Reprinted from INDUSTRIAL AND ENGINEERING CHEMISTRY, Vol. 46, Page 954, May 1954

Practical Performance of Water-Conditioning Gadgets

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Observations made by the service engineers of Hall Laboratories concerning the practical performance of various gadgets in actual plant operation are reported. Gadgets are defined as special devices requiring substantially no technical control which are alleged to treat water by nonchemical means to prevent scale, corrosion, and other troubles encountered in the industrial use of water. Gadgets are discussed in two categories—those with an external electrical circuit and those without such a circuit. References are given describing some of the various water-conditioning gadgets which have appeared on the market since 1865.

MOST human beings want to get something for nothing. Even the engineer with his basic belief that he can get out only what he puts in as far as energy and matter are concerned will hopefully buy a ticket that may give him a new auto if his number happens to be drawn. Add to this basic human trait the current belief that, tomorrow or possibly the day after, science will provide an easier way of meeting each of our needs and you have an explanation for the many millions of dollars gambled annually on gadgets.

Let's define what we mean by gadgets. For the purposes of this paper they are special devices requiring substantially no technical control which are alleged to treat water by nonchemical means so that the familiar troubles caused by deposition of scale or sludge, by corrosion and cracking, or by the accumulation of organic slimes will plague us no more. Usually they are claimed to have additional powers for good; for example, one or another will eliminate any objectionable taste and odor from water, or remove slag deposits from the outside of the tubes in a boiler fed with water passed through the gadget, or improve the taste of a cigarette laid on it.

Cathodic protection, properly designed, installed, and maintained by experienced engineers, has proved most effective in controlling external corrosion of pipelines buried in the ground. It has also shown promise in the protection of tanks, where the anodes can be distributed in such a manner as to provide an equal density of electrical current to all of the surface to be protected (*105*). However, so far as the authors are aware, no reputable proponent of cathodic protection has yet engaged to protect the internal surfaces of the complex piping or equipment in which water is conveyed and used for generation of steam, for cooling, or in a process.

The promotion of gadgets is currently at one of its periodic peaks. Any thoughtful scientist or engineer naturally tends to suspect the claims of universal utility, the explanations in pseudo-scientific gobbledygook of how each gadget is supposed to function by electrical or catalytic or supersonic means, the warm testimonials from obviously well-meaning but uncritical users.

[1] Presented before the Fourteenth Annual Water Conference, Engineers' Society of Western Pennsylvania, Pittsburgh, Oct. 19–21, 1953.

The scientist and engineer may even feel compelled to state with courage and conviction their conclusion that these promotions are the bunk, as did Eliassen and Uhlig (*19*). Always, however, the practical man in the plant wonders if the experts could be missing some new truth not yet fully appreciated.

In this paper we take an objective look at what the gadgets themselves have accomplished when applied to specific water problems in specific plants. The body of this paper, therefore, comprises condensed case histories, each observed firsthand by one of the Hall Laboratories' field engineers.

The authors have not considered testimonial letters as adequate evidence that a gadget has solved a problem of scale or corrosion. Hall Laboratories has not spent the substantial amount of money which would be required to study in detail the facts behind such testimonial letters from plants not regularly served by the company.

The case histories end rather monotonously with the gadget tossed on the junk pile. Here and there in the technical literature, however, there is a claim of a beneficial effect or a possible explanation. The claims are included in the literature cited; the explanations are reported in the text. The methods customarily employed in promoting gadgets and what can be done by the man in the plant to protect his equipment, his company, and himself are considered.

Table I is presented to place the gadgets with which we have had practical experience against the background of alleged inventions in this rather remarkable art. While Table I is not all-inclusive, it does show the ingenious lengths to which successive inventors have had to go to find something not revealed in the prior art. Certainly, there is some suggestion here of invention of patents instead of patenting of inventions.

The various gadgets in the following case histories are classified according to two types—those involving an external electrical circuit and those not having such a circuit.

EXTERNAL ELECTRICAL CIRCUIT

Gadget I-A. Gadget I-A consists of a cylindrical body in which is inserted a concentric slotted tube, both stated to be machined from castings of composition *M* naval bronze. The slotted tube is electrically insulated from the body. Water flows into the bottom of the body, from the annular space through the slots into the inner tube, and out of the top of the latter to use. The tube is the anode and the body the cathode of a cell through which a very small direct current is passed.

As stated in a descriptive brochure, the principle of Gadget I-A is as follows: "The function of —— is to pass a small electrical current (in microamperes) through the water to influence the process of crystallization without making any detectable change in the chemical composition of the water. —— causes the dissolved hardness salts to crystallize in a different manner and the deposits are soft, thin, friable, and easy to remove."

Gadget I-A has been studied under controlled conditions in our own laboratory. Operation of an evaporator was simulated by using a coil of copper tubing, internally heated by steam at 10 pounds per square inch. The copper coil was immersed in the water to be evaporated, which was at atmospheric pressure. Feed water at room temperature was supplied automatically to replace that lost by evaporation and a blowdown of 5%. All the water supplied to the simulated evaporator was passed through a commercial unit of the gadget supplied directly by one of the men at that time concerned with its promotion.

The effect of the gadget on scale formation was tested with two different types of water, Pittsburgh tap water, which deposits calcium sulfate scale, and a bicarbonate well water, which deposits calcium carbonate scale. In neither case did the passage of the feed water through the gadget show any improvement as compared to blank runs. There was no reduction in the amount of scale or the adherence of the scale to the copper surface neither the appearance of the scale nor the identity of the constituents was changed.

This gadget, which was originally developed in Great Britain, was tested there both in the laboratory and on small commercial boilers by investigators of the Department of Scientific and Industrial Research. Their adverse report (*47*) that observed differences from test to test in the quantity and nature of the deposits did not appear to be associated in any way with the electrical treatment of the feed water was challenged by the inventor (*27*), who attributed the lack of favorable results to the fact that a special schedule of blowdown had not been followed.

Our engineers have reported the following cases:

1. A Dutch engineer at one time on our staff had some firsthand experience with this contrivance at a central station in Holland in 1941. When asked how it worked, he answered, "Good—for about 6 weeks. Then we had to clean the evaporator. The make-up had been softened with lime and soda ash and then evaporated. Usually it was necessary to clean the evaporator mechanically at 6- to 8-month intervals. When chemical treatment was stopped, and this apparatus was used, production of the evaporator dropped from 8.5 to 4.5 tons per hour in 6 weeks and it was necessary to clean the evaporator."

2. A rubber manufacturer in Delaware tried this device on the make-up for a 250-pound-per-square-inch watertube boiler. As a result, the internal surfaces of the boiler became scaled to the point that it was necessary to install another boiler and place the original in stand-by. The scale was high in sodium aluminum silicate (analcite).

3. Our associates in the marine field report the following experience:

> During our regular boiler water service call on this vessel on April 19, 1951, the chief engineer and his first and second assistant engineers stated that, in their opinion, after prolonged observation, the —— unit had made no appreciable difference in the rate of deposition or character of scale accumulated in their evaporator. This was also the expressed opinion of the superintendent of engineers.
>
> During the trial all deposits examined by the writer in our laboratory exhibited a hard crystalline carbonate scale underneath the iron oxide and immediately adjacent to the tube surfaces.

Gadget I-B. Gadget I-B is a plastic cylinder to be inserted in a water line. It contains electrodes said to be constructed of "special" materials, which are connected to a power line through a transformer in a control box. The principle is explained as follows: "When water is passed through an electrical field of the proper intensity, the colloidal particles and dissolved salts act as a conducting medium. They pick up an electrical charge which is regulated in proportion to the conductivity of the water. These elements, which would ordinarily deposit on the walls and tubes of boilers and on the metal surfaces of other equipment, become repellent to these surfaces."

Installed on a line supplying a hard, bicarbonate well water to a hot water heater in an Indiana plant, the gadget failed to reduce the rate of deposition of calcium carbonate scale on the heater coils.

NO EXTERNAL ELECTRICAL CIRCUIT

An amazing variety of the more recent gadgets involve no external electrical circuit. It is as if the promoters had decided that the obviously electrical device had reached the end of its string, but that the expanding frontiers of science offered even more attractive bases for their sales stories.

Gadget II-A. Gadget II-A is composed of two copper plates shaped very much like pie pans or bowls, inverted and clamped in place over four rectangular zinc or aluminum prisms. Several of

Table I. Principles of Various Systems for Preventing Scale and Corrosion by Means of Gadgets

(Not a complete record of patents and papers in this field)

Year	Author or Inventor	Principle of System
1865	Porter (*69*)	"Lightning rod" in boiler to collect electricity
1866	Hay (*41, 42*)	Direct current from point to point through boiler steel
1869	Farmer (*24*)	Direct current from metal anode to boiler shell
1873	Hay (*43*)	Magnetic field
1888	Kotyra (*51*)	Alternating current between electrode and boiler shell
1907	Rickard (*74*)	Direct current from iron anode to boiler shell
1909–15	Cumberland (*10–16*)	Direct current from iron anode to boiler shell; 10 v., 10 amp.
1920	Sarrazin (*76*)	Direct current from iron anode to boiler shell, 10 v.
1921–2	Siemens & Halske (*90, 91*) Philippi (*65, 66*) Walde (*104*)	Transformer provides low voltage alternating current between iron, carbon, or zinc electrodes and boiler shell; current of 0.02–0.04 amp./sq. m., power consumption 0.7–1.0 w./sq. m.
1921	Rummel (*75*)	Conductivity improved by adding powdered zinc, aluminum, or graphite to boiler water in 1:10,000 ratio
1922–6	Schnetzer (*82, 84, 86*) Pothmann (*70*) Reutlinger (*73*) Schöne (*88*)	Boiler connected to negative terminal of insulated source of direct current, positive terminal remaining free
1922–5	Siemens-Schuckertwerke (*92, 93*) Mans (*54*)	Electrolysis and heat in vessel preceding boiler to precipitate sludge; as improvement, concentric tubular electrodes
1923–4	Heberlein (*44, 45*)	Direct current interrupted 500–1000 times min. by vibrator attached to boiler
1924	Kirkaldy (*48–50*)	Mechanical improvements in electrodes of Cumberland system
1925–9	Hauptvogel (*38–40*) Schulz (*89*)	Small direct current passed through boiler steel
1925–6	Schnetzer (*83, 85, 87*)	Direct current from thermoelement heated by boiler; as improvement, direction of current flow reversed at intervals
1925	Thalhofer (*98*) Gardner (*32*)	Direct current passed through boiler steel from thermoelement heated by boiler; in second patent, pulsating current produced by vibrator
1926	Freeman (*31*)	Flow of current in same direction as inherent flow within vessel
1926	Elmore and Creighton (*20*) Creighton (*8*)	Small direct current passed through boiler steel
1926	Neeley (*59, 60*)	Direct current passed through boiler steel
1927	Blass (*4*)	Magnetic field
1927	Siemens-Schuckertwerke (*94*)	Water held under vacuum during electrolytic treatment
1928	Metallbank und Metallurgische Gesellschaft. A.-G., (*58*)	Electromagnetic waves having wave length greater than a wave length selectively absorbed by water
1928	Heinrich (*46*)	Ground and antenna attached to boiler to equalize potential difference between earth and atmosphere
1930	Neeley (*61*)	Plurality of alternating electric currents of different characteristics passed through boiler steel
1930	Neeley (*62*)	Feed water subjected to electrolytic or electromagnetic treatment before entry into boiler
1931	Gunderson (*37*)	Direct current from Duriron anode to boiler steel
1931	Reichart (*72*)	Flow of current interrupted by rise and fall of water level
1933–9	Abbott (*1*) Scalebuoys, Ltd., and Willey (77) Willey (*106*)	Glass bulb containing mercury and inert gas under low pressure agitated in contact with water; as improvement, colloidal material added to water
1933–4	Schirmer (*78, 79*)	Alternate polarisation and depolarisation of internal electrode
1933–9	Gerber (*33–35*)	Alternating current limited to about 150 ma. by condensers and resistances
1933	Guldager (*36*)	Use of 10–25% of electricity at low voltage necessary to electrolytically deposit that part of bicarbonate hardness which must be removed to prevent scale
1934	Erenyi (*22*)	Special circuit involving transformer with secondaries connected together through rectifier and coupled to boiler through condensers
1935	Von Mautner-Karkhof (*56*)	Combination of high and low frequency alternating current, former transmitted from aerial stretched over boiler
1936–9	Pierpoint and Crouch (*67, 68*)	Alternating current of from 0.01–0.53 ma. from anode of metal or carbon to tank or pipeline
1937	Thomsen (*99*) Schneeweiss (*80, 81*)	Direct current at 6–10 v. from aluminum anode to hot water heater shell
1937	Splittgerber (*96*)	Summary of several systems and German patents
1938–53	Freeborn (*26–30*)	Tubular cathode containing concentric tubular anode, 0–12 mv. d.c.
1938	Mazza (*57*)	Alternating current and direct current passed through boiler metal
1939	Beatty (*3*)	Current density varied automatically with flow of water
1942	Crouch (*9*)	Alternating current through water between concentric tubular electrodes of copper and steel, respectively
1943	Barbier (*2*)	Catalysis by emanation from closed cylinder
1943	Butler (*5–7*)	Bimetallic couple of copper and zinc
1944	Lattner (*52*)	Bimetallic couple of copper and zinc, automatic indication of need for renewal of zinc
1946	Evans (*23*)	Homemade bimetallic couple of copper and zinc
1949	*Petroleum Times* (*64*)	Oscillatory current of radio frequency; aluminum electrodes within but insulated from bronze castings; power consumption 36 w.
1949	Vermeiren (*101–3*)	Water passed in reversed directions through magnetic field produced by solenoid energized by alternating current
1951	McIntosh (*53*)	Electrode for bimetallic couple containing dispersed pellets of more positive metal to create local galvanic cells
1953	*Engineer* (*21*)	Ultrasonic vibration at 28,000 cycles/sec. induced by power input of 20 w.
1953	Pourbaix (*71*)	Direct current intermittently from iron anode with control of electrode potentials

these assemblies are placed in a row in one or more of the boiler drums, the number being determined by the boiler horsepower. They are replaced after a certain number of hours of operation.

The "physio-electro" principle of the device has been described by the chief technician of the manufacturer as follows: "The —— consists of an improved type of galvanic cell, the primary purpose of which is to provide an electrically 'analogous overage' current, the electromotive force of which is greater than the system set up in the electrolytic solution formed in boiler water containing alkali and alkaline earth metal salts, and which by reason of the allied and coincidental conditions of temperature, pressure, and concentration of salts and ions by rapid evaporation, constitute a powerful, active, and very conductive electrolyte, and the immediate system set up between the electrolyte and the boiler metal.

"The primary function of this third system current is to cause accumulative and sustained secondary ionization effect which carries the intermediate scale-forming and corrosive products of the primary natural ionization to a greater degree of molecular decomposition (including the active radicals) and reintegration arrangement into inert and insoluble end point products by reason of such electronic activation in interatomic physical affinations.

"Under slow decomposition the cathodic pole material releases a gelatinous salt which is chemically and electrically amphoteric, affinitative to the various precipitates, which colloidalizes these acting as a coagulant to bring them down in a depolarized chemically inert and electrically neutral flocculent sludge mass for easier removal."

This is the record of practical performance in the field:

1. A woolen manufacturing company in West Virginia installed the gadget on a three-drum, low-head, 250-hp. boiler operated at 150 pounds per square inch gage. Make-up of about 90% was zeolite softened on the sodium cycle. A heavy scale of calcium carbonate and calcium silicate was laid down in the boiler in spite of the presence of the gadget.

2. A textile manufacturer in North Carolina discontinued internal conditioning with phosphate and installed several of the units. Two months later the operators reported that they were pleased with the results. However, after another month, the plant discovered that the 250-hp. horizontal return tubular boiler had become badly scaled. Internal chemical conditioning was reinstituted.

3. At an automotive plant in Indiana, a low make-up of lime-soda softened water was supplied to a 500-hp. watertube boiler

operating at 175 pounds per square inch gage. Substitution of the gadget for internal chemical conditioning resulted in deposition of hard scale.

4. A leather tanning company in Pennsylvania gave the gadget a second chance. Water with a hardness of 3 equivalents per million (e.p.m.) (150 p.p.m. as $CaCO_3$) was supplied to 200-hp. boilers operating at 150 pounds per square inch gage. After 3 months with the gadget installed, it was obvious that new scale had been deposited. To meet this situation, the promoter changed the electrodes in the gadget. In another 3 months, the boilers developed even more scale.

5–7. In essence, these stories are repeated at another textile plant in North Carolina, at a china company in West Virginia, and at a government installation in Washington, D. C.

Gadget II-B. Gadget II-B was described by its inventor as "— a glass bulb having within it a body of mercury and a filling of nonreactive gas or gases at a low pressure —" (*1*). When the bulb was agitated in water, it was said to give off a static charge.

1. A New England utility will probably long remember the experience with this mechanized counterpart of an electric eel. The glass bulbs containing the mercury were placed in their deaerating heaters where the agitation of the water was supposed to move them, causing the electric discharge and thereby eliminating scale. After 3 months, however, it was found that the boilers had accumulated about $^1/_{16}$ inch of rather pure calcium sulfate scale. At the end of 7 months the build-up of scale had reached $^1/_8$ inch. At that time the superintendent of the station returned to chemical treatment. Almost a year of combined chemical and mechanical cleaning was required, however, to remove the scale which had been permitted to form. These were 750-hp. watertube boilers operating at 200 pounds per square inch gage with high make-up of 3- to 4-grain water.

2. A horizontal return tubular boiler in the vicinity of Boston was equipped with this device some years ago. The feed to this boiler was 90% condensate returns and 10% make-up of Boston city water, which is relatively soft. Subsequent to the installation, the boiler was inspected at 6-month intervals. These inspections indicated a progressive scale build-up to the point that the internal surfaces of the boiler were coated with $^1/_8$ to $^3/_{16}$ inch of scale. The salesman was a charming fellow who postponed the inevitable by first stating that movement of the bulbs was insufficient so that it was necessary to attach a motor-driven agitator. Later it was concluded that the bulbs contained the wrong gas, which, when changed, was good—or bad—for another 6 months before final discard of the gadget.

Six years after the original British patent (*1*) was issued, an improvement was patented (*77*). It had been observed, according to the specifications, that the failure of the gadget to perform in some cases correlated with the absence of colloidal impurities in the water. Therefore, it was now considered desirable to add colloidal material to the water to be treated before it flowed past the glass bulb.

Gadget II-C. Gadget II-C is a cylindrical tank similar to those for domestic hot water but equipped with a perforated tube or tubes running lengthwise, with caps at the ends projecting outside the tank. The unit is installed horizontally in the cold water line ahead of equipment or water systems to be protected from scale and corrosion. Cylindrical cartridges with a brass case are slipped into the perforated tube from the outside before it is placed in use.

A novel feature of this gadget is the cycle of 2 days on and 5 days off specified to maintain the efficacy of the treatment. For 2 days, referred to as the catalytic period, the unit is on the line with water flowing through it to use. Then for the following 5 days, called the inhibiting period, the unit is by-passed with the drain cock and air vent left open.

Promotion of this gadget in the United States apparently began early in 1950. Descriptive literature characterizes the process as catalytic, claims that it is a "revolutionary" French invention and states: "The theory and basis of this invention was the results of years of research and intensive studies of magnetochemistry and chemical kinetics by such renowned physicists as Professor Pierre Curie, Bohr, and Wigner." The legend, "Patent Pending," probably refers to a patent application by Barbier in 1940 which was seized by the Alien Property Custodian and published in 1943 (*2*).

It seems scarcely possible that the renowned physicists would agree with Barbier's explanation of his invention. According to the patent application, inside the metal casing of the cartridges is a "roasted and absorbent vegetable product, such as wood charcoal, this vegetable product being impregnated with an organic liquid, for instance, ethyl alcohol extracted from garlic." (Perhaps this is an error in translation and should read ". . . .an organic liquid, for instance, that extracted by ethyl alcohol from garlic.")

Initially charged with negative electricity, this cartridge is alleged to emit electrons through the water to a grounded metal surface. "The electric field thus constituted in the interior of the mass of liquid augments the force of repulsion of the electrons around each atom, so that these electrons move farther away from one another, thereby modifying the architecture of the atom." Apparently the Government was willing to allow publication of this disclosure while the Manhattan Project went on modifying the architecture of the atom the hard way.

Promotional material distributed to prospective users contains some additional charming bits of science fiction: "When water normally used for industrial or potable purposes comes in contact with the —— catalytic cell, a para-ortho hydrogen conversion is created instantly. The ortho hydrogen acts on oxygen so that it becomes a very active element. Oxygen is a very strong paramagnetic gas. These two activated elements, the ortho hydrogen and the activated oxygen then act on all the paramagnetic elements that exist in water. Most of the impurities in water are paramagnetic.

"All of the paramagnetic elements activated by the —— in water create an increase in the molecular magnetic field which disperses all of these activated elements and they remain dispersed after precipitation. This dispersion prevents the formation of the sticky hard scale in the water carriers. The precipitated elements, in the dispersed forms, then move easily with the natural flow in the carriers and all are eliminated by draining."

The following are considerations of practical performance.

1. A Texas utility had been feeding zeolite softened water to bent-tube evaporators and blowing down about 6%. The gadget was installed on the basis that unsoftened bicarbonate water carrying about 1.5 e.p.m. of hardness (75 p.p.m. as $CaCO_3$) could be used satisfactorily if the blowdown was increased appreciably. Within 2 weeks so much scale had formed that it was necessary to shut down the evaporator for mechanical cleaning.

2. In a Kansas utility plant, the surfaces of a heat exchanger were coated with a hard, dense calcium carbonate scale in only 19 days of operation after one of these devices was installed. The temperature of the exchanger influent water was 89° F., while the effluent was 105° F. It was soon found that the effluent temperature dropped and the cause was ascertained to be the build-up of $^1/_8$ inch of scale.

3. A plant in the vicinity of Washington, D. C., conducted a trial for a period of 15 weeks. The gadget was installed on the feed line to a 20-hp. vertical firetube boiler operating at 70 to 85 pounds per square inch gage on soft, untreated Washington city water. New tubes were installed just prior to the test, and inspection showed the shell at that time to be virtually free of scale. The boiler was operated continuously 24 hours per day except for three inspections during the 15-week period. At the end of this time, a considerable amount of scale was found on the tubes and tube sheet, and corrosion had taken place on the tubes at and above the normal water level. The results were judged by the operators to be equivalent to those obtained with no

treatment. The plant was unable to contact the representatives who supplied the gadget.

4. An oil refinery in Texas installed the gadget on a pilot plant heat exchanger and cooling tower unit. Observation of the surfaces in the heat exchanger revealed no improvement, as compared to blank runs without the gadget.

5. A processor of oils and fats in Mexico found that use of this device resulted in serious scaling conditions and tube losses in a 150-pound-per-square-inch boiler producing 12,000 pounds of steam per hour.

6. A utility plant in Mexico applied the gadget to evaporator feed which constitutes the pretreatment to 675-pound-per-square-inch boilers. The process was discontinued after 3 months, since no noticeable improvement was experienced in the operation of the evaporators.

7. Results were unsatisfactory for a once-through cooling system using a high bicarbonate (400 p.p.m.) shallow well water at 70° F. in a chemical plant in the South.

Gadget II-D. Gadget II-D is a heavily galvanized cast-iron fitting shaped like an oversized pipe coupling with an interior cross post. It is alleged that the unit "is made entirely of specially processed cast metal which imparts catalytic action to water flowing through it." The user is warned that, to get quick results, "magnesium and zinc anode rods, bimetal devices, and other forms of cathodic equipment must be removed." Much is made of continuous electrical conductivity of the entire piping system. "On installations where the corrective action of —— Conditioning is not immediately noticeable on both the cold and hot water, *check the piping system thoroughly!* It will be found that their exists one or more electrically nonconductive joints of the types illustrated. When each such joint is properly shunted with bare copper wire the —— cannot fail to perform."

Although this gadget has only been called to the authors' attention during the past year, there are a number of case histories resulting from its particularly aggressive promotion:

1. A mining operation in Colorado uses 100% make-up of raw water to its 125-pound-per-square-inch boilers. Without treatment, this water deposits calcium sulfate scale in the boilers. Internal chemical conditioning was discontinued while the gadget was tried out for a 6-week period. Even in this short time, a considerable amount of new scale formed on the internal surfaces of the boilers. As a result, adequate chemical conditioning was resumed.

2. A ceramics manufacturer in western Pennsylvania heats water from the Allegheny River to 200° F. in a heat exchanger. To see whether the gadget would reduce deposition, a comparison test was run with one exchanger operating directly on raw water and a companion exchanger supplied with water passed through the gadget. After a period of 4 months, the units were inspected. Both were found loaded with deposit to the same extent.

3. A textile plant in West Virginia, using water from the Ohio River, had accumulated scale in a compressor cooling system over a period of years. Promoters of the gadget claimed that it would clean up these lines; in fact, it was stated that scale would come loose in such large chunks that there would be danger of plugging the lines. The chief engineer, a most practical person, simply tied a pillowcase over the discharge line to catch the loosened scale. After 30 days of operation with the gadget in the line, the pillowcase was still conspicuously empty.

4. A dry-cleaning company in Philadelphia was told that installation of the gadget would improve the condition of the service line, improve the taste and odor of the water, and reduce scale in the evaporator making distilled water. No benefit in any of these respects was produced by the gadget.

5. A restaurant in Pennsylvania installed the gadget on the line to a tankless-type hot water heater. After 30 days of operation, the installation was widely publicized as a success by the promoters. After another 3 months in service, the heater was found to be almost completely plugged with scale.

6. A New England utility plant installed the gadget upstream from some new piping. After several months, this piping was found to be badly corroded. The piping was replaced and a second test was made, with the same results.

7. In a steel mill in the Midwest, cooling water saturated with oxygen enters gas coolers at about 80° F. and leaves at from 125° to 180° F. New test sections of the effluent line were corroded after exposure for 30 days to water passed through the gadget installed ahead of the gas cooler. The corroded appearance was the same as that observed without any treatment.

Gadget II-E. Gadget II-E is described as an "inert metal electrode which when properly installed will, by electrical stabilization, convert usual adverse current to a vehicle promoting easier access of furnace heat to boiler water—this without changing your present method of boiler water treatment." This gadget is said to cause the normal scale forming materials to precipitate as a sludge and be removed with the boiler blowdown.

1. A unit installed in a 90-pound-per-square-inch, three-drum, low-head boiler in a Missouri plant supplied with water carrying about 1.5 e.p.m. (75 p.p.m. as $CaCO_3$) of hardness comprised heavy mesh screen welded on a number of lengths of 1-inch pipe and installed in the drum of the boiler. At the end of 60 days, the free trial was discontinued because formation of new scale was evident.

2. In a plant in Ohio, the steam drum was filled with frames of 1-inch stainless steel on which were mounted zinc screens. Two months later, the plant was shut down for a week by the failure of two tubes and the necessity of replacing 120 other tubes. Additional units of the gadget were installed in the water-wall headers. Inspection after 1 week of operation revealed that new scale was already forming on the 120 replacement tubes. Analysis showed this scale to be essentially calcium sulfate. Further replacements of tubes were necessary before the plant eventually adopted chemical treatment.

THE SHAPE OF THINGS TO COME

In addition to the preceding gadgets, for which the authors have specific case histories, we have received information concerning the following devices but do not as yet have firsthand reports concerning their use.

Gadget I-C. Gadget I-C, apparently developed in Switzerland, invokes ultrasonic vibration to remove scale continually as it is formed. A simple transformer and single tube amplifier with a power consumption of 20 watts supplies up to four oscillators from which damped vibrations of 28,000 cycles per second are transmitted to the feed or boiler water.

Gadget II-F. Gadget II-F is a cylinder said to contain a permanent magnet. As water passes through the cylinder, "the molecules of salts of calcium, magnesium, silica, and other scale forming substances which have been submitted to the electric bombardment receive a superficial tension which prevents the normal formation of carbonates, sulfates, and silicates, with waters of crystallization. When the carbonates, sulfates, and silicates precipitate they are in the amorphous form as the molecules of water of crystallization are no longer attracted. Maintaining these scale forming salts in the amorphous form, of course, prevents crystal formation and prevention of crystal formation prevents scale formation."

Gadget II-G. Gadget II-G, claimed to have been used in France since 1938, has not even arrived as yet in the United States but quite possibly will be promoted here in a year or two. It comprises an activator, which appears to be a glass tube filled with small particles of mineral. This activator is alleged to emit electromagnetic radiations, not detectable with a Geiger counter. "Under the effect of these appropriate radiations, without ever causing corrosion of the metal, all alkaline-earth salts held in solution in water, no matter what their composition or concentration may be, become amorphous as soon as they become insoluble and incapable of adhering either to one another or to any given surface."

The activators are suspended in a tank through which the water to be treated flows. However, the tank must be grounded so that the resistance in the ground circuit is less than 8 ohms. This is accomplished by means of a cage of copper strips installed in contact with the wall of the tank and linked with a copper ground wire.

DO GADGETS PREVENT SCALE AND CORROSION?

From our experience, gadgets do not prevent scale and corrosion under the varied conditions met in practice. If there were a way of achieving a consistent record of satisfactory results, then some gadget should have succeeded in establishing itself more generally than any has. Actually, in the more than three quarters of a century since the first objective engineering investigation of the "use of electricity and zinc plates for the prevention of boiler scale" was made by Fischer in 1876 (*25*), gadgets have come and gone in a motley procession. None of the four investigated by DeBaufre (*17*) in 1932 appears to be on the market today, although the inventor of one is currently listed as vice president of a company promoting a different gadget.

If we peer behind the often preposterous explanations and claims made by the promoters of gadgets, three interesting scientific phenomena are visible, all concerned only with the precipitation of calcium carbonate. Since no promoter of a gadget has yet mentioned these phenomena, we may assume either ignorance or an intent to mislead. These three phenomena are:

Water which normally should deposit calcium carbonate as a result of moderate heating or chemical treatment has a strong tendency to remain supersaturated.

Precipitation of calcium carbonate from such a supersaturated water may be prevented or greatly retarded under some conditions by very small amounts of a number of substances.

Precipitation of calcium carbonate as separate crystals may be promoted by the addition of some substances which provide nuclei for crystals to start to grow from the supersaturated solution.

Twenty years ago, toward the end of a decade in which he had explored the frequently inconsistent behavior of solutions which should deposit calcium carbonate from solution, Stumper discovered that zinc had the peculiar ability to delay precipitation, even when present in extremely small amounts in the range from 0.5 to 10 p.p.m. of Zn^{++} ion in solution (*97*). Even metallic zinc in contact with a calcium bicarbonate water interfered with the precipitation of calcium carbonate, presumably because some small amount of zinc was dissolved by the water. Stumper mentioned that salts of copper and of thorium also showed an inhibiting effect.

Apparently without knowledge of these early observations, Evans in 1946 (*23*) made himself a "gadget" which minimized scale in a laboratory still. This was a simple bimetallic couple of zinc and copper strips in contact with each other but insulated by glass from any other metal surface. When it was placed in the bottom of the still, it kept the small connection to the overflow from becoming blocked with calcium carbonate scale and caused the deposit in the still chamber to come down largely as a light, fluffy sludge. Scale that formed on the heating element itself was no longer difficult to remove.

Subsequently, the effect of zinc as an inhibitor of calcium carbonate scale was studied by Urion and Lejeune (*100*). These investigators pointed out that many of the gadgets promoted in France for the treatment of water had in common the fact that they were internally coated with zinc. Their experiments verified the fact that zinc added to a hard bicarbonate water would inhibit the precipitation of calcium carbonate but that there was no similar effect on calcium sulfate.

Stumper (*97*) found that the addition of any one of several kinds of finely divided solids produced the opposite effect and markedly increased the rate of precipitation of calcium carbonate. Graphite and other types of carbon, calcium sulfate, metallic copper, and ferric oxide were particularly effective. The most recent application of this principle of accelerating precipitation of calcium carbonate by means of a gadget has been described by Pourbaix (*71*). Colloidal iron hydroxide was produced in the feed water to an evaporator by the flow of a small current between iron electrodes. As a result, the capacity of the evaporator was maintained at an average of about 60% without cleaning. An interesting aspect was the fact that the electrodes were passivated by the flowing feed water and had to be "rested" overnight.

An inquiry into the anatomy and composition of a number of gadgets suggests that most of them probably represent attempts to apply one or the other of the two mechanisms described. Unfortunately, the introduction of a little corrosion product, whether it be zinc to try to delay precipitation of calcium carbonate or iron or copper to try to accelerate it, does not solve all of the problems to the extent the promoters wishfully allege. Our own experience indicates that it does not even have a good batting average in keeping down the formation of calcium carbonate scale, the only beneficial result the most hopeful could expect.

METHODS OF PROMOTION

In the main, gadgets are actually sold to plants by men of good reputation working for an established local company handling plumbing supplies or small items of plant equipment. In the early stages of a promotion, these salesmen are honestly enthusiastic. Later, faced with more and more instances in which a gadget has failed to produce the anticipated results, they may respond with anything from apology to argument. Admittedly, they know only what has been told them by the promoter.

The promoter himself may be an inventor with a stubborn belief that his invention must work; he may, however, be nothing more or less than a sharp operator. The man with a gadget to promote faces an intriguing series of problems. If he is aware of past experience, he realizes that he must make some fast bucks and get out. He can, of course, dissolve a dying venture under one name and start up again with a similar gadget under a new name. He can also shift his campaign from one part of the country to another, keeping one jump ahead of a disappearing reputation. He can even work on a global scale, bringing to eager Americans the gadget which no longer is able to find a market in England or in France.

The promoter has two powerful influences working for him, social hysteresis and personal pride. He can count on a period of from 1 to 3 years before the lag in communication of practical results from plant to plant has pretty well killed off further prospects. This period of hysteresis may be prolonged by the very human reluctance of the person who has been "taken" to admit the fact. Customers who have given testimonials during an early period of enthusiasm are not prone to confess that the gadget actually did not perform over the long haul.

The promoter, faced with the necessity of working fast, naturally avoids as much as possible the man with technical training. Instead, he aims his campaign below the engineer and above him. If he cannot sell the nontechnical operator, perhaps he can intrigue the plant manager or the vice president.

Not every gadget is promoted in the same way. However, the pattern is likely to comprise several of the following elements:

1. It is claimed that the gadget solves any and all problems encountered in the use of water—scale, corrosion, slime, taste, odor.
2. The gadget is alleged to produce many beneficial side effects—it improves growth of vegetation, makes water feel smoother, makes soap act more powerfully even though the hardness of the water is not decreased.
3. The gadget is stated to achieve its remarkable results because of the alleged action in peculiar ways of natural forces, such as electricity, magnetism, catalysis, radiation, ultrasonic vibration, all described in language which sounds scientific but cannot be understood.

4. The gadget requires little or no attention and no chemicals are required.

5. The gadget is represented to be so sure-fire that the initial cost will be refunded if it does not prove satisfactory during a period of 60 or 90 days.

6. Testimonial letters, stated to be unsolicited, are offered to prove that performance has been excellent.

7. Tests under controlled conditions in the laboratory are generally deprecated as not being capable of showing the performance in practice.

8. Advertising or promotion by mail is avoided or is much more conservative in tone than that supplied by direct contact.

WHAT TO DO?

What course of action is practical for the man in the plant besieged annually by a new promoter with a new gadget? Some engineers of native intelligence and good training have been known to follow a policy of trying out each device offered to them. Such a solution is perhaps an eminently practical one when the gadget has been recommended to the vice president by an influential friend over the luncheon table. It does lead immediately to the citation of the company by the promoter as a "satisfied customer." Many a large corporation has been startled to find itself in such a position as a result of having installed—and subsequently discarded—a gadget in some obscure corner of the organization. Another course of action might be to ask for evidence that the practical performance of the gadget in question had been reported objectively by a reputable engineer before some technical society *(63)*. This is a slow, hard way of building acceptance employed by companies which intend to remain in business indefinitely. If a gadget has achieved a useful result, then let the engineering profession have the opportunity to take a thorough, critical look at all of the pertinent data.

BIBLIOGRAPHY

(1) Abbott, R. H. S., Brit. Patent 391,865 (May 8, 1933).
(2) Barbier, A. J., U. S., Alien Property Custodian 340,856 (May 18, 1943).
(3) Beatty, W. A., Brit. Patent 507,052 (June 5, 1939).
(4) Blass, L., U. S. Patent 1,613,430 (Jan. 4, 1927).
(5) Butler, E. M., *Ibid.*, 2,321,796 (June 15, 1943).
(6) *Ibid.*, 2,321,797 (June 15, 1943).
(7) *Ibid.*, 2,337,151 (Dec. 21, 1943).
(8) Creighton, H. J., *Ibid.*, 1,611,583 (Dec. 21, 1926).
(9) Crouch, R. H., *Ibid.*, 2,299,964 (Oct. 27, 1942).
(10) Cumberland, E., *Trans. Faraday Soc.*, **11**, 277–81 (1915).
(11) Cumberland, P. E. G., Brit. Patent 4251 (June 13, 1912).
(12) *Ibid.*, 19,637 (June 27, 1911).
(13) *Ibid.*, 8068 (May 13, 1909).
(14) Cumberland, P. E. G., U. S. Patent 921,641 (May 11, 1909).
(15) *Ibid.*, 948,968 (Feb. 8, 1910).
(16) Cumberland, P. E. G., U. S. Patent 1,020,480 (March 19, 1912).
(17) DeBaufre, W. L., *Combustion*, 3, No. 11, 21–9 (1932).
(18) Edison Electric Institute, Power Station Chemistry, *Publ.* **85** (1932–3).
(19) Eliassen, R., and Uhlig, H. H., *J. Am. Water Works Assoc.*, **44**, 576–82 (1952).
(20) Elmore, G. H., and Creighton, H. J., U. S. Patent 1,576,581 (March 16, 1926).
(21) *Engineer*, **195**, 638–9 (1953).
(22) Erenyi, L., U. S. Patent 1,964,704 (June 26, 1934).
(23) Evans, U. R., *Chemistry & Industry*, **1946**, No. 49, 434–5.
(24) Farmer, M. G., U. S. Patent 88,285 (March 30, 1869).
(25) Fischer, F., *Dinglers Polytech. J.*, **222**, 166–74, 237–49 (1876).
(26) Freeborn, A. G., Brit. Patent 487,595 (June 20, 1938).
(27) Freeborn, A. G., *J. Inst. Water Engrs.*, **7**, 392–4 (1952).
(28) Freeborn, A. G., *Power and Works Eng.*, **35**, 245–6 (1940).
(29) *Ibid.*, **48**, 28–9 33 (1953).
(30) Freeborn, A. G., U. S. Patent 2,207,583 (July 9, 1940).
(31) Freeman, G. C., *Ibid.*, 1,568,728 (Jan. 5, 1926).
(32) Gardner, D. A., *Power*, **63**, 261–2 (1926).
(33) Gerber, J., Ger. Patent G86,561 (Oct. 6, 1933).
(34) *Ibid.*, 680,458 (Aug. 10, 1939).
(35) Gerber-Ritter, J., Brit. Patent 429,564 (May 31, 1935).
(36) Guldager, A., Ger. Patent 634,380 (Nov. 30, 1933).
(37) Gunderson, L. O., U. S. Patent 1,788,485 (Jan. 13, 1931).
(38) Hauptvogel, F., Brit. Patent 233,657 (July 9, 1925).
(39) Hauptvogel, F., Ger. Patent 459,590 (May 11, 1928.)
(40) Hauptvogel, F., U. S. Patent 1,726,738 (Sept. 3, 1929).
(41) Hay, A. T., U. S. Patent 59,768 (Nov. 20, 1866).
(42) *Ibid.*, 59,910 (Nov. 20, 1866).
(43) *Ibid.*, 140,196 (June 24, 1873).
(44) Heberlein, E. A., Brit. Patent 223,614 (April 18, 1923).
(45) *Ibid.*, 223,847 (Oct. 30, 1924).
(46) Heinrich, A., *Ibid.*, 306,145 (Feb. 17, 1928).
(47) Hurley, T. F., *et al.*, *J. Inst. Water Engrs.*, **5**, 686–99 (1951).
(48) Kirkaldy, A., U. S. Patent 1,506,306 (Aug. 26, 1924).
(49) *Ibid.*, 1,506,307 (Aug. 26, 1924).
(50) *Ibid.*, 1,506,308 (Aug. 26, 1924).
(51) Kotyra, M., *Ibid.*, 392,736 (Nov. 13, 1888).
(52) Lattner, E. J., *Ibid.*, 2,358,981 (Sept. 26, 1944).
(53) McIntosh, K. L., *Ibid.*, 2,557,989 (June 26, 1951).
(54) Mans, H., *Wärme*, **47**, 325–7, 338–40 (1924).
(55) Matthews, F. J., "Boiler Feed Water Treatment," 3rd ed., pp. 84–6, New York, Chemical Publishing Co., 1951.
(56) Mautner-Karkhof, A. von (to Paul Kahn), Brit. Patent 427,373 (April 23, 1935).
(57) Mazza, P. S. D., U. S. Patent 2,118,979 (May 31, 1938).
(58) Metallbank und Metallurgische Gesellschaft, A.-G., Ger. Patent 463,844 (Oct. 11, 1928).
(59) Neeley, G. S., U. S. Patent 1,579,453 (April 6, 1926).
(60) *Ibid.*, 1,579,454 (April 6, 1926).
(61) *Ibid.*, 1,773,274 (Aug. 19, 1930).
(62) *Ibid.*, 1,773,275 (Aug. 19, 1930).
(63) Partridge, E. P., *Univ. Mich. Eng. Research Bull.*, **15**, 97–9, 106–9 (1930).
(64) *Petroleum Times*, **53**, 341–3 (May 20, 1949).
(65) Philippi, W., *Arch. Wärmewirtsch.*, **3**, 151–3 (1922).
(66) Philippi, W., *Siemens-Z.*, **1**, 374–80 (1922).
(67) Pierpoint, A. J., and Crouch, R. H., Brit. Patent 450,594 (July 15, 1936).
(68) Pierpoint, A. J., and Crouch, R. H., U. S. Patent 2,161,933 (June 13, 1939).
(69) Porter, A. F., *Ibid.*, 50,774 (Oct. 31, 1865).
(70) Pothmann, *Speisewasserpflege*, **1926**, 70–2.
(71) Pourbaix, M., *Chemistry & Industry*, **1953**, No. 30, 780–6.
(72) Reichart, W. M., U. S. Patent 1,825,477 (Sept. 29, 1931).
(73) Reutlinger, *Speisewasserpflege*, **1926**, 72–6.
(74) Rickard, S., *Chem. Eng.*, **5**, 239–41 (1907).
(75) Rummel, O., Brit. Patent 148,778 (Oct. 20, 1921).
(76) Sarrazin, *Z. Dampfkessel u. Maschinenbetrieb*, **43**, 407–19 (1920).
(77) Scalebuoys, Ltd., and Willey, E. J. B., Brit. Patent 510,746 (Aug. 8, 1939).
(78) Schirmer, A., *Ibid.*, 397,941 (Sept. 7, 1933).
(79) Schirmer, A., Ger. Patent 595,897 (April 5, 1934).
(80) Schneeweiss, *Arch. Wärmewirtsch. u. Dampfkesselw.*, **18**, 18 (1937).
(81) Schneeweiss, *Wärme*, **59**, 805 (1936).
(82) Schnetzer, K., Brit. Patent 174,905 (March 29, 1922).
(83) *Ibid.*, 208,115 (Feb. 2, 1925).
(84) *Ibid.*, 211,588 (Nov. 24, 1922).
(85) *Ibid.*, 243,415 (Nov. 30, 1925).
(86) Schnetzer, K., U. S. Patent 1,436,686 (Nov. 28, 1923).
(87) *Ibid.*, 1,581,024 (April 13, 1926).
(88) Schöne, O., *Speisewasserpflege*, **1926**, pp. 76–7.
(89) Schulz, E., *Arch. Wärmewirtsch.*, **6**, 247–8 (1925).
(90) Siemens & Halske, A.-G., Brit. Patent 147,528 (June 9, 1921).
(91) Siemens & Halske, A.-G., Ger. Patent 340,785 (Sept. 3, 1921).
(92) Siemens-Schuckertwerke, G.m.b.H., Brit. Patent 181,018 (Aug. 2, 1922).
(93) Siemens-Schuckertwerke, G.m.b.H., Ger. Patent 420,698 (Oct. 29, 1925).
(94) *Ibid.*, 440,979 (Feb. 19, 1927).
(95) Splittgerber, A., *Vom Wasser*, **7**, 162 (1933).
(96) *Ibid.*, **12**, 177–80 (1937).
(97) Stumper, R., *Z. anorg. u. allgem. Chem.*, **204**, 365–77 (1932).
(98) Thalhofer, W., U. S. Patents 1,558,646–7 (Oct. 27, 1926).
(99) Thomsen, T. C., *Trans. 2nd World Power Conf.* (*1936*), **2**, 496–503 (1937).
(100) Urion, E., and Lejeune, G., *L'Eau*, **37**, No. 2, 23–8 (1950).
(101) Vermeiren, T. I. S., Brit. Patent 625,732 (July 4, 1949).
(102) Vermeiren, T. I. S., U. S. Patent 2,596,743 (May 13, 1952).
(103) *Ibid.*, 2,652,925 (Sept. 22, 1953).
(104) Walde, H., *Wiss. Veröffentlich. Siemens-Konzern*, **6**, 151–70 (1927).
(105) Wells, C. K., *J. Am. Water Works Assoc.*, **44**, 428–34 (1952).
(106) Willey, E. J. B., *J. Soc. Chem. Ind.* (*London*), **65**, 433–6 (1946).

RECEIVED for review October 28, 1953. ACCEPTED March 10, 1954.

290112-63-5M-554 PRINTED IN U. S. A.