SCALEBLASTER®

WATER CONDITIONER

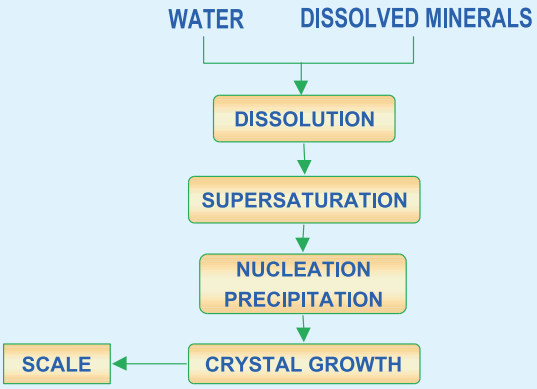
Sustainable Solutions to Hard Water

Principles of Scale Formation & Elimination

Chapter 1
Principles of Scale Formation

SCALEBLASTER® WATER CONDITIONER
Sustainable Solutions to Hard Water

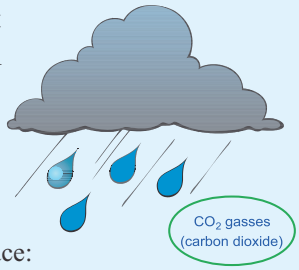
1. *SUMMARY CHART OF HOW SCALE FORMS*



2. Dissolution

How scale (calcium carbonate) gets into the water stream

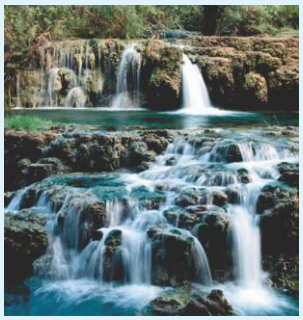
Step 1: Water becomes acidic
Whenever it rains, water in contact with air will absorb the CO2 gas in the air.



The following chemical reaction takes place:

$CO_2 + H_2O \rightarrow H_2CO_3$

3. *Step 2: Acidic water dissolves calcium carbonate*



As the acidic rain water reaches the surface, it passes over and permeates through rocks such as limestone, marble and seashells, forming soluble calcium ions and bicarbonate ions.

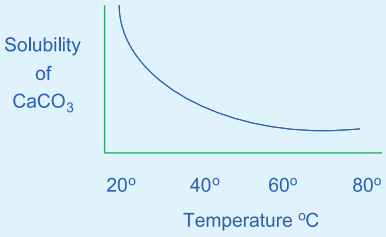
$CaCO_3$ (calcium carbonate) + H_2CO_3 (carbonic acid) $\rightarrow$ $Ca^{++}+2HCO_3$ (in solution)

4. *Step 3: Any condition which alters the solubility of calcium bicarbonate will result in the precipitation of calcium carbonate (scale)*

There are three (3) major factors that can alter the solubility of calcium bicarbonate and thus cause scale:

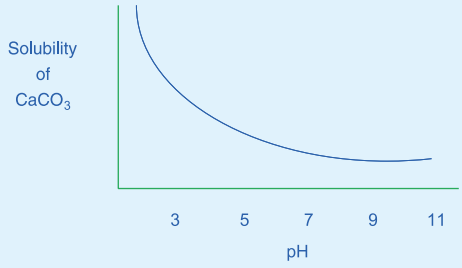
A.) Temperature effect on solubility. A change from cold to hot water will cause scale to form.

The reason?
When the temperature increases, CO_2 evaporates, allowing scale to precipitate. Heating water also causes evaporation, leaving minerals behind.



5. *B.) pH Change on Solubility*

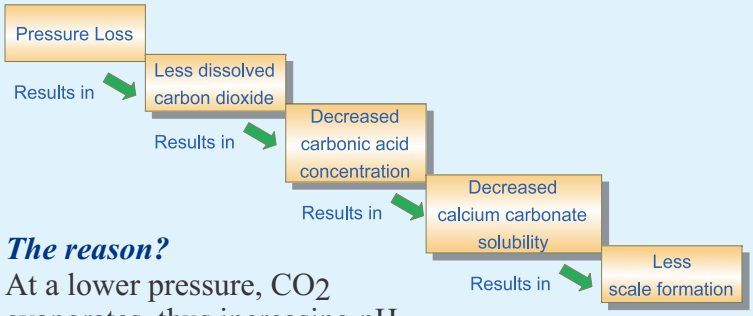
Solubility of $CaCO_3$ decreases with an increase to the pH.



The reason?
pH is a measure of the acidity of the liquid. The lower the pH, the higher the acid content. This will dissolve more calcium carbonate.

6. *C.) Pressure Effect on Solubility*

A change in water pressure from high to low will cause scale to form. Pressure drop may occur from internal friction between the molecules of water, external friction between the water and the walls of the piping system, or rough area in the channel through which the water flows.



The reason?
At a lower pressure, CO_2 evaporates, thus increasing pH. A higher pH allows for less scale formation.

SCALEBLASTER® WATER CONDITIONER
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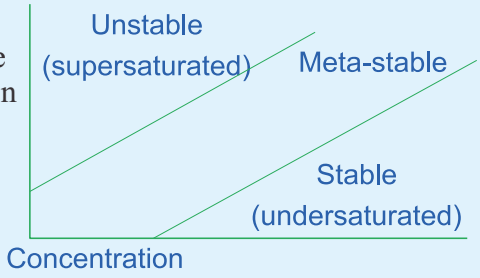
7. *Supersaturation*

Supersaturation at the point of crystallization is the primary cause of scale deposition.



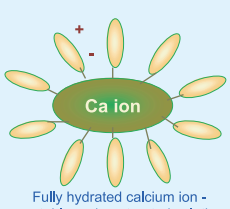
Definitions:

Saturation: The maximum equilibrium concentration of a compound that will dissolve into a solution under a given set of conditions (temperature, pressure, flow velocity, etc.).

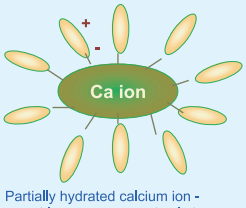
Supersaturation: The solutions that contain higher concentrations of dissolved solute than their equilibrium concentration.

8.

To simplify "supersaturation", it can best be described as scale-causing ions that barely "hang in the water" When calcium and bicarbonate ions are hydrated, molecules are attached to the calcium and bicarbonate ions via ionic bonds, which are much stronger than the van der Waal force. In a supersaturated solution, the calcium and bicarbonate ions are 'partially' hydrated by water molecules. The harder water is, the calcium and bicarbonate ions are hydrated with much weaker hydration energy. We conclude that in a supersaturated solution, calcium ions are barely 'hanging in water'.



Fully hydrated calcium ion - stable undersaturated solution



Partially hydrated calcium ion - unstable supersaturated solution

9. Causes of Local Supersaturation

- Increase in temperature
- Increase in pH
- Decrease in pressure
- Agitation of the solution
- Decrease in flow velocity

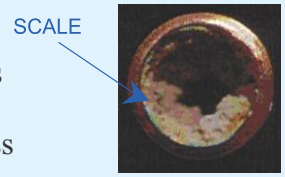
Even when the bulk solution is less than fully saturated, scale formation can occur due to local supersaturation.

10. Nucleation Precipitation

You may be wondering when scale forms, why does it stick to surfaces?

The Answer: The electrostatic attraction between the metal surface and scale-causing minerals. Gravity plays no role in scale formation.

The unique characteristics of scale deposits are its uniformity. Precipitates or crystals formed in one part of a system and carried to another part are less adherent than those crystals formed on site.

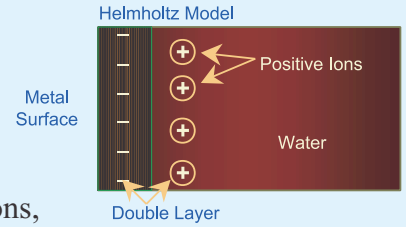


Scale deposits are due to electrostatic attraction.

11. The electrostatic attraction can be described in three theories:

A.) Helmholtz Model

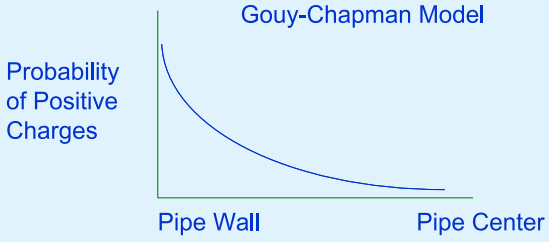
When a metal is in contact with an ionic solution such as water with scale-producing minerals, the metal surface has a high density of electrons, giving it a locally negative charge.



The solvated positive ions such as H+, Ca++ and Mg++ align themselves along the surface of the metal surface, producing an (electric) double layer-no thermal motion of ions considered.

12. B.) The Gouy-Chapman Model - Diffuse Double-Layer

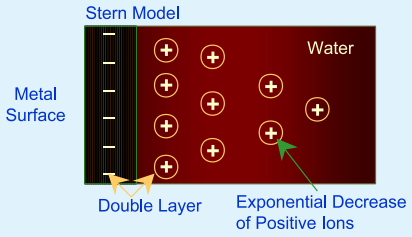
Due to the thermal motion of the ions in the solution, the population of positive charges (i.e., H+, Ca++ and Mg++) decreases exponentially with increasing distance from the metal surface.



13. C.) Stern Model - The Previous Two are Combined.

The positive ions closest to metal surface are constrained into a rigid-Helmholtz plane while outside the plane, the positive ions are dispersed as in Gouy-Chapman model.

It is this electric potential (or coulombs) difference that causes the attraction of the scale to surfaces, which explains their uniform deposition.



Chapter 2
Principles of Scale Elimination

SCALEBLASTER® WATER CONDITIONER
Sustainable Solutions to Hard Water

This section will explain how **ScaleBlaster** works and how it removes limescale within the pipes and keeps it from forming again.

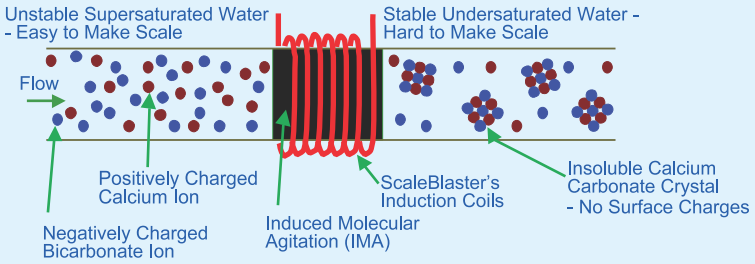
1. **ScaleBlaster® Theory** - (For Non-ferrous Based Pipes)

ScaleBlaster® unit is composed of a signal cable that is wrapped several times around a pipe and an electronic unit that sends out a complex, dynamic current to produce extremely small, time-varying, oscillating fields inside the pipe. This electronic unit is available in several sizes in terms of power. The larger the size of the pipe, the more power is required. This unit is designed to work on non-ferrous based pipes only. The current that produces an oscillating field is known as Ampere's Law.

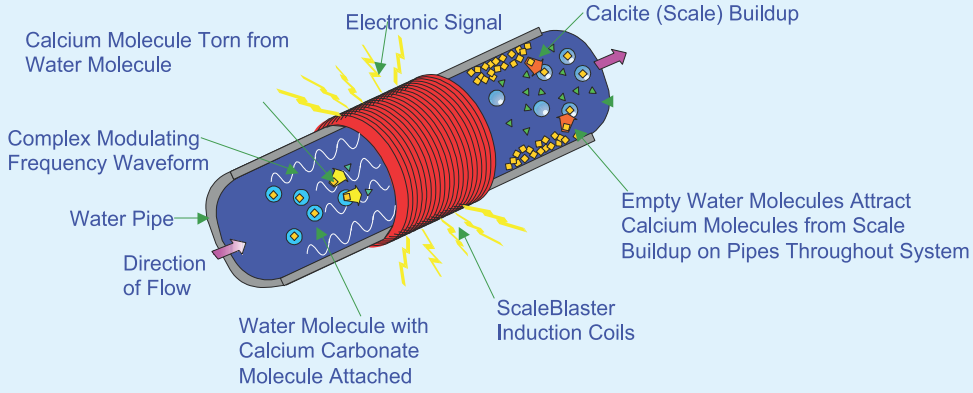
ScaleBlaster® signal produces a unique square wave current that sweeps all the frequency responses from 1,000 - 20,000 Hz at a rate of 20 times a second. When the strength of the oscillating field varies with time and changes direction, an induced current is produced inside the pipe, a phenomenon known as Faraday's Law of Induction. This induced, oscillating electric field provides the necessary molecular agitation for scale prevention and removal.

2. The induced molecular agitation (IMA) of the **ScaleBlaster®** technology causes the unstable mineral ions to precipitate, providing initial nucleation sites for further precipitation of adjacent mineral ions. A snowball effect starts, resulting in growth of many crystals, each consisting of numerous mineral ions. These insoluble crystal salts become large in size and float with water, thus they do not stick to the metal surfaces because the crystals do not have the charges at the surface anymore.

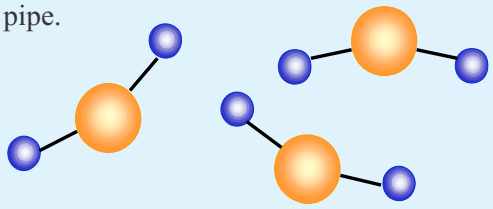
ScaleBlaster's Square Wave Current



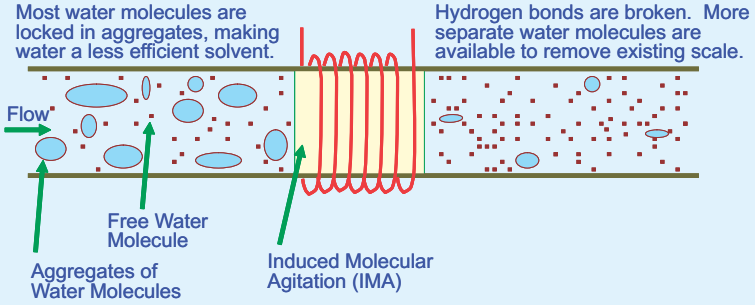
3. As the by-products of the precipitation and snowball effect of mineral particles, the free water molecules become available to dissolve existing scale. In other words, the electronic signal generated through the **ScaleBlaster®** induction coil breaks apart water molecules with calcium carbonate attached and thus becomes an empty water molecule that immediately begins to attract calcium molecules from scale buildup on pipes throughout the system.



4. It is well known in water chemistry that most water molecules are locked in aggregates in liquid water and less than 20% exists as free water molecules. This is because water molecules have a dipole moment - the hydrogen atom is attracted to the oxygen atom of the adjacent water molecule. The frequency modulation technology developed by **ScaleBlaster®** allows the induced electrical agitation to tune to the natural frequency of the water molecules vibrating in the aggregates. Through the cooperative resonance of the water molecules, free water molecules become available, dissolving existing scale in the pipe.

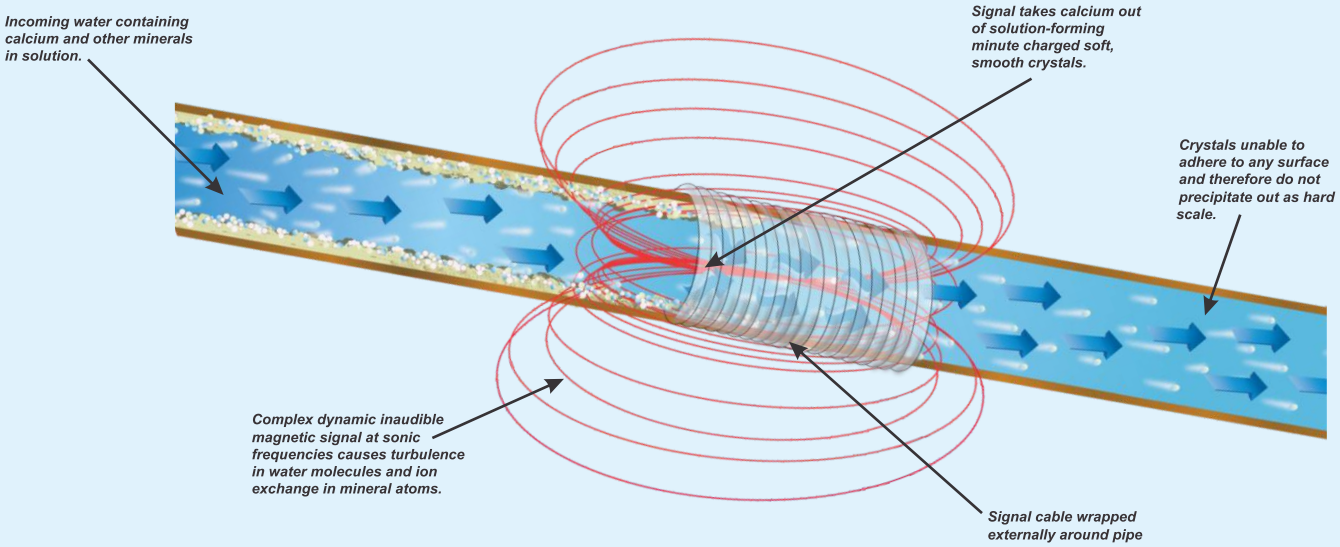


5. ***ScaleBlaster's*** **Square Wave Current**



Schematic diagram of the operation of **ScaleBlaster®** : Aggregates of water molecules contain most water molecules in liquid water. Induced molecular agitation breaks hydrogen bonds in aggregates, and separate water molecules become available, removing existing scale.

6.



7. Physical Law on the "IMA"

ScaleBlaster® signal produces an IMA, induced molecular agitation which will be fully described in this section.

As reported earlier in this chapter, the **ScaleBlaster**® unit involves an electric unit and a signal cable that is wound around the outside wall of the pipe. The unit supplies a current inside the coil to produce a magnetic field.

Ampere's Law

$B = \mu_{\bullet} nI$

Where B = resulting field vector

The "right-hand rule" determines the direction of the magnetic field inside the pipe. The strength of the magnetic field is proportional to the product of the current and the number of turns in the coil.

8. ScaleBlaster's® signal sweeps all frequency responses from 1,000 to 20,000 Hz at a rate of 20 times a second. This is done by a frequency-modulated square wave signal.When the strength of the magnetic field varies with time, an induced current is produced inside the pipe.

This is known as Faraday's Law of Induction.

Faraday's Law of Induction

$$\int E \cdot ds = -\frac{\partial}{\partial t}\int B \cdot dA$$

Where E = induced electric field vector

This induced current, when supplied with the proper amount of DC current in milliamps, produces this induced molecular agitation to take place at the coil. The strength of this electric field is important.

9. Physical Laws of Induced Molecular Agitation (IMA).

1.) As we have mentioned before, a wire is wound several times on the outside of the pipe, thus creating a solenoid coil. When there is a current flowing in the solenoid coil, a magnetic field is produced called Ampere's Law. The right-hand rule determines the direction of the magnetic field inside the pipe. The strength of the magnetic field is proportional to the product of the current, I, and the number of turns of coil, N.

B = y on I
Where B = magnetic field vector
[Wb/m2 or Ns/Cm]

The magnetic strength produced by **ScaleBlaster's**® solenoid coil is much smaller than that of permanent magnets.

10. Comparison of Strength of Various Magnets

ScaleBlaster's® -	0.2 - 1.0 Gauss
Simple "Refrigerator" Magnet -	100 Gauss
Bar Magnet -	100 - 1,000 Gauss
Magnets Intended to Remove Scale -	4,000 - 6,000 Gauss
Large Scientific Magnets -	20,000 - 40,000 Gauss
Superconductivity Magnets -	5,000,000 - 10,000,000 Gauss

As you can see, **ScaleBlaster**® does not rely on the strength of the magnetic field at all. The strength of the magnetic field produced by **ScaleBlaster**® is about 1/1000 of a simple refrigerator magnet that you use to hold notes in the kitchen!

11. 2.) **ScaleBlaster's**® signal sweeps all frequency responses from 1,000 to 20,000 Hz at a rate of 20 times a second. This step is called "frequency modulation". This frequency modulation is necessary because no one knows the natural frequency of supersaturated water--water where the calcium ions "are barely hanging on". This is the key to **ScaleBlaster's**® success.

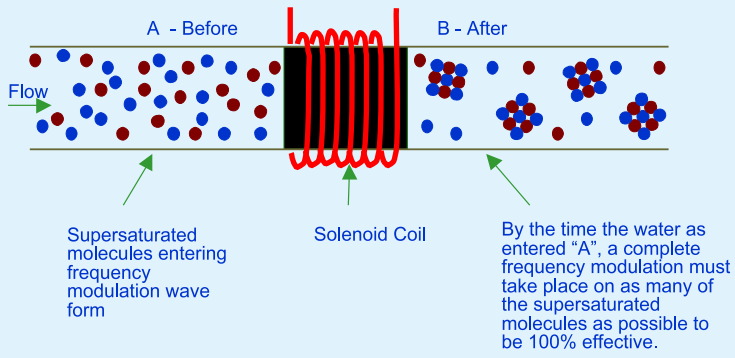
As you will see in the rest of this section, hitting the supersaturated "barely hanging in water" ions with the natural frequency is imperative for the **ScaleBlaster**® to perform regardless of flow rate and hardness level. This is when most permanent magnets fail to do the job.

12. The natural frequency of the supersaturated water critically depends on its viscosity (the tendency of a fluid to resist flowing due to internal forces such as the attraction of the molecules for each other or the friction of the molecules during flow) and water temperature. Since it is impossible to determine the natural frequency of water being treated in any given situation, a frequency modulation method needs to "self-tune" to the natural frequency of the water.

3.) **ScaleBlaster**® will sweep all the frequencies from 1,000 to 20,000 Hz at a rate of current 20 times a second. A certain amount of power, in the mA levels is applied to residential models and up to 40 amps to our largest industrial model that can handle 40" pipe. The more powerful the unit, the more power is applied. It is this change of current that created a rapid magnetic flux change. It is imperative to create as rapid a change in polarities as possible to achieve proper treatment of the water.

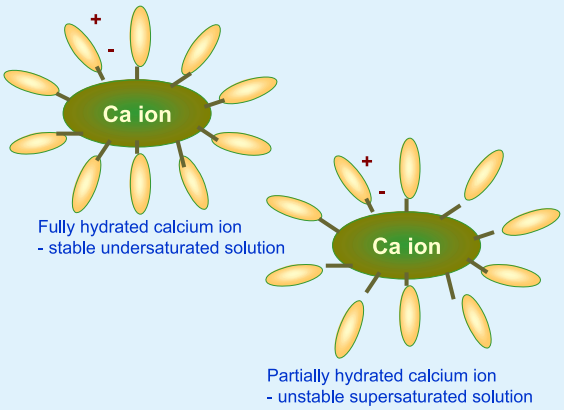
This complete frequency modulation must be done during the time the water is passing through the induced coil to hit the resonance frequency of as many supersaturated molecules as possible. This is critical to the success of the **ScaleBlaster**® where most others fail.

13. All flow rates vary as do pipe sizes. So a unit must be as sophisticated as the **ScaleBlaster**® to be successful.

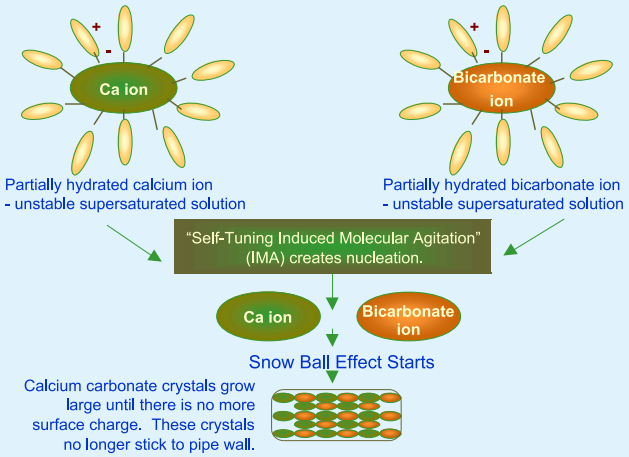


14. It is important to have the correct amount of wrapping of coil around the pipe. Too little will cause not all the supersaturated molecules from being "fine tuned" to the natural frequency as the water passes the coil. In other words, a coil only wrapped 1/2 way may, in theory, hit only 1/2 the water. The descaling process would take twice as long and the surface tension of the water molecules would not be altered much to notice any effects of the "descaled" water.

15. As the supersaturated water is being treated by the "IMA", the calcium and bicarbonate ions which are barely hanging in water collide with each other. Since these ions are not fully hydrated, the collision easily results in a solid calcium carbonate, creating a nucleation site.



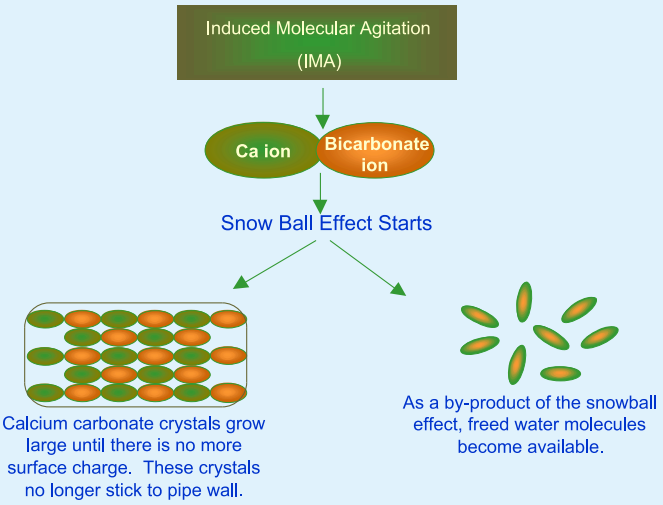
16. Once the new nucleation site becomes available, the snowball effect of precipitation occurs. A snowball of calcium carbonate will grow until it becomes so large that there are no more surface charges left to attract other "partially hydrated" calcium and bicarbonate ions. A large number of "partially hydrated" calcium ions are precipitated, thus removed from the supersaturated solution. Subsequently, the unstable "undersaturated" solution and the scale buildup stops.



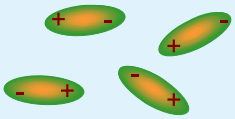
17. We mentioned earlier that scale-causing ions (calcium and bicarbonate ions) are barely "hanging in water" in a supersaturated solution. When "poorly dissolved" calcium and bicarbonate ions are removed from the supersaturated solution through nucleation and precipitation, those ions which are not involved in the precipitation become fully hydrated by freed water molecules, resulting in a thermodynamic equilibrium.

As the dissolved calcium and bicarbonate ions precipitate and are removed from the supersaturated solution through crystal growth, excess water molecules become available. These water molecules will either recombine with neighboring water molecules, thus locked in clusters of water or be used to fully hydrate the "poorly hydrated" calcium and bicarbonate ions which are barely hanging in water. Since the surface charges of calcium and bicarbonate ions are greater than that of water molecules, the temporarily freed water molecules are likely to be attracted to the surfaces of scale-causing ions.

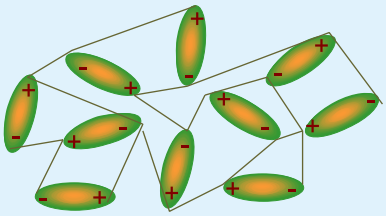
18.



19. **ScaleBlaster's**® technology takes advantage of the unique characteristics of water, the polar molecule. The positive hydrogen of one water molecule is strongly attracted to the negative oxygen of a neighboring water molecule and the connecting force is the van der Waal force, often referred to simply as "hydrogen bond". In the liquid water, there is a mixture of separate individual water molecules and aggregates of hydrogen-bonded water molecules. The water molecules in the aggregates do not function as efficiently as solvent as the separate water molecules.



Individual Water Molecules

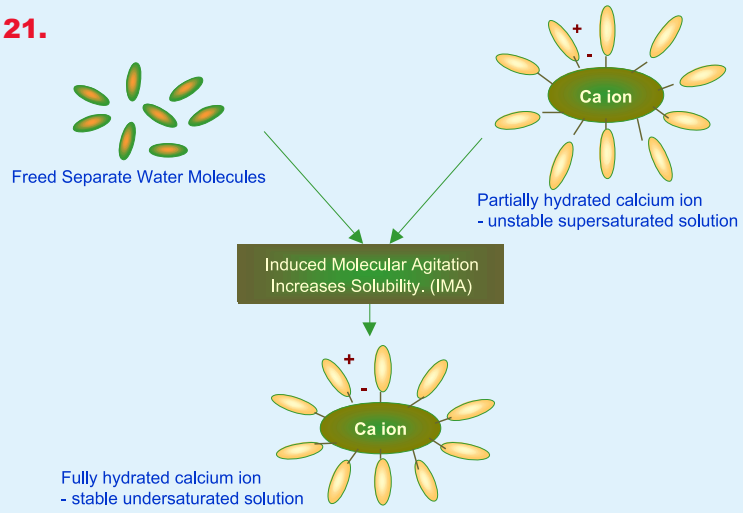


Water Molecules are Locked in a Cluster

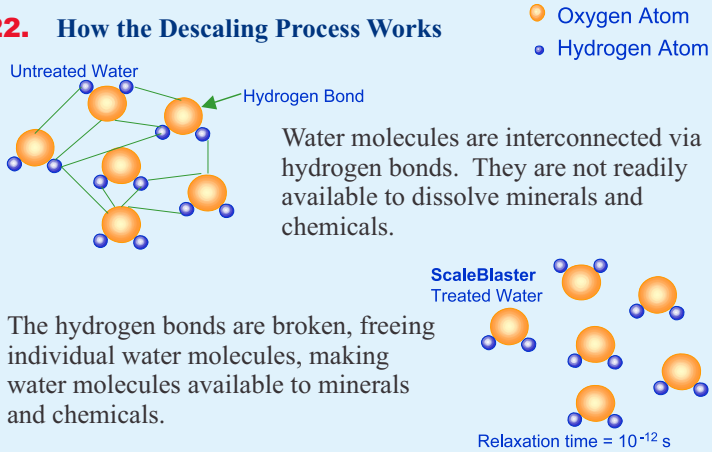
20. **ScaleBlaster's**® technology generates a self-tuning induction using the frequency modulation with its specially designed square wave form. This self-tuning dynamic induction automatically tunes to the natural frequencies of vibrating water molecules, producing a resonance between the vibrating water molecules and the dynamic induction. The resonance breaks the hydrogen bonds in a cluster of liquid water, freeing water molecules. Since the solubility depends on the number of available separate water molecules, this process of breaking hydrogen bonds dramatically increases the solubility of water.

The freed individual water molecules will either recombine with neighboring water molecules or surround (hydrate) the calcium ions. The latter is what actually happens. In a supersaturated solution, the calcium and bicarbonate ions are partially hydrated, i.e., barely "hanging in water", which is the reason they are unstable. Since the surface charges of the calcium and bicarbonate ions are greater than that of the water molecule, the freed water molecules will surround the calcium and bicarbonate ions which are not involved in the previously mentioned precipitation, thus fully hydrating them. Subsequently, the unstable supersaturated solution becomes a stable, undersaturated solution and the scale buildup stops.

21.



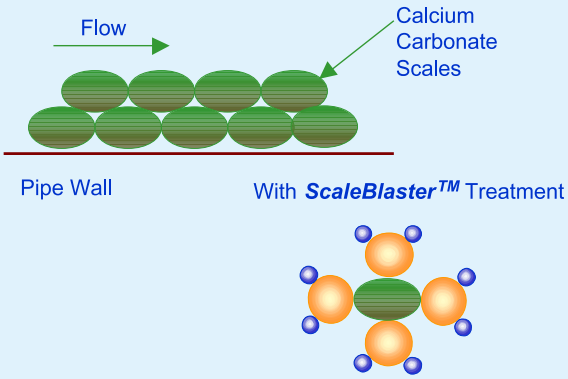
22. **How the Descaling Process Works**



This is accomplished with a time varying Magnetic field inside the pipe at 1,000 - 20,000 Hz (Faraday's Law of Induction combined with **ScaleBlaster's**® square wave signal, IMA)

SCALEBLASTER® WATER CONDITIONER
Sustainable Solutions to Hard Water

23. The Hypothesis of Descaling Process



24. The Natural Frequency of the Vibration of Water Molecules

The key to **ScaleBlaster's**® success is the way our "IMA" field hits the resonance frequency of the water molecules.

As we have mentioned before, **ScaleBlaster's**® singal sweeps all frequency responses from 1,000 - 20,000 Hz at a rate of 20 times per second as we alternate from + 5 volts to - 5 volts

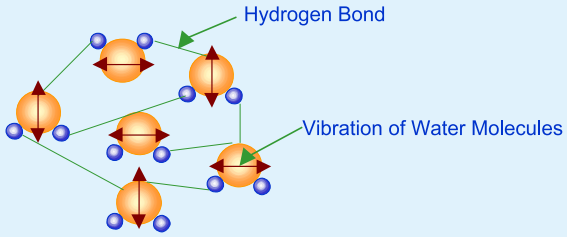
+ 5 volts
0 volts
- 5 volts

Many experts have estimated the internal frequency of water as **f = 1,000 - 20,000 Hz**

The **ScaleBlaster**® easily falls in this range and by changing the current it creates a rapid magnetic flux change. It is critical to create as rapid of a change in the polarities as possible to properly treat the water.

25.

The mechanism of breaking the hydrogen bond is resonance! When the external disturbance provided by **ScaleBlaster's**® matches the natural frequency of the hydrogen atom, the hydrogen bonds are broken instantly. It is important that **ScaleBlaster's**® frequency range exceeds the best estimate of the internal natural frequency of water because this natural frequency can vary with temperature, pressure, minerals present, pH and other factors.



Summary of ScaleBlaster's® Technology

ScaleBlaster® produces a frequency modulation signal that produces an "IMA", induced molecular agitation inside the pipe when applied with a square wave signal. When water and scale-causing ions (dissolved calcium carbonate) are treated by the "IMA", two things happen:

1.) "IMA": creates nucleation sites, initiating the "snowball" effect. Suspensions of soft and less-adherent calcium carbonate crystals are formed, thus removing dissolved calcium and bicarbonate ions from a supersaturated solution.

2.) "IMA" breaks hydrogen bonds in an aggregate of liquid water, freeing a lot of water molecules from the aggregate. More free water molecules mean an increase in the solubility of water. The unstable supersaturated calcium carbonate solution becomes a stable undersaturated solution, resulting in the prevention of scale buildup.

In order to produce the above mentioned IMA, **ScaleBlaster**® applies a frequency-modulation technology. This technology is based on a well-established induction theory. When there is a change in a magnetic field with time, an induction of electric field is produced. Since the **ScaleBlaster's**® technology utilizes a square-wave current that scans all the frequencies at 1,000 to 20,000 Hz at 20 times a second at a controlled amount of power designed specifically for the pipe size being treated. Furthermore, water molecules, although neutral, are polar molecules, thus behaving like an ion in an electric field. The oscillation of the induced electric field provided molecular agitation to these electrically active ions and water molecules. Subsequently, the scale-causing ions in a supersaturated solution begin to fall out of water, i.e., precipitate and nucleate, thus initiating the snowball effect. The solid calcium carbonate crystals which consist of numerous calcium carbonate molecules become less adherent and flow with the water in the form of suspended particles.

SCALEBLASTER® WATER CONDITIONER
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