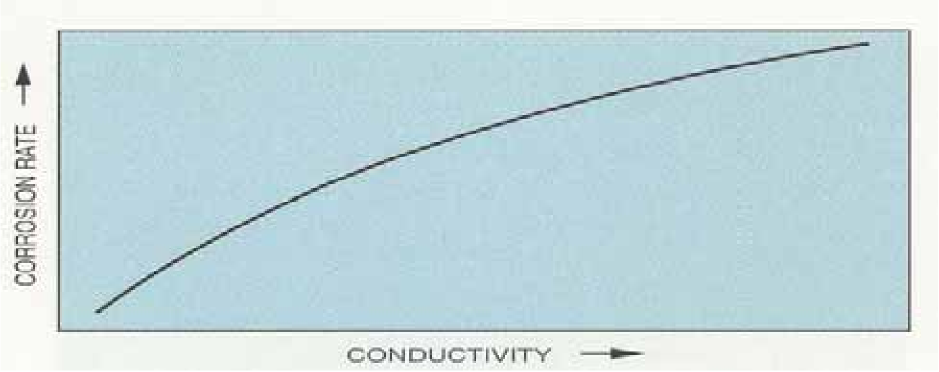
Both the partial pressure and the degree of saturation of oxygen will change with altitude. Finally, gas solubility decreases as pressure decreases. Thus, the amount of oxygen absorbed in water decreases as altitude increases because of the decrease in relative pressure.

Dissolved oxygen can destroy the protective hydrogen film that can form of many metals and oxidize dissolved ions into insoluble forms. Deposits of rust in an irrigation system is such an example of differential aeration cells and accelerate corrosion.



THE CHEMICAL MAKE UP OF WATER

Dissolved minerals in the water and the basic chemical composition of the water may have differing effects on the corrosive forces at play. For example a moderate to high level of calcium would help form a protective coating on the pipe which could slow down the corrosive effects. In general terms, the higher the total dissolved solids, or conductivity, the greater the potential for corrosion.



DISSIMILAR METALS - GALVANIC CORROSION

Galvanic corrosion, also known as electrolysis, occurs when different metals come into contact with each other. When conflicting metals are touching each other one of the metals has a tendency to give up electrons. Basically at the point of contact the metal giving up the electrons dissolves over time. The most frequent cases of this happening are when galvanized pipe and copper are connected; copper pipes touch steel studs, or steel pipe hangers. Contrary to common belief, the effects of galvanic corrosion are limited to the immediate area of contact. The use of dielectric fittings helps stop the problem but does not repair the resulting thin walled and damaged pipe.

WATER TEMPERATURE

The higher the water temperature the faster the rate of oxidation. Experience shows that corrosion is more pronounced as water temperature increases. See graph under Dissolved Oxygen above.

WATER VELOCITY

Water velocity problems are usually associated with a “closed” loop piping system where the need to pump or circulate the water is required.

Erosion corrosion occurs at locations where water turbulence develops. Turbulence can be caused by excessive velocity, sudden changes in direction (sharp turns, elbows) and through “flow” obstacles such as burrs and solder excess.

The major contributing factors to this type of erosion corrosion include:

- water velocities exceed 4 ft/sec
- oversized circulation pumps
- installation of undersized distribution lines
- multiple or abrupt changes in the direction of the pipe
- burrs on the inside of the pipe
- improper soldered joints
- improper balanced system

DETERMINING CORROSION POTENTIAL

Langelier Saturation Index (LSI)

To determine the corrosion potential for the water, the “Langelier Saturation Index” can be used. To calculate the saturation it is necessary to determine the alkalinity, pH, calcium hardness (or total hardness), conductivity and total dissolved solids content of the water. The saturation index is then determined based on a particular water temperature, typically 25 C. . .

Water with a Langelier saturation index of 1.0 is one pH unit above saturation. Reducing the pH by 1 unit will bring the water into equilibrium. This occurs because the portion of total alkalinity present as CO_3^{2-} decreases as the pH decreases, according to the equilibriums describing the dissociation of carbonic acid:

$$H_2CO_3 \rightleftarrows HCO_3^- + H^+$$

$$HCO_3^- \rightleftarrows CO_3^{2-} + H^+$$

- If LSI is negative: No potential to scale, the water will dissolve $CaCO_3$
- If LSI is positive: Scale can form and $CaCO_3$ precipitation may occur
- If LSI is close to zero: Borderline scale potential. Water quality or changes in temperature, or evaporation could change the index.

The LSI is probably the most widely used indicator of cooling water corrosion potential. It is purely an equilibrium index and deals only with the thermodynamic driving force for calcium carbonate scale formation and growth. It provides no indication of how much scale or calcium carbonate will actually precipitate to bring water to equilibrium. It simply indicates the driving force for scale formation and growth in terms of pH as a master variable. In order to calculate the LSI, it is necessary to know the alkalinity (mg/l as $CaCO_3$), the calcium hardness (mg/l Ca^{2+} as $CaCO_3$), the total dissolved solids (mg/l TDS), the actual pH, and the temperature of the water (^oC). If TDS is unknown, but conductivity is, one can estimate mg/L TDS using a conversion table such as the one presented here. LSI is defined as: **LSI = pH - pH_s**

This Saturation Index is typically either negative or positive and rarely 0. A Saturation Index of zero indicates that the water is "balanced" and is neither scale forming nor corrosive. A negative SI suggests that the water is corrosive. A corrosive water can result in the deterioration of the pipes and increased metal content of the water. A positive SI indicates that water may be scale forming.

In addition to the LSI, the **Ryznar Stability Index (RSI)** attempts to correlate an empirical database of scale thickness observed in municipal water systems to the water chemistry. Like the LSI, the RSI has its basis in the concept of saturation level. Ryznar attempted to quantify the relationship between calcium carbonate saturation state and scale formation.

The Ryznar index takes the form: **RSI = 2(pH_s) - pH.** Where:

- pH is the measured water pH
- pH_s is the pH at saturation in calcite or calcium carbonate

The empirical correlation of the Ryznar stability index can be summarized as follows:

- **RSI << 6** the scale tendency increases as the index decreases
- **RSI >> 7** the calcium carbonate formation probably does not lead to a protective corrosion inhibitor film
- **RSI >> 8** mild steel corrosion becomes an increasing problem.

These indices are typically applied to municipal drinking water and are theoretical in nature. The **best way** to determine a given system's corrosion rate is to measure it with corrosion coupons. This is a relatively simple test, but is very accurate.

Quit Guessing and Measure!

The simplest, and longest-established, method of estimating corrosion losses in plant and equipment is weight loss analysis. A weighed sample (coupon) of the metal or alloy under consideration is introduced into the process, and later removed after a reasonable time interval. The coupon is then cleaned of all corrosion products and is reweighed. The weight loss is converted to a total thickness loss, or average corrosion rate using proper conversion equations.

Weight loss determination has a number of attractive features that account for its sustained popularity.

- **Simple:** No sophisticated instrumentation is required to obtain a result.
- **Direct:** A direct measurement is obtained, with no theoretical assumptions or approximations.
- **Versatile:** It is applicable to all corrosive environments, and gives information on all forms of corrosion.

Corrosion Coupon Racks are the water professional's preferred choice for accurate corrosion monitoring of most water systems. Both PVC and CPVC coupon racks feature quick disconnect coupon holders that do not require tools for installation or maintenance. A safety cable prevents lost coupons, while nylon sample-holding screws do not alter coupon corrosion rates. For high temperature applications, coupon racks are available in carbon steel and stainless steel.