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THE FATAL LURE OF WATER TREATING GADGETS

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This paper is intended to examine the causes for the constant re-emergence of water treating "cure-alls" that claim to eliminate most or all of the ills that accompany the use of water for industrial purposes.

These devices generally invoke the well-known scientific principles of magnetism, electrostatics, electrolytic phenomena, radiation, catalysis or other physiochemical methods.

There are a number of devices using these same principles that are quite legitimate and are recognized as such.

For example, magnetic filters for removing tramp iron, for removal of solids that have been mixed with ferromagnetic substances or even those depending on the weak para and diamagnetic forces present in many substances are well-known and recognized as legitimate. Electrolysis cells that generate chlorine or other reduced ionic species have a sound place in industry.

Though less widely practiced, electrodialysis is used for the deionization of brackish waters. Ultra violet or gamma radiation sources have been often used to sterilize water as has the electrolysis of metallic silver into solution.

These and other well-known techniques produce usable results by known scientific processes and there is a legitimate capital and operating cost penalty associated with their use.

On the other hand, the devices which we shall refer to as "gadgets" offer (but do not deliver) a wide range of relief from water problems using secret or poorly explained pseudo-scientific processes and usually for little or no cost other than that which is paid to their promoter and his salesmen.

The water treating "gadget" is not a recent development nor is it limited to the United States. Such devices were known at least as early as the American Civil War and they are actively promoted in all industrial nations.

Many of the "gadgets" have the germ of a workable idea in them. This tends to make them more believable but does not necessarily make them effective as a water treating tool. For example, several of the devices are composed of magnets or zinc or aluminum alloys with either accidental or deliberate impurities (some billed as "Twenty Precious Metals") in them. These alloys corrode quite rapidly.

When these devices corrode they have the same effect as adding small quantities of soluble iron, zinc or aluminum salts to the water. It is known that low concentrations of zinc can serve as a very effective corrosion inhibitor. The "gadget" achieved a desirable result but in an expensive and uncontrollable way. The aluminum or iron salts from corroding electrodes or magnets do an acceptable job of clarification, but again there is a more controllable, less expensive way of achieving the same results.

Some of the "gadgets" use accepted technology in a non-standard manner that frequently negates their effectiveness. A German device used an electrolytic softening cell inside of a boiler. This was a technically sound application of an electrolytic cell whose cathode liquor became quite alkaline and caused precipitation of calcium carbonate in the boiler. This expensive and questionable practice from the viewpoint of water technology could have been better accomplished by the addition of a few cents worth of sodium hydroxide to the boiler.

Another device, which connected a radio type antenna to a grounded electrode in the boiler, would seem to have no possibility of having any effect at all. However, it is known that in the vicinity of large radio antennas a wire strung in the air will pick up enough power to light a house. It would not be recommended as a proper water treatment, but under ideal conditions something could happen.

Some of the "gadgets" could be nothing but deliberate frauds. One device that was very popular thirty years ago was a cylindrical brass case which, when it was cut open, was found to contain a powdered material that appeared to have been swept from the floor of a stable. (Cutting the device open voided the warranty.)

These pseudo-scientific "gadgets" are not harmless. You can't say "well, if they don't work no harm has been done." The least of the costs arising from trials of these devices is the time and money wasted in investigating and/or trying them out in a working system. The greatest expense is the damage done to the equipment in the system under test from the withholding of proper treatment for a period long enough to show that the "gadget" has not prevented corrosion or scale as claimed. Much of this damage is irreversible and is relatively large in dollar amounts.

It is not the purpose of this paper to document the persistent and wide spread existence of these devices or to prove that they are innocently or deliberately fraudulent. This has been adequately done a number of times.

The claims of several of the more actively promoted of the water treating "gadgets" along with an analysis of the technical inaccuracies or impossibilities in them are given by Eliassen and Uhlig. (1)

The actual case histories documenting the failures of a number of these devices along with an extensive bibliography (106 reference) surveying their history is given by Welder & Partridge. (2)

Eliassen and Strinde subjected a number of these devices to experimental measurement and documented their findings. (3, 5)

Henricks sounded a strong warning again in 1957. (4)

The Federal Government through the Federal Trade Commission (6) and various military installation memoranda (9) has spoken out against the use of "gadgets" on Federal installations.

Professional technical societies have tried to warn their membership against the blandishments of the "gadget" promoters but these warnings do not seem to have been heard by those who need it the most. (7, 8)

The National Association of Corrosion Engineers has a standing committee (Committee T-7K) on "Non-Chemical Water Treating Devices" (10) which maintains the most up-to-date list of these devices and can often furnish unbiased references to their performance.

There are some fundamental reasons why these devices are perennially attractive.

This paper examines some of the basic facts which encourage the regular reappearance of these gadgets time after time even when it has been well demonstrated that not one of them has ever worked well enough to establish a place alongside the legitimate water treating techniques. This paper will also offer some simple, common sense procedures that can be used as a protection from the fradulent "gadget" while not precluding the adoption of a legitimate device should one ever emerge.

Necessity is said to be the mother of invention. If ever there was an area where the economic and technical necessity is near its peak, it's the industrial water system.

Water is a nearly ideal substance for industrial cooling and heat transfer. It has unusually good thermal properties such as specific heat, heat conductivity and latent heat of evaporation. It is fluid over most of the ambient temperature range. It is non-toxic, non-flammable, and readily available and relatively inexpensive.

Water has several drawbacks, most notably that it is an excellent but inconstant solvent. More often than not it is the solutes that it carries that make the use of water such a troublesome enterprise.

When water comes to us from the sky it is relatively pure, containing only some dissolved gases plus some airborne particulate matter that it picked up on the way down. Soon after its arrival on earth the water begins to take its surroundings into solution. When this water is used for industrial purposes the soluble salts it carries plus the dissolved gases cause the water to be severely corrosive to most common metals. All of the metals except the so-called noble metals are intrinsically unstable because of their high free energy. The combination of heat, water, oxygen, and dissolved salts provide the activation energy, the easy path and the energy sink that are required for the metals to discharge their high free energy and revert to their more comfortable and stable states as ions.

Some of the materials in the water such as calcium and silica compounds become insoluble when the water is heated and concentrated in cooling towers and boilers. This scale and corrosion causes great economic loss to users of industrial water. In addition to the corrosion which destroys the function of the metallic structure and shortens their economic life, the deposits cause reduction in fluid handling capacity and loss in heat transfer. Such losses lead to frequent cleaning with acids or harsh abrasives which is expensive and further damages the equipment.

Though there are well-known technologies that can mitigate these bad side effects of industrial water, they are expensive and not always completely satisfactory. Hence we see the necessity that begets all these inventions. Nobody has ever said that the offspring of necessity were good, benevolent children, and these "gadgets" seem to prove it.

Since the users of industrial water are faced with large expenses if they do not treat the water and large expenses if they do treat the water, they are a fit audience for anyone who will tell them that all this trouble and expense can be made to go away for a small investment in the latest "gadget."

Under the best of conditions, water technology is an arcane art. It is a mixture of colloidal chemistry, equilibrium states, unstable kinetic systems, and the poorly understood fields of sequestrants and chemical complexes. Many of the critical conditions occur at concentrations so low that they are at or near the normal limits of measurement. Under these conditions it is no wonder that the specialists who are highly trained in the field are hard pressed to describe the chemistry of a water system in completely unambiguous and reliable ways. Therefore, it is not strange that the operator of an industrial water system who is not especially trained in the field of water treatment is not able to separate fact from fiction in the claims of the "gadget" salesman. One of the most important supports for the testimony supporting "gadgets" is the sound physiochemical principle that each liquid phase composition has a specific solid phase in equilibrium with it. When the liquid phase is changed, the solid phase will change too. It is in these periods between equilibriums that a solid phase or scale may be coming off the metal surfaces in large quantities. The interpretation usually is that the "gadget" is "cleaning the system up" when in actual fact one solid phase is making way for another that may be much worse than the first one.

Water systems, because of the large volumes and low concentrations involved, often come to equilibrium very slowly and observations made during the equilibrium process may not be reliable.

Since water systems are not "money making" or primary production processes, they tend to be under-instrumented and under-controlled. The observations from most water systems tend to rely on visual inspection and memory rather than recordings of quantitative measurements.

Here are some of the marks that often identify a truly fraudulent gadget:

1) The process is claimed to be a secret.

2) The process claims to rely on standard technology but the connection is not clearly made. The salesman is almost always technically unlearned in the technology and can't explain how the "gadget" works.

3) The support of the claims for the effectiveness of the "gadget" are non-quantitative testimonials by non-technical observers, statements that are not substantiated in any way or from "experts" who offer complex explanations unsubstantiated by experimental facts. The experts usually cannot be located for further discussion.

4) Often valid tests by accepted authorities are misquoted or taken out of context so that the quotation does not truly represent the finding of the test.

5) Extravagant-appearing guarantees are frequently offered by companies who could not pay off on any one single loss due to damage of a major industrial system.

Several years ago, one of the major water treating companies gave their salesmen the following summary of the marks of a "gadget." They are still good tests to apply.

Certain devices come on the market from time to time which are claimed to be effective in preventing scale, corrosion and microbiological fouling without the aid of corrective chemical treatment. The following comments are intended to explain why these devices cannot live up to the claims made for them.

1) To date, none of the currently available group of devices claimed to operate on electromagnetic, electrostatic, magnetic, sonic and other physical principles, for prevention of scale and corrosion in water-using systems have been proven effective in unbiased tests conducted by qualified water-and-corrosion-research scientists in laboratories of major universities or independent research institutes (Batelle, IIT Research Institute, MIT, etc.).

2) All of these devices (categorized as "gadgets" by consulting engineers, water chemists, and corrosion researchers) are supported only by "testimonial" letters from certain industrial users, and by self-serving research or investigations conducted by and for the promoters and manufacturers of the units.

3) Almost without exception, the "gadgets" are claimed to operate on new and mysterious scientific principles, usually in conflict with basic scientific laws, and not explained or clarified by "technical" literature and product bulletins published by manufacturers and distributors.

4) Without exception, the manufacturers claim that results of use of the equipment cannot be detected or measured by standard water analysis - since they do not alter hardness, alkalinity and other chemical characteristics of water passing through the units.

5) "Gadgets" operating on electromagnetic and electrostatic principles all claim results in direct conflict with laws of

thermodynamics which require expenditure of energy to accomplish chemical/physical changes. (Claims of useful results at power consumption less than that required by a 7 to 10 watt bulb are too ridiculous to warrant consideration.)

6) On careful investigation it often will be found that systems where improved results were claimed from use of such devices either:

a. Did not need treatment in the first place (because the makeup water was free from scaling and corrosion tendencies), or

b. Were already being treated chemically, the device being super-imposed on top of chemical protection, or

c. In the systems being "treated," blowdown (bleedoff) rates were altered drastically, so that they operated essentially once-through, with no concentration factors remaining to contribute to scaling. (Expensive in water wastage, of course), or

d. Chemical additives (soda ash, etc.) are recommended by the equipment supplier, to "aid efficiency," "increase polarization" and similar claims.

7) It is well known that almost any physical or chemical change in method of operation or preparation of feedwater and boiler water will cause sloughing off of old scale deposits for a short time, giving short-term indications of system cleanup. In the absence of chemical treatment or drastically increased blowdown, the normal result of treatment stoppage generally is sharply increased deposition of harder, more permanent scale, after existing treatment reserves in boilers and cooling towers have been depleted.

8) "Gadgets" manufacturers generally "play down" corrosion control claims, which cannot be supported by scientific facts nor recognized corrosion-control principles, and concentrate on scale-control claims.

a. "Gadgets" operating on electrostatic principles claim that the electrostatic field "utilizes oxygen to form a...thin oxide coating on internal surfaces which bars metal losses from corrosion." It is well known that oxygen in water is a powerful corrosion accelerator. It acts to depolarize protective hydrogen films on cathodic areas of metal surfaces, to allow corrosion processes to continue. It also reacts with water using electrons liberated when metals corrode, to produce hydroxyl ions (OH^-). These cause precipitation of ferrous ions eventually building up local deposits of corrosion products which further stimulate corrosion attack.

b. All of the effects claimed for the electrostatic devices (electrostatic field, protective films, etc.) if they could be confirmed, would apply only during the few seconds that water is passing through the space where the low-energy electrostatic field exists. There can be no residual effect on water that has passed the unit and entered the water-consuming system.

c. The claims of "electrons...picked up by positively charged ions of scale-forming salts..." are fallacious. The "scale-forming salts" don't exist as "salts" in solution. Rather they are present as ions. (Sodium chloride in water exists as (Na^+) and (Cl^-) ions; calcium bicarbonate hardness would be fully ionized as (Ca^{++}) and $(HCO_3)^-$ ions.) If electrons were picked up by (Na^+) and (Ca^{++}), the result would be neutral metals Na and Ca, both instantly and violently reactive with water to release hydrogen and eventually form (Na^+) and (Ca^{++}) ions again.

d. The electrostatic field can have no effect on ions which combine to form scale, in water-using equipment (boiler and cooling towers) where water evaporates and concentration occurs. In these systems ions eventually reach a concentration limit (governed by solubility product considerations) beyond which precipitation (scale-formation) of minerals occur. In other words, transient forces applied within the treater are not carried downstream to the point of use.

9) The mechanisms of scale formation are governed by temperature and ion concentrations, in the evaporative or heating unit. These mechanisms can be altered and controlled by chemical additions, but are in no way altered or controlled by exposure of make-up water to electrostatic or electromagnetic force fields. Such forces don't remove scale-forming ions nor alter their ability to react with other ions to form insoluble combinations (scale).

10) Most "gadget" manufacturers tacitly admit inability to prevent scale in heated systems (above 180° F), so don't recommend the units for boiler feedwater use. In boilers, scale formation and corrosion both are local phenomena, taking place right on the heat transfer surfaces, where water is being evaporated and dissolved solids are left behind and concentrated. When concentrations of ions such as (Ca^{++}) and (SO_4^{--}) reach their solubility limits, then they react immediately to form crystals of insoluble salts such as $CaSO_4$. Many such crystals combine to form scale layers. Apparently the "gadget" promoters believe they can pass a salt solution through their device and into an evaporator - where the solution is boiled to dryness, without leaving salt crystals behind! This is obviously impossible!

Isn't it equally illogical that passing feedwater through an upstream electrostatic field should prevent formation of insoluble scale crystals, once water in an evaporative system (boiler or cooling tower) reached solubility limits of the ions carried by entering feedwater?

11) Claims for control of microorganisms in water-using systems are not explained in any way. The manufacturer of one electrostatic treatment unit claims that his device acts as an ozonator, producing ozone which has proven efficacy in microbiological control and water sterilization. The fallacy here is that the electrostatic field is imposed across a water-filled annulus - the water having appreciable conductivity and dissolved solids content. Ozone generation requires passage of very dry air (or oxygen) through a very high voltage electrostatic field (5,000-50,000V), and power consumption in the process is appreciable. Power requirements for ozone generation are very high - yields averaging only about 50 grams/kilowatt hour. Typical power demand is 7-10 kw/hrs per pound of ozone. (Compare this with total power requirements of 7-100 watts for electrostatic water treaters.) By very dry air is meant drying to a dewpoint of 60° F. The process won't work in the presence of water.

12) A d-c electrostatic field would have some effect on suspended particles with definite charge characteristics (+ or -), causing them to drift toward the oppositely charged pole. Such a d-c field likewise would encourage drift of ions toward the oppositely charged poles. But in the absence of a membrane or similar barrier, nothing would keep such particles or ions at or near the charged poles. Moreover, since water remains in the field only a few seconds, the ions would immediately redistribute themselves throughout the water, upon leaving the device. Effect on solid suspended particles, if any, would be equally transient.

13) An important consideration which should be questioned is that of warranty on defective parts replacement, versus product liability coverage which would replace water-using equipment destroyed or damaged during the use of the device, or indemnify purchasers for costs of repairs or replacement of such damaged equipment (boilers or cooling towers). All major water treatment firms carry such product liability coverage. Do the firms that market "gadgets" carry such liability coverage?

14) Under existing state and local E.P.A. and similar regulations, installation of Electrostatic Water Treatment Systems would represent an addition to an existing public water supply, requiring construction permits, operating permits, assignment of certified (licensed) plant operators, and compliance with other applicable regulations. This should be investigated in every case a "gadget" is recommended.

15) The stipulated Underwriters Laboratories approval is meaningless in terms of operating efficiency. This listing applies only to safety characteristics of electrical equipment included in the device, including proper electrical insulation, freedom from internal or external current leakage hazards to personnel, etc.

16) The major appeal of such "gadgets" is that they promise "something for nothing," by inferring that water treatment chemical costs will be eliminated, pollution potential from discharges of treated water eliminated, etc. In fact, since the devices actually do nothing to eliminate scale and corrosion problems in evaporative equipment, and are usually quite expensive, they really offer nothing for something.

Suppose a salesman approaches you with a story that seems different (and more believable) than the usual "gadget" pitch, or one of the vice presidents of your company intimates that he wants you to give one of these devices a trial. What should you do to protect yourself and your company? Here are some simple, common sense guides that may help:

1) Try not to be the first in your area or your industry to try the device. Ask the salesman to come back when he has a successful installation nearby on equipment like yours.

2) Don't hurry. Wait until some engineer you know has had his second successful annual inspection of a system treated by the "gadget." Try to be on hand for the second inspection.

3) Ignore non-technical, non-quantitive testimonials. Even if they're right you couldn't prove it.

4) Check all legitimate references carefully. If they are all very recent, non-technical and on applications widely different from yours, ignore or discount them.

5) On any technical references, talk to the experimenter doing the work. See if:

a) He appears to be competent and

b) If he really believes the "gadget" will live up to all its claims.

6) If you must try the device, (for political reasons), install it on a small, non-critical system such as the air conditioning unit serving the office of the man who wants the test run.

7) Be sure to establish a sound, quantitive basis for comparison (corrosion rates, fouling factors, etc.) on the test system before the "gadget" is installed so that you will have something to measure against.

8) Be cautious about recommending the "gadget" even after a successful test. It may not work for everyone under all conditions. Your letter of recommendation may be accidentally or deliberately misinterpreted and misused.

9) Giving negative recommendations can also be dangerous. They may be the subject for legal action against you even when you have scientific proof on your side.

One thing seems certain. Somewhere one or more groups of people are at this time getting the next wave of "gadgets" ready for the unsuspecting market. Many people will lose time and money finding out the old truth that you can't solve difficult and complex problems easily no matter how hard you try. It is still true that "there's no such thing as a free lunch."

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