002.

Allemann 1983

Request For Proposal

For

Quantitatively Assessing The Effectiveness Of Permanent Magnetic Water Conditioning Devices

PURPOSE:

The objective of this research study is to quantitatively assess the effectiveness of permanent magnetic type water conditioning devices. The test methods selected will demonstrate the accuracy or validity of the published performance claims regarding scale formation, scale removal, and alterations of the physical and chemical properties of water.

APPROACH:

The following approach is to be considered as a suggested procedure for evaluating permanent magnetic water conditioning devices. The Water Quality Association is open to all innovative testing procedure that may be recommended as part of any proposal.

A water supply is to be used that has a positive scale forming tendency as indicated by the Langelier Index (or Ryznar Index) and as demonstrated by actual test.

There are, to the Association's knowledge, four (4) categories of permanent magnetic water conditioning devices currently available for scale control which are described as follows:

The Class I Device. This 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.

<u>The Class II Device.</u> In this case the radial magnetic field is applied transverse to the flow as it passes through an annular ring between the magnet pole pieces.

<u>The Class III Device.</u> This device is based upon the Russian designs most often reported in the literature. Here again the field is radial with the water flow passing through an annular flow tube. In this case, however, the field polarity alternates periodically along the flow axis. This is accomplished by placing a series of alternately poled cylindrical permanent magnets along the axis of the unit. Also, in some cases a moderate swirl about the axis is induced by means of the inlet port geometry.

<u>The Class IV Device.</u> This device is none of the above but more particularly a group of devices that 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.

It is imperative that the testing protocol being considered as part of the study be of such a design as to adequately cover all categories of permanent magnetic water conditioning devices that are presently known.

The arrangement of the apparatus to perform the necessary experiments for this report is to be constructed in a manner as to reduce to minimum any possible interference with the physical or chemical properties of the water supply.

The following test parameters are to be measured and reported on as a minimum requirement for the study; however, additional tests may be suggested by each bidder at the time a proposal is submitted.

1. Hot Water Scale Tendencies and Scale Evaluation
2. Boiling Point Depression
3. Surface Tension
4. Water Conductivity
5. pH Change
6. Ca^{++} Concentration

REPORTS:

Progress reports are to be submitted on a monthly basis with a final report submitted to the Water Quality Association prior to general release.

Proposal Format. Any proposal submitted for consideration must contain at a minimum the following:

1. Discussion of research problems
2. Project plan and schedule
3. A detailed description of the project plan
4. Reporting procedure
5. Project organization, staffing, and management
6. Cost information

The above in no way precludes the submission of additional information, testing procedures, etc., that the bidder deems necessary.

PROJECT PROPOSAL

on

QUANTITATIVE ASSESSMENT OF THE EFFECTIVENESS OF PERMANENT MAGNETIC WATER CONDITIONING DEVICES

Prepared by

JAMES E. ALLEMAN

SCHOOL OF CIVIL ENGINEERING
PURDUE UNIVERSITY
WEST LAFAYETTE, INDIANA 47907

Submitted to

WATER QUALITY ASSOCIATION
Lombard, Illinois 60148

Division of Sponsored Programs

WEST LAFAYETTE, INDIANA 47907
9 June 1983

Project Period 1 July 83 - 1 July 84 Amount Requested $24,083.00

PRINCIPAL INVESTIGATOR:

James E. Alleman (311-52-9112)
Associate Professor
(317-494-7705)
15 April 1983

APPROVED:

John O. Hancock
Dean, Schools of Engineering
(317-494-5142)

APPROVED:

Harold L. Michael
Head, School of Civil Engineering
(317-494-2159)
15 April 1983

I. PROJECT DEFINITION AND GOALS

A. Project Background and Definition

Although a limited amount of scale deposition within aqueous systems can be viewed as a positive deterrent to corrosion, extended scaling activity can lead to significant problems in fluid and heat transfer. Appropriate water treatment mechanisms can be applied to correct and regulate this scaling tendency to desired levels, but the operational complexity and/or sophistication of these systems oftentimes discourages potential users.

Recognizing this commercial demand for a simplified (i.e. at least from the user's perspective) approach to scale control, several manufacturers now offer proprietary water conditioning devices based upon permanent magnetic principles.[1-3] As reported by the Water Quality Association,[4] four (4) generic categories of permanent magnetic water conditioning devices (PMWCD) are currently available. Basic information on these groupings is provided as follows:

Class-I: Longitudinal magnetic field. Field concentrates and becomes transverse near the point of pole piece pipe contact.

Class-II: Radial magnetic field. Field applied transverse to flow.

Class-III: Radial magnetic field. Alternating field polarity along the flow axis.

Class-IV: Magnetic field applied parallel to flow. Internal spiral field element.

These permanent magnetic water conditioning devices have a decided marketing appeal, primarily due to their apparent ease of installation and purported effectiveness with minimal care. However, performance claims published for these PMWCD units have not been quantitatively validated under controlled testing conditions. This proposal, therefore, addresses a standardized evaluation process whereby the performance capabilities of representative permanent magnetic water conditioning devices will be documented and qualified in a defined laboratory regime.

B. Designated Project Goals

These subject PMWCD units will be selectively chosen from the existing proprietary options to represent the major generic categories for such conditioners. Each device will be quantitatively evaluated under controlled environmental conditions according to the following factors: 1) scale production, 2) scale removal, and 3) physical/chemical modifications in discharged water quality. Characterization of positive and negative scaling behavior will be identified and analyzed using a downstream water heater and suspended test coupons. Overall, the obtained results will provide a technically valid, reproducible documentation of the scale control capabilities maintained by the tested permanent magnetic water conditioning devices. These identified results will then be detailed in a final project report, with subsequent journal(s) publication as is authorized by the Water Quality Association.

II. GENERAL PROJECT PLAN AND SCHEDULE

A. Testing Protocol

1. Literature Review: In conjunction with the initiation of this study, a thorough review of the pertinent engineering literature will be conducted.

2. Market Assessment and Contact: To initiate this study, the Research Team will canvass the associated market to establish the existing proprietary options for permanent magnetic water conditioning devices. All identified manufacturers will subsequently be contacted for further details covering their unit's mode of operation, recommended applications, expected performance levels and basic cost. This information will then be organized according to the four expected generic categories discussed in the previous section, with additional groups developed as is warranted.

3. Device Procurement: Having prepared a listing of the currently marketed PMWCD units, the Research Team will select two, and possibly three, representative units from each of the generic categories for subsequent laboratory testing. Procurement of these specified devices will then be accomplished. It is anticipated that a total of eight or nine units will be purchased at this time, covering the gamut of 'internally' and 'externally' mounted devices.

4. Manufacturer Interaction: In conjunction with the purchase of these units, and prior to their

laboratory evaluation, the Research Team will again contact each selected manufacturer to advise them that their particular device has been chosen for further standardized testing. Identification of the additional units to be tested will, however, not be disclosed.

At this time, these manufacturers may also be advised of the anticipated testing protocol. In turn, they will be encouraged to provide comments and/or assistance germane to the development of the standardized testing format. After initiating such testing, though, future contact with each manufacturer will be limited to questions which may arise from the application of the testing protocol to its product(s).

5. Test Stand Development: Given the critical necessity for standardized testing of the subject PMWCD devices, the test stand apparatus must also be clearly defined and utilized. Several test stand options have been considered, including: continuous-flow and semi-batch mechanisms. Complete automation of either testing procedure will attractively be employed to ensure thoroughly reproducible performance. Each option will include three basic segments: a) the raw water source and feed pump, b) the coupled test device, and c) a closed water heater vessel and parallel flow bypass. Small-sized domestic-type water heaters (approximate volume ~ 6 to 8 gallons) will be employed as the test vessels. Use of these heaters will provide a pragmatic verification of resultant scaling tendency. Complementary test coupons will be suspended within these vessels for in-depth monitoring, documentation and analyses of such scale.

6. Standardization of Influent Raw Water: PMWCD devices will be tested using an available ground water source. Purdue's School of Civil Engineering has installed a dedicated well-system solely for the purpose of obtaining a virgin well water. The availability of this water thereby negates prospective problems with polyphosphate dosing of the municipal source.

Bi-weekly monitoring of constitutive chemical parameters will be conducted to verify quality control. Total hardness of the ground water is approximately 350 mg/L as $CaCO_3$ (310 mg/L as calcium and 40 mg/L as magnesium). The available scaling tendency (as measured by a high Langelier

Index) of this water is, therefore, ideally suited to the needs of this study. Scaling character will also be verified through implementation of control test runs in parallel with the subject devices.

7. Standardization of the Applied Testing Routine: In conjunction with the routine evaluation of the raw water character and standardization of the test stand apparatus, the evaluation protocol must also be clearly established and practiced. During any given test, routine water quality testing will be conducted at three points within the test stand: a) the raw water intake, b) conditioned treated product effluent, and c) water heater overflow or discharge effluent. Characterization and analysis of scale deposition will also be routinely conducted using a combination of chemical-testing, photographic documentation and scanning electron microscopy. Actual device testing will be conducted in three stages. During the first stage, each device will be evaluated using an ambient temperature raw water supply. The next set of tests will involve a change in the throughput flow rate applied to each of the devices. This modification will assess possible changes in device performance with respect to pipe flow. The final set of tests will be used to establish and demonstrate the performance reproducibility of the test stand using selected conditioning devices. Inconclusive test runs obtained in either of the previous testing series, will also be repeated at this time. Conditioning units which exhibited positive retardation of scale production in the previous series of experiments will also receive additional evaluation at this time, only in this case their respective boiling vessels and submersed test coupons will be precoated with scale. Hence, these latter test runs will document the effect of scale removal for units capable of such performance.

B. Testing Schedule

Figure 1 provides a chronological synopsis of the anticipated schedule for this project.

III. SPECIFIC TESTING PLAN

A. Test Stand Set-up

Task	1	2	3	4	5	6	7	8	9	10	11	12
	Project Month (1 Year Total)											
Literature Review	X	X	X	X								
Market Assessment and Contact	X	X	X									
Device Procurement		X	X									
Manufacturer Interaction	X	X	X									
Test Stand Development		X	X	X								
Raw Water Analyses	X	X	X	X	X	X	X	X	X	X	X	X
Test Stand Standardization		X	X	X								
Testing Series 1			X	X	X							
Testing Series 2						X	X	X				
Testing Series 3									X	X	X	
Monthly Report	X	X	X	X	X	X	X	X	X	X	X	X
Six Month Report						X						
Final Report												X

Figure 1. Chronological Project Schedule

Alternative modes for the test stand mechanism include: continuous-flow and semi-batch operation. As was previously emphasized, the adoption of an appropriate, standardized test stand mechanism is critically important to the validity of these studies. Flow schemes and related equipment components for these options are depicted by Figure 2. Each alternative includes a raw water reservoir, feed pump and coupled permanent magnetic water conditioning device.

In the case of continuous-flow operation, a regulated sidestream flow would be tapped from the main discharge line and used to maintain a fixed liquid volume within the water heater. Separate water heaters will be used to maintain testing uniformity.

Several disadvantages are foreseen, though, for the continuous-flow option. By nature of its operating mode, each test would consume a significant raw water volume. This, in turn, would necessitate excessive laboratory attention required for effluent monitoring. A constant flow through the water heaters would also create problems with temperature control and would not be truly representative of the practical application conditions appropriate for these devices.

The apparatus required for semi-batch processing is essentially the same as the continuous-flow system, with an additional set of inlet and outlet flow control solenoids (see Figure 2b). In this case, though, flow through the conditioning device will be regulated on an intermittent basis. When additional flow to the water heater is required (i.e. either to refill the vessel or as makeup addition), the conditioning device would be activated, with flow via the bypass channel also being initiated. After a fixed time interval, wherein the conditioning performance of the device is allowed to stabilize, the inlet solenoid would divert the flow to the water heater.

Semi-batch processing would essentially follow an established routine of Flow Input->Heat -> Flow Output. Repetitive cycling (e.g. at 2 to 4 hours) through this phased sequence would be expected to simulate a "real world" application at most user households or installations.

Implementation of the semi-batch test stand apparatus may offer several advantages. First, the overall demand for raw water would be considerably reduced from that of the continuous-flow system. This advantage would reduce laboratory handling complications and improve, or at least ease, the effort

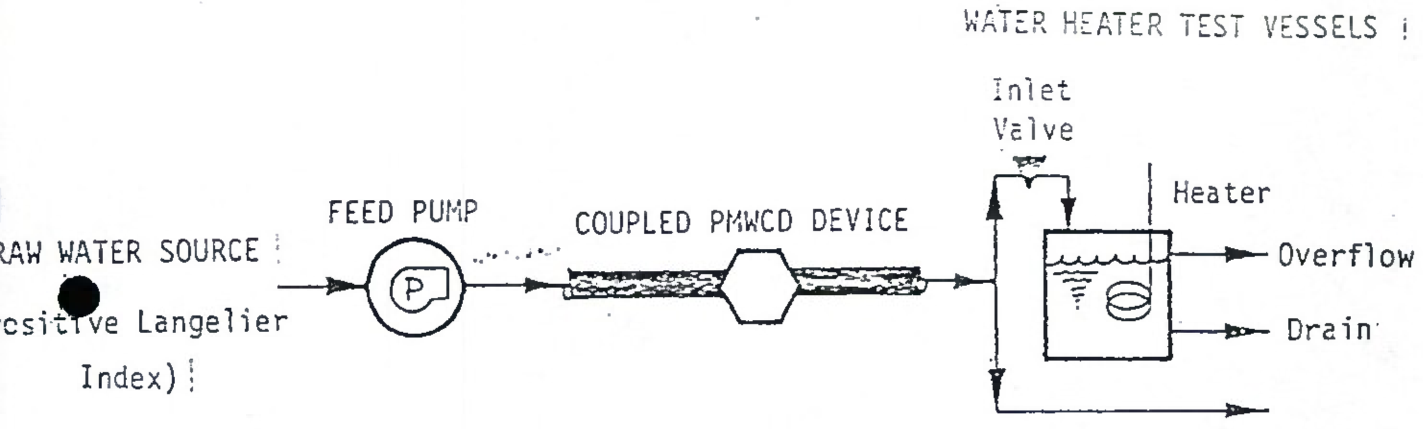


FIGURE 2a. CONTINUOUS-FLOW TEST STAND

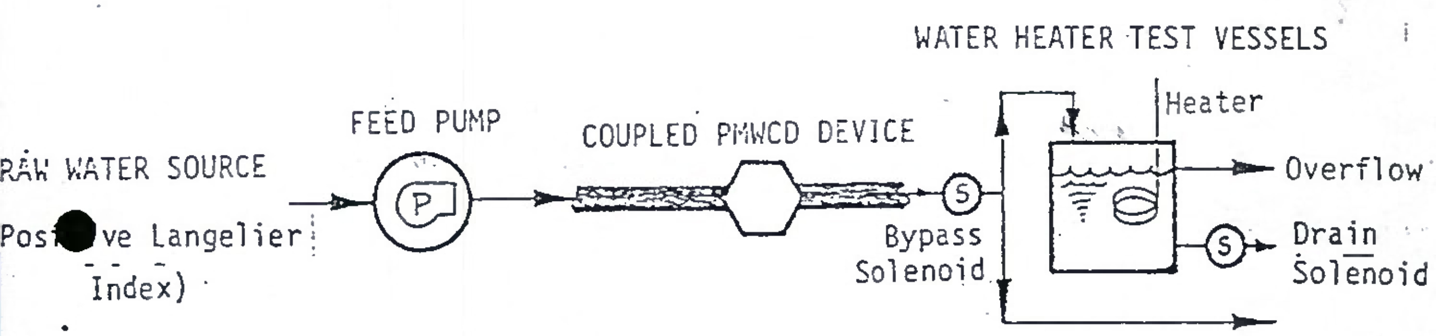


FIGURE 2b. SEMI-BATCH TEST STAND APPARATUS

FIGURE 2. GENERAL TEST STAND MECHANISMS

demanded for quality control. Secondly, the semi-batch procedure is compatible with simultaneous device testing, as demonstrated by Figure 3. In this case, one raw water feed pump could service several test stands using a controlled solenoid array for individualized flow distribution. A control (i.e. receiving 'unconditioned' flow) and numerous devices can therefore be tested in parallel, promoting the desired goal of standardized testing conditions. Non-metallic plumbing (i.e. Tygon tubing) would be used amongst the test stands on the branched feed lines to negate possible transmission of electromagnetic interference. Additional isolation of the parallel test stands would be provided as deemed necessary upon initiating the simultaneous tests. Piping in the vicinity of the devices, though, would be of metal construction to simulate a "real world" application. Finally, intermittent testing of the permanent magnetic conditioning units would likely represent a more appropriate and challenging testing mode, whereby the performance of each PMWCD device is documented under dynamic conditions comparable to their application by a standard user.

Although each of the testing options (continuous-flow and semi-batch) is amenable to automated operation, the latter mechanisms would particularly favor the use of advanced process controllers. Microprocessor-based automation of the batch test stand apparatus would accordingly be employed for these studies, as shown by Figure 3. Equipment available within the Purdue Environmental Engineering Laboratory (i.e. a Westinghouse Numa-Logic controller and associated CPU, I/O and CRT loader) ideally matches this requirement and would significantly promote the standardized operation of the employed test stands. This latter control feature represents a particularly attractive contribution to the overall testing protocol.

B. Raw Water Source

The available ground water source at Purdue offers a simplistic solution to obtaining a desired 'hard, scaling' water. Total hardness, alkalinity, total dissolved solids and pH will be routinely monitored to insure a consistently high Langelier Index.

C. Performance Evaluation Parameters

The following parameters and/or criteria will be used to qualify and quantify the performance of the permanent magnetic water conditioning devices:

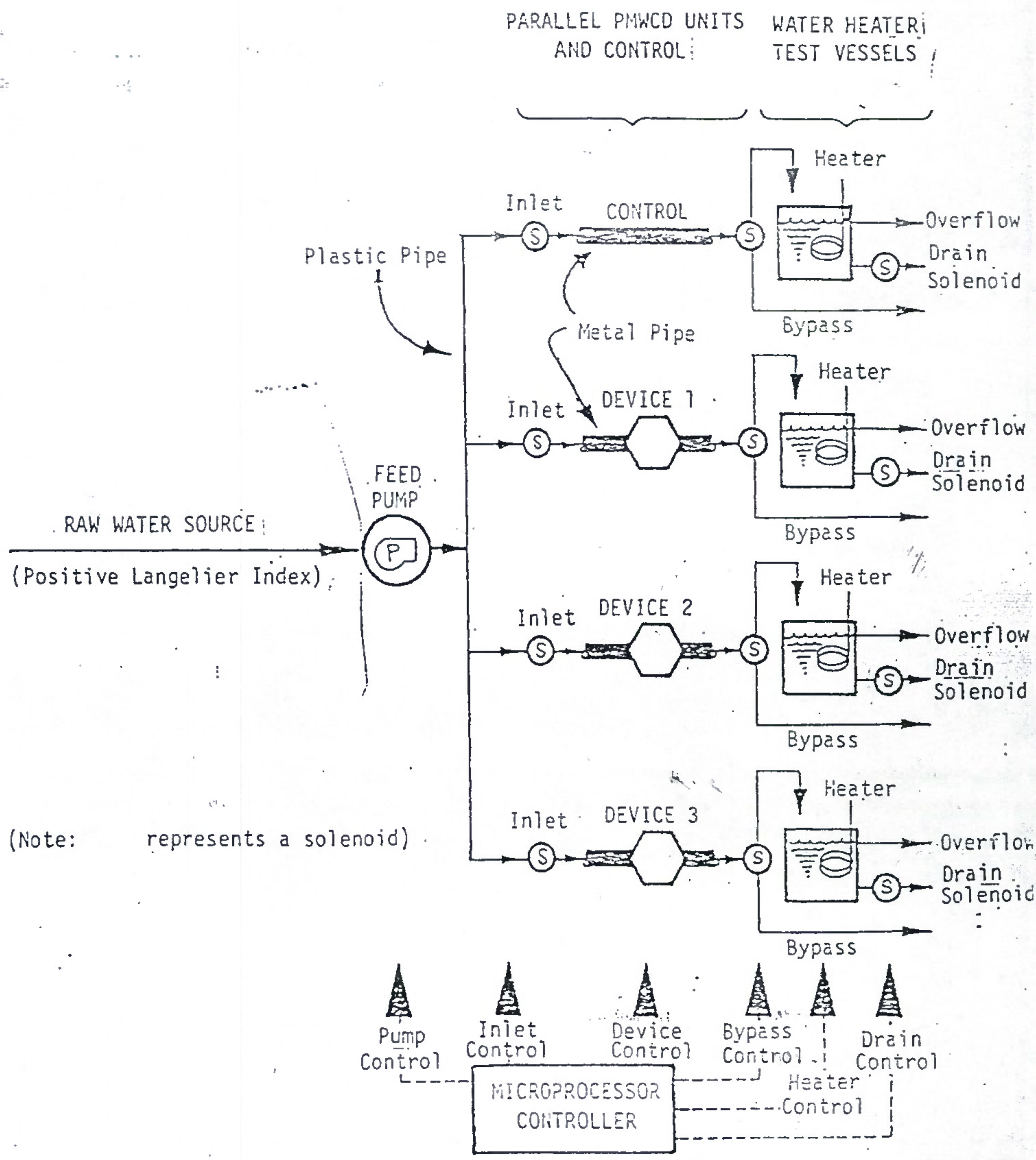


FIGURE 3. PARRALLEL SEMI-BATCH TEST STAND APPARATUS

1. Boiling water scale tendency

2. Scale characterization

3. Surface tension

4. Boiling point depression

5. Specific conductivity

6. pH

7. Alkalinity

8. Calcium

9. Magnesium

10. Total dissolved solids

Criteria 1) and 2) will be applied to the coupons submersed within the boiling vessel. Relative changes in parameters 3) through 10) will be identified using water samples taken from three locations within the test stand setup: a) the raw water feed stock (i.e. influent), b) conditioned discharge/bypass effluent, and c) conditioned water heater vessel effluent.

D. Parameter Analytical Procedures

The majority of analytical procedures employed during this study will conform to standardized techniques established by Standard Methods[5] and the American Society for Testing and Materials (ASTM).[6] Characterization of scale formation will, however, entail an observation/testing series specifically developed for this study.

Further elaboration on the applied analytical procedures for each of these evaluation factors is provided as follows:

1. Hot Water Scaling Tendency

   a. Photographic (color) documentation of consecutive test coupons.

   b. Visual observation recordings.

   c. Gravitimetric scale analysis of scale buildup (quantified using pre-weighed ASTM test coupons).

2. Scale Characterization

a. Surface sampling of scale residue (ASTM).

b. Residue analysis (Standard Methods - Atomic absorption)

- Calcium

- Magnesium

- Iron

c. Scanning electron photo-microscopy (SEM) of coupon scale.[7]

d. Energy dispersive x-ray (SEM-EDAX) analysis of coupon scale.[7]

- Calcium

- Magnesium

- Iron

3. Surface Tension (ASTM)

4. Boiling Point Depression (ASTM)

5. Specific Conductivity (Standard Methods)

6. pH (Standard Methods)

7. Alkalinity (Standard Methods)

8. Calcium (Standard Methods)

9. Magnesium (Standard Methods)

10. Total dissolved solids (Standard Methods)

E. Testing Series: 1 (Ambient Temperature Flow)

The initial series of tests will employ an ambient temperature raw water, with a total hardness of approximately 300 mg/l (as $CaCO_3$). Three chronological testing sets are envisioned during this series, with each set encompassing the parallel evaluation of one (1) control and three (3) PMWCD units. Each of these study sets will be run for a one month period, such that completion of the three testing sets will cover three (3) months (see Figure 1 regarding this testing schedule).

Quantitative monitoring of each device during its respective testing period will comprise a collection of daily, biweekly, and weekly tests. For the first week after initiating each test set, daily water samples will be obtained and analyzed for the specified parameters. Subsequent water analyses will be conducted on a biweekly basis. Visual, tactile and photographic documentation of scaling behavior will be handled on a weekly schedule, or sooner if warranted. At the end of each consecutive week, test coupons will be removed from the water heaters and stored for subsequent scanning electron microscopy study. The final (i.e. after the fourth week) test coupon will be analyzed for specific scale constituents using chemical and energy dispersive x-ray analyses.

F. Testing Series: 2 (Modified Influent Flow)

The second series of applied tests will be devised to critically ascertain the effects of variations in raw water flow rate through the PMWCD units. Flow rate will be changed at the feed pump. This series of tests will essentially follow the preceding format, with each set of three devices and a control being studied in successive one-month periods.

G. Testing Series: 3 (Scale Removal Behavior)

The final testing series will serve three functions: 1) to demonstrate test reproducibility on selected PMWCD units, 2) to repeat inconclusive tests observed in either of the two preceding testing series, and 3) to evaluate the scale removal effects offered by these 'conditioning' devices. Repetition of a limited number of device tests will serve to validate the standardized character of this project. In terms of the scale removal behavior, subject PMWCD units which display significant, positive retardation of scale deposition in either previous testing series will be subjected to further evaluation. Rather than start with a clean boiling vessel and test coupons, though, these latter studies will employ 'pre-scaled' materials. Progressive observation of the maintained scale character and presence will consequently document the potential effect of scale removal offered by these specific units.

IV. REPORTING PROCEDURE

A. Monthly progress reports:

These documents will be submitted to establish compliance with the intended testing schedule and to provide available test results and scale photographs.

B. Six Month Progress Report:

The six month report will provide further details on the progress of the overall study, particularly covering the ambient temperature results. Possible modification of future testing procedures and/or goals will be considered at this point as is warranted by prior results.

C. Final Project Report:

A final report will be submitted upon completion of the twelve month study, covering in detail the performance results observed with the subject devices. This final report will specifically address the research goals identified in Section I-B of this proposal.

D. Subsequent Report Publication(s):

Future publication of the results of this study in a suitable journal(s) will be pursued upon authorization by the Water Quality Association. Such publication will be handled using anonymous references for the subject units.

V. PROJECT ORGANIZATION/MANAGEMENT/STAFFING

A. Organization and Management:

The Research Team for this project will consist of a principal investigator and one assigned graduate research assistant. Responsibilities for this research assistant will cover the daily tasks relevant to the completion of this study as are assigned and overseen by the principal investigator. The principal investigator will handle all data evaluation, scale documentation, report development and specialized scanning electron microscopy analyses (including SEM and EDAX).

B. Staffing

1. Principal Investigator:
   James E. Alleman, Ph.D., P.E.
   Associate Professor
   Environmental Engineering Area
   School of Civil Engineering

Purdue University
West Lafayette, Indiana 47907
(317) 494-7705

2. Graduate Research Assistant:

To be selected form the existing graduate personnel pool.

VI. AVAILABLE LABORATORY SUPPORT

As a component area within the School of Civil Engineering, the Environmental Engineering Area maintains a state-of-the-art laboratory in water/wastewater systems covering over 15,000 square feet. A representative sampling of the available research-grade equipment includes: advanced atomic absorption spectrophotometer, gas chromatographs, total carbon analyzers, and microprocessor-based systems controllers. Scanning electron microscope facilities are provided both within the school, and in somewhat greater sophistication, at the adjacent Chemical Engineering Building. Dedicated CE computer facilities and terminals are extensively available within the School, as are support shops providing complete technical services for construction, wiring, and general production of laboratory reactors, etc.

VII. REFERENCES

1. Eliassen,R. and Uhlig,H.H.,"So-called Electrical and Catalytic Treatment of Water for Boilers." Jour. Amer. Water Works Assn.,576,July(1952).

2. Eliassen, R. and Skrinde, R.T.,"Experimental Evaluation of 'Water Conditioner' Performance."Jour. Amer. Water Works Assn., 1179, Sept(1957).

3. Welder, B.Q. and Partridge, E.P.,"Practical Performance of Water- Conditioning Gadgets."Industrial and Engineering Chemistry, 46,954(1954).

4. Cole, L., Request for Research Proposal: Quantitatively Assessing the Effectiveness of Permanent Magnetic Water Conditioning Devices, Water Quality Association, Lombard, IL; 16 Sept. (1982).

5. Standard Methods for the Examination of Water and Wastewater, 15th Edtn, WPCF, APHA, AWWA, Washington, DC (1981).

6. American Society for Testing and Materials (ASTM), Part 23: Water, Atmospheric Analysis, Philadelphia, PA (1970).

7. Postek, M. T., *et al.*, *Scanning Electron Microscopy*, Ladd Research Industries, Inc., Burlington, VT (1980).

VIII. BUDGET

Budget Submitted to the Water Quality Association

A.	Salaries & Wages	
	1. Senior Personnel*	
	Principal Investigator	3120
	2. Other Personnel	
	Graduate Research Assistant	6600
	Total Salaries & Wages	10320
	Grad Fee Remission	3594
	TOTAL COMPENSATION	13914
B.	Fringe Benefits	
	Total Fringe Benefits	979
C.	TOTAL COMPENSATION AND FRINGES	14893
D.	Non-Personnel Direct Costs	
	Travel - Domestic	200
	Publication & Duplication	250
	Other	1100
	Scientific Equipment**	2500
E.	Total Non-Personnel Direct Costs	4050
F.	TOTAL DIRECT COST	18943
G.	Indirect Cost 0.40 of MTD Cost	5140
H.	TOTAL COST	24083

* The senior personnel budget amount represents a 10% calendar year effort. An additional effort of 5% is envisioned and will be covered by the Principal Investigators current academic support.

** Scientific equipment purchased on this project will consist of the tested permanent magnetic water conditioning devices (8-9 each at $200 per unit) and one (1) Masterflex inlet feed pump.

Exhibit A

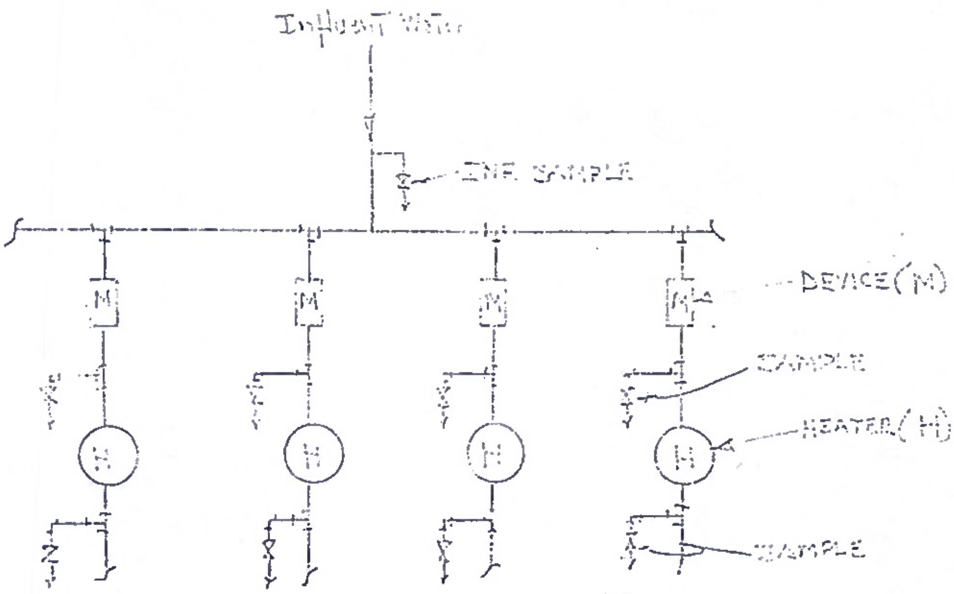


EXHIBIT A
WATER SAMPLE SCHEMATIC

INTERIM PROJECT REPORT

PROJECT: ASSESSMENT OF PERMANENT MAGNETIC WATER CONDITIONERS

TO: LUCIUS COLE, P.E.
Technical Director
Water Quality Association
4151 Naperville Road
Lisle, Illinois 60532

FROM: JAMES E. ALLEMAN
Associate Professor
School of Civil Engineering
Purdue University
West Lafayette, Indiana 47907

DATE: 23 April 1984

PROJECT: Purdue Acct. No. 0651-57-1284
DETAILS Timeframe: 1 July 1983 -> 30 June 1984

TEST STAND IMPLEMENTATION

Figures 1 and 2 provide front and rear views of the test stand developed for this project. This facility includes ten (10) identical 6-gallon electric water heaters, each of which can be connected to the same raw well water stream. Placed in parallel, these water heaters are controlled by the programmable controller shown on the right side of Figure 2. This latter microprocessor regulates two separate control schemes, including: a) line power to the heater coils within each unit, and b) opening and closing of the water solenoids to input and output water through the water heaters.

At present, eight of the water heaters are actually tied into the well water distribution system. The remaining units will be included as they are needed. Of the eight which are hooked up,

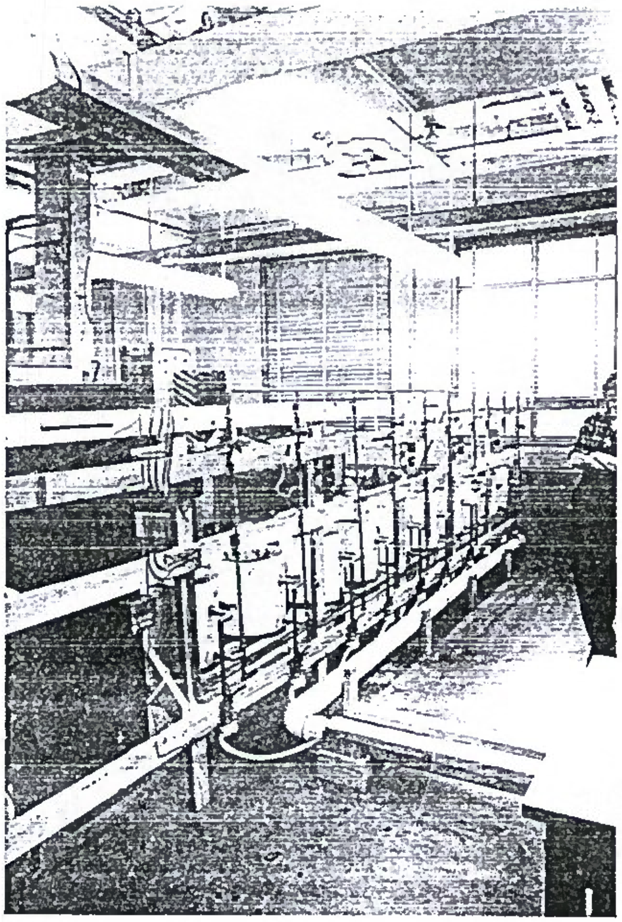


FIGURE $\boxed{1}$

Front View of the Test Stand

FIGURE $\boxed{2}$

Rear View of the Test Stand
NOTE: Computer Control System @ Right

five are equipped with magnetic water conditioners, one is used for a control, one is broken, and one is awaiting the arrival of another test device. The broken water heater has a defective heater block. However, the warranty on these water heaters was invalidated by our modification of these units (i.e. cutting holes in the tops of the tanks) and consequently the repairs will be attempted by our Civil Engineering Electrical Shop.

The control schemes employed with the current set (i.e. six) of on-line water heaters are as follows:

- The outlet valve on each unit is engaged for thirty seconds, during which one-half gallon of water is released. Regulation of this flow is accomplished by prior adjustment of a valve placed on the inlet side of each tank. This discharge corresponds to a 1.0 gpm flow rate which the manufacturers were advised would be employed in our test setup. These discharge times are staggered from one tank to the next, with the cycle being repeated every half hour.

- Two seconds after the discharge is completed for a given tank, the power to the this tank's heater is activated and maintained for five minutes. These power periods are also staggered such that a given water heater is engaged for five minutes and off for the next fifteen minutes. This pattern appears sufficient to maintain the given temperature set-point.

The only problem which has arisen with the test stand has stemmed from difficulties with sealing of the caps over each tank's sampling hole. These aluminum caps utilize a rubber gasket to seat against the tank housing and are secured by six bolts and wing nuts. However, thorough sealing of the tank requires placing an extreme torque on the nuts. In turn, several of the nuts have stripped and/or sheared off. Within the past few weeks, we have experimented with using a silicone caulk to improve our sealing procedure and have generally been pleased with the results.

INVOLVED CONDITIONER UNITS

As previously mentioned, our test stand currently has five permanent magnetic conditioning units installed. Vendor names associated with these five units are as follows:

1. Hako
2. Aqua-Flow
3. Superior
4. Descalamatic
5. Aqua-magnetics (believed to be an affiliate of Bon-Aqua)

The Aqua-Flow and Aqua-Magnetics units comprise exterior mounted magnets. The remaining units are all in-line conditioners, although each offers a different internal flow scheme.

Two additional devices have been ordered but have not been received as yet. These include:

TABLE 1

Water Sampling Results

Date	Sample	pH	Conductivity (mhos)	Calcium (mg CaCO3/L)	Tot.Hardness (mg CaCO3/L)	Alkalinity (mg CaCO3/L)
3-27-84	1in	7.27	779			
	1out	7.47	790			
	2in	7.25	756			
	2out	7.43	802			
	4in	7.32	804			
	4out	7.49	824			
	5in	7.37	806			
	5out	7.68	805			
	6in	7.32	805			
	6out	7.55	820			
	7in	7.47	807			
	7out	7.55	812			
4-3-84	1in	7.40	773	217.6	338.4	318.0
	1out	7.64	779	233.2	361.0	296.8
	2in	7.49	779	237.2	376.0	318.0
	2out	7.59	751	141.1	364.7	296.8
	4in	7.34	785	239.1	398.6	339.2
	4out	7.38	778	239.1	364.7	296.8
	5in	7.36	794	186.2	379.8	318.0
	5out	7.47	789	194.0	368.5	318.0
	6in	7.40	788	234.2	379.8	318.0

	6out	7.57	795	217.6	394.8	275.6
	7in	7.36	799	233.2	330.9	339.2
	7out	7.43	781	229.3	310.2	291.5

4-6-84	2out			182.3	338.4	

(NOTE: These samples were run to follow up on the low control samples observed on the previous sample run)

4-10-84	1in	7.51	745	176.7	376.0	317.8
	1out	7.48	730	168.6	368.5	300.4
	2in	7.62	747	199.9	376.0	313.5
	2out	7.53	736	176.4	364.7	304.8
	4in	7.54	752	188.2	372.2	317.8
	4out	7.50	744	176.4	345.9	309.1
	5in	7.68	754	164.6	376.0	322.2
	5out	7.53	750	180.3	330.9	313.5
	6in	7.59	752	192.1	361.0	317.8
	6out	7.58	749	168.6	297.0	317.8
	7in	7.63	754	192.1	357.7	317.8
	7out	7.53	753	199.9	334.6	313.5

4-17-84 These results are shown by Figures 3 -> 8

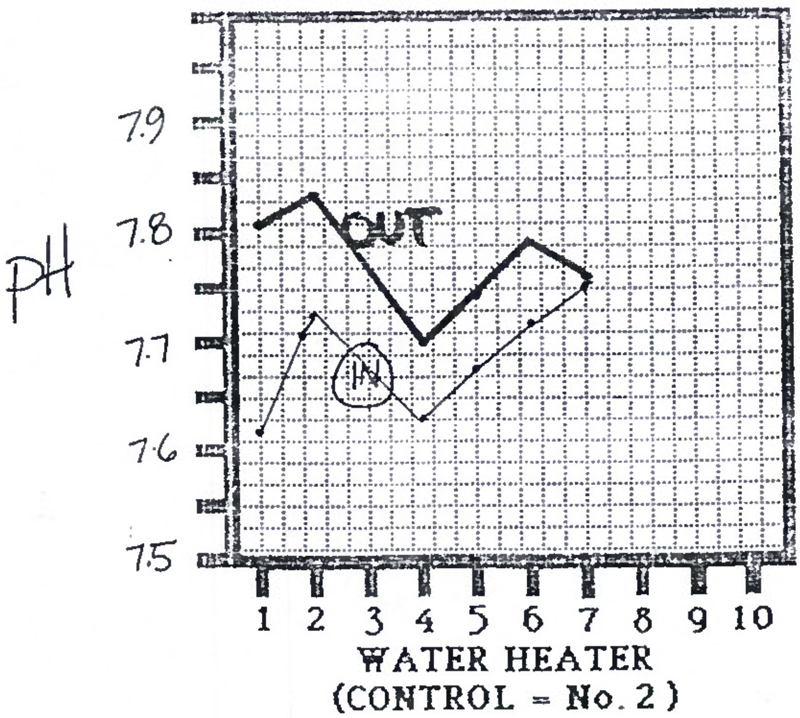


FIGURE 3

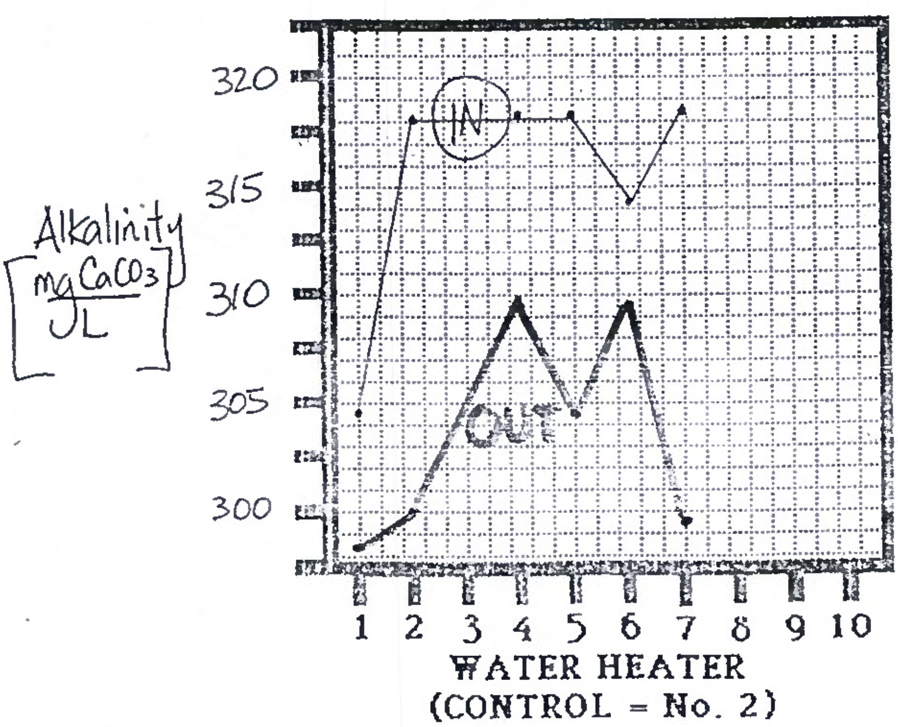


FIGURE 4

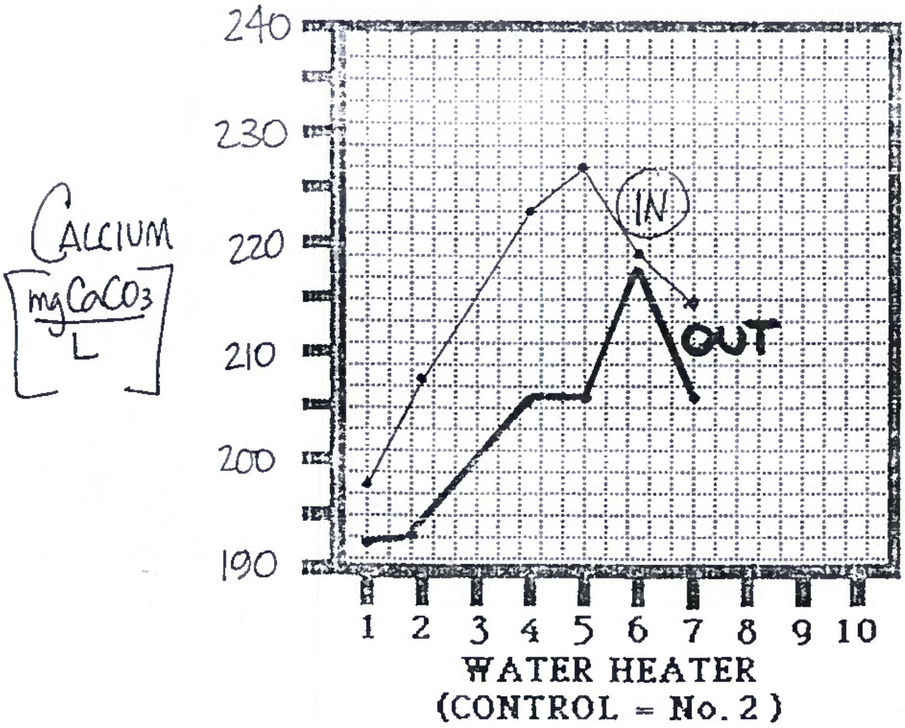


FIGURE 5

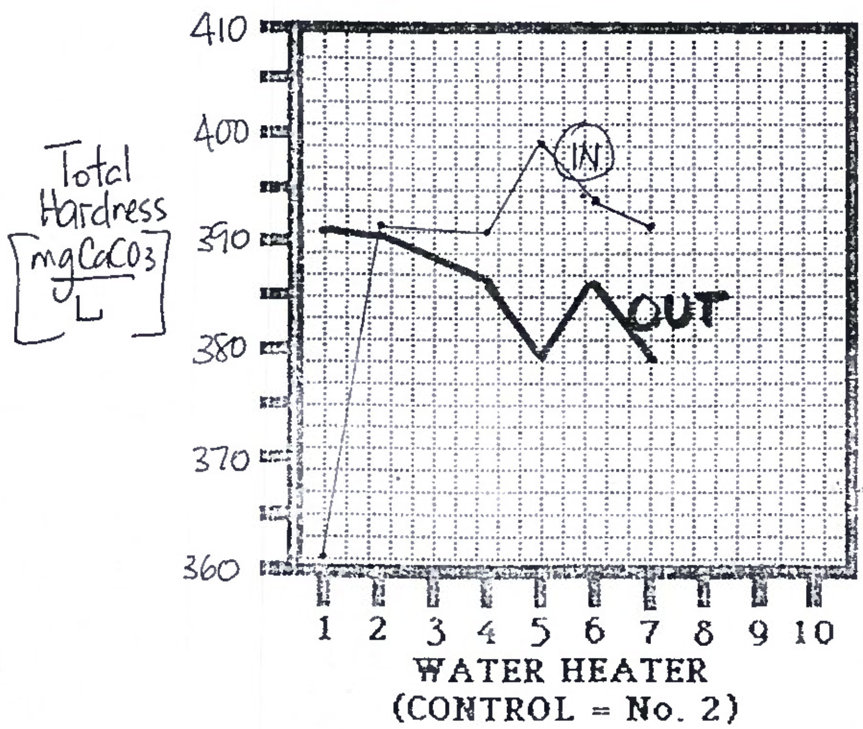


FIGURE 6

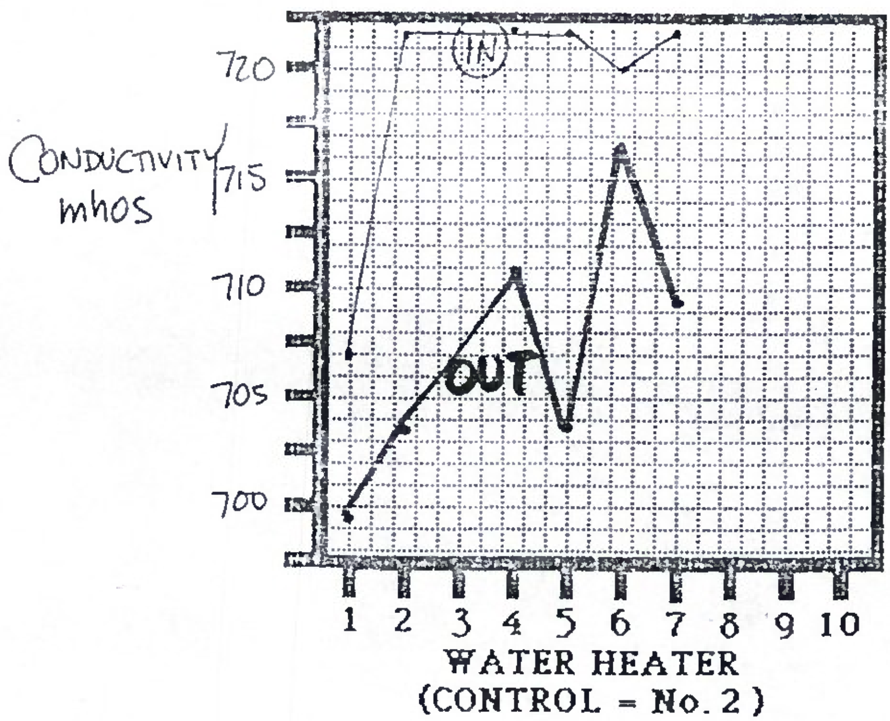
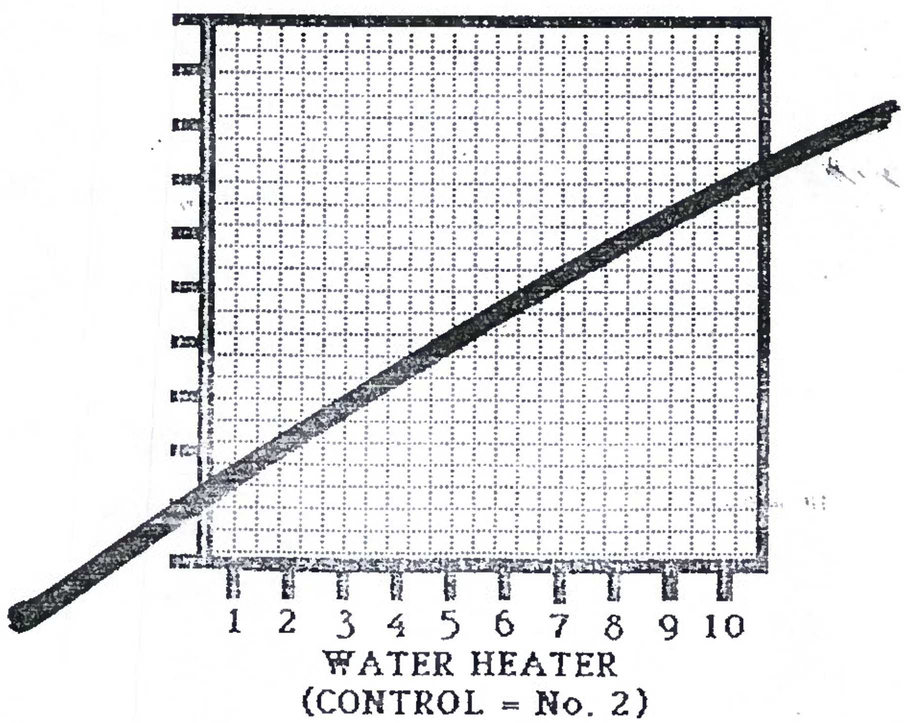

CONDUCTIVITY
mhos
720
715
710
705
700
IN
OUT
1 2 3 4 5 6 7 8 9 10
WATER HEATER
(CONTROL = No. 2)

FIGURE 7


1 2 3 4 5 6 7 8 9 10
WATER HEATER
(CONTROL = No. 2)

1. Fluid Tech

2. Hydrosystems

The Fluid Tech model was ordered several months ago but the manufacturer has since indicated an unwillingness to follow through on the order. In a recent call to the vendor, he stated that he was not going to send the unit "because of manufacturing problems." A number of other vendors have exhibited a reluctance to sell us their models....and in some instances have become rather hostile with respect to our purpose and motivation.

WATER SAMPLING

Water sampling has been completed on both the influent (untreated) stream and the outlet ("conditioned", heated) stream. All such samples are taken on the same day and as close together as possible to insure a representative sampling array.

The results of our water sampling program on all six of the on-line water heaters are given by Table 1. Representative schematics of the most recently obtained data (17 April 84) are given by Figures 3 through 7. These results do not indicate any significant differences between the magnetically treated and the control samples with respect to pH, alkalinity, calcium, total hardness, and conductivity levels.

Surface tension measurements have only recently been instituted and are as yet not available for evaluation. The instrumentation associated with this latter test is rather tedious and user-specific, such that the involved graduate student does not yet feel comfortable with the accuracy of the obtained results. However, even these results appear to parallel the indication that there is not a significant difference between the units and the control heater.

Figures 3 through 7 also indicate quantitative differences between inlet and outlet water through each of the six water heaters. In this regard, the results appear to show the following trends:

1. The pH rises slightly after passage through the tanks. This change is believed to occur in relation to a dissipation of carbon dioxide from the well water.

2. Alkalinity drops after passage through the tanks. This result may again relate to carbon dioxide dissipation.

3. Calcium and total hardness levels tended to decrease during passage through the tanks. This behavior is believed to indicate scaling deposition of hardness within the water heater.

4. Conductivity also dropped after passage through the water heaters. Again, this is believed to represent the loss of ions...possibly in relation to internal scaling.

Overall, there simply was not a lot of difference between the raw water and treated/heated water. Furthermore, the control and treated samples were also quite similar.

METAL COUPON SAMPLING

Before placing the water heaters into operation with their respective conditioning device, each was packed with four metal coupon "trees" These "trees" were fabricated from PVC pipe which had been weighted and slotted to carry twelve metal coupons in a vertical alignment within the heater. Figures 8 and 9 depict top and bottom views of one such "tree" after its removal from one of the water heaters. The twelve coupons included three specimens each of four separate metals (i.e. mild steel, stainless steel, brass, and copper). With four such "trees" placed in each heater, there are a total of 48 metal coupons to be sampled over the following months of evaluation.

Each of these metal coupons was previously weighed and cleaned according to the applicable ASTM specifications. Each coupon was also stamped with an identifying number in order to track its subsequent analysis and positioning.

To date, more than twenty of these metal coupons have been removed from the water heaters. The original plan for analyzing these specimens included weighing each to grossly assess scale deposition. However, it soon became evident that each such coupon carries an iron film in conjunction with the iron content (i.e. 1.5 to 2.0 mg/L) of our well water such that a simple weight change would not provide much information. Hence, these coupons

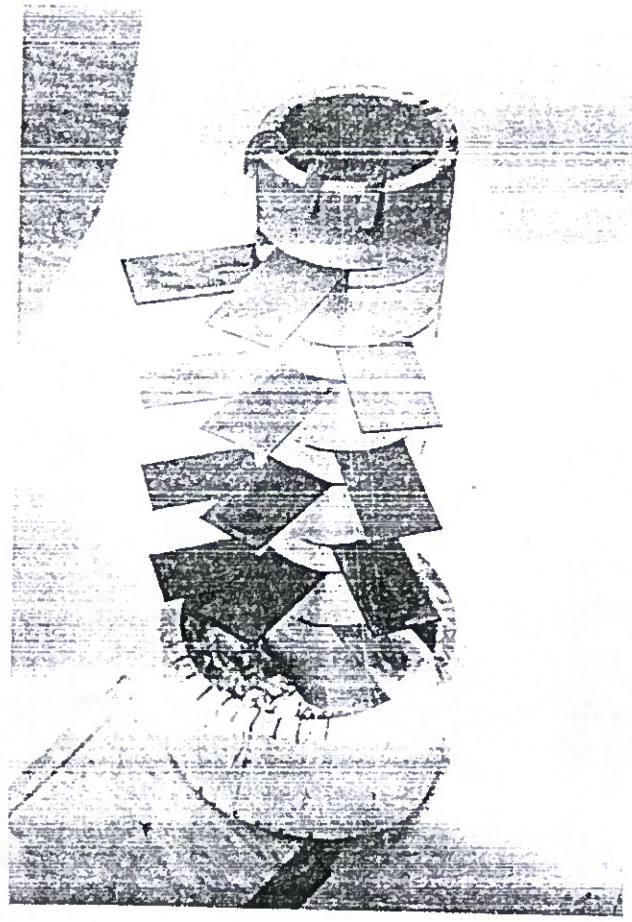


FIGURE 8

Top View of the Metal Coupon Holder

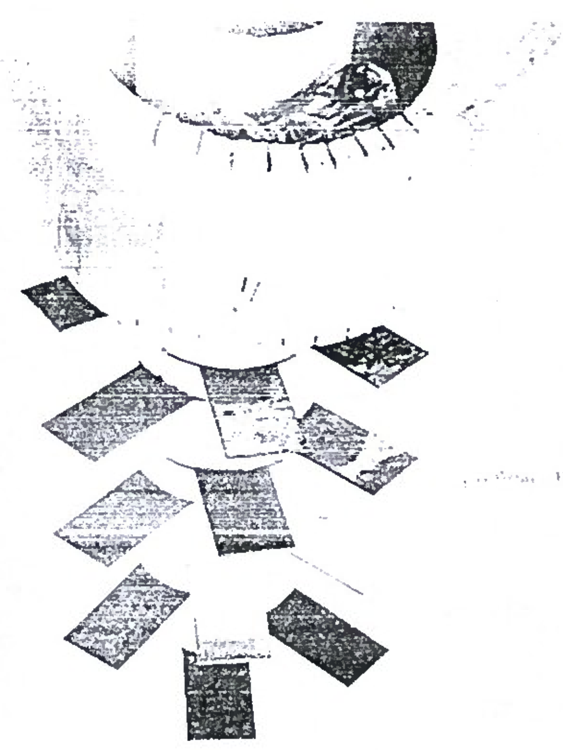


FIGURE 9

Bottom View of the Metal Coupon Holder

Hence, a new procedure for analyzing scale on these coupons is now being developed whereby each will be digested in an acid bath to remove all attached scale followed by a calcium and magnesium analysis on an atomic absorption spectrophotometer. It is believed that this latter techniqued will afford a specific determination of scale buildup on all of the withdrawn coupons. In addition, the involved graduate student has also initiated her familiarity with the use of scanning electron microscopy whereby photomicroscopy may also be initiated on these samples.

As for qualitative results on these metal coupons, there does not appear to be any significant visual difference between any of the removed coupons, including treated and untreated. Inspection of the bottom surface of each coupon may be used as a general indicator of scale development since it is not affected by the deposition of precipitated iron. As such, comparisons between similar metals from each water heater do not exhibit noticeable differences. In fact, it is rather hard to tell the difference between any of the metal specimens after a few weeks, with the exception of the mild steel samples. These coupons have shown considerable decay and exhibit a bubbling phenomenon similar to corrosion.

PROJECT SUMMARY

The project is progressing steadily at this time, although it is approximately three months behind schedule due to unforeseen difficulties in the construction of the test stand. As a result, it is projected that the project will not be completed within the 30

June 1984 timeframe. Every effort will be made, however, to expedite the study.

Although a major problem has been encountered with sealing of the water heater lids, this difficulty has apparently been solved with the use of a silicone caulk. Use of this latter gasketing compound maintains system pressure within the desired range of 15 to 20 psi.

Water sampling has not revealed a significant difference between the treated systems and our control. The only parameter which shows any such trend is pH, where a small increase of 0.1 to 0.2 units frequently develops between the influent and effluent points. This increase, however, appears consistent with an anticipated dissipation of carbon dioxide from the well water.

Sufficient analyses have not yet been completed on the metal coupon samples to establish whether scale formation has been significantly affected by the employed devices. Based solely on visual appearance, though, there does not appear to be much difference from the control system.

BUDGET REVIEW

Construction of the employed test stand required considerably more of an expenditure in time and money than had originally been planned. As a result, the study is now three months behind and more than $1500 below the budget residual projected for this period. Hence, cost cutting measures have been implemented wherever possible. Furthermore, an extension in time will be requested in conjunction with the inherent delay of the project. This request for an extension will be submitted under separate cover.

PURDUE
UNIVERSITY SCHOOL OF CIVIL ENGINEERING

August 6, 1984

Mr. Lucius Cole
Technical Director
Water Quality Association
4151 Naperville Road
Lisle, Illinois 60532

Dear Mr. Cole,

Please find attached the following items:

a) A graph on calcium accumulation for the brass metal coupons placed within our water heaters,
b) Tensiometer results on surface tension,
c) Water quality data for our 13 July '84 sampling.

The graph on calcium depicts the trend we are seeing whereby the surface coating is continuing to build, with the control being not much different from the treated systems. In fact, the control on this particular coupon set actually tends to be on the low side. Incidentally, PMWCD unit number one shows strong evidence of "promoting" scale formation.

The tensiometer results have failed to demonstrate significant variations between any of the units. I will have Joyce complete the test on a sporadic basis to verify this observation.

The provided water quality data follows the same trends we had witnessed on the preceding tests. Calcium and total hardness levels both decrease from influent to effluent sides of the heaters . . . rather telling evidence of scale formation.

Joyce is working on a new computer data management & plotting system with which we can improve our presentation of results. I'll send along these results as soon as they are available.

Best regards,

James E. Alleman /csd

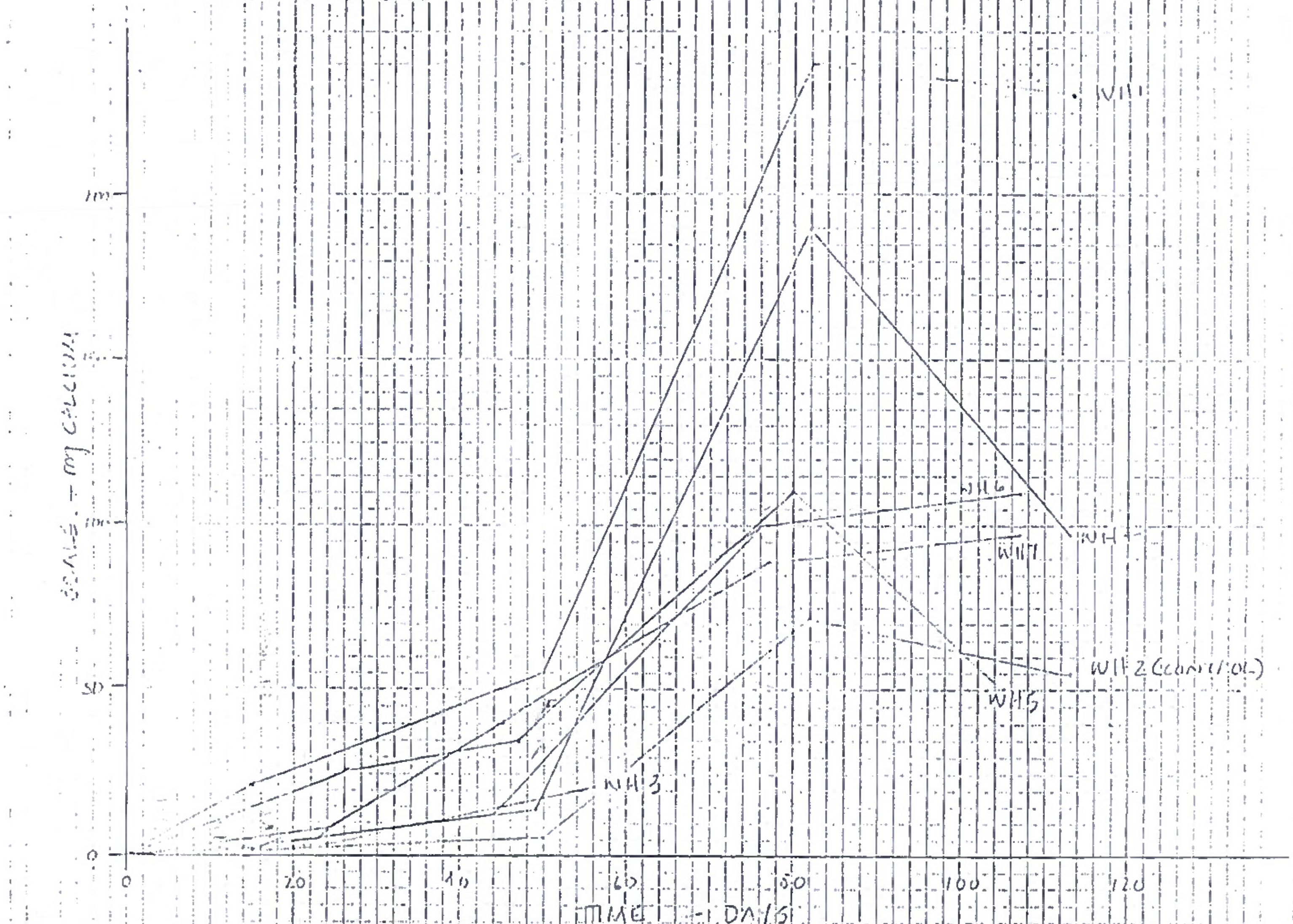
James E. Alleman, Ph.D.
Associate Professor

JEA:csd

enc.

Civil Engineering Building
West Lafayette, Indiana 47907

(PRELIMINARY) CALCIUM SCALE ACCUMULATION
ON BRASS COUPONS IN WATER HEATERS
WITH MAGNETIC WATER TREATMENT



MAGNETIC WATER TREATMENT

TENSIOMETER READINGS JUNE 21, 1984

SAMPLES TAKEN AT INFLUENT TO WATER HEATERS

RESULTS IN DYNES/CM RESULTS ARE RELATIVE, NOT ABSOLUTE

WATER HEATER	1	2	3	4	5	Avg.
WELL	71.7	71.6	71.6	71.7	71.6	71.64
1	71.8	71.8	71.5	71.5	71.6	71.64
2 (CONTROL)	71.7	71.7	71.8	71.7	71.7	71.72
3	71.7	71.8	71.8	71.7	71.7	71.74
4	71.4	71.7	71.5	71.5	71.5	71.52
5	71.8	71.8	71.8	72.0	72.0	71.88
6	71.8	72.0	71.9	71.6	71.7	71.80
7	71.9	71.9	71.9	72.0	71.8	71.90

PURDUE UNIVERSITY SCHOOL OF CIVIL ENGINEERING

MEMORANDUM

TO: Mr. Lucius Cole, P.E.
Technical Director
Water Quality Association
4151 Naperville Road
Lisle, Illinois 60532

FROM: James E. Alleman JEH/csd
Associate Professor
School of Civil Enigneering
Purdue University
West Lafayette, Indiana 47907

DATE: 15 November 1984

RE: Progress Report --
Assessment of Permanent Magnet Water Conditioners.

Since your last visit on 31 August 1984, we have completed our data acquisition and are now finishing up the analysis of the data. Highlights are as follows:

The water heaters were opened in late August to remove the 6-month coupons. Two new sets of the four (i.e. brass, stainless steel, mild steel, and copper), types of coupon were placed in the water heaters at that time to confirm our short-term scaling data. After one week, one of the new coupon sets was removed. The amount of scale was much less than expected. This is most likely because the existing scale on the old coupons and on the water heater walls provided better sites than clean metal for crystallization. In mid October all the old coupons were removed and the water heaters were thoroughly cleaned. Although not quantified, each water heater was similarly coated with scale on the inside surface. A new set of brass coupons was placed in each water heater for a period of ten days. Three of the water heaters (#1, 4 and 5) could not be resealed due to stripped bolts which could not be replaced. The purpose of this test was to confirm the short term scaling rates and to determine if there was any effect due to the water heaters at the same time. Overall the analysis of this data is not complete. It will be included in the final report.

Boiling point tests were performed on the magnetized water. Although the specialized ASTM apparatus was not available, substitute apparatus was used which is basically equivalent to the ASTM procedure. The results are enclosed. A full description of the procedure will be included in the final report.

Civil Engineering Building
West Lafayette, Indiana 47907

MEMORANDUM
15 November 1984
Mr. Lucius Cole

Surface tension measurements were repeated on the magnetized water. The results are enclosed.

Water quality testing was continued. A copy of the October results are enclosed.

The final report will be forwarded when completed. The following format will be used to present the data. Please feel free to comment on the format.

A. Water Quality Monitoring

1. The numerical values of the ran data for each parameter (temperature, pH, conductivity, hardness, calcium, Alkalinity) will be presented on separate charts. Each chart will list the values by test date (elapsed time from initial test) for each of the sample points.

2. The water quality parameters will be graphed for each water heater (influent-effluent) versus elapsed time.

B. Coupon Scaling Data

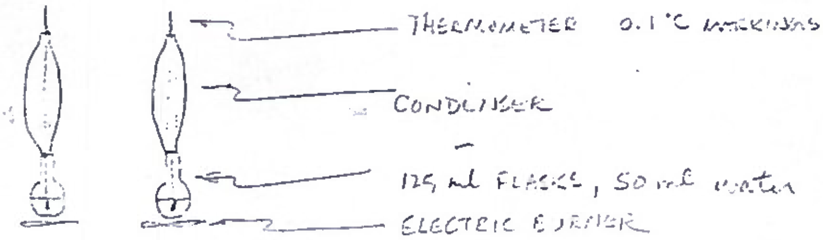
1. For each coupon material (mild steel, stainless steel, copper and brass) the amount of scale, expressed as milligrams of calcium per unit area of scaling surface, will be presented in a chart according to elapsed time in the water heater and water heater number.

2. For each coupon material and each magnetic device, the amount of scale versus elapsed time will be graphed.

JEA:csd

Enclosures

BOILING POINT TEST



EACH SAMPLE OF MAGNETIZED WATER (SAMPLED AT WATER HEATER INLET) WAS TESTED FOR BOILING POINT CONCURRENTLY WITH THE RAW WELL WATER TO CORRECT FOR ANY CHANGING ATMOSPHERIC CONDITIONS. THE SAMPLES WERE REFLUXED FOR TEN MINUTES TO ESTABLISH EQUILIBRIUM CONDITIONS. READINGS WERE TAKEN IN EACH FLASK WITH EACH OF THE TWO THERMOMETERS. THE DATA IS AS FOLLOWS:

WH #	1	2	Avg	Raw	1	2	Avg	WH Avg - Raw Avg
1	99.1	99.0	99.05		98.6	98.8	98.70	0.35
2	99.3	99.3	99.30		99.3	99.1	99.20	0.10
3	99.4	99.4	99.40		99.4	99.4	99.40	0.00
4	99.6	99.3	99.45		99.4	99.4	99.40	0.05
5	99.1	99.0	99.05		99.0	99.1	99.05	0.00
6	99.3	99.2	99.25		99.5	99.2	99.35	-0.10
7	99.3	99.2	99.25		99.2	99.3	99.25	0.00

SURFACE TENSION TEST

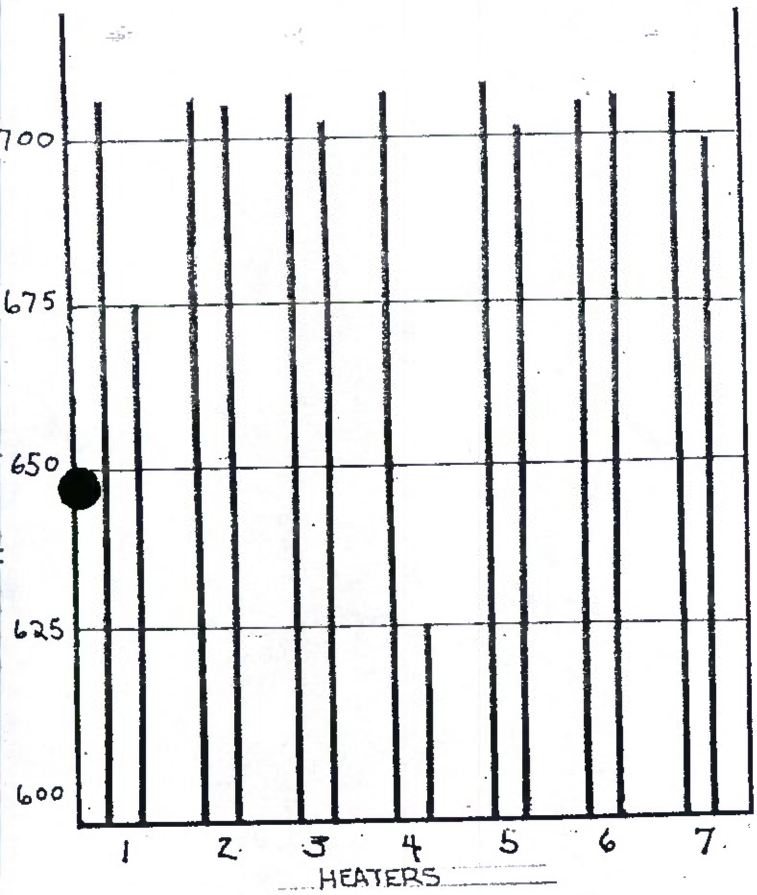
SAMPLE	AVG. READING
DI WATER	71.5
RAW	71.8
WH 1	71.8
CONTROL	72.0
WH 3	72.0
WH 4	71.8
WH 5	71.8
WH 6	71.8
WH 7	72.1

WATER QUALITY ANALYSIS 10-4-34

WATER HEATER	TEMP (C)	PH	CONDUCTIVITY	HARDNESS	CALCIUM	ALKALINITY
RAW	24	7.48	715	335	237	311
CONTROL-IN	32.5	7.56	711	397	8.2 233	315
CONTROL-OUT	53.5	7.39	701	393	8.2 233	311
WH 1 - IN	30	7.54	711	329	8.2 233	311
WH 1 - OUT	57	7.23	675	366	2.5 210	289
WH 3 - IN	26.5	7.50	714	393	11 244	320
WH 3 - OUT	53.5	7.53	708	393	16 240	315
WH 4 - IN	26	7.54	714	393	10 240	320
WH 4 - OUT	61	7.13	625	340	191	251
WH 5 - IN	24.5	7.51	716	397	7.2 229	324
WH 5 - OUT	57	7.37	704	385	7.2 229	311
WH 6 - IN	28	7.47	710	397	8.2 233	315
WH 6 - OUT	52	7.45	714	393	8.2 233	315
WH 7 - IN	25.5	7.50	713	393	16 240	320
WH 7 - OUT	56	7.40	699	382	7.2 229	289

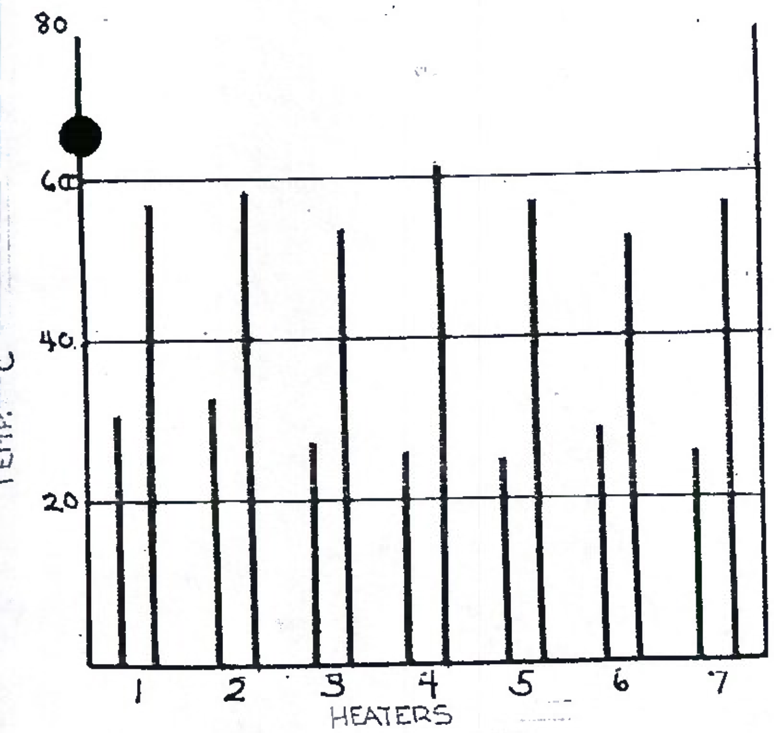
Water Quality Analysis

10-4-84

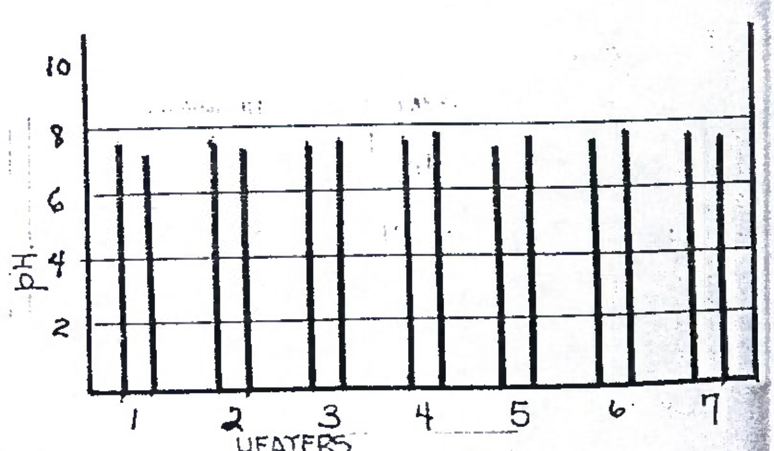


CONDUCTIVITY

HARDNESS



TEMPERATURE (°C)

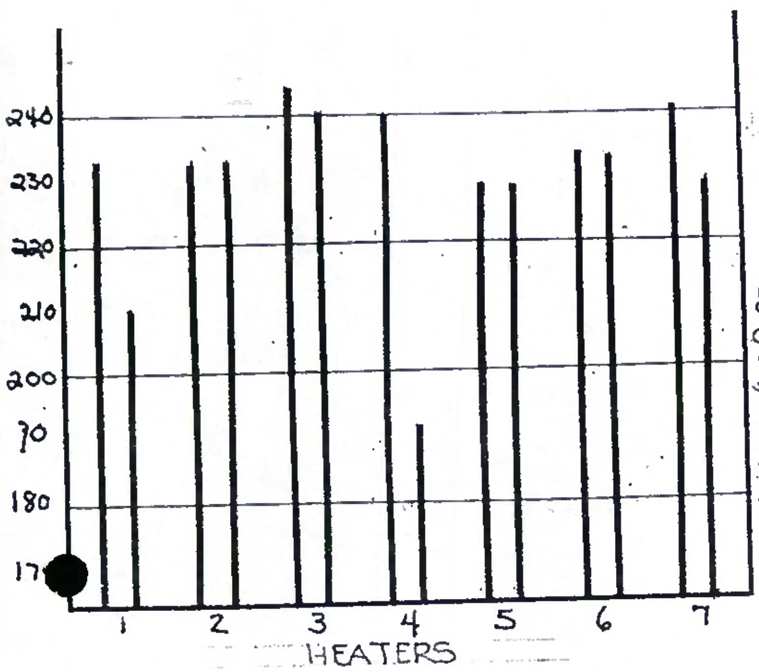


PH

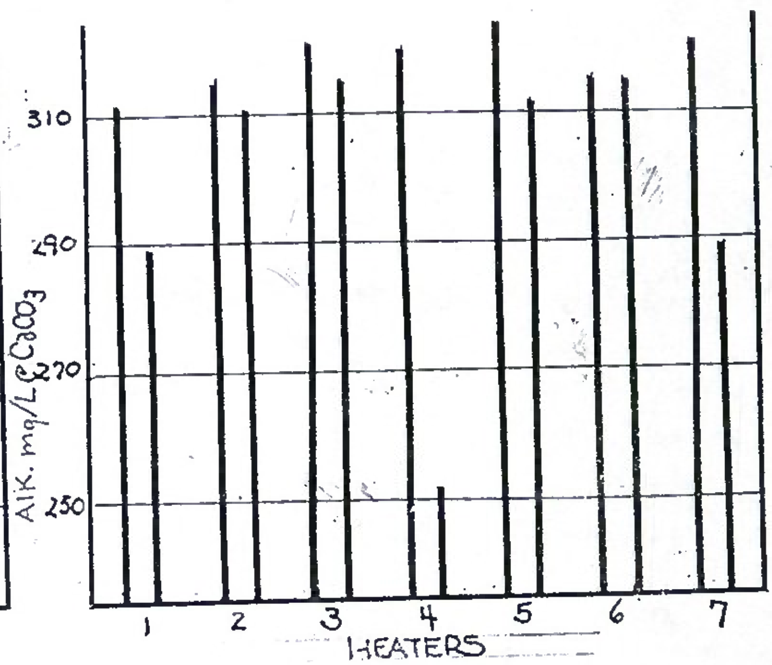
2 - CONTROL UNIT

Water Quality Analysis

10-4-84



CALCIUM



ALKALINITY