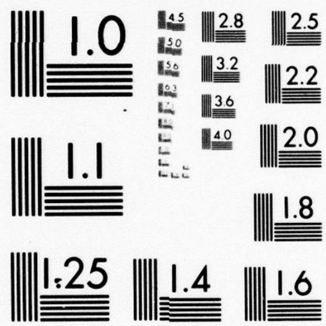
AD-A070 799 ILLINOIS STATE WATER SURVEY URBANA F/G 13/2
INDUSTRIAL WATER TREATMENT TECHNOLOGY TRANSFER, TECHNIQUES AND --ETC(U)
FEB 79 R W LANE, C H NEFF F41689-77-C-0029
UNCLASSIFIED CEEDO-TR-79-01 NL

1 OF 1
AD
A070799

END
DATE
FILMED
8-79
DDC



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF

CEEDO-TR-79-01

ADA070799

INDUSTRIAL WATER TREATMENT TECHNOLOGY TRANSFER TECHNIQUES AND MANAGEMENT

LEVEL II

RUSSELL W. LANE
CHESTER H. NEFF

ILLINOIS STATE WATER SURVEY
P.O. BOX 232
URBANA, ILLINOIS 61801

JUNE 1979

FINAL REPORT

JULY 1976 - NOVEMBER 1978

CEEDO

CIVIL AND ENVIRONMENTAL ENGINEERING DEVELOPMENT OFFICE
(AIR FORCE ENGINEERING AND SERVICES CENTER)
TYNDALL AIR FORCE BASE
FLORIDA 32403

79 07 02 109

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: CEEDO-TR-79-01

2. GOVT ACCESSION NO.:

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): INDUSTRIAL WATER TREATMENT TECHNOLOGY TRANSFER, TECHNIQUES AND MANAGEMENT

5. TYPE OF REPORT & PERIOD COVERED: FINAL REP[redacted]T. JUL[redacted]76 — [redacted] NOVEMBER 1978

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s):
Russell W. Lane
Chester H. Neff

8. CONTRACT OR GRANT NUMBER(s): F41689-77-C-0029

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
ILLINOIS STATE WATER SURVEY
P.O. Box 232
Urbana, Illinois 61801

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
PE: 64708F
JON: 20545013

11. CONTROLLING OFFICE NAME AND ADDRESS:
AFESC/RDCR
TYNDALL AFB FL 32403

12. REPORT DATE: FEB[redacted]79

13. NUMBER OF PAGES: 35

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available in DDC

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

AF Base Civil Engineering
Corrosion Control Economics
Corrosion Prevention
High Temperature Hot Water Systems
Industrial Water Treatment
Potable Water Treatment
Steam Boilers
Water Treatment Program
Water Treatment Techniques

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

To develop technology delivery methods, surveys of the water handling facilities at Chanute AFB and Scott AFB were conducted with the purpose of recognizing water-caused problems and presenting means of reducing these problems, particularly corrosion. Recommendations, purchase and installation of necessary water treating and water testing equipment were provided. Water treating chemicals were also purchased for application to reduce scale and corrosion. Base personnel were then trained in water treatment testing and control with the result that water-caused problems in boilers, → (cont.)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. (cont.) return condensate, cooling towers and potable water systems were significantly reduced at Chanute AFB. At Scott AFB, the equipment was installed and chemicals supplied; however evaluation of the results were incomplete because equipment was installed at such a late date. Consideration was given to the problems involved in setting up effective water treatment programs at other Air Force bases.

Accession For	
NTIS GRA&I	[x]
DDC TAB	[ ]
Unannounced	[ ]
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or special
A	

PREFACE

This report was prepared for the Air Force Civil and Environmental Engineering Development Office (CEEDO) under Job Order Number 20545013. Report summarizes work done between July 1976 and November 1978 by the Illinois State Water Survey under Contract Number F41689-77-C-0029.

The CEEDO Project Officer was Major Roger J. Girard. The AFESC Technical Monitor was Mr. Harold L. Stevens, and the principal investigators for Illinois State Water Survey were Mr. Russell W. Lane and Mr. Chester H. Neff.

Effective 1 March 1979, CEEDO was inactivated and became the Engineering and Services Laboratory (ESL), a Directorate of the Air Force Engineering and Services Center located on Tyndall AFB Florida 32403.

This report has been reviewed by the Information Office (IO) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

ROGER J. GIRARD, Maj, USAF
Project Officer

HAROLD L. STEVENS, GS-13, USAF
Technical Monitor

GEORGE D. BALLENTINE, Lt Col, USAF
Chief, Air Base Survivability and Vulnerability Branch

GUY P. YORK, Lt Col, USAF
Chief, Engineering Research Division

JOSEPH S. PIZZUTO, Col, USAF, BSC
Director, Engineering and Services Laboratory

(The reverse of this page is blank)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

(The reverse of this page is blank)

SECTION I
INTRODUCTION

The Illinois State Water Survey on the campus of the University of Illinois was chosen by the Department of the Air Force to develop techniques to transfer industrial water technology to Air Force bases. This was done to conserve resources now consumed by corrosion, scale formation and other consequences of inadequate water treatment. The State Water Survey was chosen particularly because of its success in improving water treatment, reducing corrosion, and maintaining more efficient operations in 175 Illinois State Institutions since 1949. Since the Air Force facilities were similar to the State institutional facilities and fairly close to the location of the Water Survey, it was considered worthwhile to apply Water Survey techniques towards accomplishing similar improvements at the Air Force bases.

A complete plant survey was first conducted at Chanute AFB, and as the success of this program became evident, it was extended to Scott AFB. On completion of the surveys, including corrosion rate studies, necessary water treatment equipment was purchased with contract funds and was installed by base personnel. Treatment instructions, using specified testing equipment purchased on contract, were provided by the Water Survey. Since that time, weekly reports, monthly samples, and periodic consulting visits have been provided to assure that the prescribed water treatment program continued being maintained and to determine the extent of its effectiveness.

SECTION II
WATER SURVEY RESULTS AND ACCOMPLISHMENTS

The following information is presented based on the results of the surveys and accomplishments at the individual Air Force bases:

1. CHANUTE AIR FORCE BASE

a. Main Power Plant

(1) Serious deficiencies in boiler water treatment and control were disclosed in the initial survey. Since that time definite improvement in operating efficiency has been shown by the observance of cleaner boilers, decreased need for boiler cleaning, more consistent boiler water tests, improved boiler blowdown control, and reduced maintenance of return condensate lines. In addition, there has been freedom from serious boiler outages and the costly repair of water wall headers and tubes which was necessary in 1968.

(a) In confirmation of these observed improvements, boiler personnel report that only wire-brushing of boilers (no chipping of scale) is required and that about 25 percent less time is required in cleaning the boilers.

(b) A study of Chanute heating plant records did not reveal any advantages after the new treatment was initiated apparently because the metering of steam production, flue gas temperature, coal usage, feedwater heater temperature and make-up water usage were generally inaccurate. More attention should be directed to accurate metering, as this is extremely important in monitoring and maintaining daily efficient power plant operation.

(2) In Table 1, it is striking to observe that the condensate corrosion rates have been reduced to 6-20 percent of that previously experienced. This proves the effectiveness of the new treatment systems, chemicals and testing control. Continuous application (as opposed to the previous manual slug treatment of quebracho and phosphate) of organic blend (antifoam), phosphate, sulfite and amines plus accurate blowdown control provides more complete treatment. This treatment inhibits the carry-over of boiler water solids, improves sludge conditioning, and provides for the production of oxygen-free steam for reducing corrosion. In addition, the accurate continuously applied amine treatment neutralizes the carbon dioxide derived from make-up water, which primarily causes return condensate line corrosion.

(a) The organic blend treatment is composed of 85 percent partially desulfonated sodium lignosulfonate, 4 percent polyamide or polyhydric alcohol type antifoam, and sufficient sodium sulfite to provide a homogeneous dry powder. This blend, used for over 25 years, has been found to be a particularly good sludge conditioning agent for boiler water sludges composed mainly of calcium and phosphate. The phosphate prescribed is sodium tripolyphosphate (an inexpensive source of PO_4), which inhibits $CaCO_3$ scale formation in feed lines and reverts to orthophosphate to react with residual calcium in the boiler water. Maintenance of adequate hydroxide ion in the boiler water insures precipitation of magnesium as the hydroxide, a non-adherent sludge. Sodium sulfite is applied to react with residual oxygen not removed in the feedwater heater and insures the production of oxygen-free steam. Frequent testing for sulfite serves as a monitor of the deaeration accomplished by the feedwater heater.

(b) The previous amine treatment included only morpholine, while both cyclohexylamine and morpholine, amines of different volatility, are now continuously applied to provide more uniform pH control throughout the system. The importance and need for repair of many hot water heat exchangers were shown by conducting a survey to determine the sources of raw water contamination. This reduced the corrosion in the return system by decreasing the introduction of oxygen and dissolved solids into the condensate. Also, boiler cleanliness has been improved by decreasing the amount of boiler scale and sludge formed from the hard water entering the boilers. (See Table 2 for typical power plant water analyses.)

(c) A typical plant condensate survey (Table 3) was conducted 31 January 1978 to determine the sources of raw water contamination still occurring after replacement of many heat exchangers. It will be noted that about 30 percent of the samples were still contaminated (>100 μmhos/cm conductivity).

(d) Previously morpholine treatment was controlled by adjusting treatment according to the pH test. Since the raw water contamination influenced this test appreciably, applied amine dosages for neutralization of CO_2 were inexact. Amine treatment should be applied to provide neutralization of the carbonic acid (CO_2) in the condensate return water. The source of carbon dioxide is from bicarbonate and carbonate ions in the feedwater, and from the decomposition of these chemicals in the boiler and release of carbon dioxide into the boiler steam. By determining the total alkalinity (methyl orange) in the feedwater and multiplying this value by 0.8 to obtain the potential carbon dioxide in the steam, the neutralizing amine requirement per 10,000 gallons of feedwater may be calculated as in the following example:

M Alkalinity = 15 mg/l × 0.8 = 12 mg/l CO_2 in the steam

Since 12 divided by 12 converts milligrams per liter to pounds CO_2 per 10,000 gallons feedwater or one pound CO_2 and since 3-3/4 pounds morpholine (40 percent) or 2-1/2 pounds cyclohexylamine (60 percent) is required to neutralize one pound CO_2, this fixes the quantity of amine to be applied per 10,000 gallons of feedwater.

Usually in power plants having an extensive steam distribution system, equal quantities (as 1.8 pounds morpholine (40 percent) and 1.2 pounds cyclohexylamine (60 percent) per 10,000 gallons feedwater) are applied continuously. In plants in which there is little if any raw water contamination from leaking heat exchangers, the amine treatment is based on the gallons of make-up water (of known total alkalinity) introduced daily, however in plants in which raw water contamination is appreciable, the amine dosage will need to be calculated from the gallons of feedwater (make-up + condensate) of determined alkalinity applied daily. The most simple and convenient method of continuous treatment application is to charge the chemical treatment tank daily, to set the chemical pump to empty the tank in 24 hours and to add sufficient amine to neutralize the total gallons of make-up or feedwater to be used that day. This estimate is usually based on the previous day's usage.

By continuous application rather than slug treatment, more uniform neutralization of carbon dioxide throughout the day is attained. While metered proportional feed would provide even more uniform neutralization, the results of condensate corrosion tests in the State institutions has not indicated the need for this more complicated and costly feeding equipment.

(e) In confirmation of the reported improved condensate corrosion tests, the steam fitters report a significant reduction in observed wet steam and a 25 to 30 percent reduction in the necessary repair of condensate line leaks due to corrosion.

b. HTHW (Steam Pressurized System)

(1) When first surveyed in 1976, this system which is operated only during the winter had been experiencing corrosion and corrosion product accumulations because of underground exterior corrosion of return hot water lines. Leaks and outages due to repair were causing high make-up and corrosion product accumulations in the boilers.

(2) In the summer of 1977, this piping was replaced with an overhead system; however it was still necessary to increase boiler blowdown in the winter heating season of 1977-78 to relieve the boiler of corrosion product accumulations from the previous years of operation. Then during practically all of the winter of 1977-78, the boiler blowdown pump, which provides the main source of treatment (pH increase by alkaline chemical addition plus sulfite) to the heating system water, became inoperative. In order to provide adequate treatment to this system, higher than normal alkalinity and sulfite had to be maintained in the boiler to provide the necessary minimum treatment for corrosion control in the hot water\system. This was accomplished by some of the boiler water being circulated through a bypass line to treat the return system water. Results of tests conducted on HTHW and return hot water samples are shown in Table 4.

c. Cooling Tower Systems

(1) During the initial survey in 1976, cooling tower treatment was observed to be generally ineffective, as evidenced by frequent shutdowns for acid cleaning, the lack of proper treatment control and testing, and inadequate treatment systems. Often there was not an adequate supply of treatment chemicals, particularly acid, on hand.

(2) The necessary additional treating equipment, as specified in the contract, included accessories such as blowdown controllers, chemical vats, water meters and treatment means such as slowly soluble polyphosphate in plastic bags for the smaller towers. This equipment, including water treating chemicals, was provided and installed before the 1977 cooling season in all of the 38 water cooled air conditioning systems. While modern automatic treating equipment had been installed in nine towers previously, too much reliance had been placed on this equipment to operate without attention or water testing. As a result, over and under acid feed and inaccurate blowdown occurred even in the towers that were treated, and as a result, corrosion or excessive scaling occurred.

(3) In the summers of 1977 and 1978 after the addition of treating equipment and the new chemicals, proper testing and control procedures were initiated, and as a result a reduction in corrosion and scale to the extent of 30 to 90 percent, as shown in Table 1, was achieved. The water analyses reported in Table 5 show that water treatment was much superior to that shown in analyses listed in 1976 reports.

(4) In confirmation of the above accomplishments, there was only one summer shutdown for acid cleaning, a reduction of 75% over past summers, and it was not necessary to de-scale (acid-clean) the towers during the winter shutdown period as in the past. Condensers were inspected and wire-brushed but not rodded-out as had been required in past years. This made it possible to spend more time on needed preventive maintenance and reduced overtime requirements significantly. During the regular monitoring of the water treatment, personnel were also able to inspect the rest of the air conditioning equipment to insure that malfunctioning did not occur.

(5) Maintenance of sufficient treatment supplies had always been a problem but now has largely been solved, since purchase of a bulk sulfuric acid (580 gallon) storage tank has alleviated the sulfuric acid supply problem by alleviating the need for frequent ordering of acid in small quantities (5 to 6½ gallon carboys). Also, considerable savings in chemicals result, as bulk sulfuric acid can be purchased for approximately one-half the cost of sulfuric acid purchased in carboys. Also, advice has been given on ordering the other needed chemicals in sufficient quantities.

(6) Based on a previous requirement of 3 men for 8-16 hours (or a total of 24-48 man-hours) for mechanical cleaning during winter overhaul, only 2 men for 4 hours (or a total of 8 man-hours) were required during the past winter. This amounted to a labor savings of about 67 to 83 percent. There has unquestionably also been a considerable savings in power costs. Based on the graph shown in Figure 1, a 22 percent increase in power costs results when there is a scale thickness of only 0.025 inch. Chanute AFB has some 1,700 tons of electrically powered air conditioning and, assuming a cost of 3.0 cents per kilowatt-hour, this could amount to an additional annual power cost of $50,000 to $100,000 based on operation of seasonal air conditioning for 24 hours per day for 90 days. In addition, there are over 2,000 tons of steam absorption air conditioning, which would require increased steam consumption and increased coal usage in case of scaled condensers.

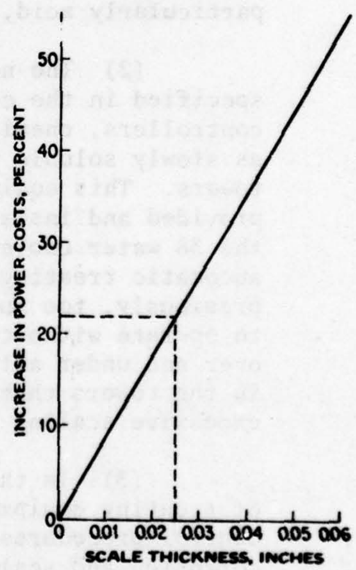


Figure 1. Impact of condenser-tube scale on power costs; fouling will vary, depending on local water conditions.

d. Lithium Bromide Systems in Air Conditioning Absorbers

(1) Corrosion of copper and steel in the lithium bromide systems of air conditioning absorbers has been a serious problem in recent years, because the corrosion products foul the bromide systems causing serious corrosion of internal parts. By maintaining a lithium chromate level in these systems at 1500 to 2500 parts per million and controlling the alkalinity at 500 to 1500 parts per million alkalinity (as $CaCO_3$), the corrosion can be properly controlled, as shown in Table 6.

(2) Advice on treatment application and control was also provided in order to make this important method of corrosion control effective.

e. Potable Water Treatment

(1) Despite lowering the water temperature, reducing the polyphosphate feed, and applying sodium silicate treatment (all measures generally known to reduce the corrosion of copper in hot water systems), erosion-corrosion of copper in the domestic hot water systems of buildings using B-system water has continued to be a problem, as disclosed in potable water corrosion tester results shown in Table 1 and the analyses listed in Tables 7 and 8.

(2) As results reported in Technical Report No. AFWL-TR-73-84 prepared for the Air Force by the State Water Survey indicated an advantage in applying zinc-acid-phosphate type treatment, this treatment has been applied April to October 1978. While the corrosion rate of copper has been reduced in cold water, no particular advantage has been shown over the lower polyphosphate treatment previously tested. Soluble copper results are lower in hot water with zinc-acid-phosphate treatment; however copper corrosion tester results continue to be higher than desired.

(3) Essentially the corrosion of the copper tubing has been caused by the design of the domestic hot water systems causing too high velocities (up to 20 feet per second) in the circulating systems. Chemical treatment cannot be expected to completely correct corrosion caused by an improperly designed circulating system. It is understood that replacement of the copper tubing is planned and that the circulating systems will be designed to provide a proper maximum velocity of 4 feet per second.

2. SCOTT AIR FORCE BASE

a. Main Power Plant

(1) Installation of the continuous chemical feeding equipment to apply organic blend, sulfite, phosphate and cyclohexylamine was completed in July 1978. This equipment should provide improved boiler cleanliness and reduced boiler corrosion, better quality steam, and reduced condensate corrosion.

(2) The treating equipment and chemicals have been in use for too short a period to determine their actual advantages. Tests to date have indicated good treatment and control (see Table 9). Repair of heat exchanger leaks has resulted in improved condensate quality.

(3) The split stream ion exchangers need replacement and recommendations for a dealkalizer (a carboxylic acid-sulfonic acid stratabed unit) have been presented. Any future evidences of poor quality feedwater or boiler water would likely come from these ion exchangers.

(4) Initial corrosion test results shown in Table 10 indicate that excellent corrosion inhibition is being maintained in the return condensate lines, however recommendations have been given to initiate morpholine treatment in a 1:1 ratio with cyclohexylamine to further improve condensate corrosion inhibition.

b. Outlying Boiler Water Treatment

(1) As the method of slug feeding liquid mixtures of quebracho and phosphate was also being used in these boilers as well as the main boilers, and as the method of preparation of the liquid mixtures was time-consuming as well as cumbersome, modern equipment to provide continuous feed of organic blend, phosphate, sulfite and cyclohexylamine was specified for these facilities. This equipment was put into service this fall (1978) when operation of these heating systems was started.

(2) It is also too early to observe advantages in boiler cleanliness and reduced boiler corrosion, better quality steam and reduced condensate corrosion. Need for repair of the return lines and possibly the heat exchangers in the outlying buildings appears necessary to improve condensate and feedwater purity.

c. Cooling Tower Treatment

(1) After completing the plant survey in 1977 and ordering the necessary proportional treatment equipment and chemicals, it was planned to show improved operation of the air conditioning equipment in the summer of 1978. Two complete meter-controlled water treatment assemblies, 14 blowdown conductivity controllers, 15 tank-mixer assemblies, 21 water meters, and 20 blowdown solenoid valves costing over $12,000 were purchased to supplement present treating equipment so that 22 towers would have proportional feed and blowdown control. Chemical treatment and water testing chemicals and equipment costing $4,000 were also supplied.

(2) While all the equipment and chemicals were received in January 1978, the installation of eight new systems with proportioning equipment was not completed until 1 October 1978. As a result, the systems were operated a minimal time before shutdown, and the advantages of proper treatment and control could not be demonstrated. Only the system at Military Airlift Command Headquarters was operated as recommended, and results obtained (see Table 10) were of questionable accuracy. Results at the hospital (Building 1530) showed excessive scaling; however treatment control was poor due to cooling tower basin overflow, irregular treatment caused from inadequate information on make-up water usage, and construction changes in the system. Another four systems which had previously been installed did not have a proper assignment of personnel to add chemicals and to test and control the water treatment. It was reported that the reason for this lapse was that a 60-day period must elapse before an employee could be reclassified as a water treatment operator for controlling the treatment in these cooling towers.

(3) In the meantime some four towers were changed to air cooling due to the problems previously experienced with inadequately treated water cooled equipment. Installation of the water treatment equipment provided and proper control of the water treatment could have probably prevented this expense. In general, the only accomplishment this summer (1978) was installation of the new proportioning equipment. Evaluation of the new water treatment or improvement in water conditions was not accomplished.

(4) The irregularity in natural water constituents [sulfate, chloride, alkalinity, hardness (calcium and magensium)], and dissolved and suspended solids shown in the cooling tower water samples in Table 11 illustrate the lack of proper blowdown control. Such control is essential for effective scale and

corrosion inhibition. Also the irregularity of the treatment levels of inorganic and organic phosphate, most important in controlling scale and corrosion, illustrate the need for the proportional feed equipment and the need for qualified personnel to test and properly control the treatment of the water.

(5) The high hardness and alkalinity of this supply makes this water difficult to treat to control scale formation and to maintain an economical blowdown rate using the presently available scale inhibitors. Acidic type treatments, therefore, would be advantageous; however safety in handling and more effective corrosion inhibitors, which would generally be unacceptable as effluent to the Scott AFB sewage system,would then be required.

d. Corrosion Control of Lithium Bromide in Air Conditioning Systems

(1) Advice on corrosion inhibiting treatment of lithium bromide in the air conditioning absorbers has also been provided for two systems. Results are shown in Table 12.

e. Closed Hot or Chilled Water Systems

(1) To date only the chilled water system in Building 1600 (see Table 13) of all the closed water systems has been treated with nitrite-borax-MBT treatment of the following composition:

Borax ($Na_2B_4O_7 \cdot 5H_2O$)	8 to 12 percent
Sodium Nitrite ($NaNO_2$) noncaking	65 to 70 percent
Sodium Mercaptobenzothiazole, 50 percent aqueous solution (causticized $C_7H_5NS_2$)	4 to 5 percent
Soda Ash, light, (Na_2CO_3) a diluent for preventing caking	15 to 20 percent

This treatment is recommended to be maintained at 600 mg/l Nitrite (as NO_2) and is compatible with ethylene glycol. Initial dosage requirement is 11 pounds per 1,000 gallons of system volume.

(2) The need for treatment of closed systems is recognized as more important than was previously considered. This treatment provides a clean system, free of scale, corrosion products, and suspended matter, which may cause increased maintenance of pumps, control valves, and miscellaneous parts.

f. Cold and Hot Distribution Water

(1) The potable water is generally satisfactorily treated for corrosion control by application of supplemental caustic soda and chlorination at the base. (See the quite satisfactory $CaCO_3$ saturation indices listed in Table 14.)

(2) Scaling of hot water heaters may be expected when the $CaCO_3$ saturation index exceeds about +0.4 at 130°F (54.5°C). This means that the pH should not be maintained above about 7.5 when the hardness exceeds 200 mg/l and that the temperature should not be maintained above 130°F. At this pH level a limited degree of corrosion may occur at cold water temperatures; however more attention must be devoted towards maintaining the pH at this low level in order to control the scale formation in the hot water heaters.

(3) Hot water heaters required to be maintained at 180°F (82°C) for dishwasher or laundry purposes will experience scale in the heat exchangers. Periodic scale removal using inhibited muriatic acid should be scheduled as a necessary scheduled maintenance procedure.

(4) The high hardness and alkalinity of this water supply makes it scale-forming at temperatures of 140°F (60°C) and 180°F (82°C). Partial zeolite softening by blending softened water with 1/3 hard water would serve as a proper method for correcting scaling problems encountered in hot water systems on the base.

SECTION III
CONCLUSIONS

1. WATER TREATMENT ACCOMPLISHMENTS

In providing advice on proper water treatment for Chanute AFB and Scott AFB, it was hoped that exact financial savings could be included in this report; however it was soon noted that the operating and maintenance records were not sufficiently complete or accurate. It should be recognized that there are many intangible advantages, such as the elimination of all boiler and air conditioning shutdowns due to water treatment deficiencies. The elimination of these previously costly events should be recognized as real accomplishments; however the true value probably cannot be properly evaluated financially. The accomplishments at each base are discussed briefly in this Section.

a. At Chanute AFB definite boiler plant operational improvements were demonstrated by the cleaner boilers which undoubtedly reduced fuel costs appreciably. Also, reduced cleaning requirements of 25 percent were reported.

(1) The reduction in condensate line corrosion was most strikingly illustrated by 80 to 94 percent lower corrosion rates (see Section II, paragraph 1a(2) and Table 1). This improvement was largely accomplished by elimination of hard water contaminated condensate from leaking heat exchangers after initiating an improved technique for monitoring condensate and adjusting treatment dosage. Essentially this consisted of the following actions:

(a) Frequently monitoring of total plant condensate purity by electrical conductivity

(b) Conducting outlying plant surveys to locate and repair raw water leaks

(c) Controlling continuous amine treatment according to the known CO_2 introduced by the make-up water as opposed to the previous inaccurate pH method of control.

(2) In the case of cooling water treatment, distinct improvements were made, as the initial survey disclosed inadequate treatment equipment and insufficient attention to application and monitoring. Once the new treatment equipment was properly operating and attention to proper application, testing and control was initiated, results were excellent.

(a) Appreciable electrical and fuel savings [see Section II, paragraph 1c(6)] were undoubtedly accomplished, the life of the equipment appreciably extended [see Section III, paragraph 2h, and Table 1], as well as the more efficient use of manpower for maintenance of the equipment.

(3) In the case of the erosion-corrosion of the copper tubing in the circulating hot water systems, it was concluded that this corrosion problem caused by excessive velocity in the systems could not be solved satisfactorily by chemical treatment but rather by redesign of the systems to provide lower flow rates [see Section II, paragraph 1e, and Table 1].

b. At Scott AFB, although the main boiler plant conditions were quite satisfactory [see Section II, paragraph 2a], it is still expected that the new treatment and equipment will show advantages in scale and corrosion control and decreased fuel consumption. The outlying boiler plants also showed particular need for more modern means of treatment application and control.

(1) The cooling tower treatment facilities in general were very inadequate [see Section II, paragraph 2c], and when the new system chemicals and testing and treatment control are started, definite improvement in scale and corrosion control, increased equipment life, and electrical and fuel savings are expected to be attained as well as the more efficient use of manpower in maintenance.

2. PLANNING A WATER TREATMENT PROGRAM

a. The experiences at Chanute AFB and Scott AFB should serve as good examples of the variation in time required for implementation of a water treatment program at other bases.

(1) At Chanute, a single mission-training base (Air Training Command), the treatment programs were put into effect immediately upon receipt of the new chemicals and treating equipment. Also, base personnel were assigned to positions of definite responsibility to follow the recommendations submitted. As a result, the benefits were derived almost immediately.

(2) At Scott, 6 to 12 months elapsed before the treatment equipment was installed and the assignment of responsible personnel completed. The explanation for this difference may probably be found in Scott AFB being the Military Airlift Command Headquarters base with many and varied responsibilities. Perhaps because of

these varied responsibilities, the water treatment program did not receive as high a priority as it did at Chanute AFB.

(a) The boiler treatment program appears now to be functioning satisfactorily after 6 to 10 months after the receipt of materials.

(b) The air conditioning treatment program cannot be started until April or May 1979 (about 16 months after receipt of materials). It has not been possible, therefore, to evaluate the benefits of the water treatment program in this report.

b. It is expected that the costs of post chemical treatment equipment for boilers at the different bases will vary depending on water quality, boiler sizes (or capacities), and on equipment already on hand. General cost based on a power plant containing several 200 horsepower boilers and above is about $1500.

c. In estimating the cost of water treatment equipment for air conditioning systems of 100 tons and above, water quality, type of air conditioning system, size (capacity), location within the building, and degree of accuracy required in the proportioning system would affect the cost per unit, but a range of $500 to $1500 in cost can be expected.

d. It would be preferred to have sufficient trained Air Force specialists located in various areas of the country to solve water-caused problems and to monitor water treatment programs. Instead, consultants may have to be hired in different areas of the country to obtain this service. In this case, these costs will likely vary; however $200 per day (plus travelling expenses) might be used as an average. The complexity of the base, of course, would affect the length of time required and could vary from 25 to 200 days or more, including initial surveys plus subsequent follow-ups. The training of water treatment personnel would be expected to be provided by the consultant.

e. Guidelines on base manpower requirements may be taken from the cooling tower treatment experience at Chanute AFB in which two men are required to service 47 air conditioning systems. At Scott AFB, it is expected one man will service about 20 towers plus the main power plant in the summer and all boiler plants in the winter. At Chanute, an airman is responsible for conducting all boiler water tests, including outlying boilers and the HTHW system. Boiler operating personnel are responsible for interpreting the tests and applying the treatment.

f. Chemical costs also will vary considerably because of differences in water quality; however guidelines based on Chanute AFB requirements would be about $10,000 per year for both boilers and cooling towers, while Scott AFB requirements would be approximately one-half this amount.

g. Based on Chanute tests, the life of condensate piping is estimated to be extended by 5 to 10 times by application of proper treatment.

h. The life of cooling tower piping and heat exchanger tubing is estimated to be extended by two to four times or more by application of proper treatment.

3. TYPICAL PROBLEMS ENCOUNTERED IN SETTING UP A WATER TREATMENT PROGRAM AT OTHER AIR FORCE BASES

a. Communications lag between Air Force Headquarters, Command Headquarters and base personnel.

b. Relatively low priority of indirect mission support activities.

c. Frequent rotation of personnel responsible for management and operation of heating and cooling systems.

d. Insufficient employee motivation.

e. Insufficient personal contact between knowledgeable specialists and operation personnel.

f. Insufficient recognition of the complexity of water treatment technology and the need for specialized engineering and training on the subject.

g. Specialists are not sufficiently knowledgeable about specific physical facilities and conditions on each Air Force installation.

h. Heating and cooling plant operators lack needed knowledge concerning their equipment.

4. CORROSION COST REDUCTION

a. In Section II it was stated that condensate corrosion rates at Chanute AFB were reduced to 6 to 20 percent of prior rates, and that this resulted in a 25 to 30 percent reduction in necessary repair of condensate line leaks due to corrosion. Both the corrosion rate and repair reductions occurred over a two year period between 1976 and 1978.

b. During 1975 the estimated cost of condensate corrosion at Chanute AFB was determined to be $284,500 as reported in AFCEC TR 77-17, Corrosion Costs of Air Force and Army Facilities and Construction of a Cost Prediction Model, Table 4, page 14. With this cost figure and the above rates a corrosion cost reduction or cost avoidance graph can be prepared as shown in Figure 2. In this case, the following assumptions were made:

(1) A corrosion rate equal to 20 percent of prior rates represented the maximum unavoidable corrosion of condensate lines.

(2) An effective corrosion control program could continue to provide a 25 percent reduction in necessary repairs every two years until the unavoidable corrosion loss level was reached.

(3) Cost of corrosion control and inflation were not considered in order to simplify the graph. Likewise, neither were energy savings nor dollar savings other than maintenance costs considered.

c. The purpose of Figure 2 is to illustrate that you cannot expect to stop all corrosion or to realize all cost savings immediately. The cost avoidances, though, continue as long as the corrosion control program remains in effect. The maximum cost benefits occur about six to seven years after effective water treatment is initiated. Conversely, if adequate treatment ceases, then it would take six to seven years before the full consequences could be realized.

d. Figure 2 and the information provided in the above paragraph are an interpretation of the actual materials savings attained by the improved corrosion inhibiting treatment of the return condensate at Chanute Air Force Base, as determined by Mr. Harold Stevens of the Air Force Engineering and Services Center. This evaluation seems very fair and unbiased as recognition is given that substantial savings will be attained, however these savings cannot be expected to be immediate or complete. It is felt by inclusion of this interpretation in this report that a more complete analysis of the corrosion savings has been provided.

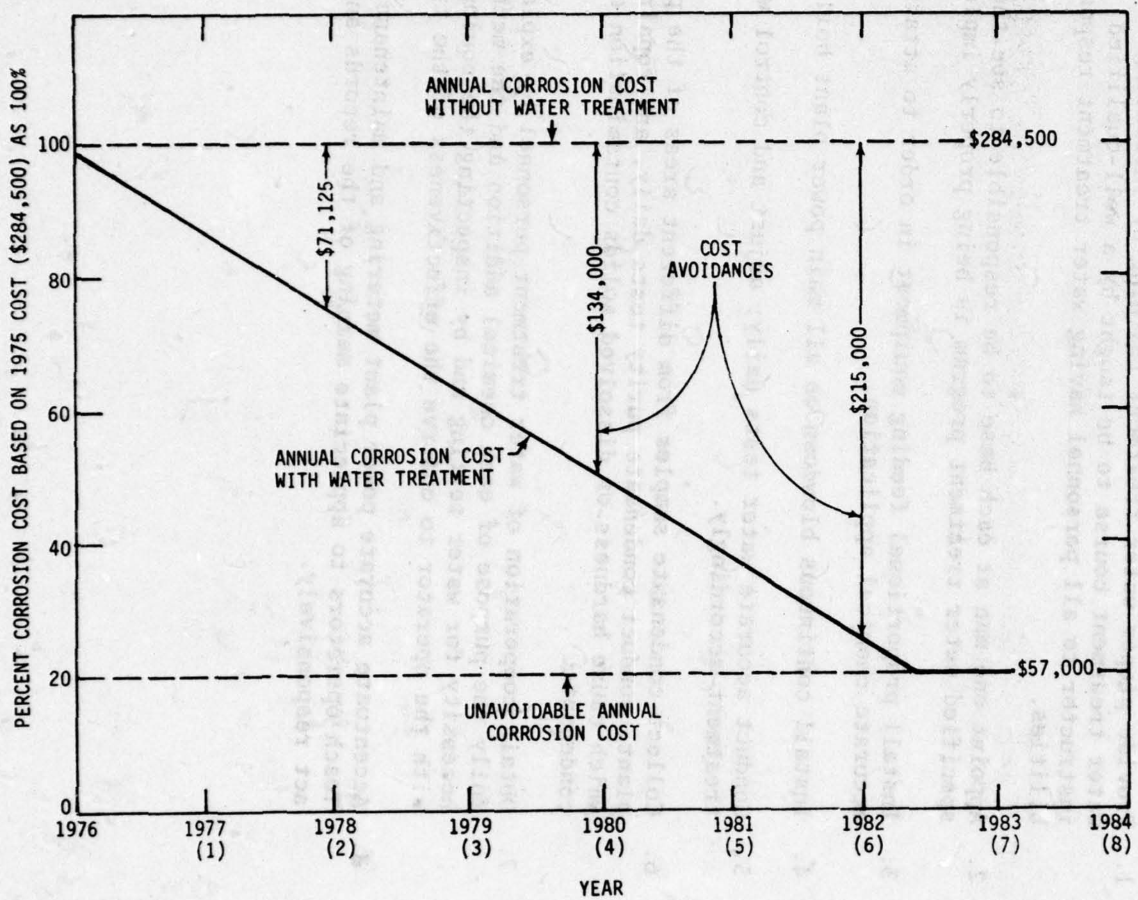


Figure 2. Costs of condensate corrosion at Chanute AFB

SECTION IV
RECOMMENDATIONS

1. Provide proper water treatment training by initiating a brief water treatment course to be taught by a well-qualified instructor to all personnel having water treatment responsibilities.

2. Appoint one man at each base to be responsible to see that the specified water treatment program is being properly implemented.

3. Install proportional feeding equipment in order to attain accurate chemical application.

4. Install continuous blowdown on all main power plant boilers.

5. Conduct accurate water tests daily; adjust and control water treatment accordingly.

6. Collect condensate samples from different areas of the physical plant, conduct condensate purity tests daily, and repair leaks which cause hardness or dissolved solids contamination of the condensate.

7. Obtain cooperation of water treatment personnel by explaining fully the purpose of each chemical addition and the method and necessity for water testing and by inspecting the equipment with the operator to observe the effectiveness of the treatment.

8. Accentuate accurate power plant metering and maintenance. Teach operators to appreciate meaning of the records and to act responsively.

TABLE 1. CORROSION TEST RESULTS AT CHANUTE AFB

1. Return condensate (Test Method - ASTM D2688 Method A)

Location	Dates of exposure	Corrosion rate (mdd)
801	7/15/76-9/24/76	78.8
801	9/25/76-5/10/77*	16.9
801	10/21/77-4/21/78	6.7
801	4/21/78-10/31/78	2.1
344	7/15/76-9/24/76	18.1
344	9/25/76-5/10/77*	15.3
344	10/21/77-4/21/78	specimens lost
344	4/21/78-10/31/78	3.6
H8	7/15/76-9/24/76	45.4
H8	10/21/77-4/21/78*	3.3
H8	4/21/78-10/31/78	4.1

2. Cooling towers (Test Method - ASTM D2688 Method C)

Location	Dates of exposure	Corrosion rate (mdd) Copper	Corrosion rate (mdd) Steel	Treatment
300	7/15/76-9/27/76	3.7	106	Acid + Betz 605
	5/18/77-10/26/77**	0.33	4.7	Acid + S.W.S. Item 43***
300	6/16/78-10/6/78	0.28	1.8	Acid + S.W.S. Item 43
303	7/15/76-9/27/76	1.6	7.4	Acid + Betz 605
	5/18/77-10/26/77**	0.58	3.3	Acid + Betz 605
303	6/16/78-10/6/78	0.68	6.9	Acid + Betz 605 (June-Aug.) Acid + S.W.S. Item 43 (Sept.-Oct.)

* In Nov. 1976, start continuous feed of new treatment composed of organic blend, sulfite, morpholine and cyclohexylamine.

** Proper treatment equipment and chemicals, testing and control were initiated in summer of 1977. A supply of Betz 605 left from 1976 was used up during 1977 and 1978.

*** State Water Survey Item 43 is composed of: Sodium Bichromate ($Na_2Cr_2O_7 \cdot 2H_2O$) 80-83%; Sodium Polyphosphate (as $Na_{12}P_{10}O_{31}$) 10-12%; Zinc Sulfate ($ZnSO_4 \cdot H_2O$) 7-9%.

3. Potable water systems (Test Method - ASTM D2688 Method C)

System	Dates of exposure	Corrosion rate (mdd) Copper	Corrosion rate (mdd) Galv.
Cold	8/1/76-9/27/76	3.6	--
Cold	9/27/76-3/3/77	1.7	6.6
Cold (aver. 61°F)	3/3/77†-7/20/77	1.4	2.5
" " "	7/20/77Δ-11/18/77	2.9	4.1
Cold	4/10/78-11/17/78	0.73	2.4
Hot	8/1/76-9/27/76	16.6	--
"	9/27/76-3/3/77	8.4	2.5
" (aver. 127°F)	3/3/77-7/20/77	4.3	5.6
" (aver. 128°F)	7/20/77-11/18/77∇	4.8	4.4
"	4/10/78-11/17/78°	4.5	5.1

† On 3/30/77 polyphosphate feed was reduced by 1/4 (from 4 mg/l to 3 mg/l) in the B system.

Δ On 7/19/77 a further polyphosphate reduction of 1/4 (to 2-1/4 mg/l PO_4) and the initiation of 4 mg/l SiO_2 in the form of liquid sodium silicate was started. Silicate treatment was increased to 8 mg/l SiO_2 on 8/15/77. On 10/20/77, the polyphosphate was further reduced by 1/2 to provide a 1 mg/l PO_4 dosage effective on this date.

∇ Silicate treatment discontinued 12/15/77, 3 mg/l polyphosphate treatment resumed.

° 1 mg/l Zn^+ (added as $ZnSO_4 \cdot H_2O$) and 1 mg/l PO_4 (added as NaH_2PO_4); adjustments to increase treatment were made 7/7/78.

Conclusions: Reduction in polyphosphate treatment reduced corrosion of copper but silicate addition did not reduce corrosion. Both silicate and zinc-phosphate treatment improved corrosion inhibition in cold water but not in hot water, although soluble copper tests were definitely lower (Table 8).

TABLE 2. ANALYSES OF CHANUTE MAIN BOILER PLANT WATER SAMPLES

Sampling Point	Date	Iron (as Fe)	Silica (as SiO_2)	Suspended Solids	Hardness (as $CaCO_3$)	Sulfite (as SO_3)	Poly Phosphate (as PO_4)	Ortho Phosphate (as PO_4)	Chloride (as Cl)	Nitrate (as NO_3)	Sulfate (as SO_4)	P Alkalinity (as $CaCO_3$)	M Alkalinity (as $CaCO_3$)	Dissolved Solids	pH @ 25°C	Color*	Ammonium (as NH_4)	Morpholine	Cyclo-hexylamine
Boilers: #1	10/15/77	24.8	11	198	0	70	--	363	195	--	157	410	780	2376	--	--	--	--	--
#3	10/15/77	5.8	76	84	0	25	--	119	50	--	43	160	260	878	--	--	--	--	--
#1	11/3/77	12.5	183	166	10	10	--	26	85	--	38	350	480	1094	--	--	--	--	--
Bldg. 589, #2	11/18/77	1.7	20	6	4	84	--	75	14	6	200	360	600	1218	--	298	--	--	--
#4	1/12/78	41.0	156	464	2	11	--	22	90	32	29	530	610	1230	11.55	76	--	--	--
#2	1/12/78	0.9	58	0	2	15	--	88	98	16	3	92	160	636	10.05	6.7	--	--	--
#2	2/24/78	100.0	84	234	4	36	--	152	260	45	59	248	384	1384	11.1	197	--	--	--
#1	3/23/78	10.0	94	178	3	65	--	47	162	47	102	510	610	1416	11.6	197	--	--	--
#2	4/20/78	13.0	166	330	--	48	--	16	190	32	59	1880	2160	2906	12.1	136	--	--	--
#5	5/1/78	110.0	143	1398	--	27	--	28	162	38	56	472	580	1278	11.35	166	--	--	--
#3	5/15/78	7.2	79	220	--	15	--	42	170	37	24	290	360	982	11.35	152	--	--	--
#5	6/2/78	18	45	88	--	16	--	37	14	31	8	190	250	646	--	11	--	--	--
#5	6/14/78	520	221	1324	4	24	--	62	54	39	53	540	670	1262	11.7	152	--	--	--
#5	6/30/78	3.2	77	78	4	21	--	28	65	42	58	380	480	916	--	181	--	--	--
#1	8/30/78	4.0	90	196	--	36	--	31	42	117	66	700	780	1180	11.8	191	--	--	--
#5	9/15/78	6.0	38	222	2	21	--	4	20	30	24	470	710	1038	11.7	92	--	--	--
#2	10/12/78	10.0	52	306	2	27	--	5	30	35	29	580	870	1192	11.8	111	--	--	--
#1	10/24/78	3.6	104	84	2	23	--	27	65	29	21	620	720	1102	11.75	119	--	--	--
#2	10/24/78	5.4	98	222	0	27	--	26	55	29	20	600	690	1040	11.70	115	--	--	--
Make-up:	12/13/77	0.4	15	--	2	--	0.4	1.4	8	--	0	--	14	62	--	--	0.2	--	--
	4/20/78	0.2	10	--	12	--	1.5	0.3	10	--	0	--	16	66	--	--	0.6	--	--
Condensate: P54, #1	10/14/77	2.1	--	--	3	--	--	--	--	--	--	--	8	17	--	--	0.6	2.1	2.0
	1/12/78	1.9	--	--	28	--	--	--	5	--	0	--	79	180	--	--	2.0	3.0	2.5
	1/23/78	0.6	--	--	19	--	--	--	2	--	3	--	62	140	--	--	2.7	--	2.9
	4/18/78	0.5	--	--	5	--	--	--	--	--	--	--	19	42	--	--	2.1	8.0	4.8
	5/1/78	1.4	--	--	13	--	--	--	4	--	0	--	38	102	--	--	5.1	2.3	3.5
	5/15/78	0.5	--	--	31	--	--	--	8	--	0	--	71	193	--	--	1.2	1.9	1.8
	6/2/78	0.5	--	--	11	--	--	--	2	--	0	--	33	77	--	--	1.1	6.2	4.5
	6/14/78	0.2	--	--	6	--	--	--	--	--	--	--	21	44	--	--	1.3	6.7	5.0
	6/30/78	3.6	--	--	17	--	--	--	0	--	0	--	33	90	--	--	0.8	3.6	2.1
	7/25/78	0.2	--	--	48	--	--	--	1	--	0	--	127	280	--	--	2.0	0.0	0.8
P54, #2	10/14/77	1.9	--	--	4	--	--	--	--	--	--	--	8	20	--	--	1.0	2.1	0.4
	1/23/78	0.3	--	--	3	--	--	--	--	--	--	--	9	22	--	--	1.3	--	0.7
	4/18/78	0.4	--	--	4	--	--	--	--	--	--	--	3	27	--	--	2.1	7.7	4.9
	5/15/78	2.7	--	--	9	--	--	--	--	--	--	--	20	57	--	--	1.1	2.7	1.9
	6/14/78	0.2	--	--	7	--	--	--	--	--	--	--	19	44	--	--	1.1	6.2	4.7
	6/30/78	0.6	--	--	8	--	--	--	0	--	0	--	18	50	--	--	1.3	4.8	2.2
P54, #3	10/14/77	0.9	--	--	4	--	--	--	--	--	--	--	8	18	--	--	1.1	2.1	1.2
P54, #4	1/23/78	0.5	--	--	12	--	--	--	3	--	0	--	36	87	--	--	1.9	4.0	2.9
	5/1/78	2.0	--	--	4	--	--	--	--	--	--	--	16	43	--	--	2.7	2.1	3.7
	6/2/78	0.6	--	--	6	--	--	--	--	--	--	--	18	44	--	--	1.2	7.0	2.9
	7/25/78	0.1	--	--	27	--	--	--	0	--	0	--	62	140	--	--	1.5	3.1	1.5

* Lignin color at 470 mμ

TABLE 3. CONDENSATE CONDUCTIVITY TESTS CONDUCTED TO DETERMINE LEAKS IN THE PERMANENT (#1) SECTION OF THE CONDENSATE RETURN SYSTEM AT CHANUTE AFB

Building number and sample location		Conductivity (μmhos)
Powerhouse return		40
851	Main collection tank	120
"	Heating system collection tank	200
"	Downstairs converter	12
"	" "	13
"	Main domestic hot water tank (Right)	450
"	" " " " " (Left)	150
"	Small domestic hot water tank	20
806	Receiving tank	20
805	" "	12
802	" "	10
801	" "	13
P-12	A131 Pump room receiving tank	10
P-2	D121 " " " "	11
"	D101 " " " "	12
"	Pump room #3	24
"	B103 Pump room receiving tank	300
"	B103 Converter	320
P-7	Mechanical room receiver	14
P-1	B108 Pump room receiving tank	12
"	B107 " " " "	13
"	C158 Converter	13
"	C150 Mech. room tank	15
P-3	B section receiving tank	550
"	D section " "	600
P-4	Mechanical room receiving tank	20
"	" " " "	15
23	Pump room receiving tank	12

TABLE 4. ANALYSES OF CHANUTE HIGH TEMPERATURE HOT WATER SAMPLES

Sampling Point	Date	Iron (as Fe)	Sulfate (as SO_4)	Sulfite (as SO_3)	Chloride (as Cl)	P Alkalinity (as $CaCO_3$)	M Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$)	Dissolved Solids	Copper (as Cu)	pH	Silica (as SiO_2)	Suspended Solids	Phosphate (as PO_4)
Boiler	12/13/77	0.2	320	--	3	336	496	1	1034	0.09	11.3 at 25°C	31	--	--
Boiler	1/12/78	0.3	525	265	29	700	1040	2	1790	0.09	11.55 " "	--	--	--
Boiler	1/23/78	0.3	619	245	23	480	770	2	1642	0.10	11.5 " "	--	--	--
Return	1/23/78	0.1	188	82	3	0	216	2	518	0.04	7.4 " "	--	--	--
Boiler	2/24/78	--	--	500	--	810	1600	tr.	--	--	11.1 at 30°C	--	--	--
Return	2/24/78	--	--	105	--	0	315	0.0	--	--	7.4 at 40°C	--	--	--
Boiler	3/23/78	--	--	725	--	900	1850	0.0	--	--	11.1	--	--	--
Return	3/23/78	--	--	100	--	0	232	0.0	--	--	6.9	--	--	--
Boiler	11/22/78	--	--	550	--	560	1050	3	--	--	11.4 at 25°C	--	--	--
Return	11/22/78	--	--	90	--	0	144	2	--	--	7.4 at 27°C	--	--	--
Boiler	12/8/78	--	--	600	--	570	1180	tr.	--	--	11.5 at 21°C	--	--	--
Return	12/8/78	--	--	160	--	0	268	tr.	--	--	7.6 at 25°C	--	--	--

TABLE 5. ANALYSES OF CHANUTE COOLING TOWER WATER SAMPLES

Sampling Point	Date	Iron (as Fe)	Silica (as SiO_2)	Sulfate (as SO_4)	Chromate (as CrO_4)	Chloride (as Cl)	Organic Phosphate (as PO_4)	Poly Phosphate (as PO_4)	Ortho Phosphate (as PO_4)	P Alkalinity (as $CaCO_3$)	M Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$)	Dissolved Solids	Suspended Solids	Calcium (as Ca)	Magnesium (as Mg)	Copper (as Cu)	Zinc (as Zn)	pH at 25°C
Bldg. P-2	9/30/78	0.1	--	1491	28	20	3.5	1.6	6.7	0	44	640	2302	10	144	68	0.04	0.21	7.3
Bldg. P-12	6/30/78	1.6	68	1400	50	18	0	2.7	2.3	0	20	604	2250	22	136	64	0.06	--	6.2
Bldg. P-12	9/6/78	1.9	--	1805	30	38	1.8	2.7	2.4	0	64	650	2856	26	148	68	0.06	0.06	7.3
Bldg. P-12, High Bay	9/8/78	0.5	--	--	--	6	0.2	8.9	1.9	32	392	164	418	0	40	15	--	--	8.7
Bldg. P-12	9/30/78	1.1	--	1977	34	30	4.7	3.7	4.4	0	32	760	2996	14	174	79	0.06	0.76	6.7
Bldg. 68	9/6/78	2.0	--	1779	64	32	3.1	4.2	4.8	0	38	745	2796	24	184	70	0.14	1.8	6.9
Bldg. 96	6/30/78	0.1	--	1435	64	18	--	2.2	7.6	0	44	756	2246	14	213	55	0.06	--	7.1
Bldg. 96	9/6/78	0.2	--	1347	38	28	1.6	0.5	9.4	0	32	795	2448	18	220	60	0.09	0.14	6.8
Bldg. 96	9/30/78	0.4	--	1748	48	30	3.0	2.0	7.6	0	44	810	2592	30	224	61	0.06	0.14	6.9
Bldg. 203	6/30/78	1.3	44	984	7	26	16.6	4.3	4.5	0	92	388	1610	18	88	41	0.09	--	7.6
Bldg. 203	9/6/78	3.0	--	1226	6	24	15.4	4.1	3.9	0	64	520	2020	20	128	49	0.10	2.5	7.5
Bldg. 203	9/30/78	3.1	--	1333	6	28	11.4	3.5	4.0	0	104	570	2254	28	140	54	0.08	1.6	7.9
Bldg. 206	9/6/78	1.4	--	1523	34	38	9.4	1.5	8.5	0	60	640	2506	28	156	61	0.32	0.95	7.5
Bldg. 260	6/30/78	.02	--	1490	38	32	1.1	0.1	3.2	16	68	600	2394	20	144	58	0.02	.00	9.1
Bldg. 260	9/19/78	0.9	--	28	57	24	9.3	3.4	0.9	168	1030	320	1282	12	74	33	0.19	1.1	9.3
Bldg. 300	9/6/78	2.1	--	1441	116	30	2.8	3.7	9.9	0	64	630	2456	30	152	61	0.10	1.3	7.1
Bldg. 300	9/30/78	1.7	--	1735	34	36	6.1	3.7	9.2	0	44	700	2750	36	168	68	0.11	1.9	6.9
Bldg. 303	9/6/78	1.9	--	1571	34	34	3.5	2.9	3.9	0	46	632	2402	18	154	60	0.09	0.61	7.0
Bldg. 303	9/19/78	1.8	--	1499	14	26	2.5	3.2	5.6	0	8	596	2346	18	152	53	0.07	2.5	6.2
Bldg. 306	6/30/78	1.1	77	1435	30	0	0.1	2.7	5.9	0	34	594	2250	20	144	57	0.04	--	6.8
Bldg. 306	9/19/78	2.2	--	1644	24	32	1.9	2.9	5.0	0	64	672	2614	26	168	62	0.03	0.23	7.6
Bldg. 306	9/30/78	2.5	--	1735	20	34	2.7	2.9	6.0	0	48	640	2364	22	160	59	0.03	0.42	7.3
Bldg. 851	6/30/78	0.7	64	1190	66	22	0.0	4.6	5.1	0	76	496	1930	16	120	48	0.06	--	7.5
Bldg. 851, Small	8/24/78	0.7	--	--	--	24	0.3	1.9	0.0	122	644	140	734	102	10	28	--	--	9.5
Bldg. 851	9/6/78	1.3	--	1679	38	35	3.6	2.8	1.2	0	20	760	2644	24	200	63	0.16	79.0	6.3
Bldg. 851	9/19/78	1.5	--	1248	32	22	2.2	2.3	2.5	0	44	504	2042	10	124	47	0.05	1.4	7.2

TABLE 6. ANALYSES OF LITHIUM BROMIDE FROM ABSORBERS AT CHANUTE AFB

	Bldg. P-1	Bldg. P-2	Bldg. P-12	Bldg. 68	Bldg. 260	Bldg. 300	Bldg. 303	Bldg. 306
Reported 11/8/77								
Specific Gravity	1.68	1.60	1.68	1.43	1.55	1.50	1.54	1.52
Lithium Bromide (%)	58	54	58	43	51	47	51	49
P Alkalinity (ppm $CaCO_3$)	600	660	500	280	410	440	660	320
M Alkalinity (ppm $CaCO_3$)	1270	1500	640	620	1000	770	770	1220
Chromate (ppm Li_2CrO_4)	1350	1650	0	850	1620	140	0	1960
Iron (ppm Fe)	--	--	--	--	--	--	--	--
Copper (ppm Cu) soluble	--	--	--	--	--	--	--	--
pH (10% soln.)	10.2	10.2	10.3	10.2	10.2	10.5	10.5	9.7
Inhibitor requirements (per 100 gals. of absorber charge)								
48% Hydrobromic Acid (gals.)	OK	OK	OK	OK	OK	OK	OK	OK
35.5% Lithium Chromate (gals.)	0.2	OK	0.7	0.4	OK	0.6	0.7	OK
99% $LiOH \cdot H_2O$ (gals.)	--	--	--	--	--	--	--	--
Reported 9/20/78								
Specific Gravity	1.69	1.70	1.69	1.44	1.57	1.68	1.56	1.69
Lithium Bromide (%)	58.9	59.8	58.9	<45	52.7	58.5	52.0	58.9
P Alkalinity (ppm $CaCO_3$)	944	929	130	42	547	415	26	886
M Alkalinity (ppm $CaCO_3$)	1381	1623	201	250	1094	534	141	1630
Chromate (ppm Li_2CrO_4)	753	1054	53	450	1339	80	158	1521
Iron (ppm Fe)	--	--	--	--	--	--	--	--
Copper (ppm Cu) soluble	23	15	48	13	9	5	35	33
pH (10% soln.)	10.0	9.9	8.5	6.9	9.7	9.3	6.7	9.85
Inhibitor requirements (per 100 gals. of absorber charge)								
48% Hydrobromic Acid (gals.)	OK	OK	--	--	OK	OK	--	OK
35.5% Lithium Chromate (gals.)	0.4	0.3	0.7	0.5	0.2	0.7	0.6	OK
99% $LiOH \cdot H_2O$ (gals.)	--	--	0.4	0.3	--	--	0.4	--

TABLE 7. CHANUTE AFB COLD DISTRIBUTION WATER SAMPLES, ZINC-ACID-PHOSPHATE TREATMENT SAMPLED AFTER 5 MINUTES FLOW AT LOCATION SPECIFIED; pH, TEMP., Cl_2 ANALYSES CONDUCTED AT SITE

Location	Date	pH	Temp. °C	Free Cl_2	Total Cl_2	Total Iron	Hardness (as $CaCO_3$)	Calcium (as Ca)	Magnesium (as Mg)	Copper (as Cu)	Zinc (as Zn)	Ammonium (as NH_4)	Poly Phosphate (as PO_4)	Ortho Phosphate (as PO_4)	Silica (as SiO_2)	Chloride (as Cl)	Sulfate (as SO_4)	Alkalinity (as $CaCO_3$)	Dissolved Solids
Water Plant	4/10/78	7.8	13°	0.4	>1.0	0.6	120	30	11	0.00	0.00	1.7	1.5	0.4	13	7	0	328	338
	5/1/78	7.7	12°	0.2	>1.0	1.0	108	25	11	0.02	0.32	1.8	1.7	1.4	20	7	0	326	344
	5/8/78	7.6	12°	0.2	>1.0	0.5	120	29	12	0.01	0.29	1.7	1.6	1.0	20	5	0	336	385
	5/15/78	--	13°	0.2	>1.0	0.7	140	33	14	0.00	0.29	2.1	1.2	1.1	19	6	0	360	393
	6/2/78	7.75	13°	0.2	2.0	0.3	110	26	11	0.0	0.27	1.4	0.8	1.1	7	6	0	324	299
	6/5/78	7.7	13°	0.3	2.0	0.2	110	26	11	0.00	0.28	1.7	1.7	1.0	10	7	0	326	308
	6/14/78	7.5	13°	0.3	3.0	0.1	160	38	16	0.00	0.47	4.2	1.8	1.2	19	16	0	360	405
	6/23/78	--	13°	0.3	2.0	0.9	136	32	14	0.03	0.30	1.5	1.5	1.0	17	36	0	344	399
	6/27/78	7.85	13°	0.3	1.5	0.7	120	26	13	0.00	0.31	1.4	1.5	0.9	11	6	0	340	367
	7/7/78	7.6	13°	0.4	3.0	0.5	116	28	11	0.05	0.50	1.7	1.4	1.1	18	8	0	344	382
	7/14/78	7.65	13°	0.3	>2.0	0.5	108	26	11	0.00	0.39	2.0	1.3	1.2	12	6	0	360	397
	7/25/78	7.6	13°	0.3	2.0	0.16	116	29	11	0.00	0.50	0.5	1.5	1.4	15	7	0	328	378
	8/10/78	7.7	13°	0.3	2.0	0.56	124	30	12	0.00	0.01	2.1	1.2	0.5	15	6	0	336	345
	8/24/78	7.7	16°	0.3	3.0	0.02	130	32	12	0.00	0.19	1.9	1.4	0.2	14	8	0	360	377
	8/31/78	7.6	13°	0.3	>2.0	0.5	170	38	18	0.01	0.49	2.2	1.3	0.3	17	7	0	360	379
	9/6/78	7.6	13°	0.4	>2.0	0.7	150	35	15	0.00	0.61	2.8	1.4	0.8	16	8	0	324	355
	9/15/78	7.6	13°	0.3	>2.0	0.6	120	30	11	0.00	0.25	2.1	1.5	0.3	16	8	0	350	340
	9/19/78	7.6	13°	0.3	>2.0	0.5	120	29	12	0.01	0.20	2.4	1.4	0.6	14	7	0	340	365
	10/6/78	7.6	13°	0.3	>2.0	0.4	104	26	9	0.00	0.28	2.0	1.6	1.0	15	7	0	340	369
	10/12/78	7.6	13°	0.2	>2.0	0.4	96	25	8	0.00	0.22	1.8	1.7	1.0	12	8	0	330	349
	10/24/78	7.8	13°	0.3	>2.0	0.2	112	27	11	0.00	0.26	1.4	1.8	0.8	16	3	0	320	322
	10/31/78	7.8	13°	0.3	1.5	0.2	120	29	12	0.00	0.28	1.8	1.9	1.0	16	3	0	330	349
	11/10/78	7.7	13°	0.3	1.5	0.4	148	35	15	0.00	0.06	4.1	1.6	0.4	18	5	0	330	325
Bldg. 303	4/10/78	7.75	20°	0.3	>1.0	0.5	120	29	12	0.19	0.01	1.4	1.5	0.4	13	9	0	328	337
	5/1/78	7.6	20°	0.3	>1.0	0.7	132	31	13	0.09	0.30	2.0	1.5	1.2	20	10	0	324	342
	5/8/78	7.6	19°	0.3	>1.0	1.6	132	31	13	0.09	0.31	1.7	1.4	1.3	20	6	0	344	400
	5/15/78	--	20°	0.3	>1.0	0.8	138	33	13	0.10	0.25	1.8	1.4	1.2	19	6	0	352	399
	5/22/78	7.8	18°	0.3	1.5	1.2	156	36	16	0.11	0.33	2.9	1.4	0.8	11	6	0	336	376
	6/2/78	7.75	21°	0.3	1.5	0.3	124	30	12	0.09	0.28	1.6	0.8	1.0	7	6	0	328	305
	6/5/78	7.7	20°	0.4	2.0	0.3	134	32	13	0.08	0.33	1.4	1.5	1.1	14	7	0	324	309
	6/14/78	7.55	20°	0.5	3.0	0.7	124	32	11	0.13	0.33	1.3	1.3	0.9	19	9	0	336	373
	6/23/78	--	21°	0.2	0.9	0.4	126	29	13	0.07	0.28	1.3	1.4	1.1	17	6	0	336	358
	6/27/78	7.75	21°	0.4	1.5	0.6	148	35	15	0.08	0.30	1.8	1.9	1.0	11	16	0	336	375
	7/7/78	7.75	22°	0.4	1.5	0.9	132	32	13	0.07	0.37	1.6	1.5	1.1	16	17	0	342	381
	7/14/78	7.65	22°	0.4	>2.0	0.8	124	30	22	0.08	0.39	1.5	1.4	1.9	15	5	0	352	396
	7/25/78	7.5	21°	0.4	2.0	0.2	132	32	13	0.05	0.65	2.0	1.9	1.5	16	7	0	328	366
	8/10/78	7.8	21°	0.5	2.6	0.5	128	33	11	0.08	0.07	2.1	0.5	0.6	18	5	0	328	433
	8/31/78	7.7	21°	0.4	>2.0	0.3	150	37	14	0.08	0.35	1.8	1.4	0.2	14	8	0	356	379
	9/6/78	7.8	21°	0.5	>2.0	0.6	140	32	15	0.07	0.51	1.8	1.3	0.8	14	8	0	324	345
	9/15/78	7.7	22°	0.4	>2.0	0.5	148	35	15	0.08	0.33	2.2	1.4	0.5	16	6	0	360	349
	9/19/78	7.7	22°	0.5	>2.0	0.4	140	34	14	0.07	0.24	2.5	1.4	0.5	16	6	0	340	356
	10/6/78	7.9	22°	0.3	1.5	0.2	104	25	10	0.08	0.33	1.5	2.0	1.0	14	5	0	350	377
	10/12/78	7.7	21°	0.3	1.5	0.5	100	26	9	0.07	0.19	1.7	1.3	0.9	9	7	0	330	356
	10/24/78	7.9	20°	0.3	1.5	0.5	128	31	12	0.07	0.34	1.4	1.8	1.2	17	8	0	320	319
	10/31/78	7.8	21°	0.3	1.5	0.2	124	31	11	0.06	0.30	1.8	1.8	1.1	18	4	0	330	348
	11/10/78	7.7	20°	0.3	1.0	0.7	128	33	11	0.08	0.26	1.8	1.3	1.0	16	5	0	330	342

TABLE 7. CHANUTE AFB COLD DISTRIBUTION WATER SAMPLES, ZINC-ACID-PHOSPHATE TREATMENT SAMPLED AFTER 5 MINUTES FLOW AT LOCATION SPECIFIED; pH, TEMP., Cl_2 ANALYSES CONDUCTED AT SITE (CONCLUDED)

Location	Date	pH	Temp. °C	Free Cl_2	Total Cl_2	Total Iron	Hardness (as $CaCO_3$)	Calcium (as Ca)	Magnesium (as Mg)	Copper (as Cu)	Zinc (as Zn)	Ammonium (as NH_4)	Poly Phosphate (as PO_4)	Ortho Phosphate (as PO_4)	Silica (as SiO_2)	Chloride (as Cl)	Sulfate (as SO_4)	Alkalinity (as $CaCO_3$)	Dissolved Solids
Bldg. 306	4/10/78	7.75	13°	0.3	>1.0	0.6	126	29	13	0.04	0.14	1.4	1.5	0.5	13	12	0	324	348
	5/1/78	7.45	13°	0.3	>1.0	0.7	120	28	12	0.03	0.37	2.1	1.7	1.1	20	7	0	324	334
	5/8/78	7.6	13°	0.2	>1.0	1.7	128	31	12	0.03	0.38	1.8	1.4	1.1	20	7	0	348	409
	5/15/78	--	13°	0.2	>1.0	0.9	140	34	13	0.03	0.34	1.8	1.2	1.2	19	7	0	356	405
	5/22/78	7.75	13°	0.2	1.0	1.4	156	37	15	0.03	0.42	3.2	1.4	1.1	15	5	0	340	376
	6/2/78	7.65	14°	0.3	2.0	0.8	122	30	11	0.03	0.33	1.5	0.4	1.4	8	7	0	328	306
	6/5/78	7.7	14°	0.3	2.0	0.3	132	30	14	0.05	0.38	1.4	0.3	2.2	8	6	0	322	320
	6/14/78	7.5	14°	0.4	3.0	0.5	124	30	12	0.04	0.20	1.3	1.4	0.7	19	8	0	336	381
	6/23/78	--	15°	0.2	0.8	0.4	126	30	12	0.03	0.33	1.3	1.4	1.1	17	6	0	340	350
	6/27/78	7.75	15°	0.3	1.0	0.7	144	34	14	0.04	0.41	1.8	1.9	1.0	13	11	0	332	367
	7/7/78	7.75	15°	0.3	2.0	1.0	128	30	13	0.03	0.39	1.8	1.4	1.0	17	8	0	342	382
	7/14/78	7.8	15°	0.3	>2.0	1.7	120	29	12	0.04	0.55	1.4	2.9	2.0	12	8	0	352	404
	7/25/78	7.5	16°	0.3	1.5	0.2	132	32	13	0.02	0.63	1.4	1.7	1.8	17	5	0	332	367
	8/10/78	7.8	15°	0.3	2.0	0.5	128	33	11	0.04	0.13	1.9	0.7	0.6	14	5	0	336	397
	9/6/78	7.7	15°	0.3	>2.0	0.5	120	30	11	0.03	0.49	1.6	1.4	0.8	13	8	0	320	354
	9/15/78	7.7	17°	0.4	>2.0	0.5	144	36	13	0.04	0.38	2.6	1.5	0.7	17	6	0	350	344
	9/19/78	7.5	16°	0.4	2.0	0.4	136	34	13	0.03	0.31	2.6	1.3	0.5	13	7	0	330	361
	10/6/78	7.9	15°	0.3	2.0	0.2	100	25	9	0.02	0.36	1.5	1.9	1.0	16	5	0	340	377
	10/12/78	7.7	15°	0.3	2.0	0.6	96	24	9	0.01	0.28	1.5	1.4	0.9	8	7	0	330	355
	10/31/78	7.9	15°	0.3	1.5	0.2	124	31	11	0.04	0.38	1.6	1.7	1.2	17	4	0	330	350
	11/10/78	7.7	15°	0.2	1.0	0.5	128	34	10	0.03	0.36	1.7	1.3	1.0	16	5	0	340	344
Bldg. 851	4/10/78	7.55	10°	<0.1	0.4	0.4	114	26	12	0.04	0.03	0.5	1.1	0.4	13	10	0	340	361
	5/1/78	7.45	11°	0.1	0.1	0.7	132	31	13	0.04	0.27	1.1	1.5	1.0	20	7	0	336	355
	5/8/78	7.5	11°	0.1	0.5	1.3	144	34	14	0.04	0.31	1.1	1.4	1.2	20	9	0	336	401
	5/15/78	--	12°	0.1	0.5	0.7	140	33	14	0.03	0.07	1.1	0.9	0.5	19	6	0	328	370
	5/22/78	7.6	12°	0.1	>2.0	1.1	164	34	19	0.04	0.32	1.2	1.3	0.9	19	10	0	326	369
	6/2/78	7.5	14°	0.0	0.6	0.3	120	28	12	0.03	0.22	0.7	0.7	0.9	8	6	0	310	288
	6/5/78	7.5	14°	<0.1	0.5	0.8	116	28	11	0.04	0.15	0.7	1.0	1.1	9	7	0	312	305
	6/14/78	7.45	15°	0.2	0.6	0.2	130	31	13	0.05	0.23	1.0	1.0	0.9	18	6	0	330	363
	6/23/78	--	15°	0.1	0.4	0.5	144	34	14	0.03	0.28	0.9	1.2	1.0	17	8	0	328	349
	6/27/78	7.6	15°	0.3	1.0	0.5	124	30	12	0.04	0.25	1.0	1.8	1.0	12	7	0	328	336
	7/7/78	7.55	17°	0.1	0.5	0.3	136	33	13	0.05	0.32	0.8	1.5	0.8	16	7	0	336.	373
	7/14/78	7.55	18°	0.2	0.6	0.2	148	33	16	0.04	0.26	0.9	0.8	0.9	11	6	0	336	325
	7/25/78	7.3	17°	0.2	0.4	0.26	128	30	13	0.06	0.36	0.6	0.5	1.5	13	6	0	320	358
	8/10/78	7.6	17°	0.1	0.6	0.4	128	31	12	0.04	0.05	0.5	1.1	0.5	15	6	0	332	350
	8/24/78	7.6	17°	0.3	0.9	0.2	140	32	15	0.04	0.04	0.8	1.3	0.0	14	10	0	348	370
	9/6/78	7.6	17°	0.3	1.0	0.3	140	34	14	0.03	0.31	1.2	1.3	0.6	12	8	0	328	363
	9/15/78	7.5	18°	0.2	0.8	0.5	128	30	13	0.04	0.27	1.2	1.0	0.3	15	6	0	350	349
	9/19/78	7.5	17°	0.3	0.8	0.2	124	30	12	0.04	0.17	1.4	1.0	0.5	15	6	0	340	382
	10/6/78	7.7	16°	0.3	0.5	0.3	136	32	14	0.02	0.10	3.7	1.4	0.6	16	5	0	350	376
	10/12/78	7.7	15°	0.2	1.0	0.4	96	24	9	0.04	0.18	1.2	1.4	0.8	10	6	0	330	345
	10/24/78	7.6	15°	0.2	0.5	0.3	128	31	12	0.05	0.24	1.5	1.8	1.0	14	4	0	320	327
	10/31/78	7.7	14°	0.2	0.5	0.5	140	35	13	0.04	0.27	0.7	1.7	1.3	18	7	0	350	366

TABLE 8. CHANUTE AFB HOT DISTRIBUTION WATER SAMPLES, ZINC-ACID-PHOSPHATE TREATMENT SAMPLED AFTER 5 MINUTES FLOW AT LOCATION SPECIFIED; pH, TEMP., Cl_2 ANALYSES CONDUCTED AT SITE

Location	Date	pH	Temp. °C	Free Cl_2	Total Cl_2	Total Iron	Hardness (as $CaCO_3$)	Calcium (as Ca)	Magnesium (as Mg)	Copper (as Cu)	Zinc (as Zn)	Ammonium (as NH_4)	Poly Phosphate (as PO_4)	Ortho Phosphate (as PO_4)	Silica (as SiO_2)	Chloride (as Cl)	Sulfate (as SO_4)	Alkalinity (as $CaCO_3$)	Dissolved Solids
Bldg. 303	4/10/78	7.8	51°	0.6	1.0	0.5	120	26	13	0.19	0.01	1.5	1.2	0.6	13	7	0	328	346
	5/1/78	7.7	53°	0.7	1.0	0.4	122	30	11	0.11	0.21	1.8	1.2	1.3	20	7	0	336	347
	5/8/78	7.6	51°	0.6	0.8	0.6	140	33	14	0.11	0.22	1.8	1.0	1.2	20	7	0	344	398
	5/15/78	--	51°	0.4	0.6	0.5	140	32	15	0.12	0.11	1.7	1.0	0.9	20	6	0	340	375
	5/22/78	7.80	49°	1.5	>2.0	0.8	164	36	18	0.17	0.29	3.0	1.3	1.3	11	7	0	336	374
	6/2/78	7.75	48°	0.6	0.8	0.4	128	31	12	0.12	0.27	1.8	0.7	1.6	8	6	0	328	308
	6/5/78	7.75	47°	0.8	0.8	0.3	126	30	12	0.10	0.30	1.5	1.4	1.3	8	7	0	324	318
	6/14/78	7.65	47°	0.8	0.8	0.4	128	30	13	0.11	0.32	1.3	1.2	1.2	11	6	0	336	381
	6/23/78	--	49°	0.3	0.3	0.2	126	30	12	0.09	0.26	1.2	1.3	1.3	18	8	0	332	351
	6/27/78	7.8	48°	0.8	0.8	0.4	140	35	13	0.12	0.20	1.8	1.3	1.3	18	8	0	332	364
	7/7/78	7.8	48°	0.9	0.9	0.5	136	33	13	0.10	0.31	1.7	1.4	1.0	17	8	0	340	384
	7/14/78	7.7	48°	0.6	0.8	0.4	136	31	14	0.09	0.29	1.7	1.1	1.7	12	6	0	336	380
	7/25/78	7.8	48°	0.8	0.9	0.40	128	33	11	0.08	0.46	0.5	1.1	1.5	17	6	0	328	367
	8/10/78	7.8	48°	0.8	0.8	0.4	128	32	12	0.13	0.12	1.8	0.6	0.8	16	6	0	332	395
	8/31/78	7.7	50°	1.0	1.0	0.0	140	35	13	0.12	0.27	1.7	1.0	0.6	16	8	0	344	363
	9/6/78	7.8	49°	2.0	2.0	0.4	140	34	14	0.11	0.36	1.8	1.1	0.8	14	9	0	328	362
	9/15/78	7.7	49°	1.0	1.0	0.4	144	33	15	0.09	0.33	2.4	1.0	0.7	11	8	0	360	341
	9/19/78	7.8	49°	1.0	1.0	0.3	136	34	13	0.10	0.25	2.3	1.0	0.9	15	7	0	350	386
	10/6/78	7.9	52°	0.6	0.6	0.3	100	25	9	0.09	0.23	1.5	1.2	1.1	15	7	0	350	378
	10/12/78	7.8	50°	0.8	0.8	0.4	100	24	10	0.11	0.15	1.7	1.1	1.0	10	7	0	330	351
	10/24/78	7.9	50°	0.8	0.8	0.4	128	31	12	0.09	0.33	1.5	1.6	1.3	18	6	0	320	310
	10/31/78	7.9	52°	0.8	0.8	0.3	128	32	12	0.10	0.30	2.4	1.7	1.5	19	5	0	340	333
	11/10/78	7.7	48°	0.5	0.5	0.4	132	34	11	0.11	0.18	1.7	1.4	0.9	18	5	0	340	355
Bldg. 306	4/10/78	7.75	65°	0.5	1.0	1.0	120	27	13	0.27	0.17	1.3	0.9	0.8	13	7	0	332	346
	5/1/78	7.6	65°	0.6	0.8	0.2	128	30	13	0.13	0.18	1.8	0.8	1.1	20	6	0	342	349
	5/8/78	7.6	62°	0.6	1.0	1.4	140	33	14	0.12	0.53	1.8	1.1	1.6	20	7	0	348	412
	5/15/78	--	65°	0.6	1.0	0.8	148	34	16	0.17	0.22	1.8	0.9	1.2	20	6	0	344	387
	5/22/78	7.75	63°	2.0	3.0	1.6	168	35	19	0.19	0.48	3.0	1.1	1.2	11	7	0	336	373
	6/2/78	7.6	65°	0.4	0.5	0.3	132	30	14	0.12	0.25	1.5	0.9	1.3	8	6	0	328	310
	6/5/78	7.6	64°	0.8	0.8	0.2	118	30	10	0.13	0.36	1.4	0.4	2.2	9	6	0	324	318
	6/14/78	7.6	64°	0.3	0.3	0.2	130	31	13	0.12	0.28	1.4	0.8	1.5	11	5	0	340	384
	6/23/78	--	58°	0.4	0.6	1.6	130	31	13	0.12	0.67	1.2	1.5	1.6	18	7	0	336	353
	6/27/78	7.85	58°	0.8	1.0	1.3	132	32	13	0.15	0.47	1.7	2.4	1.5	11	7	0	332	363
	7/7/78	7.8	65°	0.5	0.5	0.2	136	33	13	0.15	0.25	1.7	1.3	0.7	16	8	0	336	389
	7/14/78	7.8	63°	0.5	0.8	0.6	136	31	14	0.10	0.42	1.5	1.1	2.1	11	8	0	336	435
	7/25/78	7.8	64°	0.6	0.8	0.2	132	32	13	0.10	0.71	1.2	1.4	2.0	15	7	0	328	374
	8/10/78	7.9	62°	0.8	0.8	0.6	128	32	12	0.17	0.15	1.5	0.4	0.8	15	5	0	328	401
	9/6/78	7.8	64°	2.0	2.0	0.2	130	22	12	0.12	0.32	1.9	1.1	0.9	14	8	0	328	359
	9/15/78	7.7	63°	1.0	1.0	0.3	136	33	13	0.12	0.27	2.2	0.9	0.7	16	8	0	360	358
	9/19/78	7.6	65°	1.0	1.0	0.1	132	33	12	0.12	0.20	2.1	0.5	1.0	13	7	0	350	381
	10/6/78	7.9	65°	0.5	0.5	0.2	104	26	10	0.13	0.18	1.6	0.9	1.2	13	7	0	340	378
	10/12/78	7.8	63°	0.8	0.8	0.4	96	25	8	0.13	0.24	1.6	1.1	1.1	11	7	0	330	336
	10/31/78	7.9	60°	0.8	0.8	0.2	124	30	12	0.09	0.30	1.7	1.6	1.4	18	4	0	330	350
	11/10/78	7.8	63°	0.5	0.5	0.4	128	34	10	0.19	0.20	1.8	1.0	1.1	16	5	0	350	349

TABLE 8. CHANUTE AFB HOT DISTRIBUTION WATER SAMPLES, ZINC-ACID-PHOSPHATE TREATMENT SAMPLED AFTER 5 MINUTES FLOW AT LOCATION SPECIFIED; pH, TEMP., Cl_2 ANALYSES CONDUCTED AT SITE (CONCLUDED)

Location	Date	pH	Temp. °C	Free Cl_2	Total Cl_2	Total Iron	Hardness (as $CaCO_3$)	Calcium (as Ca)	Magnesium (as Mg)	Copper (as Cu)	Zinc (as Zn)	Ammonium (as NH_4)	Poly Phosphate (as PO_4)	Ortho Phosphate (as PO_4)	Silica (as SiO_2)	Chloride (as Cl)	Sulfate (as SO_4)	Alkalinity (as $CaCO_3$)	Dissolved Solids
Bldg. 851	4/10/78	7.5	47°	<0.1	<0.1	0.4	118	27	12	0.37	0.13	0.6	0.4	0.9	13	10	0	344	370
	5/1/78	7.5	46°	<0.1	0.1	0.5	124	30	12	0.33	0.17	0.9	0.6	1.6	20	8	0	336	357
	5/8/78	7.5	45°	0.1	0.2	0.9	136	30	15	0.32	0.21	1.0	0.6	1.8	20	8	0	332	400
	5/15/78	--	48°	<0.1	0.1	0.4	132	30	14	0.28	0.21	0.7	0.4	1.1	19	6	0	320	356
	5/22/78	7.5	46°	<0.1	0.2	0.7	142	32	15	0.37	0.20	0.8	0.5	1.6	12	10	0	328	372
	6/2/78	7.5	47°	0.0	0.0	0.2	136	31	14	0.32	0.17	0.5	0.0	1.8	6	8	0	326	316
	6/5/78	7.5	46°	<0.1	0.1	0.4	126	29	13	0.32	0.19	0.7	0.5	1.6	8	8	0	324	318
	6/14/78	7.4	51°	0.1	0.2	0.3	128	30	13	0.32	0.21	0.9	0.6	1.6	19	8	0	328	370
	6/23/78	--	48°	0.1	0.1	0.4	126	30	12	0.31	0.24	0.7	0.6	1.6	17	7	0	324	345
	6/27/78	7.6	48°	0.1	0.1	0.5	144	32	16	0.32	0.18	0.9	0.7	1.5	10	7	0	328	364
	7/7/78	7.55	48°	0.0	0.0	0.3	134	32	13	0.36	0.20	0.6	1.6	0.2	17	7	0	334	372
	7/14/78	7.6	52°	0.0	tr.	0.2	136	32	14	0.15	0.25	1.0	0.4	1.4	11	6	0	332	372
	7/25/78	7.6	52°	tr.	tr.	0.26	128	30	13	0.19	0.32	1.0	0.6	1.3	12	6	0	324	366
	8/10/78	7.6	51°	tr.	tr.	0.4	128	32	12	0.16	0.15	0.8	0.3	0.8	18	6	0	328	390
	8/24/78	7.6	47°	<0.1	<0.1	0.5	140	32	15	0.34	0.13	0.9	0.2	0.7	16	11	0	336	363
	9/6/78	7.6	47°	0.1	0.1	0.3	140	30	16	0.31	0.21	0.9	0.4	1.1	12	8	0	336	372
	9/15/78	7.5	49°	0.1	0.1	0.3	124	28	13	0.24	0.20	0.9	0.2	1.1	14	6	0	340	345
	9/19/78	7.5	47°	0.2	0.2	0.3	124	30	12	0.28	0.20	1.3	0.0	1.5	13	6	0	340	357
	10/6/78	7.7	52°	0.2	0.2	0.3	124	30	12	0.15	0.13	0.9	1.1	1.0	14	6	0	350	395
	10/12/78	7.6	47°	0.0	0.0	0.4	104	27	9	0.35	0.17	12	0.5	1.8	11	7	0	330	359
	10/24/78	7.6	46°	0.1	0.1	0.4	128	31	12	0.34	0.21	1.3	0.6	1.7	18	7	0	340	340
	10/31/78	7.6	46°	0.1	0.1	0.3	136	34	12	0.31	0.17	2.7	0.7	1.7	18	5	0	350	368

TABLE 9. ANALYSES OF SCOTT AFB POWER PLANT SAMPLES

	Date	Iron (as Fe)	Silica (as SiO_2)	Sulfate (as SO_4)	Sulfite (as SO_3)	Chloride (as Cl)	Ortho Phosphate (as PO_4)	P Alkalinity	M Alkalinity	Nitrate (as NO_3)	Hardness	Dissolved Solids	Suspended Solids	Oil	Color	Calcium (as Ca)	Magnesium (as Mg)	Cyclo-hexylamine	Conductivity in μmhos
Boilers:																			
Main: #1	11/30/77	10.2	38	785	5	460	53	380	820	154	4	3238	584	tr.	732 (A)	--	--	--	--
#1	3/22/78	8.0	32	600	2	270	100	440	520	73	--	2154	242	--	576 (A)	--	--	--	--
#1	4/12/78	7.2	32	745	3	580	48	530	630	228	--	3340	224	tr.	835 (A)	--	--	--	--
#1	5/16/78	5.5	31	600	2	420	101	500	620	148	--	2526	234	--	377 (A)	--	--	--	--
#1	6/20/78	4.2	35	928	7	380	114	330	540	128	4	3230	288	tr.	387 (A)	--	--	--	--
#2	10/13/77	17.6	56	580	4	350	57	680	850	112	--	2784	258	tr.	675 (A)	--	--	--	--
#2	11/30/77	168.0	54	952	int.	515	26	540	1030	234	4	3942	11860	tr.	343 (A)	--	--	--	--
#3	12/29/77	5.0	9	647	9	550	12	140	272	167	7	2546	320	--	766 (A)	--	--	--	--
869	12/29/77	113.0	13	619	6	420	68	660	860	124	3	2934	936	tr.	532 (C)	--	--	--	--
3191	12/29/77	1.6	8	183	2	295	23	124	180	30	6	1136	4	tr.	786 (C)	--	--	--	--
3670	12/29/77	4.8	20	327	4	225	135	390	540	75	4	1786	50	tr.	956 (C)	--	--	--	--
Make-up:	10/3/77	0.3	8	48	--	35	--	--	132	--	10	330	--	--	--	--	--	--	--
	11/30/77	0.1	8	50	--	35	--	--	142	--	20	299	--	--	--	--	--	--	--
Sod. Soft.	11/30/77	0.0	9	45	--	35	--	--	174	--	50	321	--	--	--	10	6	--	--
H^+ Unit	11/30/77	0.0	8	48	--	35	--	--	172	--	34	344	--	--	--	6	5	--	--
	12/29/77	0.1	8	55	--	60	--	--	16	--	44	262	--	--	--	8	6	--	--
	3/22/78	0.1	--	49	--	26	--	--	4	--	36	151	--	--	--	6	5	--	--
	4/12/78	0.0	--	33	--	38	--	--	22	--	12	180	--	--	--	--	--	--	--
	5/16/78	0.2	3	36	--	32	--	--	28	--	24	194	--	--	--	4	3	--	--
	6/20/78	1.0	5	55	--	19	--	--	2	--	12	205	--	--	--	--	--	--	--
Feedwater:	10/3/77	2.6	5	10	--	10	--	--	52	--	4	115	--	--	--	--	--	--	--
	11/30/77	0.7	4	10	--	12	--	--	52	--	14	87	--	--	--	--	--	--	--
	5/16/77	7.0	3	8	--	10	--	--	32	--	16	78	--	--	--	--	--	--	--
Return Condensate:																			
Main Pwr.	10/3/77	16.6	--	--	--	--	--	--	19	--	1	--	--	--	--	--	--	32.0	38 @ 25°C
" "	11/30/77	0.2	--	--	--	--	--	--	18	--	13	--	--	--	--	--	--	18.4	55 @ 25°C
" "	12/29/77	3.2	--	0	--	5	--	--	29	--	22	--	--	--	--	--	--	27.0	100 @ 25°C
" "	3/22/78	2.2	--	--	--	--	--	--	17	--	4	--	--	--	--	--	--	22.9	38 @ 26°C
" "	4/12/78	1.1	--	--	--	--	--	--	22	--	8	--	--	--	--	--	--	21.6	70 @ 25°C
" "	5/16/78	10.0	--	6	--	10	--	--	41	--	2	--	--	--	--	--	--	29.5	168 @ 25°C
" "	6/20/78	2.0	--	5	--	3	--	--	42	--	2	--	--	--	--	--	--	49.7	(TMC)* 133
" "	6/21/78	48.0	--	20	--	13	--	--	78	--	3	--	--	--	--	--	--	48.0	(TMC) 295
" "	7/19/78	1.0	--	0	--	--	--	--	21	--	5	--	--	--	--	--	--	19.7	(TMC) 51

(A) Tannin color at 470 mμ
(C) Lignin color at 470 mμ
* Total mineral content

TABLE 10. CORROSION TEST RESULTS AT SCOTT AFB

1. Return condensate (Test Method - ASTM D2688 Method A)

Location	Dates of exposure	Corrosion rate (mdd)
MAC Hdqts. (1600)	4/7/77-7/11/77	10.1
" " "	7/13/77-11/8/77	1.0
" " "	11/8/78-4/11/78	0.47
" " "	4/18/78-10/23/78	0.83
Med. Center (1530)	7/13/77-11/8/77	1.0
" " "	11/4/77-4/20/78	0.67
" " "	4/20/78-10/23/78	1.08

Conclusions: Very good corrosion inhibition except initially at MAC Hdqts. (4/7/77-7/11/77), where low flow and wet steam could be a problem during summer operation.

2. Cooling towers (Test Method - ASTM D2688 Method C)

Corrosion testing at the hospital (1530) was not conducted due to relocation of the cooling tower.

Location	Dates of exposure	Treatment	Corrosion rate (mdd) Steel	Corrosion rate (mdd) Copper
Med. Center (1530)	4/21/77-6/17/77	Dearborn 361	0.70	0.27
" " "	6/28/77-10/4/77	" "	25.1*	5.8
MAC Hdqts. (1600)	6/13/77-6/28/77	" "	8.1	2.2
" " "	6/28/77-10/4/77	" "	4.8**	1.0
" " "	7/15/78-10/15/78	" "	68.0***	4.8***

* Excessive scale formation
** Appreciable scale formation
*** High results could be due to uncertainty of date of installation of corrosion testers. Most of the previous tests showed evidence of scale formation, which reduced corrosion but caused fouling of heat exchangers. Future tests will more accurately indicate actual corrosion test results.

3. Potable water systems (Test Method - ASTM D2688 Method C)

Location	Dates of exposure	Corrosion rate (mdd) Galv. Steel	Corrosion rate (mdd) Copper
Med. Center (1530) Hot	4/25/77-6/17/77	2.8	0.20
MAC Hdqts. (1600) Cold	12/15/77-10/15/78	1.2	0.13

Conclusions: Very satisfactory corrosion rates

TABLE 11. ANALYSES OF SCOTT AFB COOLING TOWER SAMPLES

Sampling Point	Date	Iron (as Fe)	Sulfate (as SO_4)	Chloride (as Cl)	Ortho Phosphate (as PO_4)	Poly Phosphate (as PO_4)	P Alkalinity (as $CaCO_3$)	M Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$)	Dissolved Solids	Suspended Solids	Calcium (as Ca)	Magnesium (as Mg)	Copper (as Cu)	pH at 25°C	Organic Phosphate (as PO_4)
Base Exchange	6/21/78	0.1	208	112	0.2	0.2	84	456	730	1076	18	144	90	0.14	8.9	8.0
Base Exchange	7/20/78	0.54	1200	340	0.0	0.1	0	588	2520	4498	38	377	384	0.40	--	8.4
P-4	8/3/78	0.28	22	40	0.0	0.0	0	172	240	304	6	58	23	0.06	8.1	0.0
P-4	8/28/78	0.02	47	40	0.0	0.0	8	180	240	324	2	53	26	0.06	8.4	0.0
P-40N	7/19/78	0.78	0	334	105.0	2199.0	0	332	357	3238	264	78	40	1.0	--	0.0
P-40N	7/19/78	0.10	26	40	0.0	0.0	12	172	240	306	4	56	24	0.05	8.4	0.0
P-40N	8/3/78	1.24	18	36	0.7	0.0	0	152	220	256	4	53	22	0.06	8.0	0.1
P-40N	8/28/78	0.02	47	38	1.1	0.1	8	176	240	330	0	54	25	0.06	8.5	0.1
P-40W	7/19/78	0.50	34	48	0.0	0.1	44	204	270	350	32	69	24	0.10	9.2	0.4
P-40W	8/28/78	0.04	49	42	0.0	0.0	12	208	260	370	12	61	26	0.11	8.7	0.1
Bldg. 350	8/28/78	0.06	388	192	0.0	0.0	108	576	910	1480	4	188	107	0.38	9.0	1.6
Bldg. 700	9/27/78	0.0	120	124	1.8	0.5	32	316	460	752	8	107	47	0.31	8.8	4.0
Bldg. 859W	9/27/78	0.0	111	112	1.1	0.7	36	312	440	722	4	101	46	0.52	8.9	6.3
Bldg. 1523	7/19/78	0.10	637	486	0.0	0.1	112	628	1480	2710	18	256	205	0.12	8.9	0.8
Bldg. 1523	8/28/78	0.16	1345	675	0.0	0.0	124	704	1950	3828	24	240	329	0.33	9.0	6.1
Bldg. 1523	9/27/78	4.7	89	104	0.2	0.1	12	184	330	530	16	82	31	0.08	8.2	1.3
Bldg. 1530	5/31/78	0.3	129	84	0.1	0.1	32	392	620	782	28	148	61	0.13	8.5	6.5
Bldg. 1530	6/21/78	0.3	65	44	0.3	0.1	18	224	330	490	6	77	34	0.07	8.6	1.8
Bldg. 1530 (Addition)	6/21/78	0.5	93	60	2.6	0.2	32	294	470	658	40	104	51	0.31	8.6	13.5
Bldg. 1530	8/28/78	0.36	290	144	0.0	0.1	104	636	860	1326	20	192	93	0.12	9.0	2.4
Bldg. 1530	9/27/78	0.3	135	146	1.8	3.1	24	300	460	818	58	109	46	0.10	8.7	12.8
Bldg. 1530 (Addition)	9/27/78	0.3	88	96	0.6	1.7	16	200	310	534	14	74	31	0.17	8.6	9.3
Bldg. 1600	10/4/77	0.1	156	106	0.1	0.2	72	384	625	930	24	156	57	0.02	8.7	8.5
Bldg. 1600	4/13/78	0.2	122	122	0.2	0.1	72	396	660	914	8	160	63	0.05	8.7	4.6
Bldg. 1600	5/2/78	0.1	97	63	0.3	0.1	--	260	390	--	--	96	36	--	--	--
Bldg. 1600	5/16/68	0.2	66	64	0.3	0.1	28	200	344	530	8	83	33	0.03	8.7	4.6
Bldg. 1600	5/31/78	0.2	89	66	0.2	0.1	34	256	488	616	8	124	43	0.03	8.6	3.4
Bldg. 1600	6/21/78	0.1	196	110	0.2	0.2	88	492	704	1074	10	62	134	0.03	9.0	3.9
Bldg. 1600	7/19/78	0.84	173	104	0.2	0.2	52	448	684	930	24	156	72	0.05	8.8	2.0
Bldg. 1600	7/19/78	0.3	53	64	1.0	1.2	40	304	392	518	0	98	36	0.04	8.7	5.7
Bldg. 1600	9/27/78	0.0	126	130	2.0	0.9	28	268	420	718	4	104	39	0.03	8.7	4.0
Bldg. 1650	5/16/78	0.4	47	50	0.2	0.1	16	176	252	484	12	61	24	0.10	8.6	12.9
Bldg. 1961	8/28/78	0.02	49	42	0.2	1.4	16	216	270	348	14	64	27	0.02	8.6	0.3

TABLE 12. ANALYSES OF LITHIUM BROMIDE FROM ABSORBER AIR CONDITIONING SYSTEMS AT SCOTT AFB

Location	Date		
Bldg. 1530 Addition	12/5/77	Specific Gravity	1.50
		Lithium Bromide (%)	48%
		P Alkalinity (ppm $CaCO_3$)	800
		M Alkalinity (ppm $CaCO_3$)	1150
		Chromate (ppm Li_2CrO_4)	1030
		Iron (ppm Fe)	--
		Copper (ppm Cu) (soluble)	--
		pH (10% soln.)	10.70
		Inhibitor requirements (per 100 gals. of absorber charge)	
		48% Hydrobromic Acid (gals.)	--
		35.5% Lithium Chromate (gals.)	--
Bldg. 1650	10/17/78	Specific Gravity	1.56
		Lithium Bromide (%)	52%
		P Alkalinity (ppm $CaCO_3$)	2591
		M Alkalinity (ppm $CaCO_3$)	2771
		Chromate (ppm Li_2CrO_4)	0
		Iron (ppm Fe)	--
		Copper (ppm Cu) (soluble)	4
		pH (10% soln.)	10.9
		Inhibitor requirements (per 100 gals. of absorber charge)	
		48% Hydrobromic Acid (gals.)	0.8
		35.5% Lithium Chromate (gals.)	0.7

TABLE 13. ANALYSIS OF SCOTT FIELD CHILLED WATER SAMPLE

Sampling Point		Iron (as Fe)	Borate (as B_2O_3)	Copper (as Cu)	Nitrite (as NO_2)	Dissolved Solids	Ethylene Glycol	pH at 25°C
Bldg. 1600	4/12/78	9.4	3585	0.01	1000	16413	34.1	9.1

TABLE 14. ANALYSES OF SCOTT AFB COLD DISTRIBUTION WATER SAMPLES

Date	Iron (as Fe)	Aluminum (as Al)	Silica (as SiO_2)	Calcium (as Ca)	Sulfate (as SO_4)	Magnesium (as Mg)	Copper (as Cu)	Chloride (as Cl)	Zinc (as Zn)	Poly Phosphate (as PO_4)	Ortho Phosphate (as PO_4)	Fluoride (as F)	M Alkalinity (as $CaCO_3$)	Nitrate (as NO_3)	Hardness (as $CaCO_3$)	Ammonium (as NH_4)	Dissolved Solids	pH	$CaCO_3$ Saturation Index (cold)	$CaCO_3$ Saturation Index (hot 60°C)
10/3/77	0.2	0.01	6	62	52	18	0.02	36	0.02	0.1	0.1	0.8	140	15	230	1.1	299	--	--	--
11/30/77	0.0	0.01	9	63	46	23	0.01	35	0.05	0.1	0.2	0.6	180	15	252	1.0	128	--	--	--
12/29/77	0.1	0.03	8	64	56	24	0.01	50	0.1	0.0	0.0	0.6	160	20	260	0.8	393	7.35 @ 4°C	-0.6	+0.5
3/22/78	0.1	0.13	7	46	54	15	0.00	27	0.05	0.1	0.1	0.6	104	10	176	1.6	257	7.72 @ 7°C	-0.5	+0.4
4/12/78	0.0	0.03	9	54	33	20	0.00	38	0.02	0.1	0.1	0.7	146	15	218	1.1	295	7.75 @ 12°C	-0.1	+0.7
5/15/78	0.1	0.02	5	45	33	16	0.00	30	0.05	0.1	0.0	0.8	112	13	179	0.4	301	--	--	--
7/19/78	0.4	0.03	6	50	29	18	0.01	54	0.10	0.0	0.0	0.7	128	17	200	0.6	278	7.3 @ 25°C	-0.3	+0.3
8/3/78	0.1	0.01	6	52	27	19	0.00	32	0.08	0.0	0.0	0.8	140	14	208	0.5	290	7.7 @ 25°C	-0.1	+0.6

INITIAL DISTRIBUTION

HQ AFESC/DEMR	20
HQ ADCOM/DEMUS	2
HQ AFSC/DEMU	2
HQ AFLC/DEMU	2
HQ ATC/DEMU	2
HQ AAC/DEMUC	2
HQ MAC/DEMP	2
HQ PACAF/DEMU	2
HQ SAC/DEMH	2
HQ TAC/DEMU	2
HQ USAFE/DEEO	2
HQ USAFSS/DEMU	2
HQ AFRES/DEMM	2
HQ USAFA/DEVCT	2
AFRCE-ER/S4	2
AFRCE-WR/PREHW	2
AFRCE-CR/CRNI	2
AFIT/DET	2
NGB/ANG/FSC/DE	2
HQ AFCS/DEE	2
HQ AFESC/TST	1
HQ AFESC/RDCS	2
DDC/DDA	2
HQ AUL/LSE 71-249	1
3345CES/DE	2
NCEL/L52	2
375CES/DE	2
HQ AFESC/RDCR	5
AFIT/CES	2
AFML/MXP	2
CERL	2