The University of Michigan

SCHOOL OF PUBLIC HEALTH
DEPARTMENT OF ENVIRONMENTAL
AN6 INDUSTRIAL HEALTH

109 OBSERVATORY STREET
ANN ARBOR, MICHIGAN 48109-2029
U.S.A.

THE UNIVERSITY OF MICHIGAN
INSTITUTE OF ENVIRONMENTAL & INDUSTRIAL HEALTH

PRELIMINARY INVESTIGATION OF THE FIELD CONTROLS CLEARWAVE WATER CONDITIONER

Prepared by
K. H. Mancy
Professor & Director of the Institute of Environmental & Industrial Health

CONTENTS

INTRODUCTION

This report includes the results of preliminary testing of the Clearwave Water Conditioner, manufactured by the Field Controls Company. The final section of the report includes conclusions and recommendations.

The purpose Of this investigation was to assess the effect of the Clearwave water conditioner on calcium carbonate scale formation under laboratory conditions. More specifically, this was of the study has the following objectives:

1. Determine the nature and magnitude of the Clearwave output signals.
2. Determine the effect of the Clearwave treatment on ionic conductance and dissolved oxygen levels in water,
3. Determine the effect of the Clearwave treatment on the calcium carbonate deposition test (CCDT).

The preliminary investigations described in this report are considered to be a first phase laboratory testing under controlled conditions, A second phase of this project is planned to include full scale testing simulating the effects in house plumbing.

EXPERIMENTAL CONDITIONS

The testing of the Clearwave Water Conditioner was conducted at a temperature of 22 ± 2C°. Two types of waters were used in this testing program; (a) City of Ann Arbor tapwater (Table 1 gives results of analysis of tapwater), and (b) synthetic waters prepared in the laboratory at different hardness levels. In certain experiments, the pH and hardness of a given water sample were altered in an attempt to assess the effect of these variables,

All tests were conducted on pipe segments, about 8" in length and 1.5" in diameter, made of cast iron or copper. These were typical samples of pipes used in house plumbing, provided by the Field Controls Co.

The pipe segments were sealed at one end and mounted in an upright position on a stand. The Clearwave device and associated coils were mounted on the outside of the pipe segments which were filled with the test water. Typically each test was repeated until two consecutive reproducible results were observed.

Table 1: Analysis of Ann Arbor Tap Water[1]

Water Quality Parameter	8/96	9/96	10/96	11/96	12/96	1/97	Dates 2/97	3/97	4/97	5/97	6/97	7/97
pH	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3
Total Alkalinity	32	28	33	57	50	45	51	33	50	33	28	34
Total Hardness	101	121	125	144	129	143	155	143	154	134	107	110
Calcium	28	35	24	68	54	46	40	46	62	37	28	32
Magnesium	8.0	8.7	6.0	5.3	4.5	6.0	13	7.0	3.1	3.0	10.0	11.1
Temp C°	23.5	17.7	13.6	9.1	6.7	3.9	5.7	6.5	9.7	11.9	19.0	21.5

1. Concentrations are given in units of mg/l.

CHARACTERIZATION OF THE CLEAR WATER OUTPUT SIGNAL

The experimental set up is shown in Figure 1. Potential measurements were made at different points of contact using a digital voltammeter (Simpson Model 312). Point A is in contact with test water, B is connected to ground, and C and D are upper and lower coil terminals, respectively.

Potential differences between points C and D indicated a.c. voltage in the order of IIV and d.c. voltage in the order of 50 mV. There was no significant potential difference between A and D. However, a square wave signal in the order of 100 mV was detected between A and B.

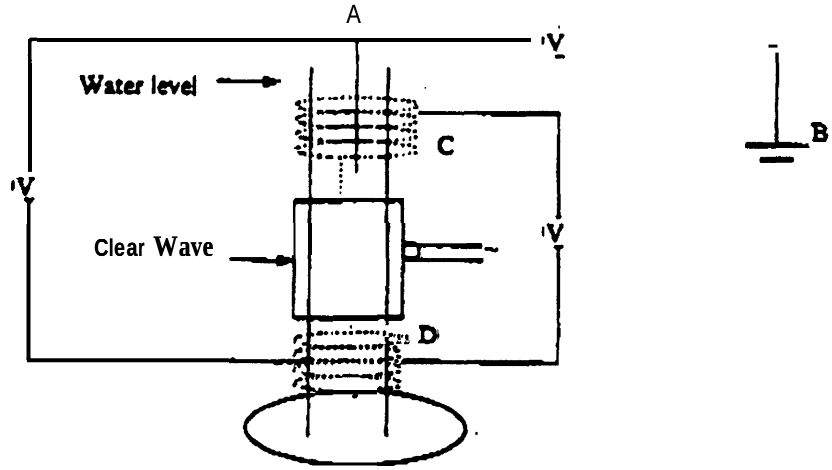


Figure 1: Potential Measurements of Contacts with Clearwave Instrument

EFFECT OF CLEARWAVE TREATMENT ON ELECTRICIAL CONDUCTIVITY

Electrical conductivity of solutions depends on theconcentrations and mobility of ions (and charged particles). Therefore, conductivity measurement of a given water sample can be interpreted *to* indicate the mobility of the ions which is dependent on the degree of solvations, complexation, or association of ions.

The electrical conductance of a given water sample can be expressed as follows

$$L = K_c \sum_{i}^{n} C_i \lambda_i \, Z \qquad (1)$$

L = specific conductance (mhos/cm)
K_c = cell constant (cm.s./ohm.mole)
C_i = ionic concentration(moles/cm^3)
λ_i = ionic mobility (cm/s)
Z = ionic valency

The test was based on applying *the* Clearwave treatment to a given water sample and to observe for any changes in electrical conductivity using a YSI conductivity meter. Since C and Z are constant for the treated water sample, changes in electrical conductance would indicate changes in ionic mobility, Consequently, an increase in electrical conductance would indicate an increase in ionic mobility and the reverse relationship would also apply,

This could be also interpreted in terms of change in the degree of hydration of the ions in solution, and their tendency to precipitate.

The electrical conductivity of samples of tap water were determined before and after the application of the Clearwave treatment. The results are shown in Figure 2. Our findings, so far, indicate no changes in the electrical conductivity of water samples as a result of the Clearwave treatment.

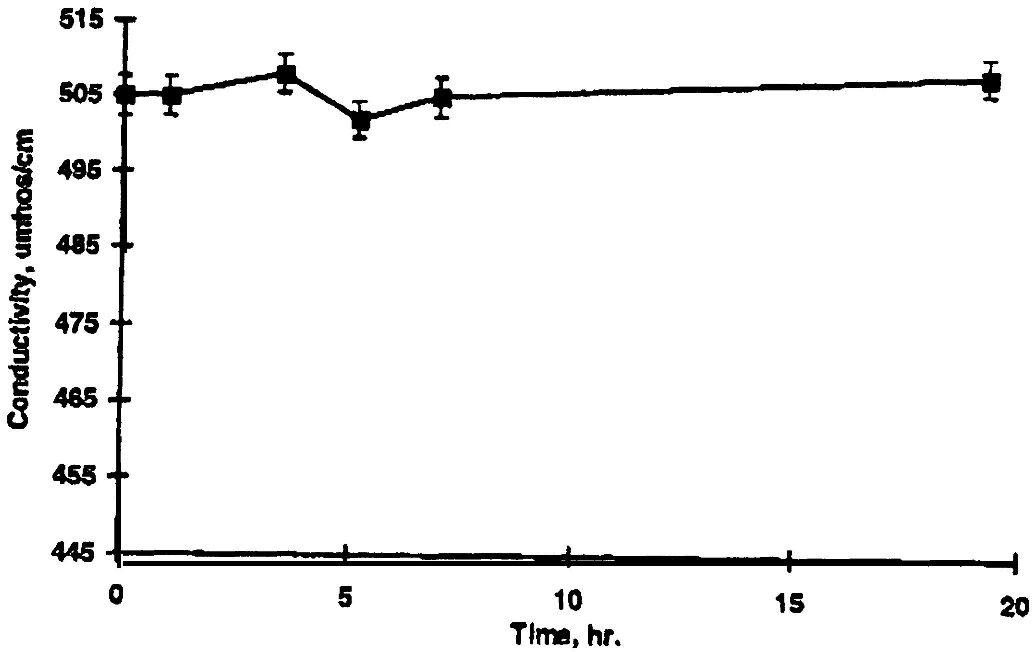


Figure 2: Effect of Clearwave treatment on conductivity of tap water

EFFECT OF CLEARWAVE TREATMENT ON DISSOLVED OXYGEN CONCENTRATION

This experiment was conducted to find out if the Clearwave treatment has an effect on the solubility of molecular oxygen in the test water. Dissolved oxygen is an important variable which should be determined before performing the Calcium Carbonate Deposition Test (CCDT). This test can only be valid if the dissolved oxygen concentration is maintained at a constant level.

Similar to the previous electrical conductance experiment, dissolved oxygen concentrations of tap water samples were determined before and after the application of the Clearwave treatment. Dissolved oxygen measurements were conducted by a YSI oxygen probe. The results of this experiment are shown in Figure 3. Dissolved oxygen levels, expressed in terms of units of % saturation with air, did not show significant 'variation over a period of 20 hours.

Our findings, so far, indicate that the application of Clearwave treatment has no effect on the dissolved oxygen level in the test solution.

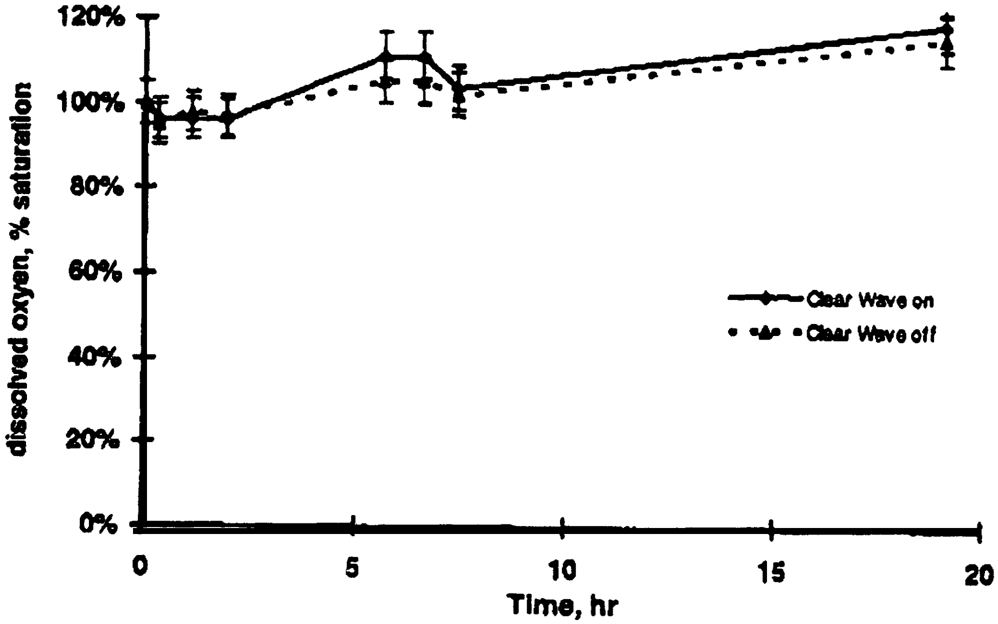


Figure 3: Effect of ClearWave treatment on tape water dissolved oxygen (% saturation at mm temperature).

EFFECT OF THE CLEARWAVE TREATMENT ON CALCIUM CARBONATE DEPOSITION TESTS

The Calcium Carbonate Deposition Test (CCDT) was originally developed to assess and explain the rates and amounts of scale formation in water distribution systems (1,2 and 3). The mechanism of scale formation was depicted to involve dissolved oxygen. The electrolytic reduction of molecular oxygen on the surface of metal pipes will result in the generation of hydroxyl ions, i.e.

$$O_2 + 2H_2O + 4e \longrightarrow 4OH \qquad (2)$$

This will be followed by the deposition of $CaCO_3$ on the metal surface,

$$HCO_3^- + OH \longrightarrow CO_3^{2-} + H_2O \qquad (3)$$

$$Ca^{2+} + CO_3^{2-} \longrightarrow CaCO_3 \downarrow \qquad (4)$$

This mechanism of calcium carbonate scale formation is predominantly applicable to water distribution systems. Scale formation in hot water heaters and boilers cannot be explained by this theory where at high temperatures calcium carbonate spontaneously precipitates.

The theory and the application of the CCDT test are detailed in references 1 - 3. The test is based on the reduction of dissolved oxygen in the test solution using a rotating ring-disc gold electrode. The experimental set up is shown in Figure 4. The rotator-electrode system is shown in Figure 5.

Typical CCDT curves for waters with different rates of $CaCO_3$ deposition are shown in Figure 6. The slope of the current-time curve is proportional to the rate of $CaCO_3$ deposition.

At steady state conditions, the current values can be expressed as follows:

$$i = \emptyset(Pm/l) \qquad (5)$$

where i = limiting current
$\emptyset$ = proportionality coefficient which is equal to nF/C
where n = number of electron transferred per mole
F = farady constant
C = dissolved oxygen concentration in the test solution in moles/l.
Pm = permeability coefficient of the $CaCO_3$ film.
l = thickness of the $CaCO_3$ film.

Results of the CCDT experiment with tap water are shown in Figure 7. The most striking feature of the results is the difference between the CCDT curves for the control and the water sample treated with the Clearwave conditioner. Repeated runs indicated a significant difference between the control and treated water samples. As shown in Figure 7, the flat CCDT curves obtained with the treated water samples indicate the absence or a slow rate of $CaCO_3$ deposition. In contrast, the CCDT curves obtained with the control (untreated) water samples are indicative of high rates of $CaCO_3$ deposition.

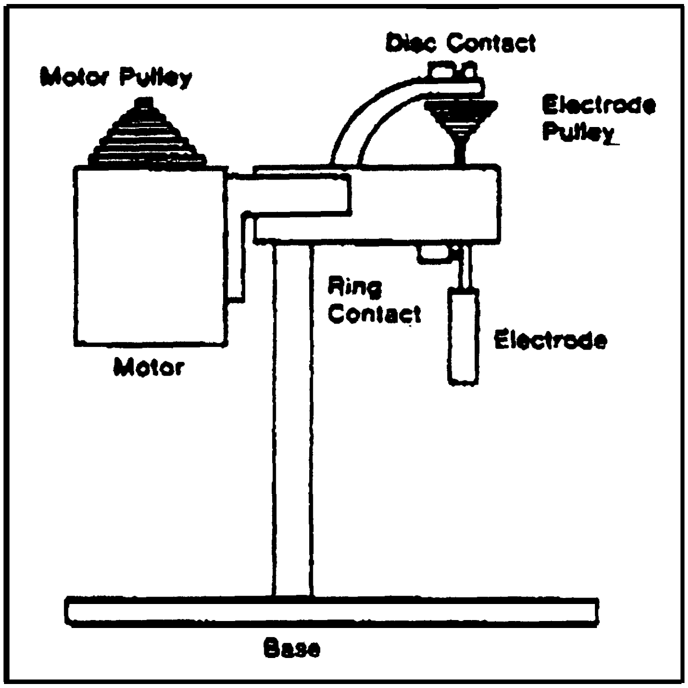
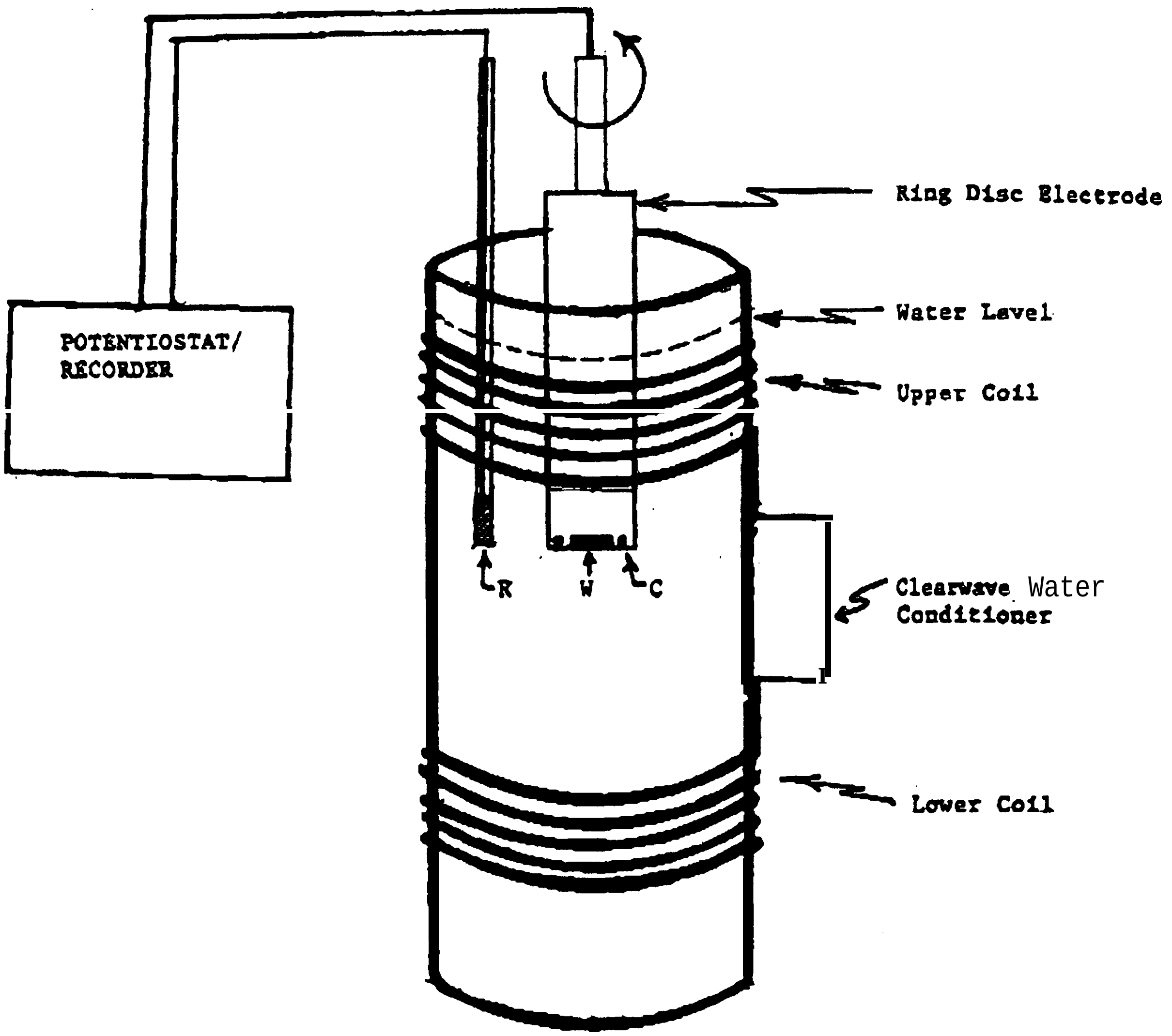


Figure 4: Rotator- Electrode System



R = Reference Electrode (Ag/AgCl)
W = Working Electrode
C = Counter Electrode

Figure 5: Experimental Setup for the Calcium Carbonate Deposition

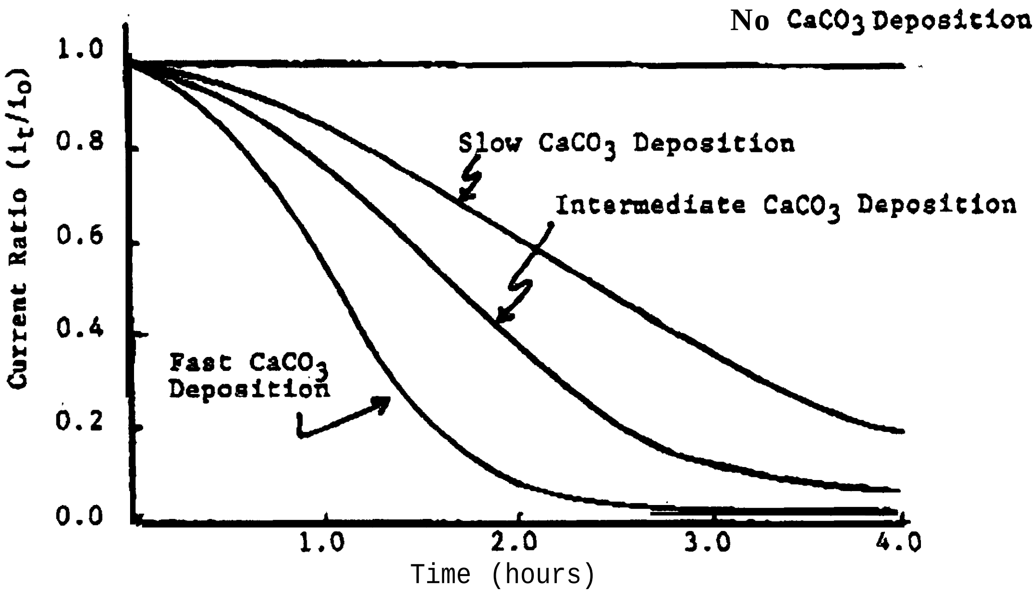


Figure 6: CCDT Response For Different **Rates** of $CaCO_3$ Deposition

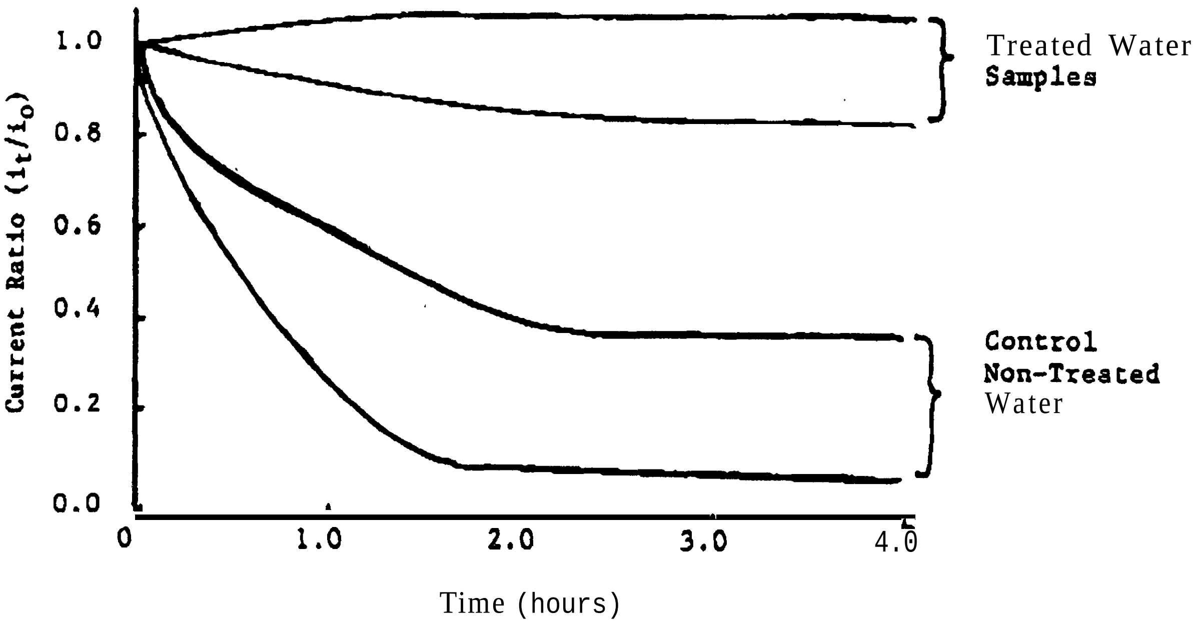


Figure **7:** **The** Effect of **Clearwave** Treatment on CCDT Response

DISCUSSION

Results of the CCDT experiments show a significant difference between treated and nontreated water by the Clearwave Conditioner. The CCDT response for the treated water samples in Figure 7 exhibited typical patterns of no or very limited $CaCO_3$ deposition. In contrast, the CCDT response for the control, nontreated water samples in Figure 7 exhibited typical patterns of high or moderate $CaCO_3$ deposition. The only variable in these experiments was the application of the Clearwave treatment.

These results could be interpreted that the Clearwave treatment interfered with $CaCO_3$ deposition *under* test conditions,

At this time, I have no explanation of the underlying mechanism, Attempts to study the mechanism will require in depth investigations.

CONCLUSIONS

Laboratory controlled CCDT experiments revealed that the Clearwave treatment interfered with CaC03 deposition. These results were obtained with Ann Arbor tap water.

Calcium carbonate deposition is a complex phenomenon which is largely dependent on water quality characteristics, e.g.

1. Water hardness
2, pH and alkalinity
3. Presence of Mg^{2+}, silicates, and certain organics

It is important to extend this investigation to other waters with different water quality characteristics,

In addition, it is believed that the full scale experiment, considered for Phase II will provide the decisive evidence of the effectiveness of the Clearwave Water Conditioner,

REFERENCES

1. McClanahan, M.A. and K. H. Mancy, "Effect of pH on Quality of Calcium Carbonate Film Deposited from Moderately Hard and Hard Water," J. American Water Works Association, 49 . 53, January 1974,

2. McClanahan, M.A. and K. H. Mancy, "Comparison of Corrosion Rate Measurements on Fresh vs. Previously Polarized Samples." J. American Water Works Association, 461 - 466, August 1974.

3. McClelland, Nina I and K. H. Mancy, "CCDT Bests Ryzner Index as Pipe $CaCO_3$ Film Predictor." Water & Sewage Works, 77 - 82, June 1979.