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With the increased costs of maintaining boilers and chillers, entrepreneurs around the country have offered magnetic and similar devices to facilities as viable alternatives to their maintenance program. This report gives a brief history of some of the previous research on the validity of these manufacturers' claims and details controlled laboratory and field tests performed by the U.S. Army Construction Engineering Research Laboratory (CERL). CERL test results failed to substantiate claims of the magnetic device manufacturers that their units stop scale deposition. Moreover, the claims concerning corrosion control in the systems treated by their devices were also unsubstantiated.

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US Army Corps
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Construction Engineering
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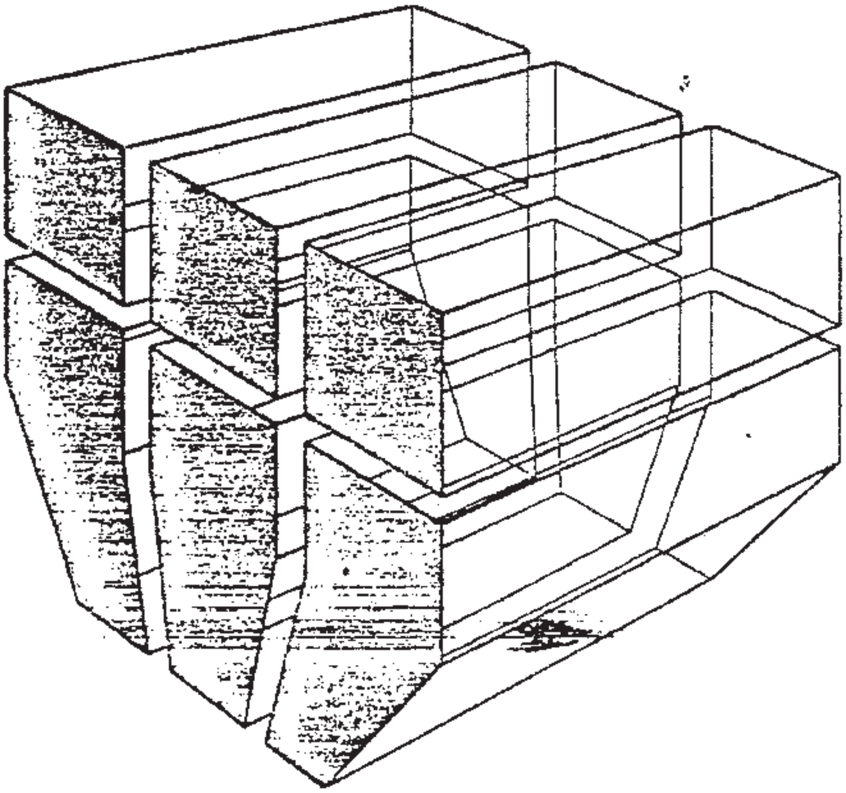
TECHNICAL REPORT M-342
May 1984

# EVALUATION OF COMMERCIAL MAGNETIC DESCALERS



by
Debbie J. Lawrence

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# FOREWORD

This work was performed by the U.S. Army Construction Engineering Research Laboratory (CERL) for the Assistant Chief of Engineers, under Operation and Maintenance, Army (OMA) Work Unit "Magnetic Descaler." The Technical Monitors were Bernard Wasserman and Homer Musselman, DAEN-ZCF-U.

Appreciation is extended to R. W. Lane and C. H. Neff of the Illinois State Water Survey for their technical support and consultation, and to Diane Smith and Ben Bland of CERL for setting up and running the in-house laboratory tests. Appendix B is a report performed by the Illinois State Water Survey under contract DACA-81-Q-0102.

The research was performed by CERL's Engineering and Materials Division (EM). Dr. R. Quattrone is Chief of CERL-EM. COL Paul J. Theuer is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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# EVALUATION OF COMMERCIAL MAGNETIC DESCALERS

## 1 INTRODUCTION

### Background

The cost of chemical boiler and chiller treatment is ever increasing; for example, the generic chemicals used in chiller treatment cost 50 to 100 percent more than in 1976.[1] Army facilities engineers are continually searching for a less expensive, more efficient method. There are several scientifically proven alternatives to chemical treatment, but capital and operating cost penalties are associated with their use.[2] In addition, nearly 100 nonchemical, magnetic devices are currently manufactured that claim to reduce both corrosion and scale with substantially no technical control. Furthermore, some of these devices are alleged to improve the water's biological properties, leading to better crops or eliminating slime and bacterial growth. With these claims and numerous testimonial letters, millions of dollars have been spent on the manufacture and purchase of these devices. But whether they actually perform as claimed, under what circumstance, and how remain unanswered.

Between 1865 and 1953 more than 50 patents were issued for these devices.[3] In the past few decades, interest in such equipment has greatly increased, spurring much research into the validity of claims for chemical and physical changes imparted to the water "treated." In general, the studies published in Russia have concluded that the units work, whereas the American studies usually concluded the units do not work as claimed.

Despite the past negative findings and warnings by corrosion engineers and water technology experts, magnetic water treatment devices continue to be promoted for scale and deposit prevention, as well as microbiological growth and corrosion mitigation in systems that use water. Army facilities have been approached by numerous salespersons for magnetic devices, and the performance promised by the manufacturer seems very attractive compared with chemical treatment. Some Army facilities have purchased units and feel they work.

In an effort to determine if the magnetic units as currently produced work reliably and safely, CERL conducted laboratory and field tests. Until the beginning of this research, no controlled in-situ tests had been run at Army facilities.

### Objective

The objective of this study was to determine the effectiveness of commercial magnetic descaling devices in:

1. Changing the solubility of scale-forming minerals, such as calcium carbonate (calcite or aragonite), calcium sulfate (gypsum), or magnesium carbonate (magnesite or other hydrates)

2. Changing the mode of precipitation from one crystalline form to another (e.g., aragonite precipitates instead of calcite)

3. Residually altering the amount of scale formed in the system at any given distance from the magnetic field after water treatment

4. Altering natural and reagent-grade waters to abate scaling effects in heat exchangers.

### Approach

1. A literature search on descaling systems was conducted. (Chapter 2 is a brief review of works consulted.)

2. Four magnetic descaling units were evaluated in laboratory and field tests. Two basic laboratory tests were done with a permanent magnet-type descaler (unit A; see Table 1). One set of tests simulated low temperatures whereas the other set simulated boiler temperatures. In addition, two field tests were conducted – one using an electromagnetic system (unit B) on a high-pressure boiler at Fort Hood, TX, and the other using a permanent-type descaler (unit C) on the cooling tower side of an air conditioner at Chanute Air Force Base, IL.

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[1] C. H. Neff, Illinois State Water Survey, personal communication.

[2] J. C. Dromgoole and M. C. Forbes, *The Fatal Lure of Water Treatment Gadgets*, Paper IWC-79-21, Proceedings from 40th Annual Meeting International Water Conference, Pittsburgh (October 1979), p 1.

[3] B. Q. Welder and E. P. Partridge, "Practical Performance of Water Treating Gadgets," *Ind. Eng. Chem.*, Vol. 46 (1954), pp 954-960.

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**Table 1**

**Types of Commercial Descalers Tested**

| Unit | Method of Operation |
|---|---|
| A | Permanent magnet |
| B | Electromagnet |
| C | Permanent magnet |
| D | Electromagnet |

Another field test was initiated at Fort Monmouth, NJ, using a different electromagnetic system (unit D), but it was not completed because of equipment failure.

3. Finally, case studies from Army facilities that use magnetic descalers were evaluated.

# 2 LITERATURE REVIEW

For a better understanding of previous work with magnetic descalers, a brief review of the literature follows.

In 1979, Martynova, Kopylov, Tebenikhin, and Ochkov of the Moscow Power Institute published a paper in which they formulated a "probable mechanism of the effect of a magnetic pretreatment apparatus on the processes of scale formation and corrosion in heat exchange systems."[4] This formulation consists of:

> (a) the magnetic apparatus retains ferromagnetic material in the gap, as a result of which over a certain intermediate period of time $\tau_{int}$ a suspended layer with a well developed surface is formed; (b) if the water supplied to the magnetic unit is not stable, i.e., it is supersaturated with respect to a certain component (gaseous, solid), it will be absorbed at the surfaces of the particles suspended in the magnet gap; (c) the substance removed from the supersaturated solution can either accumulate in the gap (in practice the magnetic treatment plant often becomes fouled with iron-scale deposits), or it can be washed away by the flow of water in the form of seeding crystals (supersaturated with respect to salt composition) or by the free gaseous phase with corresponding supersaturation; in this case dynamic equilibrium is established between the processes of sorption and washing away; (d) the ferromagnetic particles in the magnet gap may coagulate, forming agglomerates covered by a layer, calcium carbonate for example, which can also serve as centers of crystallization.

They further state that "the magnetic treatment of mineralized feedwater retards scale formation as a result of contact stabilization and the introduction of ferromagnetic particles and in this case, magnetic treatment can be regarded as heterogeneous catalysis, speeding up the process of phase transition in supersaturated water systems."[5]

Their investigation concluded: (a) the period of activation of the magnetic apparatus, which allows time for the surface of the particles retained in the gap to become appreciable, must be met in terms of operational time of the units; (b) there is an optimal velocity of water in the magnet gap which is within .4-.6 $V_{max}$ where $V_{max}$ = 1.8-2.5 m/s; (c) the efficiency of magnetic treatment is affected not only by the strength of the magnetic field in the gap but also by such characteristics as the configuration of the field, hydrodynamics of the flow, dispersion, and magnetic properties of the particles in the water; (d) "prior removal of gas from the water of heat exchangers when employing magnetic treatment leads to corrosion in them being reduced."[6]

Martynova et al. indicate that many Russian scientists believe the water must be supersaturated with scale salts when it passes through the magnetic field to obtain the antiscaling effect. This and other information, such as the effect of aggressive carbon dioxide ($CO_2$) on the crystallization of calcium carbonate out of solution, probably led to the Soviet laws that O'Brien lists in his translations of Russian papers.[7] "Soviet law forbids the presence of aggressive $CO_2$ in waters that are to be treated magnetically. The second

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[4] O. I. Martynova, A. S. Kopylov, E. F. Tebenikhin, and U. F. Ochkov, "The Mechanism of the Influence of Magnetic Treatment of Water on the Processes of Scale Formation and Corrosion," *Thermal Eng.*, Vol 26, No. 6 (1979).

[5] O. I. Martynova, A. S. Kopylov, E. F. Tebenikhin, and U. F. Ochkov.

[6] O. I. Martynova, A. S. Kopylov, E. F. Tebenikhin, and U. F. Ochkov.

[7] W. P. O'Brien, Jr., *On the Use of Magnetic (and Electric and Ultrasonic) Fields for Controlling the Deposition of Scale in Water Systems*, a review of papers translated from Russian for the Navy Civil Engineering Laboratory, Port Hueneme, CA (October 1979).

rule of Gosgortekhnadzor [State Mining Engineering Administration] limits the maximum specific volume of applicable boilers to 50 ℓ/m², and the third rule sets maximum water hardness at 5 mg-equiv/ . . . "[8]

A sales peak of magnetic descalers in the 1950s prompted several investigations into the devices. Most of the American research concluded the magnetic units did not work or lacked a sound scientific reason for claiming to work. One paper presented by Eliassen and Uhlig of MIT[9] looked into the scientific aspects of explanations presented by the manufacturers. After analyzing some of the major claims such as control of bacteria, scale, turbidity, odors, and corrosion, they obtained scientific facts disputing these claims. They found no technical data from the manufacturers to substantiate the claims made for the units. In regard to scale formation from salt crystallization in the water, Eliassen and Uhlig stated that "Ionization occurs immediately when a salt is dissolved, and no electric current will do any more dispersing or ionizing as claimed . . . . No amount of mysterious dispersion by small so-called electrical forces will prevent this crystallization. The only means of prevention is to treat the feedwater by adding chemicals, at times both inorganic and organic, to the water to remove the scale-forming substances in the form of a soft sludge, either ahead of the boiler or in the boiler."

Welder and Partridge did a study as a follow-up on the practical performance of various "gadgets"* in actual plant operation. They noted that no matter how emphatically engineers and scientists might state that the magnetic devices do not work, "the practical man in the plant wonders if the experts could be missing some new truth not yet fully appreciated." Therefore, one of their laboratory's field engineers observed first-hand the use of these devices at various sites and presented case histories, most of which ended with the "gadget" being "tossed on the junk pile." They concluded that "from our experience, gadgets do not prevent scale and corrosion under the varied conditions met in practice."[10]

Eliassen, Skrinde, and Davis later did a study involving both laboratory and field tests.[11] In the laboratory, they tested three commercial magnetic devices. Included in their study was treatment of water by a very strong magnetic field, about 20 times the strength of the magnetic devices. (Physicists have shown that magnetic fields on the order of 1,000,000 gauss are needed to influence the particles within an atom.[12] The device tested at CERL had a magnetic field strength of only 7200 gauss and is typical of the field strength used by similar devices.) Their field test evaluated corrosion rates over 4 months. They concluded that: (a) "Water which passed through magnetic fields as strong as, and much stronger than, that of the magnetic water conditioners was unaffected with respect to scale formation," (b) "'Conditioning' did not affect the rate of solution of substances commonly found in hard-water scales," (c) "In field studies, 'conditioning' did not affect the rate of corrosion on steel pipes over a 4-month period."

In 1974 another sales peak of electric and electronic water conditioners prompted Meckler to test the validity of manufacturers' claims. He compared the promotion techniques to those in the 1950s, stating, "Then, as now, accompanying literature was filled with scientific jargon – ions, electrons, magnetic fields, polarization – used (often without supporting test evidence) to weave a fascinating tale of mechanisms involving molecular interactions triggered by the devices to work wonders."

Six months of inservice testing with domestic hot and cold water piping was performed in which Meckler found no benefits from using an electrostatic descaler. He "concluded that the test descaler was not effective in preventing scale deposition," and was "unable to detect any measurable reduction in corrosion potentials."[13]

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[8] B. A. Speranskiy, V. V. Vikhreu, V. N. Vinogradou, and Y. I. Dolya, "Experience of Magnetic Treatment of Feed Water for pKN-Is Boilers," in W. P. O'Brien (Trans.), *On the Use of Magnetic (and Electric and Ultrasonic) Fields for Controlling the Deposition of Scale in Water Systems* (Civil Engineering Laboratory, Port Hueneme, CA, October 1979), pp 10-15.

[9] R. Eliassen and H. H. Uhlig, "So Called Electrical and Catalytic Treatment of Water for Boilers," *J. Am. Waterworks Assoc.*, Vol 44 (1952).

*They define gadgets as "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."

[10] B. Q. Welder and E. P. Partridge, p 960.

[11] R. Eliassen, R. T. Skrinde, and W. B. Davis, "Experimental Performance of Miracle Water Conditioners," *J. Am. Water Works Assoc.*, Vol 50 (1958), pp 1371-1389.

[12] H. P. Furth, et al., "Strong Magnetic Fields," *Sci. Am.*, Vol 28 (February 1958), p 198.

[13] M. Meckler, "Electrostatic Descaler Testing: An Evaluation," *Heating, Piping, Air Cond.* (August 1974).

One of the most extensive studies to date is a thesis by Edward Duffy. Literature cited in his thesis comprises 145 references, including many Russian articles. Among his conclusions were:

> (a) Commercial magnetic devices did not affect the rate of precipitation of $CaCO_3$: (b) commercial magnetic devices did not significantly quantitatively or qualitatively affect the formation of $CaCO_3$ scale at 85°C under any of the operating conditions examined; (c) addition of $Fe(OH)_3$ to the feed water decreased the amount of scale formed in a laboratory sized heat exchanger. This effect was directly related to the concentration of $Fe(OH)_3$ added to the feed water and inversely related to the temperature of scale formation; (d) magnetization of a 1018 steel rod caused an 18.6 percent increase in the rate of corrosion at 25°C in a 3-percent NaCl solution; (e) $Fe(OH)_3$ retarded the formation of $CaCO_3$ under the allotropic crystallization form of calcite; (f) $Fe(OH)_3$ retarded the rate of $CaCO_3$ precipitation. This effect was directly related to the concentration of $Fe(OH)_3$ in the solution and was valid over the pH range of 6 to 11.[14]

Duffy found that his results suggested a mechanism by which commercial magnetic antiscalers could indirectly retard calcium carbonate scale formation. "According to this mechanism iron ions retard the growth of $CaCO_3$ under certain defined conditions and the function of the magnetic device is to increase the concentration of iron ions in solution by increasing the rate of corrosion of the attached iron pipe by either magnetic and/or galvanic effects."

Duffy further stated that "due to the adverse effect of the magnetic device on the corrosion rate of the iron pipe and the limited conditions under which the mechanism functions it is not here recommended that these devices be used for scale control in commercial heat exchangers and boilers."

The South Dakota School of Mines and Technology received a grant from the Water Quality Association to evaluate the performance of permanent magnetic water conditioners in an environment representative of typical residential and light commercial applications. Researchers Gruber and Carda started by surveying the magnetic devices for water treatment currently available, classifying them into four categories. (They did not include the recently developed high-field magnetic gradient devices in these categories.)

Their four categories provide an overview of the basic directions manufacturers have taken in modifying the magnetic devices. Their Class I device "clamps onto the outside of a water pipe and produces a generally longitudinal magnetic field which concentrates and becomes transverse near the point of pole piece contact with the pipe." In a Class II device, a "radial magnetic field is applied transverse to the flow as it passes through an annular ring between the magnet pole pieces." The Class III device is based on the Russian designs most often reported in the literature: "The field is radial with the water flow passing through an annular flow tube." The field polarity alternates periodically along the flow axis. Some of these devices also induce a moderate swirl about the axis by means of the inlet port geometry. The Class IV devices "generally have the magnetic field parallel to the flow, using a collinear solenoid and some type of spiral metallic element that rotates inside the pipe containing the field."[15]

Gruber and Carda used four test flow streams in their experiments. The water was from the Rapid City, SD, water main supplying their research laboratory. The streams studied were raw water, water processed by a conventional residential ion exchange water softener, and two streams processed by magnetic treatment devices. The two magnetic descalers tested were Class I and Class III devices, respectively.[16]

These experiments included physical property and electrochemical measurements of the water, scale deposition and analysis, metal coupon corrosion, and many other parameters. Their conclusions were that "the only observable chemical change was in the ion exchange stream," and "the generally reported claims of the magnetic water conditioning manufacturers that there is a change in the physical properties; i.e., lowering of the boiling point, surface tension reduction, and the treated water is nonscaling, were not substaniated by the research project . . . . There was no evidence of a reduction of scale forming tendencies in water using magnetic devices."

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[14] E. A. Duffy, *Investigation of Magnetic Waste Treatment Devices*, thesis (Clemson University, 1977).

[15] C. E. Gruber and D. D. Carda, "Performance Analysis of Permanent Magnetic Type Water Treatment Devices," research project for the Water Quality Association at South Dakota School of Mines and Technology (July 1981).

[16] J. Barber, "Scale Eliminator Devices Under Increased Scrutiny," *Energy User Needs*, Vol 7, No. 28 (July 12, 1982).

# 3 LABORATORY TESTS

**Low Temperature Tests**

Saturated calcium sulfate solution (2.41 g/L) was recirculated through two identical parallel test loops. One loop used the 56.8-L/min (15 gpm) descaling unit A and the other had no magnet ("dummy" unit). Recirculation was done for designated time periods of 8 hours and 1 week. At the end of the recirculation period, 1400 ml of 50 percent saturated sodium carbonate solution (35.5 g/L) was injected and circulated for approximately 15 minutes. The resulting precipitate was allowed to settle in two 50-L reservoirs and excess water was then siphoned off. This test loop is detailed in Figure 1.

The 8-hour runs were repeated with the magnetic unit and "dummy" unit positions switched on the two test loops. The 1-week run was performed only once. For each run, the remaining precipitate suspension was filtered, and the filtercake was rinsed three times with distilled water and allowed to air-dry. The resulting precipitate was then subjected to:

1. X-ray analysis to obtain relative amounts of aragonite and calcite in the scale deposits.

2. Hydrometer tests performed on the 1-week specimens to determine differences in the particle size distribution for the magnetically versus nonmagnetically treated precipitate.

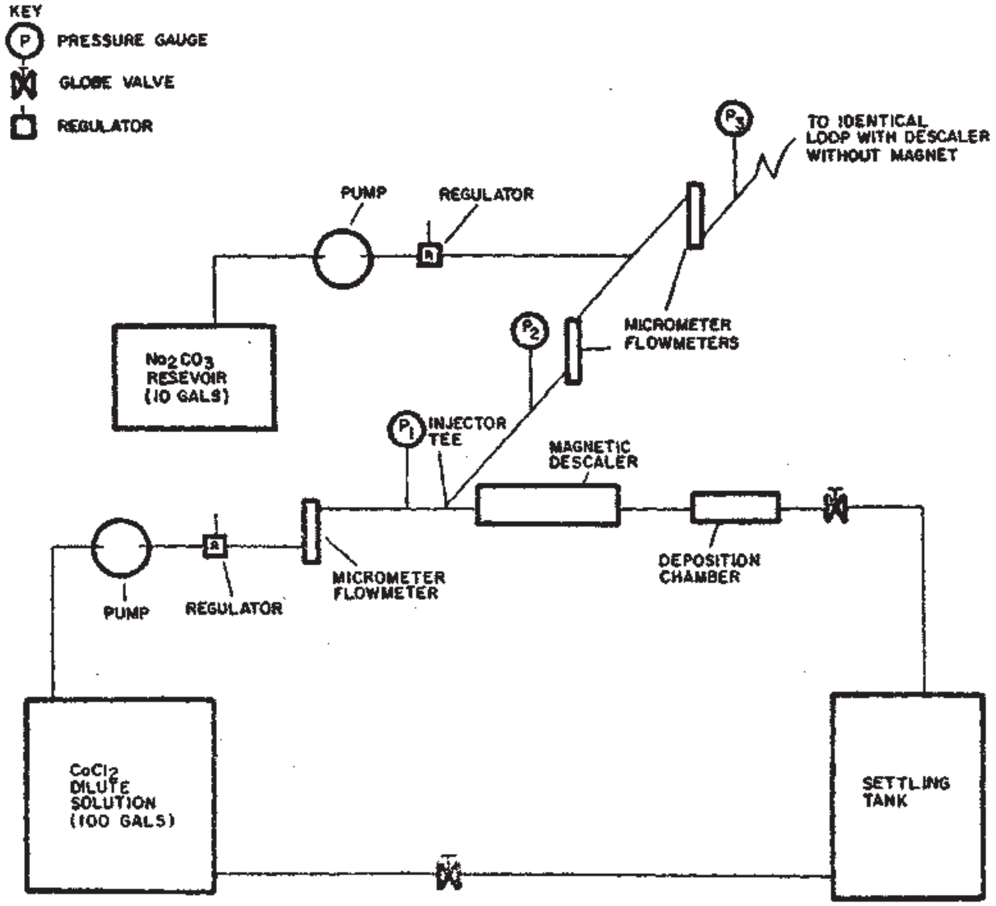

Figure 1. Test loop for determining deposition quantity and crystalline form, 1981 test.

3. Atomic absorption analysis performed on the week-long run using a Bechman model 444 atomic absorption spectrophotometer with air acetylene flame to determine iron, copper, and calcium contents.

4. Conductivity tests twice a day to compare conductivity differences in the solution recirculated in a magnetically treated loop versus that in the non-magnetically treated loop.

5. Microscope analysis with a high-powered microscope to look at filtercake samples that had been air-dried on glass slides.

### Simulated Heat Exchange Test

Two series of tests were run. The first series, run in 1981, did not produce a scale in the time available. Therefore, the test loop was totally redesigned in 1982. The new system allowed the water to stay in the furnace as long as possible with a higher flow rate while maintaining heat transfer in the recirculated water. In addition, the 1981 test used a natural water with low scaling tendencies, whereas the 1982 design used reagent-grade water simulated for higher scaling tendencies.

*1981 Test*

Tap water was circulated through two loops. Each loop passed through a furnace set at 260°C (500°F) and through a small heat exchanger to cool the water. Water was passed through the loops only once; the temperature differential in the furnace was about 56°C (132°F): 3.3°C (38°F) entering and 76.3°C (170°F) leaving the furnace. The flow through the loops was regulated to 27.6 KPa (4 psi). One loop contained a magnetic descaling device and the other had a "dummy" descaler (a unit with an iron bar in place of the magnet). Water was circulated through the loops for 7 days. Before the test began, the straight sections of copper tubing in the furnace part of the test loop were weighed; to determine the amount of scale formed during the test, the straight sections were weighed again at the end of the test. This test loop is detailed in Figure 2.

*1982 Test*

A limited, set quantity of chemically altered water was recirculated through two identical loops, with each loop passing through a furnace set at 286.5°C (550°F) and through a small heat exchanger to cool the water. The temperature differentials in and out of the furnace were monitored; that of the water in the furnace was about 3.9°C (7°F) – 37.8°C (100°F) entering and 41.7°C (107°F) leaving the furnace. The flow was regulated to 7.6 L/min (2 gpm), and the waters' chemistry was continually monitored to detect the rate of scale deposit. To determine the amount of scale formed during the test, the straight sections of copper tubing in the furnace were weighed before and after testing. This test loop is detailed in Figure 3.

### Analysis and Results

*Low-Temperature Tests*

**X-ray Analysis.** X-ray diffraction was used to obtain the weight fractions of aragonite and calcite in the specimens. The internal standard method was used with sodium chloride as internal standard. The focus of this test is the differences in aragonite content found in the precipitate of the two loops. Results obtained were:

8-hour test run 9013 $W_{AR} = .0687$ $W_{cal} = .7033$
9015 $W_{AR} = .0735$ $W_{cal} = .5260$
1-week test run 9013 $W_{AR} = .1090$ $W_{cal} = .9557$
9015 $W_{AR} = .0855$ $W_{cal} = .7858$

where 9013 is the "dummy" unit without the magnet
9015 is the manufactured descaling device
$W_{AR}$ is the weight fraction of aragonite
$W_{cal}$ is the weight fraction of calcite.

An error analysis of the X-ray procedure was performed* showing that these differences are just outside the equipment accuracy.

**Hydrometer Analysis.** Following the addition of saturated sodium carbonate solution, the pumps were shut off, and the precipitate was allowed to settle. The excess water was then siphoned off, leaving approximately 1 L of percipitate. (During the several siphoning steps the precipitate was transferred to a beaker.) Sodium tripolyphosphate (15 ml, .4 N) was added as a dispersant. The solution was then stirred for approximately 5 minutes with a high-speed magnetic stirrer. Except for slight deviations, the rest of the process followed EM-1110-2-1906.[17]

Stokes law, $A = \frac{1800_{\eta}}{(G_s - G_w)_{\alpha w}}$ and $D = \overline{AV}$, was

---

*$\Delta W = \pm .0063$ = calculated error analysis for $\Delta W$ due to equipment accuracy.

[17] EM-1110-2-1906, *Hydrometer Analysis* (Office, Chief of Engineers, November 1970).

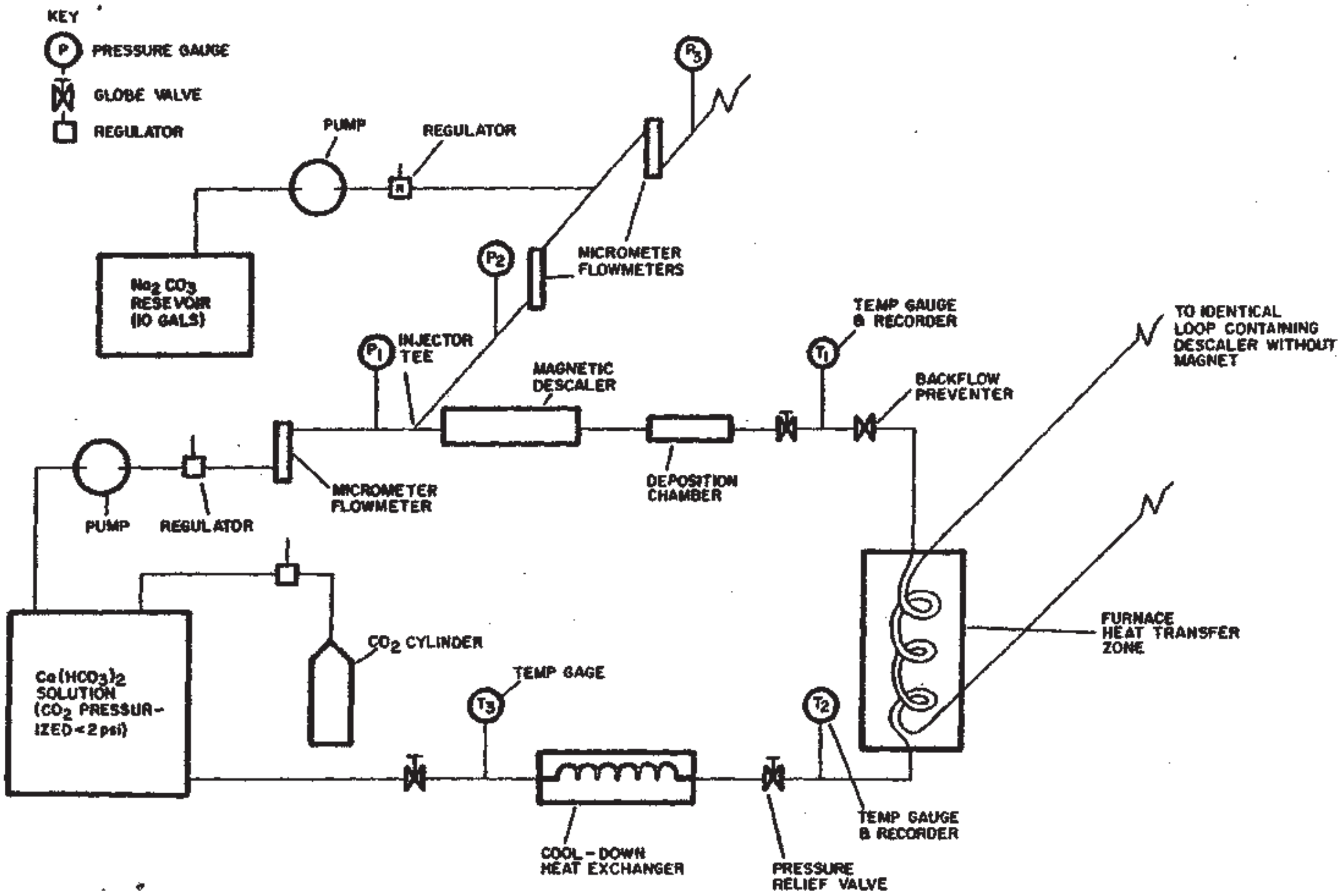

Figure 2. Test loop for scaling tendencies, 1981 test.

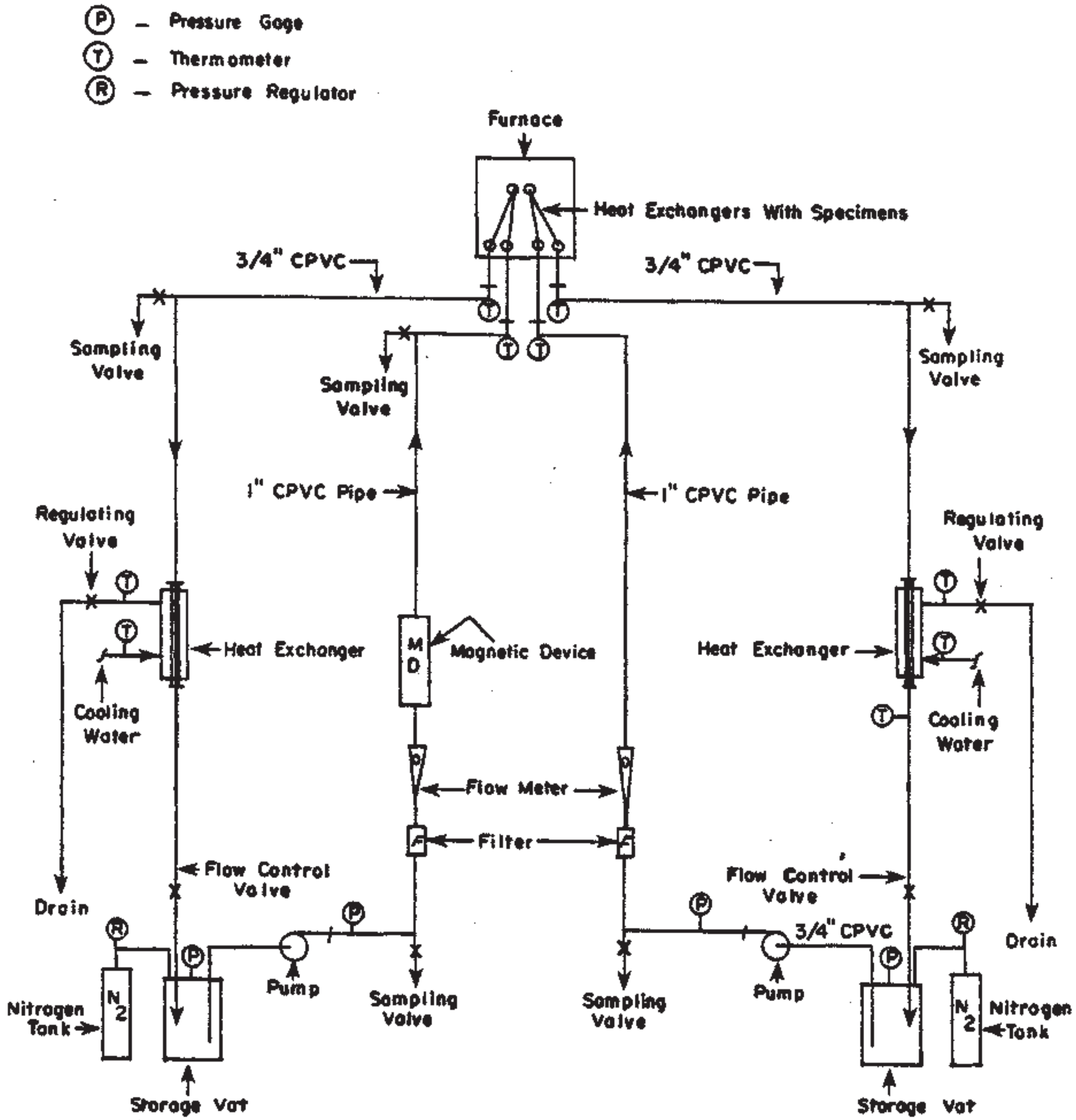

Figure 3. Flow diagram for test loops, 1982 test.

used to determine the particle size distribution of the two precipitates, where:

$A$ = constant
$\eta$ = viscosity of $H_2O$
$G_s$ = specific gravity of scale
$G_w$ = specific gravity of $H_2O$
$\alpha_w$ = density of water
$D$ = particle diameter
$V$ = velocity of particle = hydrometer reading/time

Results showed a maximum of 10 to 20 $\mu$m difference in particle size.

**Atomic Absorption Analysis.** A Bechman model 444 atomic absorption spectrophotometer with an air-acetylene flame was used for analysis. For iron determination, the instrument was set in the atomic absorption mode at a wavelength of 248.3 nm. A standard stock solution of iron sulfate in distilled water was made at a concentration of 100 ppm. Dilutions of this solution gave calibration standards at 1, 2, 5, and 10 ppm. The relative absorbance of these standards was measured and a calibration curve was drawn.

When the samples were agitated to disperse the settled solids, sample 9013 contained 1.3 ppm iron and sample 9015 contained 1.4 ppm iron. When the samples were filtered to remove the solids, both showed only a trace of iron.

For copper determination, the instrument was set in the atomic absorption mode at a wavelength of 324.7 nm. Compared with a standard solution of cupric acetate, only a trace (less than 1 ppm) of copper was found in samples 9013 and 9015.

Calcium was determined by flame emission at a wavelength of 422.7 nm. A standard stock solution of calcium sulfate in distilled water was made to a concentration of 140 ppm. To obtain a calibration curve, this sample was diluted to 14, 28, 35, and 70 ppm. To bring the concentration of calcium within the range of the instrument, the samples had to be diluted. To check the method's accuracy, two different dilutions were made of each sample. Samples 9013 gave 750 and 860 ppm Ca, whereas sample 9015 gave 800 ppm both times. (The samples were agitated before each measurement.) The saturated calcium sulfate solution was found to have 700 ppm calcium. This solution had no suspended solids.

**Conductivity Analysis.** The conductivity of the two recirculating calcium sulfate solutions was taken about twice a day for 11 days of total running time. The principle behind this test was that if the descaler increased solubility, its solution should have a higher conductivity than the "dummy" unit's solution.

Both solutions' conductivities rose simultaneously beyond the rise possible from instrument error. But, because no temperatures were taken, the data are invalid.

**Microscope Analysis.** No obvious differences in the two precipitates could be pinpointed that could not have resulted from sampling error.

*Simulated Heat Exchange Test*

**1981 Test.** This test design circulated tap water through a loop only once at a 56°C (133°F) temperature difference. The thermocouples used to detect temperature differentials erroneously showed a decrease in water temperature for incoming versus outgoing solutions. The test was then ended. The tubes in the loop were weighed to measure scale deposit but no appreciable amounts could be detected. Thus, no meaningful results were obtained from this test.

**1982 Test.** The first run basically provided operating and control experience. The second run was more sound; however, experimental limitations were presented by trying to chemically control the two loops to simulate identical situations with limited water supplies. These problems are not encountered in the "real world." The ideal test would have split an incoming water line into two identical streams, set the flow just under the maximum flow suggested for the device, heated water in the furnace 10°C (50°F), and continued for at least 1 year to build up enough measurable scale from a stabilized test system.

The result was that the magnetic device did not prevent scale from forming and did not lower the scale deposition rate. The loop without the magnetic device averaged .161 g of scale compared with .177 g of scale with the magnetic device. These weights are probably within experimental error of each other because of the difficulty in keeping the conductivities of the solutions similar.

**X-ray Analysis.** X-ray diffraction was used to obtain the weight fractions of aragonite and calcite in the specimens (details are in Appendix B). The results showed:

$$\frac{\text{Wt \% Aragonite} \times 100}{\text{Wt \% Aragonite} + \text{Wt \% Calcite}}$$

| | 1st Test Run | 2nd Test Run |
|---|---|---|
| Magnetic unit scale | 11.0 | 14.9 |
| Control scale | 10.6 | 18.9 |

Results from the atomic absorption test were:

| | % Iron | % Calcium |
|---|---|---|
| Magnetic unit scale | .17 | 22.66 |
| Control scale | .23 | 40.23 |

| | % Magnesium | % Copper |
|---|---|---|
| Magnetic unit scale | .24 | 1.54 |
| Control scale | 1.24 | 3.62 |

The chemical analysis and weights of the scales deposited in the loops with and without magnetic treatment are listed in Appendix A. A summary of the observations and tests is reported in Appendix B.

# 4 FIELD TESTS AND RESULTS

Most magnetic descalers are promoted through verbal testimonials which usually are supported by anecdotal data, not by chemical or other definitive evaluation procedures. Also, the chemistry of the water in many places is such that only small amounts of scale will form. When magnetic devices are installed, the facility often is told to increase its blowdown, which in itself greatly reduces the amount of scale formed. These two conditions have led many people to believe the magnetic descalers work.

Some of the devices that add small amounts of soluble iron, zinc, or aluminum salts to the water also appear to produce desirable results. Low concentrations of zinc can inhibit corrosion and scale effectively;[18] however, this method is expensive and uncontrolable. To obtain data from the actual operation of these devices, CERL conducted the following field tests. Results from sample analysis are shown in Table 2.

**Fort Hood, TX**

The unit B electromagnetic descaler was installed and tested on a 156.6-kW (210-hp) Superior natural-gas-fired boiler at Darnall Army Hospital, Fort Hood, TX, in June 1980. Two other identical boilers with nearly identical load cycles to this one were used as controls for the field test.

For 6 months the boiler with the descaling unit B was monitored with the same chemical treatment as that used for control boilers. No noticeable improvement was seen in chemical usage, fuel consumption, or steam production. Chemical treatment was then stopped on the boiler with descaling unit B. After 1 year without chemical treatment, except for sodium sulfide to keep oxygen out of the water, the boiler had developed a dark skin of scale. Based on past experience, the boiler operator said this amount of scale is what he would expect without chemical treatment as the hospital's water is processed through water softeners.

**Chanute Air Force Base, IL**

The magnetic descaler unit C was field-tested on a condensing chilled water line that cools a York lithium bromide absorber of 257 tons. For comparison, a Carrier absorption system of 183 tons was monitored. This unit is normally treated with sulfuric acid to control scale and with zinc-polyphosphate-chromate to inhibit corrosion. Both systems have a two-cell Baltimore Air Coil cooling tower and similar loads.

Chemical analysis of the chiller water in the two systems was performed periodically by the Illinois State Water Survey to monitor apparent solubility changes. All chemical tests indicated calcium carbonate was coming out of solution somewhere in the system using the unit C descaler.

For the 1981 and 1982 cooling seasons, steel and copper coupons were placed in the two cooling systems. Corrosion tests were conducted using American Society for Testing and Materials (ASTM) Standard D2688, Method C.[19] The corrosion and scaling rates found by the Illinois State Water Survey are condensed in Table 3 for the first period.[20] The only unacceptable corrosion rate was for copper corrosion in building 306. The specimens from building 306 were covered with a dense, white deposit compared with those in building 203, which had a light film of corrosion.

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[18] R. Stumper, *Z. Anorg. U. Allgem. Chem.*, Vol 204 (1932), pp 365-377.

[19] American Society for Testing and Materials, *Annual Book of ASTM Standards*, Standard D2688-79, Method C (1982), pp 10, 31.

[20] Ltr, dtd 14 Jan 1982, to D. Lawrence, CERL, from C. Neff, Illinois State Water Survey.

## Table 2

## CERL Samples from Field Tests

| Sample Identification | Observations after Addition of 2 ml $HNO_3$ | Sample digested in 2 ml $HNO_3$ and DI water, cooled, diluted to 200 ml Analyzed by Atomic Absorption (in %) | | | |
|---|---|---|---|---|---|
| | | Fe | Ca | Mg | Cu |
| Fort Stewart, GA, gray scale and fine powder/dirt | Effervescence, flecks in solution, insoluble particles | .21 | 31.47 | 2.02 | .05 |
| Fort Stewart, GA, gray pellets and finer powder/dirt | Effervescence, black solids, insoluble brown particles | .80 | 11.58 | 3.71 | .04 |
| Fort Monmouth, NJ, brown powder/dirt | No effervescence, brown liquid, brown flecks. Many insoluble rust-colored particles | 3.89 | 24.39 | 4.48 | .27 |
| From Cooling Tower 14 Feb, 83, tan-gray scale powder (Bldg 306, Chanute) | Effervescence, yellow gas, black insoluble flecks, insoluble light brown dirt | 1.15 | 22.82 | 4.01 | .36 |
| From Inside Tubes 14 Feb 83, white scale/powder (Bldg 306, Chanute) | Effervescence, small amount of insoluble white powder | .43 | 23.53 | 5.92 | .65 |
| 2W-With Descaler | Effervescence, floating brown particles | .17 | 22.66 | .24 | 1.54 |
| 2E-WO Descaler | Effervescence, brown gas, yellow liquid, brown floating particles | .23 | 40.23 | 1.24 | 3.62 |

## Table 3

## Corrosion and Scaling Rates: 22 Jun 81 to 15 Oct 81

| Building | Specimen | Treatment | Scale and Corros. Prods. (MDD*) | Corrosion Rate (MDD) |
|---|---|---|---|---|
| 203 | Steel | Acid-Zn-$CrO_4$ | 12.88 | 4.85 |
| 203 | Copper | Acid-Zn-$CrO_4$ | .45 | .30 |
| 306 | Steel | Magnetic device | 46.3 | 6.63 |
| 306 | Copper | Magnetic device | 19.7 | 1.13 |

*MDD = $mg/dm^2/day$.

During the 1981 cooling season, the cycles of concentration were kept low in building 306 using a high bleedoff rate. Reported makeup water averaged 27,633.5 to 54,131.4 L (7300 to 14,300 gal) for building 306 compared with only 18,927 to 34,069 L (5000 to 9000 gal) for building 203 (see Appendix B). In addition, daily applications of biocide to control algae growth were required in building 306, compared with only weekly applications for building 203. The total dissolved solids (TDS) was around 1000 in building 306.

Coupons from the 1982 cooling season (below normal temperatures) also revealed high scale deposition rates for building 306. Both systems showed copper corrosion rates higher than desired for properly treated systems. The corrosion and scaling rates are condensed in Table 4 for the second period.[21]

Another site of scale formation was on the bypass valve for diverting water from the cooling tower straight into the absorption unit with the magnetic device. The lime buildup on this valve caused locking. The TDS was around 2400 in building 306 during 1982. Periodically, the Illinois State Water Survey sampled and analyzed water in the two test boilers. These tests indicated the concentration of soluble hardness per cycle was much lower for building 306 than for building 203, which suggests that appreciable hardness was precipitating as scale or sludge in the system with the magnetic treatment device. The water's magnesium content was not significantly different between the magnetically treated water and nonmagnetically treated water. A cold distribution system was also compared to the magnetic descaler. Analysis of the treated and untreated waters for magnesium and calcium contents also showed no drastic difference (see Appendix B).

At the end of both cooling seasons, building 306's chiller required acid cleaning to remove the large quantity of deposits on the tube surfaces. Acid cleaning decreases the system's life because the tubes dissolve somewhat with each treatment. An average of .01 cm (.025 in.) of scale was deposited on the chiller tubes in building 306 during 1982. The scale was thicker at the entrance end of the chiller than the unit end, as would be expected. (Roughly, .318 cm [.125 in.] of scale increases fuel costs by 25 percent.)

### Fort Monmouth, NJ

The electromagnetic unit D was installed in January 1981 on the #2 hospital boiler at Fort Monmouth, NJ. This boiler uses about a 20-percent makeup water rate because of leaks and steam losses. Unit D was used on this boiler until August 1982. At this time the boiler was inspected and apparently was in satisfactory condition. Boiler operators at Fort Monmouth believe this electromagnetic unit is preventing scale buildup on their boiler.

Before entering the Fort Monmouth boiler system, city water is processed by a water softener; the system also uses a deaerator. These devices should help reduce scale-forming constituents in the water before it enters the system. The inside of the boiler did not appear to have a "hard" scale buildup. According to the operators, when they cleaned the boiler, all they had to do was scoop out a large amount of "muddy" residue that accumulated in the bottom. To compare the boiler's condition with and without use of unit D, Fort Monmouth started operation in late August without it. But, their water softener malfunctioned in September so they switched to chemical treatment, ending the test.

As Fort Monmouth was using a water softener and a deaerator for this boiler, the test could not be

**Table 4**

**Corrosion and Scaling Rates: 22 Jul 82 to 27 Oct 82**

| Building | Specimen | Treatment | Scale and Corros. Prods. (MDD) | Corrosion Rate (MDD) |
|---|---|---|---|---|
| 203 | Steel | Acid-Zn-$CrO_4$ | 4.68 | 3.69 |
| 203 | Copper | Acid-Zn-$CrO_4$ | 4.93 | 1.94 |
| 306 | Steel | Magnetic device | 17.18 | 1.19 |
| 306 | Copper | Magnetic device | 17.99 | 12.25 |

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[21] Ltr, dtd 4 Jan 1983, to D. Lawrence, CERL, from C. Neff, Illinois State Water Survey.

completed fairly until both systems were functioning again. Fort Monmouth expects the water softener to be functional and inline, ready to complete testing, if desired, in late 1983.

A scale sample was taken from the inside of the boiler for analysis. The analysis exhibited a high content of iron, indicating that iron corrosion is probably occurring within the system (see Appendix A, Table A4).

### Amoco Field Study

Amoco Oil Company is doing a study to demonstrate the feasibility of magnetic water treatment using a dual 189 L/min (50-gpm) heat exchanger-cooling tower system. From this testing, they hope to define the magnetic devices' limitations in preventing scale in heat exchangers. They are also testing units in their Texas City refinery. Their tests appear to be well planned and aimed at determining the scientific limitations of these devices through "real world" operation.

### Evaluation of Case Studies

Additional information on the operation of these devices was collected from the manufacturers and from Army facilities using them. A few sites claiming the units work were contacted or visited, and a summary of findings follows.

#### *Fort Story, VA*

Fort Story is cited by one company as a location using their magnetic descaling units successfully. A visit to the site indicated otherwise – it was found that the magnetic descaler was no longer used. The bottom two rows of tubes in this boiler had to be replaced after 7 years of magnetic treatment with the unit A descaler. (The boiler was new at the beginning of magnetic descaler use.) They now use chemical treatment with very satisfactory results.

#### *Fort Stewart, GA*

Fort Stewart has been using a permanent magnet-type unit on a 125-ton air conditioner for about 6 years. This site had scale problems before, even when using chemical treatment. As work there does not require a thorough chemical knowledge of the system's operation, personnel have no expertise in water treatment. The performance of this unit is thus rated by anecdotal data and is not supported by chemical or other definitive evaluation procedures. Moreover, appropriate instrumentation has not been installed on the system to test water temperature fluctuations, TDS, or other properties that establish scaling tendency.

Scale samples from the cooling tower basin and fins were collected for analysis. Nothing out of the ordinary was noted. The results are shown in Appendix A, Table A4.

#### *U.S. Army Facilities Engineer Activity, Korea (FEA-K)*

Operators in Korea are convinced the unit C descalers they have been using for 2-1/2 years are 100 percent effective. According to FEA-K, there are pipe samples showing the effectiveness of the unit installed at Camp Casey, Korea. The performance of these units is supported by anecdotal data, however, and not by chemical or other definitive evaluation procedures.

# 5 CONCLUSIONS AND RECOMMENDATIONS

Three of four different magnetic descalers tested were not effective for water treatment in CERL's laboratory and field studies. Testing on the fourth unit was incomplete.

Analysis of field test waters indicated no significant change in the solubility of scale-forming minerals such as the calcium compounds. Also, analysis of scale deposits from the field samples showed no difference in aragonite and calcite contents in scale formed from water treated with and without magnetic devices.

In field tests, both boiler efficiency and scale buildup were examined. The unit B descaler at Fort Hood, TX, did not improve boiler efficiency or prevent scale formation. The unit C descaler tested at Chanute AFB, IL, also did not prevent scaling (boiler efficiency was not tested). CERL laboratory tests indicated that unit A neither prevented scale formation nor reduced the amount of scale deposited.

Field tests of natural water and laboratory tests of reagent-grade water in heat exchangers showed no decline in scaling tendency from magnetic treatment.

Army-wide use of magnetic descalers is not recommended based on these findings. Moreover, current operation of such devices at Army facilities should be quantified and validated. An indepth scientific analysis is recommended at three specific sites:

1. The descaling units installed at the U.S. Army Facilities Engineer Activity, Korea (FEA-K), should be

investigated further and should address the following questions:

- Does the system put iron, lead, zinc, or tin into the water, possibly affecting calcium carbonate solubility?
- Does the water form scale if all systems are operated identically in terms of blowdown, total dissolved solids, etc.?
- What is the current water chemistry?
- Is scale eliminated at the cost of increased corrosion?

2. Fort Monmouth, NJ, has a 1-1/2-year run with the unit D descaler and is willing to run the same boiler without the device for comparison. This test would require minimal effort and should be completed.

3. The water at Fort Stewart, GA, should be analyzed to determine its current scaling properties. The descaler operating procedures also should be investigated.

In addition the research in progress by Amoco should be followed closely.

If any of these field tests scientifically validates the performance of magnetic descalers, the water analyses and operating procedures should be used as a basis for determining which other sites might benefit from using these units. The whole picture of corrosion, scaling, and water properties should be investigated.

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# APPENDIX A: DIFFRACTION ANALYSIS

### Phase Identification

The diffractometer study was conducted on a North American Phillips Norelco diffractometer. Specimens were scanned at a rate of 1° $2\theta$ per minute in the angular range of 10° to 70° $2\theta$. The ratemeter for the scans was set at 500 counts per second full scale. The phases present were identified through using the ASTM Powder Diffraction File.[24]

### Quantitative X-Ray Diffraction Analysis

To determine the weight percentages of calcite and aragonite present in the unknown samples, calibration curves were needed. The curves were constructed by the following procedure.

1. Various percentages of calcite and aragonite were combined with a constant amount of anatase ($TiO_2$)* and tricloroethane. For simplicity, 3-g samples were used. See Table A1.

2. The mixtures were placed in a spex mill and ground to less than 5 μm in size.

3. This slurry was then placed in an evaporating dish and dried at 105°C.

4. The dried powder was analyzed by Quantitative X-ray-Diffraction Analysis (QXDA) methods. The scanning rate was 1/8° $2\theta$ per minute and the ratemeter was set at 500 counts per second full scale. See Table A2.

5. The areas under the diffractometer peaks were measured from the diffractometer chart with a Hruden planimeter.

6. Plotting area under calcite peak/area under $TiO_2$ peak versus weight percentage calcite and area under aragonite peak/area under $TiO_2$ peak versus weight percentage Aragonite gives the calibration curves (Figures A1 and A2).

Once the calibration curves were constructed, the unknown samples were mixed with 10 weight percentages of $TiO_2$ and 6 ml of tricloroethane. These samples were then analyzed by QXDA methods. The areas under the diffractometer peaks were measured with a Hruden planimeter. By determining the area under calcite peak/area under $TiO_2$ peak, it was possible to enter the calibration curves and find the weight percentages of calcite and aragonite in the unknown samples (see Table A3).

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[24] ASTM Powder Diffraction File, Cards 5-0586, 5-0453, 4-0477, *Am. Soc. Test Mat. Publ. No. PDIS-171* (1967).

*The anatase ($TiO_2$) served as internal standard.

**Table A1**

**Weight Percentages of Constituents Used to Construct Calibration Curves**

| Calcite (wt %) | Aragonite (wt %) | $TiO_2$ (% of total) | Tricloroethane (ml) |
|---|---|---|---|
| 20 | 80 | 10 | 6 |
| 50 | 50 | 10 | 6 |
| 80 | 20 | 10 | 6 |

## Table A2

### X-Ray Diffraction Peaks Studied for QXDA Analysis*

| Phase | $2\theta$ Value | d (A) |
|---|---|---|
| Calcite | 23.0 | 3.86 |
| Aragonite | 37.9 | 2.37 |
| $TiO_2$ | 25.4 | 3.51 |

*Peak overlap was evident and the 100 percent peaks were not used.

## Table A3

### Weight Percentages of Calcite and Aragonite in Unknown Samples

| Sample* | Wt % Calcite | Wt % Aragonite | $\frac{\text{Aragonite} \times 100}{(\text{Aragonite + Calcite})}$ |
|---|---|---|---|
| W2 #1 | 78.6 | 9.7 | 11.0 |
| E2 #1 | 69.3 | 8.2 | 10.6 |
| W2 #2 | 58.1 | 10.2 | 14.9 |
| E2 #2 | 50.5 | 11.8 | 18.9 |

*W refers to the west test loop with the magnetic device, whereas E refers to the east test loop with the "dummy" unit.

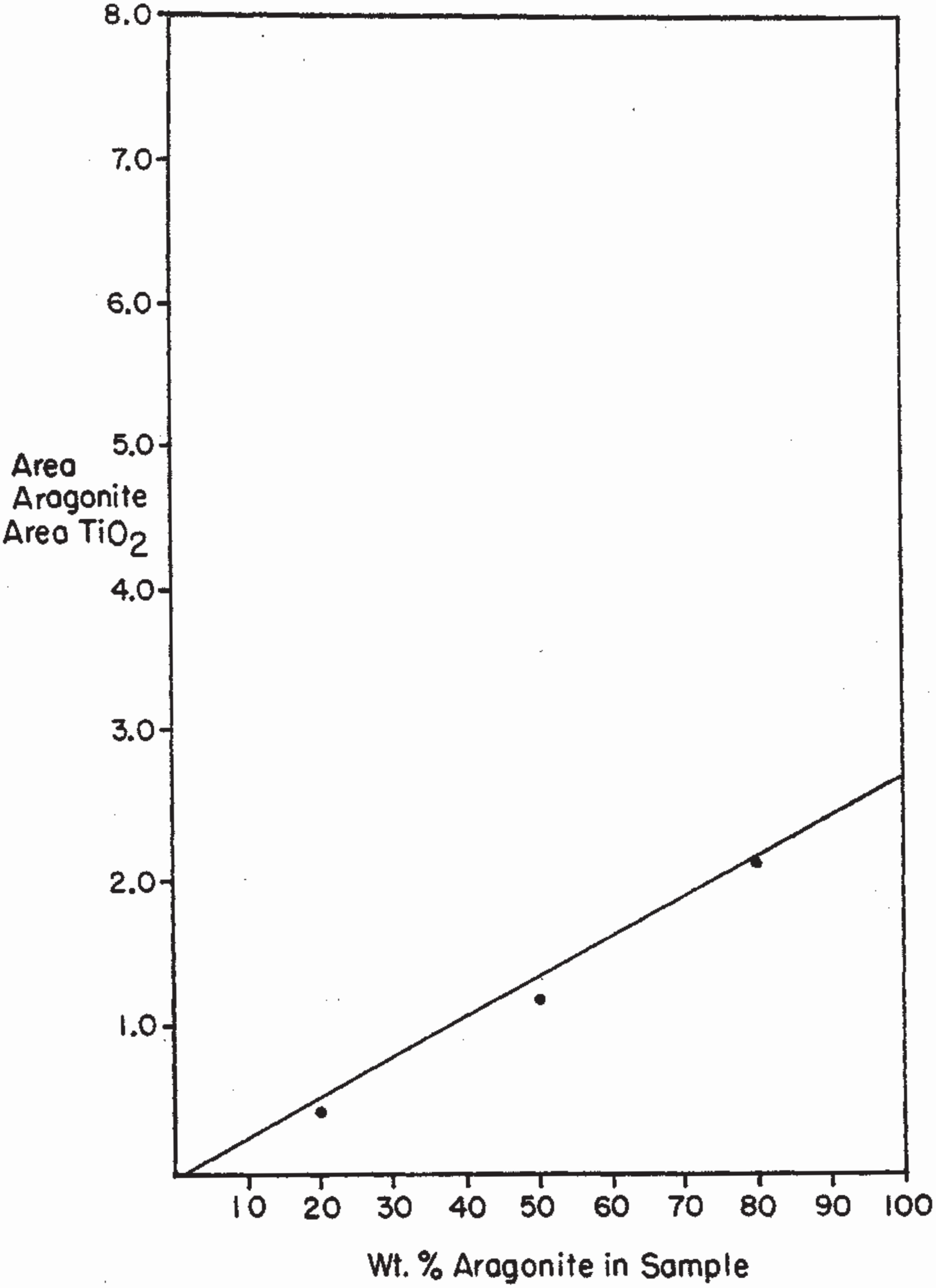

**Figure A1.** Quantitative X-ray diffraction analysis curve for aragonite.

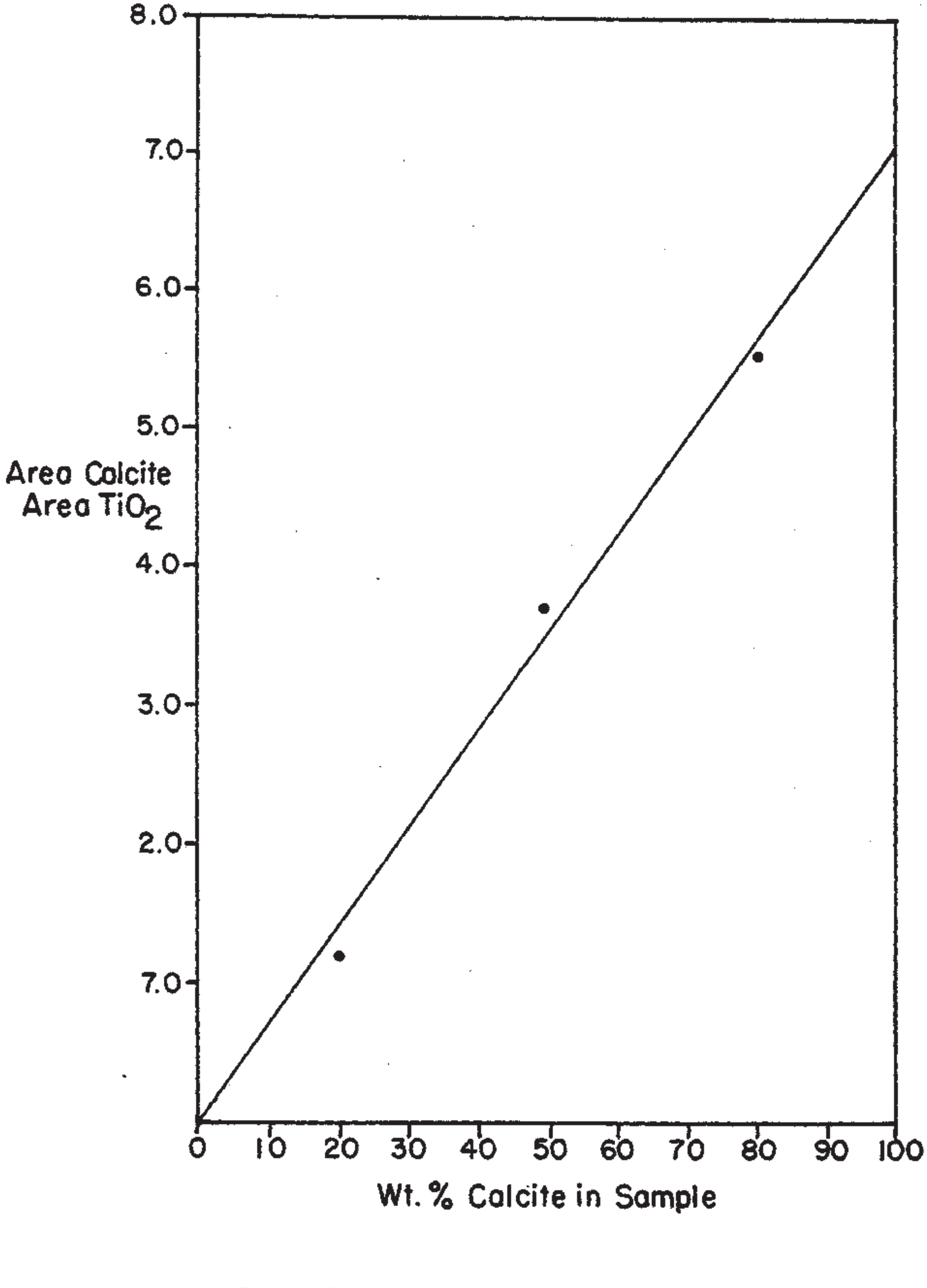

Figure A2. Quantitative X-ray diffraction analysis calibration curve for calcite.

# APPENDIX B: THEORY AND TECHNOLOGY OF MAGNETIC WATER TREATMENT: FIELD STUDY*

### Objective

Objectives will be: (1) to examine the proposed laboratory test plan and to suggest a test plan, (2) to comment on the Fort Hood, TX, tests on a nonchemical device, and (3) to examine and report on the Chanute Air Force Base (AFB), IL, test being conducted on a nonchemical water treatment device.

### Background

Several manufacturers of nonchemical devices claim to inhibit scale and corrosion in water systems by passage through these devices. Various physical forces, such as magnetic, electrostatic, ultrasonic, etc., even in combination, have been claimed to alter the crystal structure of the scale formed and inhibit its adherence to piping or heat transfer surfaces. In general, it is theorized that the potential scale or sludge is formed and suspended in the water flow and does not crystallize and form scale on the piping or heat transfer surfaces.

When success with these devices has been reported,[25] it has been learned that maximum blowdown was applied to the cooling tower systems whereby only 1.5 to 3 cycles of concentration have been maintained. Under these conditions, it is known that many systems can operate without serious scale formation; however, increased requirements of energy and makeup water result. There are many low-hardness waters[26] which may be used for cooling that do not require any chemical treatment additions. Even some low-pressure boilers employing very little makeup or using self-purging waters (natural alkalinity > hardness) need not be chemically treated. In these cases, the installation of magnetic treatment devices is not required. Therefore, reports of effective scale inhibitation at these sites are unwarranted.

Although the chemical literature contains information about the effects of magnetic treatment[27] on industrial water, it is recognized that nonsusceptibility of colloidal, flocculated, or ionic species to magnetic treatment exists. It is also recognized that the amount of magnetism required to effectively reduce the scaling tendency of a water may be economically impractical. Assuming magnetic treatment is effective to a degree, the concern of the water treatment chemist is that it is generally unpredictable and cannot be engineered properly to provide practical results in water systems.

Regardless of the information in the literature and personal experience in the field, an unbiased evaluation of the devices was provided.

### Investigation

*CERL Laboratory Assembly for Evaluating Amount of Scale Formed With and Without Magnetic Treatment (Unit A)*

Inspection of the constructed test assembly indicated that an evaluation of scale formation likely could be obtained; however, it seemed that a simpler mechanism based on past methods of evaluating the scaling tendencies would prove to be more successful. The equipment design seemed more complicated than necessary and provided no real assurance that an accurate evaluation would be attained.

It is therefore recommended that the equipment be designed as described by National Association of Corrosion Engineers' committee T-7K-2[28] or as described by Ryznar.[29] There are proven methods of scale evaluation and results would be so recognized.

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*By R. W. Lane, Principal Scientist, Illinois State Water Survey, Champaign, IL (Aug 1981).

[25] National Association of Corrosion Engineers (NACE), *Minutes of NACE Committee T-7K Non-Chemical Water Treating Devices* (NACE, March 1979, March 1980, April 1981); G. Krajic and M. Milosevic-Kvajic, *Magnetic Field Conditioning of Industrial Waters* (International Water Conference Proceedings, 40th, 1979), pp 153–160; J. F. Wilkes and R. Baum, *Water Conditioning Services – An Update* (International Water Conference Proceedings, 40th, 1979), pp 161–167; J. Dromgoole and M. C. Forbes, *The Fatal Lure of Water Treatment Gadgets* (1979), pp 169–173; R. M. Westcott, "Non-Chemical Water Treating Devices," *Materials Performance* (November 1980), pp 40–42; P. Puckorius, "Mechanical Devices for Water Treatment: Just How Effective Are They?" *Power* (January 1981), pp 60–62.

[26] R. W. Lane and C. H. Neff, *Life Cycle Analysis (LCCA) Package for Cooling Tower Treatment* (U.S. Army DACA-88-86-M-0298, submitted).

[27] G. Krajik and M. Milosevic-Krajic.

[28] National Association of Corrosion Engineers (NACE), *Report of NACE Committee T-7K-2 on Methods of Performance Testing Non-Chemical Water Treatment Devices* (October 1980).

[29] J. Ryznar, "A New Index for Determining Amount of Calcium Carbonate Scale Formed by a Water," *J. Am. Water Works Assoc.*, Vol 36, No. 4 (April 1944), pp 472–486.

The following specific suggestions for designing the test assembly should be considered:

- Using 1-in. galvanized piping for passage into and through the electric furnace. This will allow passage of 56.8 L/min (15-gpm) flow at a reasonable flow rate through the magnetic treatment device

- Using the Langelier Saturation Index[30] for deciding water composition, temperature, and treatment

- Using thin-walled, galvanized pipe, as in American Society for Testing and Materials Standard D2688, Method C,[31] to provide more accurate evaluation of scale by weight gain

- Initial tests using Champaign-Urbana water heated to about 60°C (140°F) or above to provide appreciable scale within 24 hours.

*Fort Hood – Comparison of Boiler Results With and Without Magnetic Device*

It has been reported that the two heating boilers at the hospital have shown no difference in boiler efficiencies regardless of the magnetic device (unit B) installed to treat the feedwater of one boiler. Quebracho-phosphate treatment is also being applied to both boilers. These boilers use very little makeup and are exposed to self-purging water (M alky. > H).

In determining the efficiency of boilers, complete, precise, and standardized instrumentation with respect to flowmeters and thermometers as well as closely monitored testing are required. Such instrumentation is generally not provided in boiler rooms of this size. It is not surprising that no difference in efficiencies has been shown, and this test would be considered inconclusive for determining the effectiveness of the magnetic device. It is seriously questioned whether a test can be designed to compare efficiencies of these boilers unless considerable financial expenditures in equipment and personnel are allotted.

CERL notes that these magnetic treatment devices have been reported to treat boilers effectively at some Army bases. Again, it should be pointed out that many low-hardness waters do not require treatment for scale prevention. Most likely, the success of these devices in supposedly preventing scale results from the lack of a need for treatment rather than the efficiency of the device.

*Chanute AFB – Comparison of Air Conditioner Results With and Without Magnetic Device*

At Chanute AFB a magnetic device (unit C) was installed in the cooling tower circulating line of the air conditioner in building 306. This air conditioner is composed of a York absorption system of 257 tons and a two-cell Baltimore Air Coil galvanized cooling tower. To compare with this system, a Carrier absorption system of 183 tons and a two-cell Baltimore Air Coil cooling tower were chosen; the latter is treated with sulfuric acid for scale control and with zinc-polyphosphate-chromate for corrosion inhibition.

Samples were taken and analyzed periodically to determine the comparative effectiveness of the two methods of treatment. Table B1 shows the result of the analyses. Table B2 shows the results of the inspection of the cooling towers and calculations obtained from the water analyses. In Table B2, it will be noted that the soluble hardness per C (cycles of concentration) is much lower (38) in building 306 than in building 203 (142). This indicates that appreciable hardness has precipitated as scale or sludge in the system in which the magnetic treatment device was installed. To date there has been no noticeable difference in heat transfer between the two adsorption machines; however, it is expected that the tube surfaces of the machine using the magnetic device will show appreciably more scale. This observation is based on the calculated lower soluble hardness/C. Daily applications of biocide were also required to control algae growth whereas only weekly application of biocide was required for the building 203 cooling tower. Higher bacterial plate counts were also observed in circulating water of building 306.

This fall when the air conditioners are shut down, inspection of the heat exchanger tubes of the absorption systems will disclose the effectiveness of the two methods of treatment. Also at that time, the Illinios State Water Survey corrosion tester inserts will be removed for evaluation of scale and corrosion. The inspection of the heat exchanger tubing and the corrosion tester results to be reported at that time will provide the true comparison between the two methods of teatment.

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[30] *Calcium Carbonate Saturation*, Standard Methods, 14th edition, Section 203, pp 61-63; R. W. Lane, ISWS Internal Communication on Calcium Saturation Index.

[31] *Annual Book of ASTM Standards*, Part 31, American Society for Testing and Materials, ASTM D2688, Method C (ASTM, 1981), p 170.

# Table B1

## Results of Analyses of Cold Distribution Water and Chanute AFB Cooling Towers

| Date Sampled | Unit Sampled | P Alkalinity (as $CaCO_3$) | M Alkalinity (as $CaCO_3$) | Hardness (as $CaCO_3$) | Orthophosphate (as $PO_4$) | Polyphosphate (as $PO_4$) | Organic phosphate (as $PO_4$) | Chromate (as $CrO_4$) | Chloride (as Cl) | Sulfate (as $SO_4$) | Silica (as $SiO_2$) | Calcium (as Ca) | Magnesium (as Mg) | Iron (as Fe) | Copper (as Cu) | Zinc (as Zn) | Residue | pH @ °C Temperature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cold distribution | | | | | | | | | | | | | | | | | | |
| 6/8/81* | | - | 388 | 114 | 0.1 | 0.1 | | - | ? | 0.7 | | 27 | 11 | 4.4 | 0.0 | 0.3 | 449 | - |
| 7/8/81 | | 0.0 | 290 | 160 | - | - | | - | ? | - | | 43 | 13 | - | - | - | - | - |
| 8/13/81 | | 0.0 | 340 | 128 | - | - | | - | 6 | - | | - | est.<br>14 | - | - | - | - | - |
| 8/19/81 | | 0.0 | 375 | 152 | - | - | | - | 14 | - | | 34 | 16 | - | - | - | - | - |
| | | | | Avg- 139 | - | - | | - | | | | | | - | - | - | - | |
| Bldg 306 (Magnetic water treatment device) | | | | | | | | | | | | | | | | | | |
| 6/11/81 | | 87 | 952 | 201 | 3.6 | 0.6 | | - | 20 | 0.0 | | 24 | 35 | .06 | .04 | .01 | 1060 | 9.04/22.7 |
| 7/8/81 | | 16 | 433 | 104 | 0.3 | 0.3 | | - | 4 | 0.0 | | 14 | 17 | .22 | .02 | .0 | 564 | 8.62/30 |
| 8/11/81 | | 160 | 1176 | 212 | 0.6 | 0.5 | | - | 30 | 0.0 | | 8 | 47 | .32 | .09 | .0 | 1342 | 9.36/24.5 |
| 8/13/81 | | 192 | 1252 | 238 | 0.8 | 0.5 | | - | 38 | 40 | | 9 | 53 | .1 | .08 | .0 | 1446 | 9.37/25.2 |
| 8/14/81 | | 600 | 2200 | 375 | - | - | | - | 41 | - | | - | - | - | - | - | - | - |
| 8/19/81 | | 120 | 992 | 219 | 0.5 | 0.8 | | - | 26 | 10 | | 9 | 48 | .22 | .07 | .0 | 1162 | 9.19/25.5 |
| | | | | Avg- 225 | | | | | | | | | | | | | | |
| Bldg 203 (Conventional – acid-zinc-polyphosphate-chromate treatment) | | | | | | | | | | | | | | | | | | |
| 6/11/81 | | 0.0 | 55 | 622 | 9.9 | 4.6 | | 54 | 22 | 1199 | | 162 | 53 | 2.6 | .13 | 1.7 | 2260 | 6.9/23 |
| 7/8/81 | | 0.0 | 36 | 1000 | 3.7 | 2.1 | | 32 | 42 | 2042 | | 256 | 88 | 0.8 | .08 | 1.4 | 3540 | 6.9/30 |
| 8/11/81** | | 52 | 1272 | 359 | 3.8 | 1.4 | | 6 | 46 | 525 | | 23 | 74 | .31 | .08 | .03 | 2254 | 8.86/24 |
| 8/13/81 | | 0.0 | 72 | 1782 | 3.3 | 2.0 | | 12 | 36 | 2659 | | 533 | 110 | 0.6 | .07 | .27 | 4566 | 7.72/25.5 |
| 8/14/81 | | 0.0 | 38 | 735 | - | - | | 10 | 20 | - | | - | - | - | - | - | - | - |
| 8/17/81** | | 164 | 1400 | 350 | - | - | | <5 | 34 | - | | - | - | - | - | - | - | - |
| 8/19/81 | | 0.0 | 76 | 934 | 2.9 | 3.2 | | 10 | 38 | 1949 | | 222 | 92 | .57 | .04 | .18 | 2935 | 7.26/25.5 |
| | | | | Avg- 826 | | | | | | | | | | | | | | |

*Na – 141, $NH_4$ – 0.4, $SiO_2$ – mg/L

**Acid treatment was out of service.

## Table B2

### Results of Inspections and Calculations Obtained from Water Analyses

| | Cycles of conc (C)[13] based on | | | | Based on 50% load* | | | |
|---|---|---|---|---|---|---|---|---|
| | Cl⁻ | Mg⁺⁺ | Avg C | Inspection of towers | $\frac{\text{Avg H}}{\text{Avg C}}$ | Calculated makeup/day | Calculated blowdown/day | Reported makeup (gpd) |
| Bldg 306 (magnetic device) | 2.9 | 3.2 | | | | | | |
| | 0.6 | 1.3 | | | | | | |
| | 4.3 | 3.3 | | No scale on fill; appreciable algae on distribution deck | | | | |
| | 5.4 | 3.8 | | | | | | |
| | 5.9 | – | | | | | | |
| | 3.7 | 3.0 | | No scale on fill; less algae on distribution deck;<br>sludge in basin | | | | |
| Avg | 3.8 | 2.9 | 3.35 | | 38 | 10180 | 3040 | 7300–14300 |
| Bldg 203 (conventional treatment) | 3.1 | 4.8 | | | | | | |
| | 6 | 8 | | | | | | |
| | 6.6 | 6.7 | | | | | | |
| | 5.1 | 8 | | Slight scale on fill; no algae on distribution deck;<br>no sludge in basin | | | | |
| | 2.9 | – | | | | | | |
| | 4.9 | – | | | | | | |
| | 5.4 | 5.7 | | Slight scale on fill;<br>no algae on distribution deck;<br>no sludge in basin | | | | |
| Avg | 4.9 | 6.7 | 5.8 | | 142 | 2460 | 420 | 5000–9000 |

*1 gpd = 1.84 × $10^{-7}$ $m^3$/min.

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