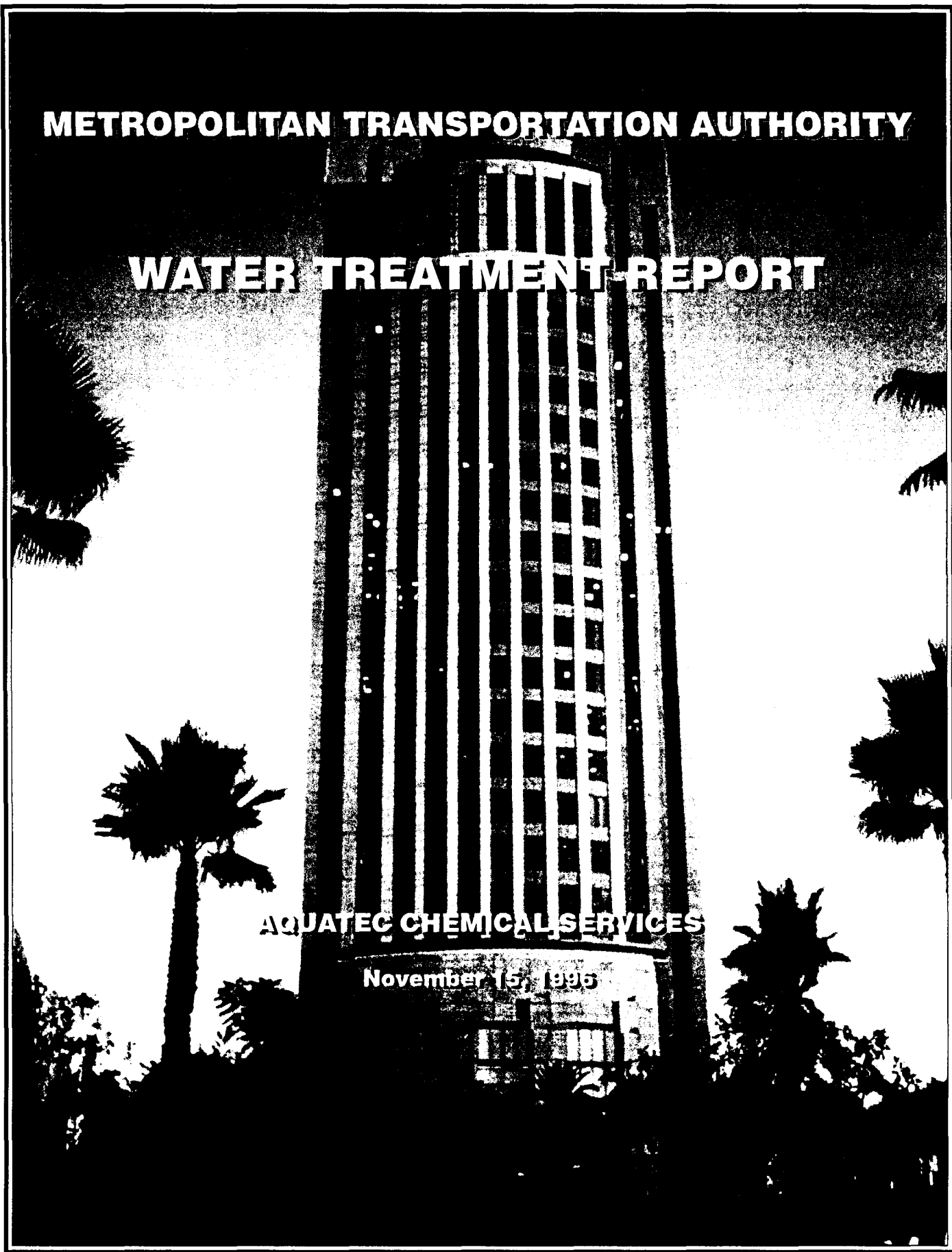


METROPOLITAN TRANSPORTATION AUTHORITY

WATER TREATMENT REPORT

AQUATEC CHEMICAL SERVICES

November 15, 1996





November 15, 1996

Key Air Conditioning Contractors, Inc.
10905 laurel Ave.
Santa Fe Springs, CA
90670

Attn: Robert Donat

Water Treatment Services
Environmental Assessment

1500 W. El Camino Ave. Suite #309
Sacramento, CA. 95833

916-863-9616
800-719-1765 (pager)

Sir;

The evaluation of the water systems at the Metropolitan Transit Authority is included herein. The report is focused on the primary cause of the corrosion in the water systems, the impact on the equipment, and the necessary action that will mitigate the situation.

The data and evaluation has been collected from the building engineers, telephonic interviews, personal interviews, and the contractors involved.

I have utilized the services of a local water laboratory to review the water chemistry of the systems. A metallurgist has evaluated the condition of the pipe surfaces for failure analysis. A water treatment specialist has produced a position paper validating the course of action that you have taken, and verification of the conclusions.

The evaluation project can be considered completed at delivery of this report. Please consider the confidential nature of the cleaning procedure, as I have developed this process over 10 years of testing and modification.

I would like to thank Ken Martin of Martin Mechanical, the building engineers, Johnny Morgan of Pankow Builders, and yourself for the assistance in assembling this information.

Sincerely;

A handwritten signature in cursive script that reads "M. Burns".

Michael Burns
General Manager

Executive Summary

EXECUTIVE SUMMARY

The water systems that have been evaluated in this report are the closed circuit condenser water, the chill water, hot water, evaporative coolers, and the cooling tower.

Each water system has been independently tested to profile the current water chemistry and evaluate biological contamination. A sample of the mild steel piping was tested at a metallurgical laboratory by an expert in failure analysis, Nathan Tiner, PhD.

The field data was reviewed to determine the sequence of events that have contributed to the current condition, and the magnitude of each event.

An evaluation to validate the analysis procedure and the overall condition was performed by a noted water treatment specialist, Dick Dudley, PhD.

The present condition of these water systems cannot be attributed to any one condition or even one contractor. The results are due to a combination of events.

The prolonged recirculation of the cleaning solution in the hot and chill waters, failure to properly passivate and chemically treat the evaporative coolers, and the ineffective cleaning of the closed circuit condenser water have created the environment for the corrosion process to occur.

Once this type of corrosion mechanism had started in the water systems, the subsequent cleanings were ineffective and actually exacerbated the corrosion to the metal surfaces.

The use of an alkaline cleaning regime did not remove the iron oxides and mineral salts that had precipitated on the metal surfaces. The continuous drain and flush without corrosion inhibitor accelerated the corrosion process.

In each of the water systems there were time periods where there was no chemical treatment, either for corrosion or biological control. Even a modest chemical cleaning with the correct chemical treatment being monitored and properly administered would result in a recirculating water that was free from corrosion products.

The design specifications calls for very specific conditions with the chemical cleaning, treating, and monitoring of these systems. The specification calls for particular chemical agents, so named, to be added to the closed systems and the cooling tower.

These conditions were not fulfilled by the chemical vendor. The impact to the successful operation of the equipment and the corrosion of the water systems cannot be quantified due to the many variables that have contributed to the present condition.

Once the hot water and the chill water had been cleaned, the systems drained and flushed, and the corrosion inhibitor added, the precipitated corrosion products will begin to reach equilibrium with the recirculating water.

Particles that are inherent to the corrosion products will dissolve and become solubilized in the recirculating water; i.e., iron hydroxides. The particle size of these dissolved solids are less than 5 microns in size.

The use of the Lakos filters to remove the hydroxides and the dissolved mineral salts from the chill water and the hot water would be ineffective. The centrifugal filter removes particles down to 80 micron, and the bag filter is currently sized for 25 micron.

The closed system condenser water was not cleaned well enough to remove the mill scale and the construction debris from the system. The lack of flow velocity during the cleaning resulted in larger particles remaining in the system.

The use of the Lakos filters to remove the debris from the closed circuit condenser would be more effective. The centrifugal filter will not impact the removal of these particles, but the bag filter at 25 micron will remove the sludge that would be in the system.

The regular treatment of the water systems during the first year has been less than satisfactory.

The maintenance of the corrosion inhibitors and the biocidal control has been out of specification on numerous occasions. This condition will exacerbate the existing corrosion in the water systems.

The evaporative coolers will continue to experience unabated corrosion due to the dezincification of the galvanized surfaces. The lack of biological control in the cooling tower will create microbiologically induced corrosion.

The closed water systems have experienced conditions of low corrosion inhibitor. When the nitrite level is less than 300 ppm, the corrosion is accelerated in the system.

By and large the chemical cleaning of each of the systems was not adequate and did not promote a clean surface that would allow the corrosion inhibitors to perform the primary function.

The chemical treating of each system was laden with equipment problems and poor chemical selection of the subsequent cleanings and the maintenance treatment.

The selection and installation of the Lakos filtration system was premature and will not effect the desired results. Given the water chemistry and the continued occurrence of high iron levels, a sand filter would be more appropriate.

The current corrosive environment can be mitigated with the implementaton of a proportional chemical feed system and the chemical treatments that are specific for removal of iron oxides and mineral salts from the recirculating water.

The corrosion products in the systems can be removed and the metal surfaces passivated. Once cleaned the water systems can be treated and maintained to achieve the desired performance of the equipment.

Analysis of Field Data

Closed Loop Chill Water;

The closed loop chill water system was constructed by Martin Mechanical. The system was cleaned at the completion of the construction. The laterals that did not have adequate recirculation were outfitted with bypass loops to insure chemical cleaner would contact all the metal surfaces.

The cleaning solution was added to the system on 6-1-95 and recirculation was established. The cleaning solution remained in the chill water piping for 3 months.

Several satellite systems were joined into the main core piping that was installed by Martin Mechanical. When these system were added the cleaning solution was diluted, and there was an increase in the concentration of contaminants; i.e. , construction debris, oil, and mill scale.

The water was tested during the cleaning period and found to have 90 ppm or iron, both suspended and dissolved.

The drain and flush occurred 8-28-95, and continued through to 9-1-95. At that time the iron level was < 1 ppm, and the system was charged with the nitrite inhibitor.

As per the specification the required addition of biocide did not occur.

The chill water was tested on 9-26-95 and found to have 500 ppm of nitrite.

On 10-10-95 the chill water is tested for nitrite and found to be 1000 ppm. Not until 11-7-95 was the iron level tested and is now up to 1.0 ppm, the nitrite level is 700 ppm.

The water is noted to be cloudy.

The next test is December 11, 1995. The water is dirty and the nitrite level is now 900 ppm. No iron tests were performed.

The system is recleaned using the drain and flush method to lower the iron level and discharge the discolored water.

On 2-16-96 an independent lab tests the chill water and finds iron levels at 7.25 ppm, and copper levels at 0.49 ppm. The high iron is indicative of a corrosion process in the system.

The system is being cleaned until 2-28-96. The nitrite is added to a level of 600 ppm.

By 3-15-96 the iron level in the chill water is > 10 ppm, and the nitrite level is down to 400 ppm. A drain and flush procedure is started.

The draining and flushing continues to April 2, 1996 at which time the iron level is < 1 ppm. Additional chemical cleaner is added and recirculation is established.

The system is again flushed to dilute the iron concentrations.
By 6-13-96 the iron levels = 0.5 ppm.

The drain and flush with no inhibitor would promote a condition of flash corrosion and result in increased iron levels.

The end of the drain and flush by 6-20-96, and the iron levels are now 6 ppm.

The installation of the Lakos filters on June 3, 1996 will do little to reduce the iron levels in the chill water. The corrosion mechanism has been in place since the first three months of recirculating cleaning solution.

The particle size of the iron oxides and hydroxides is less than 5 micron.

Iron levels remained in excess of 3 ppm after the installation of the filter.

The water analysis performed by Aquatec on 10-8-96 shows the iron levels in the chill water to be 5.2 ppm, and the copper level at 0.9 ppm.

The drain and flush procedure did not cause the problem of high iron and the corrosion of the piping. The corrosion mechanism was in place and generating iron oxides in the recirculating water.

The drain and flush procedure exacerbated or accelerated the corrosion process.

This condition will remain unabated until the entire system is chemically cleaned to remove the source of the problem. The introduction of the corrosion inhibitor was to no avail as the surfaces on the mild steel piping were fouled and would not permit the formation of the protective coating.



CHILL AND HOT WATER - POC

Date; 11-8-96

This photo shows the point of connection between the Martin Mechanical piping system for the hot and chill water with the Pro Mechanical piping system.

The configuration does not lend itself to effective recirculation of the hot and chill waters independantly from the main core piping water.

The piping configuration is designed to drain and flush a system, but not to recirculate.

The bypass size for the hot water is 3/4", and the bypass size for the chill water is 1". The diameter of the bypass would not allow for the required flow velocity to achieve the proper chemical cleaning.



ANALYTICAL REPORT

Sample From:
METROPOLITAN TRANSIT AUTHORITY
One Garden Plaza
Los Angeles, CA.
90012

Date Sampled: 10/8/1996
Date Received: 10/16/1996
Date Reported: 10/30/1996

System Identification: CHILL WATER

Sample Description: Closed System - Chill Water

Table with 2 columns: TEST DESCRIPTION and RESULTS. Rows include pH (9.4), P Alkalinity (123.2), M Alkalinity (385.2), Calcium Hardness (120.3), Magnesium Hardness (72.2), Total Hardness (230.0), Chloride (42.0), Sulfate (180.0), Silica (7.8), Conductivity (1,930.0), Nitrate (22.0), Nitrite (329.0), O-Phosphate (N/A), Iron (5.2), and Copper (0.9).

Hot Water Heating System;

The hot water heating piping was cleaned and operational by September 1, 1995. The main distribution piping was fitted with bypass loops at the end of each lateral. This was performed by Martin Mechanical to facilitate the cleaning of the distribution piping.

The water was tested by the chemical vendor on 9-1-95, and found to have an iron level of 1.5 ppm, the sample was clear.

The system was again tested on 9-26-95 and found to contain iron at a level of 0.5 ppm, and the corrosion inhibitor, nitrite = 0 ppm.

The system was cleaned at the core, and then the laterals at each floor were added to the recirculating system. The hot water loops were tested at each floor on 9-26-96 and found to have high iron levels, ranging from 0.5 ppm to 10.0 ppm. All floors had hot water that was cloudy and discolored.

— The addition of the hot water loops at each floor diluted the cleaning solution and impacted the core piping with the contaminants from the laterals.

— On 10-10-95 the hot water heating system had a nitrite level of 1200 ppm. This is the target control range for the nitrite inhibitor in hot water systems.

By 11-7-95 the hot water nitrite level had dropped to 500 ppm, and the iron level in the water was 1.0 ppm.

The system was tested again on 12-11-95 and the nitrite level was now at 900 ppm. The next test was performed on 1-8-96 and the nitrite level is 800 ppm. Indicative of dilution from other piping systems.

The next test was performed on 2-6-96, the nitrite is 300 ppm and the water sample is cloudy and dirty. No iron test was performed.

The hot water heating system was then cleaned and flushed using the drain and flush technique prescribed by the chemical vendor.

On 2-16-96 the hot water was tested by an objective laboratory. The iron level in the water was 80.7 ppm, and the copper level is 5.73 ppm.

This condition would be indicative of a chemical cleaning that was removing or solubilizing the iron and copper corrosion products from the pipe surface or areas of low flow.

The hot water system was tested again on 3-26-96. The nitrite level was 300 ppm, and the iron level was 67 ppm.

This quantity of iron present will result in the formation of insoluble particles that will precipitate in areas of low flow, such as the heat pumps.

The next test is on 4-2-96. The nitrite is added to the system and the residual is 600 ppm. The water quality is cloudy.

By 5-23-96 the next cleaning starts using the drain and flush technique with no corrosion inhibitor present.

The drain and flush has reduced the iron levels to 0.5 ppm as noted on 6-13-96.

By 6-18-96 the iron levels have increased to 4 ppm. This is the direct result of draining and refilling the system without the use of corrosion inhibitors.

The next test is 6-24-96, and the iron level is 3.5 ppm.

The installation of the Lakos filters has had little effect on this condition. The iron levels remain high and will continue to be high until the system has been chemically cleaned with an iron specific compound.

As of 10-8-96 when Aquatec sampled and performed the water chemistry, the iron level was 0.6 ppm, and the copper level was 0.4 ppm.

The biological testing shows no active bacteria or fungi in this system.

The hot water heating system will react much faster than the chill water and the closed condenser water due to the high heat.

Iron levels will continue to fluctuate as the demand for heat changes. These systems are notorious for having pockets of water that is not recirculated frequently.

Testing of the iron and nitrite should be performed frequently to insure the presence of some corrosion inhibitor and that the iron levels are not becoming exorbitant.



ANALYTICAL REPORT

Sample From:
 METROPOLITAN TRANSIT AUTHORITY
 One Garden Plaza
 Los Angeles, CA.
 90012

Date Sampled: 10/8/1996
 Date Received: 10/16/1996
 Date Reported: 10/30/1996

System Identification: HOT WATER HEATING

Sample Description: Closed System - Hot Water Heating

<u>TEST DESCRIPTION</u>	<u>RESULTS</u>
pH	9.8
P Alkalinity (as CaCO3)	302.2
M Alkalinity (as CaCO3)	649.8
Calcium Hardness (as CaCO3)	323.8
Magnesium Hardness (as CaCO3)	10.5
Total Hardness (as CaCO3)	333.3
Chloride (as CL)	41.0
Sulfate (as SO4)	182.0
Silica (as SiO2)	6.1
Conductivity, umhos/cm	2,680.0
Nitrate (as NO3).....	0.0
Nitrite (as NO2)	458.0
O-Phosphate	N/A
Iron (as Fe)	0.6
Copper (as Cu)	0.4

Closed Circuit Condenser Water;

The closed circuit condenser water could not have been effectively cleaned given the piping configuration. This system never received an adequate cleaning and treating.

The bypass loop that was placed into the piping system would not allow for recirculation at the desired flow velocity to achieve an effective cleaning.

The IBM system was cleaned by using a temporary recirculating pump, installing bypass loops at the ends of the laterals. Cleaning solution was added and recirculated. The system was drained and flushed, refilled with city water.

There was no corrosion inhibitor added prior to the introduction into the main water system.

The closed condenser water was placed into operation, and by 10-10-95, the water was "extremely dirty", and there was a strong odor.

A strong odor in a closed water system is indicative of biological fouling. Biological activity would be in the form of sulfate reducing bacteria, and are extremely corrosive to mild steel piping.

The specification calls for the addition of a biocide to the water in conjunction with the addition of the corrosion inhibitor. There is no evidence of this addition.

The system was cleaned by Burke Mechanical on 10-12-95. Comments from field reports are that the water was dirty.

The first iron test for this system was performed on 11-15-96, one month after the Burke cleaning, the results were 3 ppm.

On 11-20-96, Willardson reports on the cleaning of the Parking level. Cleaning was performed completely independent of the Burke piping

system. There is no definitive analysis of this water.

One month later, 12-11-96, the system is reported as dirty, the nitrite level is tested and found to be 100 ppm. Low nitrite levels, below 300 ppm, will accelerate corrosion.

On January 8, 1996, the system is tested and found to have only 200 ppm of nitrite corrosion inhibitor. At this time a biocide is added to the recirculating water, three months after the odor has been detected.

A pipe was damaged in the system on 2-6-96, treated water was discharged. The nitrite level was 600 ppm before the break, and reduced to 0 ppm as a result of the lost water.

At the same time several heat pumps are going off on high head pressure, and required acid cleaning to maintain the system.

Several times during the first year of operation the condensers were acid washed to reduce the head pressure.

The combination of an acid wash on a condenser and an alkaline cleaning will elevate the pH of the recirculating water and force the precipitation of metal salts; i.e., iron hydroxide and copper hydroxide.

The closed condenser water was again tested on 2-28-96. The nitrite level was 0 ppm. Water was said to be dirty. A drain and flush was established to remove the dirty water and dilute the iron.

The drain and flush continued through to 3-15-96. Heat pumps were shutting down and required acid cleaning. The nitrite level was 0 ppm, and the iron results were +10 ppm.

The system was tested again on 5-2-96. The iron level was 2 ppm, and individual units were being backwashed to improve efficiency.

By 5-23-96 the iron level had reached 6 ppm, no test for nitrite at this time.

The system was cleaned starting on 6-13-96 using an alkaline cleaning

solution, and the drain and flush procedure.

Within 1 week, 6-20-96, the iron level was 10 ppm, with no inhibitor present.

The drain and flush lowered the iron level to 1.5 ppm on 6-24-96, no inhibitor present.

During the month of July the closed condenser water was tested for iron levels and found to ranging from 2 to 3 ppm.

The water analysis that was performed by Aquatec showed iron at 2.8 ppm, and copper at 0.2 ppm.

The water chemistry is very low in hardness indicating the precipitation of the calcium and magnesium on the heat transfer surfaces. The alkalinity is excessive at 1,121.6 ppm, and the nitrite inhibitor level is low at 188.0 ppm.

The conditions in this system are indicative of a highly corrosive environment. The presence of iron will promote corrosion, the lack of corrosion inhibitor will not prevent the problem and only exacerbate the condition.

■ Draining and flushing the system for several weeks with no corrosion inhibitor present will result in flash corrosion and perpetuate the condition.

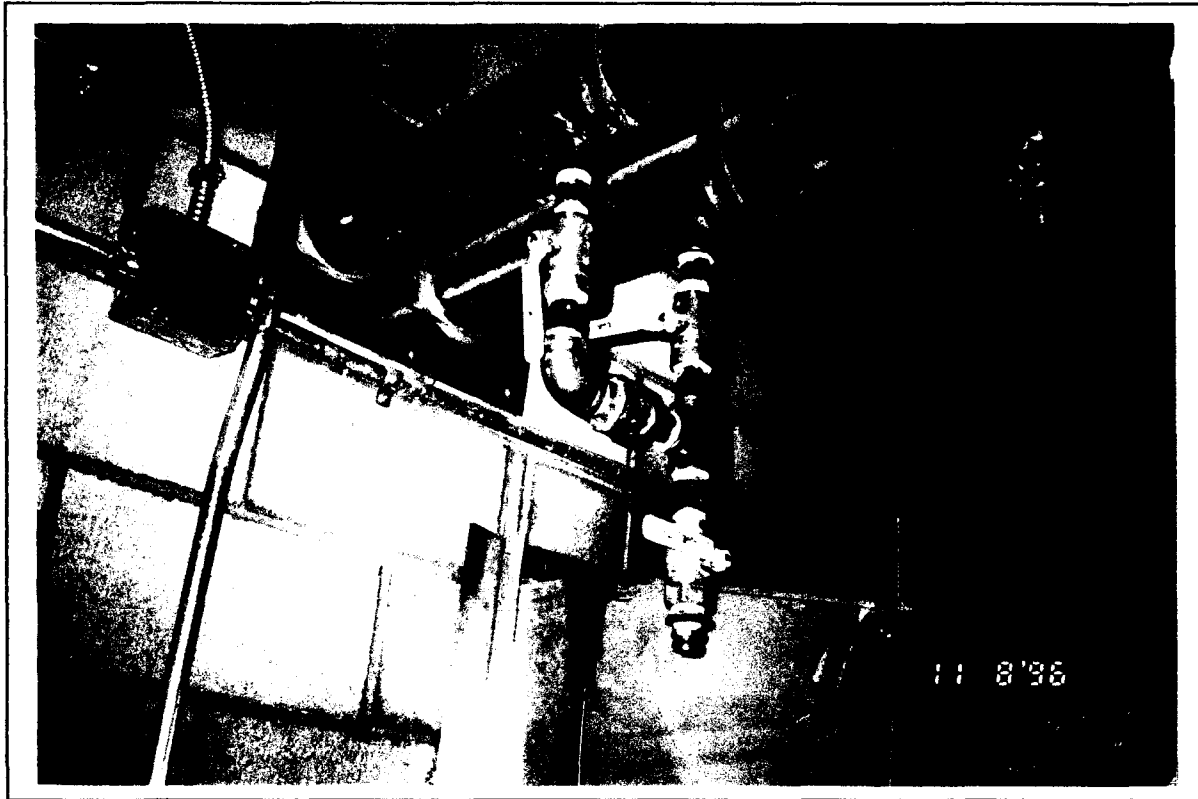
The biological testing resulted in no active algae or fungi in this system.

Due to the deposits of mineral salts, this system will require acid cleaning of the condensers on a regular basis until the entire system has been chemically cleaned and the corrosion inhibitors maintained.

The Lakos filtration system would be beneficial in removing the sludge that was generated by the combination of acid cleanings of the heat pumps, and the subsequent alkaline cleanings of the recirculating system.

These two cleaning programs will cause the pH of the system to fluctuate and promote the formation of sludge. This sludge will build up in the areas of low flow and must be removed from the system.

The samples of debris that were removed with the Lakos bag filter are indicative of this type of sludge formation. Continue to use the filtration system and maintain the nitrite levels of corrosion inhibitor.



CLOSED CONDENSER - POC

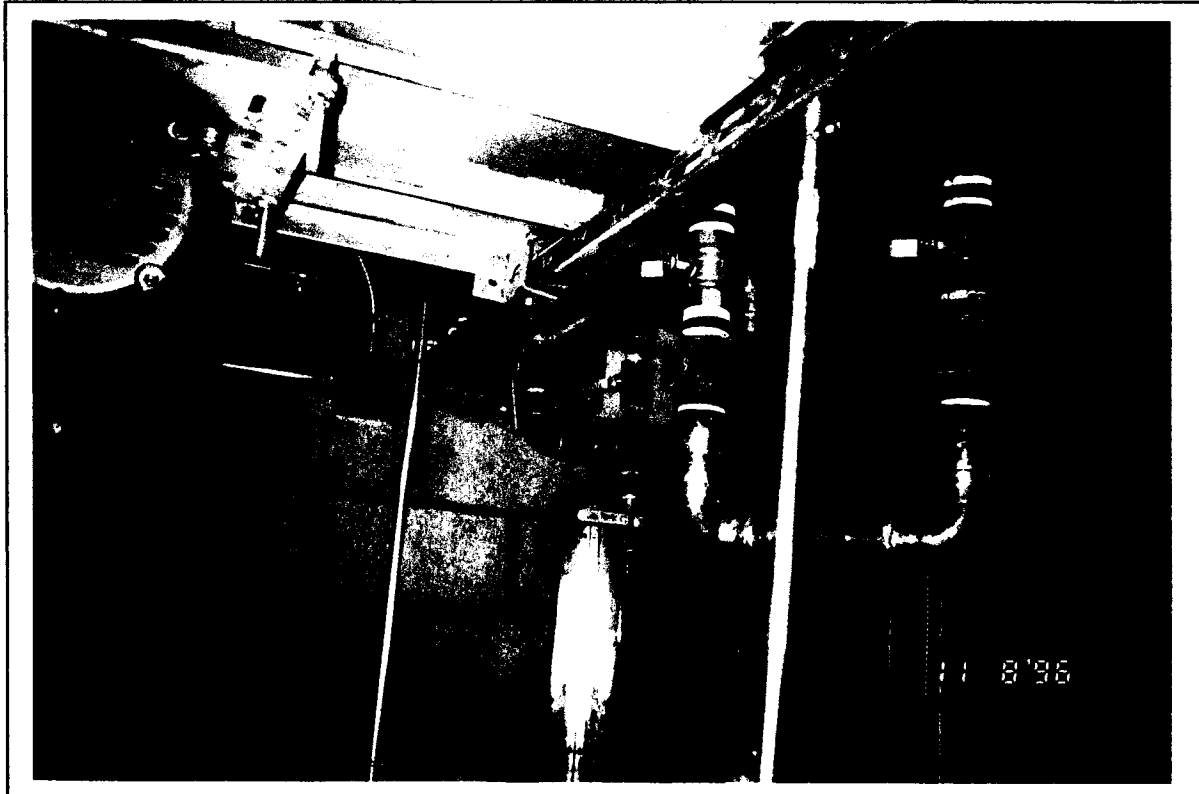
Date; 11-8-96

This photo shows the point of connection between the Burke Mechanical piping system for the closed circuit condenser water with the Willardson Mechanical piping system.

The piping configuration is designed to drain and flush a system. The two valves at the 4" pipe could be used to recirculate if a temporary pump was used.

The bypass size for the 4" recirculating line is 1" in diameter. This piping configuration could be used as a loop to promote recirculation during the cleaning process.

The flow through the 1" bypass is not adequate to achieve the desired flow velocity for a chemical cleaning.



CLOSED CONDENSER - POC

Date; 11-8-96

This photo shows the piping configuration used by Willardson Mechanical for the chemical cleaning of the piping system, closed condenser circuit water.

The bypass that has been installed is 2", for a 4" distribution pipe. The system can be isolated from the main distribution water.

The recirculating pumps in this area would be adequate, with the 2" bypass to generate the desired 3 to 5 feet per second flow velocity.

The piping configuration and the pump rating will produce an effective chemical cleaning.



ANALYTICAL REPORT

Sample From:
 METROPOLITAN TRANSIT AUTHORITY
 One Garden Plaza
 Los Angeles, CA.
 90012

Date Sampled: 10/8/1996
 Date Received: 10/16/1996
 Date Reported: 10/30/1996

System Identification: CLOSED CONDENSER WATER

Sample Description: Closed System - Closed Circuit Condenser

<u>TEST DESCRIPTION</u>	<u>RESULTS</u>
pH	10.7
P Alkalinity (as CaCO3)	711.8
M Alkalinity (as CaCO3)	1121.6
Calcium Hardness (as CaCO3)	11.4
Magnesium Hardness (as CaCO3)	3.3
Total Hardness (as CaCO3)	14.7
Chloride (as CL)	45.0
Sulfate (as SO4)	184.0
Silica (as SiO2)	8.2
Conductivity, umhos/cm	2,780.0
Nitrate (as NO3).....	14.0
Nitrite (as NO2)	188.0
O-Phosphate	N/A
Iron (as Fe)	2.8
Copper (as Cu)	0.2

Cooling Tower Condenser Water;

This system was cleaned out prior to operation. The cooling towers were drained and flushed and hosed out, and the condenser piping was cleaned with a chemical cleaner.

The specification calls for the use of "molybdate" corrosion inhibitors and alternating biocides. This condition of the specification was clearly not met.

The chemical treatment that was provided was a blend of phosphonates and dispersants. The benefit of having molybdate as the primary corrosion inhibitor is the ability to passivate and prevent corrosion.

The phosphonates that were used are primarily scale inhibitors that prevent the formation and deposition of calcium carbonate scale. There is no corrosion protection provided by the scale inhibitors.

The concept is that if there are no calcium carbonate deposits, then there will be no underdeposit corrosion, and no need for the corrosion inhibitor.

The use of molybdate would also provide metals passivation of the galvanized and mild steel surfaces. The absence of the passivation step and the lack of corrosion inhibitor has resulted in the corrosion that has occurred in this system.

The iron levels to date are not excessive, < 0.5 ppm, and the chiller tubes have not been compromised. There has been "excessive" build up of iron oxides and corrosion products on the ends of the chillers. This condition has been corrected.

Presently the mechanical discharge of water from the system is fully operational, and the control equipment is working well. A corrosion coupon rack should be installed on the condenser water to monitor the corrosion and fouling.



ANALYTICAL REPORT

Sample From: METROPOLITAN TRANSIT AUTHORITY
One Garden Plaza
Los Angeles, CA.
90012

Date Sampled: 10/8/1996
Date Received: 10/16/1996
Date Reported: 10/30/1996

System Identification: COOLING TOWER

Sample Description: Cooling Tower Recir. Water

Table with 2 columns: TEST DESCRIPTION and RESULTS. Rows include pH (7.4), P Alkalinity (<0.1), M Alkalinity (38.8), Calcium Hardness (696.3), Magnesium Hardness (269.0), Total Hardness (965.3), Chloride (98.0), Sulfate (1040.0), Silica (76.9), Conductivity (2,250.0), Nitrate (NA), Nitrite (NA), O-Phosphate (4.7), Iron (NA), and Copper (NA).

Evaporative Coolers;

The evaporative coolers were cleaned prior to operation. There is no documentation regarding the chemical concentrations or duration of cleaning.

On 8-18-95 the chemical treatment was started for the system. There were no provisions for the metals passivation as specified by the equipment manufacture.

The construction specification calls for the use of "molybdate" corrosion inhibitors and alternating biocides. This condition of the specification was clearly not met.

The chemical treatment that was provided was a blend of phosphonates and dispersants. The benefit of having molybdate as the primary corrosion inhibitor is the ability to passivate and prevent corrosion.

The phosphonates that were used are primarily scale inhibitors that prevent the formation and deposition of calcium carbonate scale. There is no corrosion protection provided by the scale inhibitors.

The concept is that if there are no calcium carbonate deposits, then there will be no underdeposit corrosion, and no need for the corrosion inhibitor.

The use of molybdate would also provide metals passivation of the galvanized and mild steel surfaces. The absence of the passivation step and the lack of corrosion inhibitor has resulted in the corrosion that has occurred in this system.

The importance of the passivation step can only be realized when this procedure has not been completed. The galvanized surfaces will quickly begin to degrade and the zinc will go into solution with the recirculating water.

Within two months of operation the chemical vendor documented the "dirty water" that being recirculated in the evaporative condensers and recommended an additional cleaning.

On 10-10-95 the condition of the system had deteriorated to the point of having scaled heat transfer surfaces, white rust is evident, the chemical residual is low, the water is dirty.

The white rust becomes an issue, and by 10-19-95 the dezincification and the formation of the zinc salts is excessive.

The use of pH controllers at this point will have little if any effect on the white rust. Lowering the pH will prevent any further zinc removal, but it will not remove the existing white rust.

The condition of precipitated salts of zinc and calcium will promote underdeposit corrosion. The system must be chemically treated within industry guidelines and maintained.

The corrosion is not excessive at this point in time. The chemical treatment has been as high as 60 ppm, the normal operating parameters are 4 to 10 ppm.

The conditions that were observed on 10-8-96 resulted in the following chemical analysis.

The pH was high at 9.0, normally the pH should be 7.6 to 8.0. The corrosion inhibitor, 2.7 ppm, levels were within normal ranges.

This system must be watched very closely to insure the zinc hydroxides and calcium salts do not form.



ANALYTICAL REPORT

Sample From:
 METROPOLITAN TRANSIT AUTHORITY
 One Garden Plaza
 Los Angeles, CA.
 90012

Date Sampled: 10/8/1996
 Date Received: 10/16/1996
 Date Reported: 10/30/1996

System Identification: EVAPORATIVE CONDENSER

Sample Description: Evap. Condenser Recirculating Watr

<u>TEST DESCRIPTION</u>	<u>RESULTS</u>
pH	9.0
P Alkalinity (as CaCO ₃)	64.2
M Alkalinity (as CaCO ₃)	453.2
Calcium Hardness (as CaCO ₃)	579.1
Magnesium Hardness (as CaCO ₃)	300.1
Total Hardness (as CaCO ₃)	879.2
Chloride (as CL)	114.0
Sulfate (as SO ₄)	550.0
Silica (as SiO ₂)	61.9
Conductivity, umhos/cm	2,060.0
Nitrate (as NO ₃).....	NA
Nitrite (as NO ₂)	NA
O-Phosphate	2.7
Iron (as Fe)	NA
Copper (as Cu)	NA

Analytical Documentation - Field Reports and Correspondence

8-1-95

Chill water; chill water iron < 1 ppm.
Hot water;
Closed condenser;
Evaporative Condensers;
Cooling Towers;

8-18-95

Chill water;
Hot water;
Closed condenser;
Evaporative Condensers; started chemical treatment.
Cooling Towers;

9-1-95

Chill water; clear sample, iron < 1 ppm, added inhibitor
Hot water; clear sample, iron = 1.5 ppm
Closed condenser; IBM system cleaned, no inhibitor
Evaporative Condensers;
Cooling Towers;

9-26-95

Chill water; nitrite = 500 ppm.
Hot water; nitrite = 0 ppm, iron = 0.5 ppm.
Closed condenser;
Evaporative Condensers;
Cooling Towers; cycles are high.

9-26-95

Hot Water;

<u>Floor</u>	<u>Iron</u>	<u>Clarity</u>	<u>Floor</u>	<u>Iron</u>	<u>Clarity</u>
27	0.5	clear	11	4.0	cloudy
25	8.0	cloudy	9	3.0	cloudy
23	3.0	clear	7	3.0	cloudy
21	8.0	cloudy	5	3.0	cloudy
19	10	clear	3&4	3.0	cloudy
17	3.0	cloudy	1	10	cloudy
15	2.0	clear	13	4.0	cloudy

10-5-95

Evaporative condensers; Systems are on line, Chempro recommends Burke reclean due to dirty water.

10-10-95

Chill water; nitrite = 1,000.

Hot water; nitrite = 1,200 ppm.

Closed condenser; water is extremely dirty, and has not been cleaned, strong odor.

Evaporative Condensers; scaled and dirty, cycles are high, chemical inhibitor level is low

Cooling Towers; cycles are high.

10-12-95

Closed condenser; water is extremely dirty, Burke cleans the piping.

10-19-95

Evaporative Condensers; white rust is observed on evaporative condensers.

11-7-95

Chill Water; nitrite = 700 ppm, iron = 1.0 ppm, cloudy

Hot Water ; nitrite = 500 ppm, iron = 1.0 ppm

Evaporative Condensers; tubes are scaled, and the inhibitor level is low for both units.

Closed condenser; iron = 3 ppm.

Cooling Tower; good control, no problems

11-15-95

Evaporative Condensers; Chempro recommends the installation of loaner pH controllers to prevent white rust formation.

11-20-95

Closed condenser; Willardson reports on the cleaning of the Parking Level, independent of the recirculating water.

12-11-95

Chill water; nitrite = 900, dirty.

Hot water; nitrite = 900 ppm.

Evaporative Condensers; scale on both units.

Closed condenser; nitrite level = 100 ppm, dirty water

Cooling Towers; good control, no problems.

1-8-96

Chill water; nitrite = 700, water is dirty and discolored

Hot water; nitrite = 800 ppm.

Closed condenser; nitrite = 200 ppm, added biocide.

Evaporative Condensers; dirty water and scale on both units. Extremely high chemical residual, 60 ppm, normal level is 10 ppm.

Cooling Towers; good control, no problems.

2-6-96

Chill Water; nitrite = 800 ppm, water is dirty

Hot Water; nitrite = 300 ppm, cloudy and dirty.

Closed Condenser; nitrite = 600 ppm, break in the pipe and water loss.

2-8-96

Closed condenser system; Airflow units were shutting down due to high head pressure.

2-15-96

Chill Water; system is being recleaned with a cleaning solution and by a drain and flush method.

Hot Water; system is being recleaned with a cleaning solution and by a drain and flush method.

2-16-96

(Analytical report from Michelson Laboratories)

Chill Water; Copper = 0.49 ppm, iron = 7.25 ppm, ash = ND

Hot Water; Copper = 5.73 ppm, iron = 80.7 ppm, ash = 0.03

2-28-96

Chill Water; nitrite = 600 ppm, cleaning in process.

Hot Water; nitrite = 700 ppm, draining

Closed Condenser; nitrite = 0 ppm, water is dirty, flushing to lower iron.

3-15-96

Chill Water; dirty and muddy, iron > 10 ppm, nitrite = 400 ppm, draining

Hot Water;

Closed Condenser; heat pumps are going off on high head pressure, iron level is > 10 ppm, nitrite = 0 ppm.

Evaporative Coolers;

Cooling Towers;

3-16-96

Closed Condenser; units were acid washed, strainers revealed "construction debris and mud."

3-27-96

Hot Water; nitrite = 300 ppm, iron level = 67 ppm

4-2-96

Chill Water; flushing, iron < 1 ppm.

Hot Water; nitrite = 600 ppm, cloudy

4-5-96

Chill Water; chemical cleaning, recirculated for minimum 72 hours.

5-2-96

Closed Condenser; individual units are being acid washed and backflushed,
iron = 2 ppm

5-23-96

Chill Water; flushing to dilute iron levels
Hot Water; flushing to dilute iron levels
Closed Condenser; iron = 6 ppm

6-13-96

Chill Water; continuous flushing, iron level = 0.5 ppm.
Hot Water; continuous flushing, and backflushing units, iron = 0.5 ppm
Closed Condenser; reclean with cleaning solution.

6-18-96

Chill Water; iron = 6 ppm
Hot Water; backflushed garage units, iron = 4 ppm
Closed Condenser; acid cleaned condensers

6-20-96

Chill Water; iron = 8
Hot Water; iron = 3 ppm
Closed Condenser; alkaline chemical cleaning, iron = 10 ppm

6-24-96

Chill Water; iron = 8
Hot Water; iron = 3.5 ppm
Closed Condenser; drain and flush, no inhibitor, iron = 1.5 ppm

7-3-96

(filters are going in)

Chill Water; iron = 16 ppm

Closed Condenser; iron = 3 ppm

7-29-96

Chill Water; Eddy current test on chiller tubes, no problems with corrosion, chiller heads have excessive amounts of rust and mud.

iron = 10 ppm

Hot Water; iron = 2 ppm

Closed Condenser; iron = 2 ppm

10-8-96

Chill Water; iron = 5.2 ppm, copper = 0.9 ppm, nitrite = 458 ppm

Hot Water; iron = 0.6 ppm, copper = 0.4 ppm, nitrite = 188 ppm

Closed Condenser; iron = 2.8 ppm, copper = 0.2 ppm, nitrite = 188 ppm

Evaporative Coolers;

Cooling Tower;

Technical Treatise

TECHNICAL TREATISE

The information included in Dr. Dudley's report is a validation of the efforts made by the contractors, Key Mechanical and Pankow Builders.

The recommendations to seek expert advice and generate an evaluation of the conditions and the recommendation to clean the system verifies the action taken by all parties is sound and will be beneficial.

The conclusion from his report also supports the conclusions derived from the field data and the analytical work included herein.

Dr. Dudley has addressed the contributing factors that have resulted in the present condition, the use of the Lakos filters, and the scope that is included in this report.

Albeit technical in nature Dr. Dudley concurs with my analysis and supposition that the root cause of the problem with the closed water systems was the initial cleaning and treating of the systems.

The use of the Lakos filtration system will not be effective with the corrosion products that have resulted from the inadequate chemical cleaning. Although, filtration can be beneficial in this type of system.

The resulting condition of the closed condenser water has been greatly enhanced by the Lakos filters, as there was considerable debris in the closed condenser loop.

The subsequent cleaning procedures are also addressed by Dr. Dudley. His finding is in concert with the analysis of the field data.

The condition can be corrected chemically and with proper maintenance of the systems will be completely mitigated.

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METROPOLITAN TRANSPORTATION AUTHORITY **CHILLED WATER SYSTEM** **POSITION PAPER**

PREPARED FOR:

CHARLES PANKOW BUILDERS, LTD. AND
KEY AIR CONDITIONING CONTRACTORS

Analysis & Report By:

Richard P. Dudley, Ph.D.
Owner/Principal
Water Treatment Specialist

November 14, 1996

"We Treat the Problem - Not Just the Water"

I. INTRODUCTION AND REPORT ORGANIZATION

A.) BACKGROUND

This report has been prepared for you by Water Management Services at the request of Mr. Mike Burns. The purpose is to address a chilled water corrosion problem that exists in the new MTA facility in Los Angeles.

This report and the recommendations contained herein are based on conversations with Mr. Mike Burns, and are accurate to the best of his knowledge and our discussions concerning the situation.

This report provides a brief discussion of the problem, suggests a direction for you to follow to correct the problem that currently exists, and shows you how to keep the problem from recurring in the future.

This report briefly discusses why the problem happened, but will concentrate more on the aspects of the problem pertaining to "What do we do to get out of this problem" and "How do we keep from doing it again".

B.) REPORT ORGANIZATION

The report is organized as follows:

Section I - Introduction & Report Organization

Section II - Summary

Section III - Defining the Problem

Section IV - What Happened?

Section V - What Went Wrong and What to do Next Time

Section VI - What Should Be Done Next?

Section VII - What Would an Evaluation Entail?

II. SUMMARY

A.) THE DIRECTION YOU SHOULD BE HEADED

There are basically four steps that must occur to resolve this situation in which you find yourself. Based on discussions with Mike Burns, plus my perception of the situation you are in, the direction in which you should be headed is as follows:

(1) You need to understand what happened so you won't make the same mistake again. However, what you need most is to have someone help you find a cost effective way out.

(2) We need to determine the owner's exact criteria for acceptance of the system, and determine whether they will believe recommendations from an independent third party like Water Management Services. This is absolutely critical to successful resolution of the problem.

(3) You need to have someone evaluate the chilled water system to determine the exact problem as it now exists. A plan then needs to be developed to correct system deficiencies to get the system to the point that the owner will accept it, and then the project needs to be followed up to assure that things are being done as recommended.

(4) As part of the problem resolution the owner should be provided with recommendations for a chilled water system treatment program which will assure that problems won't arise in the future. This should be considered as a bonus for both you and the owner, because this will greatly minimize the chance for a recurrence of problems in the future that could be blamed on the problems you're having right now.

(5) Develop your own cleaning specifications so you won't have to go through this again.

B). WHY AN ON-SITE EVALUATION WILL BE NECESSARY

Because this is a unique problem which will require a custom designed solution, the solution to this particular problem is not available in any book and won't be available until an on-site evaluation and analysis have been completed.

You will need a specialist to help you resolve the problem because many assumptions will be required while making the evaluation and analysis.

For a problem like this one, it is important to use a rifle rather than a shotgun approach to achieve an effective solution at a reasonable cost.

III. DEFINING THE PROBLEM

A.) EXACTLY WHAT IS THE PROBLEM?

The full extent of the problem won't be known until an evaluation has been completed. However, following is my perception of the problem based on the information now available.

- Chilled water system contains high levels of iron.
- Iron deposition has been observed in a section of pipe about 20 to 30 feet downstream of the pump.
- Minor corrosion has been observed. A pipe sample analyzed by Dr. Tiner indicates iron deposition to the extent of about 1/16 inch in chilled water pipe and 1/32 inch in hot water system. Deposit was around entire circumference of pipe but was thicker on bottom of pipe. Metal loss reported to be 5%, with some pitting.
- Some compressors cooled by chilled water have required cleanings, but it is unclear whether it was caused by corrosion or slime forming bacteria.
- The real problem appears to be that the owner fears major problems with the chilled water system after he accepts the systems. This is because of high iron levels in the water and iron deposition in the piping system.

B.) WHY DID THE PROBLEM DEVELOP?

The problem developed because the right combination of events occurred. The right combination of events is absolutely essential for a problem like this to occur. Under different conditions the problem might have been much less severe.

The severity of the problems you experienced is dependent on many factors - such as the make up water used, the types of ingredients in the alkaline cleaner, decomposition products of the cleaner which formed during extended operation, operating conditions during the cleaning, the amount of debris in the system, and length of time the solution was in the system.

Prolonged circulation of cleaner without recharging and draining to remove debris removed by cleaning, coupled with alternating between circulation and stagnation, is far more corrosive to a chilled water system than just allowing the system to sit full of stagnant city water.

Being exposed to weak cleaning solution and debris from cleaning for three months probably caused the majority of corrosion.

Repeated cleanings probably didn't cause as much corrosion as the original 3 month cleaning. However, the 3 additional cleanings may not have helped that much either - because the type of deposits laid down during the initial 3 month period would probably NOT be removed by alkaline cleaner.

Alkaline cleaners are designed primarily for mill scale, grease, oil, and dirt. To remove deposited iron generally takes acid cleaning or one of several types of sequestrant or chelant treatment under controlled pH conditions. What to do is a judgement call.

Filtration was probably NOT very effective. The Lakos filter and 25 micron bag filter are good for things like pipe scale and sand. They are generally NOT good for iron (rust) resulting from corrosion. The dispersant will also generally keep the iron in a finely dispersed state - often less than 5 to 10 microns - which makes it more difficult to remove.

C.) HOW SERIOUS IS THE PROBLEM?

Because this can't be determined without investigating the problem in more depth, an evaluation will be required before the extent of the problem will be known.

D.) FACTORS CONTRIBUTING TO THE PROBLEM

- The way the initial cleaning was done.
- Lack of draining after each segment was cleaned.
- Subsequent cleanings.
- Not recharging with cleaner as system volume increased and cleaner strength decreased.
- Things that happened as a result of cleanings and flushes.
- Possible lack of proper filtration.

E.) HOW DIFFICULT WILL THE PROBLEM BE TO CORRECT?

For someone who knows what he is doing - it will be relatively straight forward.

The way people normally fix a problem like this is to attempt to figure it out by themselves using trial and error. This is not advisable for a situation like this one unless you've had many years of water treatment experience and you really understand what you're doing. Mistakes can be costly.

It is important to use the rifle rather than the shotgun approach to get the best solution in the least amount of time.

IV. WHAT HAPPENED?

A.) PREDICTIONS ARE DIFFICULT WHEN DATA IS LACKING

Trying to predict exactly what happened or what it will take to get you back to normal is like looking at someone in poor health and trying to guess whether it was caused by smoking, drinking, carousing, lack of sleep, poor nutrition, high stress, poor hygiene, etc.

A similar problem exists when trying to predict what happened in your system because we don't know exactly what cleaner was used and how much of each ingredient it contained. We don't know how soon each ingredient in the cleaner became expended. We don't know what the critical water parameters like pH were during cleaning. Nor do we know the types and amounts of contaminants present in the water or how much dirt, mill scale, oils, etc., was on the pipes. Without this information - which will probably NOT be available - we can only speculate.

What we can tell you is that the problems from which your system is suffering are treatable, and that we can show you how to help the system regain it's "good health" status.

The types of water problems people experience as a result of improper treatment are analogous to the way people respond upon exposure to disease causing germs. Some people remain healthy, some get sick, and some die. Improper water treatment likewise can result in no problems, minor problems, or major problems.

What happened in your system seems to be like the one who was exposed to germs and got sick. What is needed now is a diagnosis of what kind of "sickness" your chilled water system has so we can get you back on the road to recovery.

B.) WHAT PROBABLY HAPPENED

- The alkaline cleaner became weaker through dilution as the laterals were cleaned and more water was added to the system.
- The pH dropped with time and corrosion protection decreases as the pH drops.
- The detergent(s) in the cleaner, in addition to being diluted as more water was added to the system, may have become expended from reacting with oil and grease in the pipes.
- Copper corroded by the chilled water generated soluble copper ions which then plate onto steel surfaces - which dramatically increases corrosion of steel. Copper plating would be worse if the pH dropped below 8.5 - which it probably did.

- Stagnant conditions lead to deposition in piping, as indicated by thicker deposits in the bottom of pipe samples inspected.
- Los Angeles city water is corrosive due to high chloride at a relatively neutral pH. High chloride in the make up water leads to dramatically increased under deposit corrosion, pitting, and acceleration of general corrosion.
- Hardness present in the water at high levels will precipitate with phosphate to form sludge deposits containing calcium and magnesium phosphate.
- Deposits harbor anaerobic corrosive bacteria that generate acids which corrodes steel.
- The pH of the system when the cleaner was present undoubtedly dropped below 10.5 (which is about the lowest pH which gives consistently good corrosion protection). Once pH drops below 10.5 localized and under deposit corrosion occurs and become serious. If the pH had remained above 11.0, corrosion would probably have been minimal.
- Corrosion occurred due to flash rusting as the system was being drained after cleaning, since corrosion inhibitor was NOT added until after iron levels dropped to 1.0 ppm or less as a result of the drain & flush following each cleaning.
- Because of the length of time the cleaner was allowed to remain in the chilled water system, the detergent and dispersants could have broken down into acidic components that could actually have contributed to corrosion.

V. WHAT WENT WRONG & WHAT TO DO NEXT TIME

The major contributor to the problem was probably the circulation of the cleaning solution for three months without replenishing the treatment chemicals or draining to remove sludge and debris.

However, circulating cleaning solution for three months could probably have been done if you had controlled it differently. The word probably has been used because an evaluation has not been performed yet and we're having to make some assumptions. Here's what you could have done.

A.) HOW SYSTEM COULD HAVE BEEN SUCCESSFULLY CLEANED

(1) You could have added fresh cleaner to maintain certain ingredients and chemical parameters in the water - to replace chemicals expended and lost during the cleaning and flushing process. This would require testing of a few different parameters.

- Think about the last time you washed dishes by hand. When you ran out of suds you added more soap. It's the same with the cleaning solution used in chilled water systems - you need to keep adding cleaner when you keep adding piping and equipment to be cleaned.

(2) Drain the system after cleaning each new segment. Discharging water to drain is usually necessary as the cleaning progresses to remove particulate matter and debris before it settles out in the system - especially if stagnant conditions will exist (as they undoubtedly did).

(3) Because hard water make up to this system was used, lime scale would be expected to have precipitated in the water to form sludge. To avoid sludge formation would have required the use of a water softener to remove hardness from the make up. To avoid sludge formation, soft water should be used for alkaline cleaning and for repeated drain and flush operations.

The cleaning might have worked without incident if water had been drained from the system after each new segment was cleaned, followed by the use of additional cleaner to bring the cleaner level up to operating specs as established by the chemical company.

The correct way to have done the cleaning is to treat, drain, flush, and add more cleaner. If required to do what you did, it is necessary to add more chemical, test to maintain levels of phosphate and keep pH in spec; and discharge from various points in the system to remove mill scale, dirt, oil & grease, and other debris removed by cleaning.

B.) HOW TO MAINTAIN CLEANER LEVELS IN SYSTEM

A key point is to add more cleaner when make up water is added to the system or whenever water is discharged. There are several ways to do this:

- (1) Monitor make up into the system (if it only goes in one location) and add cleaner automatically by pump whenever make up is added.
- (2) Monitor make up addition as in (1) but slug feed cleaner using a pot feeder.
- (3) Test the water for phosphate, pH, and detergency (foam) and add cleaner as needed (using pump or pot feeder).

C.) DEVELOP CLEANING SPECS TO AVOID FUTURE PROBLEMS

For future cleanings, it would help considerably if you were to develop some specifications for the alkaline cleaner needed to do the job. You could eliminate quite a few problems by doing this. This is the only way to achieve uniformity. Otherwise what you need to do to stay in spec will vary quite a bit from one manufacturer to another. You don't need to be "overly exacting" - you will just need to specify the type of ingredients and levels of treatment required.

Specify levels of product or activity - like suds in a water sample that has been shaken. For example:

- (1) The pH should be an absolute minimum of 10.5 (11.0 would be even better), and higher if specified by the chemical company.
- (2) Enough detergent (surfactant) should be maintained in the system to generate a at least a thin layer of foam when a sample of treated water is collected in a jar and shaken vigorously. This means enough detergent is left to in the water to handle grease, oil, etc. in the new piping being tied into the system. If we wanted to get specific on foam we could say how thick the foam level should be, what size jar should be used, to what level it should be filled, and for what amount of time it should be shaken.
- (3) The level of phosphate would also be tested by the operators and would be maintained at a level to be specified by the supplier of the cleaner.
- (4) The level of dispersant polymer would probably NOT be specified because that test is generally difficult and somewhat inaccurate.
- (5) Draining & flushing at low points in the system to remove debris from the water each time another segment is added to the main loop would be mandatory.

The problem with long term circulation of cleaner is that if pH drops below 10.5,

bacteria can degrade the dispersant and detergent, resulting in breakdown products that could actually increase corrosion as well as NOT be available for cleaning - resulting in dirty piping with many sites for under deposit corrosion . In a high chloride water like you've got, this could result in serious corrosion problems.

The exact pH and levels of ingredients required to clean a chilled water system can't be listed in this letter because required levels will depend on the exact types and levels of caustic, phosphate, dispersant, and detergent in the cleaner being used - which will vary between manufacturers.

VI.) WHAT SHOULD BE DONE NEXT?

A.) DO AN EVALUATION

Just as a Medical Doctor can't prescribe a drug for a condition he hasn't diagnosed (and they won't try to diagnose it over the phone) - a treatment can't be recommended until an on-site evaluation has been completed when the problem is unusual - like this one is.

When you're sick, it takes a trip to the doctor for an evaluation and diagnosis before you can be cured and things return to normal. In your case you need someone to come to your site, evaluate your problem, analyze your situation, form a diagnosis, look at available options, develop recommendations, and then prepare an action plan specifically to meet your needs.

Your next step should be to have your system evaluated by an experienced water treatment specialist - someone who specializes in resolving water treatment problems and who has experience with chilled water systems.

As a result of the evaluation, you need to develop a plan to define success in the eyes of the customer, determine how you will convey this to the customer, and help them choose a water treatment program that will preclude future problems.

B.) UNIQUE PROBLEMS REQUIRE CUSTOM SOLUTIONS

Because the circumstances surrounding your particular problem are unique, a custom solution developed specifically for this problem will be required.

Also, because all of the data necessary to make decisions is generally NOT available during the evaluation, assumptions are required.

For instance you're probably wondering if another cleaning is in order - and if so - what type. This is a judgement that cannot be made until the evaluation has been completed and the data analyzed.

C.) LETTER TO THE OWNER MIGHT BE HELPFUL

A letter to the owner from a third party might help you by explaining the situation, discussing the evaluation, and submitting a plan to resolve it, including benchmarks and monitoring tools to show the success of the program.

D.) ESTIMATED TIME REQUIREMENTS FOR EVALUATION & REPORTING

Many different steps are required, as shown in the attached seven step plan used by my company to resolve problems.

- On-site data and information gathering would be expected to take about 2 to 3 days.
- The time required off-site will depend on what you want to do. Analyzing the data gathered; developing a diagnosis; evaluation of options; preparing recommendations & an action plan; preparation of report; and time to help you follow up the project would normally be expected to take about 6 to 8 days (and possibly less if things go smoothly).
- Optional help, such as writing a letter to the owner, developing a chilled water treatment program specification for the owner to preclude future problems, and development of specification for future cleaning chemicals could take several additional days.

E.) FACTORS INFLUENCING EVALUATION & REPORTING REQUIREMENTS

A number of different factors will have an impact on time requirements and cost for resolving this problem. They include:

- What will constitute success in the mind of the owners?
- Will the investigation cover one building or two?
- What is the possibility that the legal departments will get involved? (A higher degree of accuracy of writing is required).
- Will additional visit(s) be required?
- Will meeting(s) with the owner be required?

VII. WHAT WOULD AN EVALUATION ENTAIL?

Following is a partial listing of what should be done during an evaluation.

- Based on the composition of the cleaner chemical and operating conditions during the cleaning - reconstruct what might have happened.
- Inspect pipe internals at locations other than those already done.
- Devise a plan to estimate the extent of damage by corrosion and deposition.
- Estimate the ease of removal of the deposits.
- Investigate various cleaning options - both chemical & mechanical, both on-line and off-line.
- Evaluate chilled water treatment options.
- Select treatment programs. Design one if necessary.
- Evaluate various filtration options.
- Help size and select sites for filter.
- Look at system operations that could impact cleaning and/or treatment - such as flow rates, the way in which water is cycled, the presence of stagnant zones and time duration, leaky valves, etc.
- Monitor results of what is currently being done versus what should be done to adequately monitor results.
- Provide owner with accurate treatment program specifications which will completely stop corrosion and assure that corrosion will NOT be a problem in the future.

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• UNBIASED TECHNICAL REFEREE •

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 - Scale
 - Deposition
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 - Pre-treatment
 - Cooling
 - Boiler
 - Process
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• FAILURE RESOLUTION - CHEMICALS, EQUIPMENT, OPERATION •

- Diagnose and Analyze the Cause of Failures
- Teach You What To Do to Avoid a Recurrence

• FAILURE AVOIDANCE - PREDICT AND AVOID PROBLEMS •

• Program Verification & System Audits

- Is Technology Correct?
- Procedural Accuracy
- Identify Problem Areas
- Safety Hazards
- Zebra Mussel Control
- Legionnaires Disease

• Bid Reviews and Design Reviews

- Write Bid Specs
- Justify Decisions
- Better Job/Lower Cost
- Evaluate Proposals
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- Equipment Selection
- Hazardous Waste & Sludge Volume Reduction
- Protein Recovery
- Zero Discharge
- Water Recycle and Reuse

==== *"We Treat the Problem - Not Just the Water"* =====

WHY USE OUTSIDE TECHNICAL RESOURCES?

•YOU NEED HELP NOW - WHEN YOU DIDN'T IN THE PAST - BECAUSE:

Resolving today's water problems alone - without expert help - is like doing your own taxes and tuning up your own car. You could do them by yourself in the past, but today it's just too complicated! Most people need help! We provide that help! We work with your suppliers.

•COMPANIES NEED A FINAL TECHNICAL AUTHORITY/REFEREE BECAUSE:

There are normally many groups involved in water treatment - often with differing opinions. A typical breakdown is as follows:

Internally - Engineering staff, chemistry, maintenance (operators and supervisors), production, environmental, purchasing, corporate staff, and others.

Externally - Chemical suppliers, equipment suppliers, consulting engineers, A/E design engineers, and environmental engineers.

•YOU NEED WATER MANAGEMENT SERVICES BECAUSE: We do things for you that you can't do for yourself. Most companies have engineering expertise, yet often lack the chemical and microbiological expertise needed to resolve today's complex water problems.

•OUR FOCUS IS DIFFERENT! We provide the chemical and microbiological expertise you need to help you resolve those problems. We also bring you new ideas from other industries. Also, our goal is to make your job easier while saving your company money. And we can show you how to calculate cost savings.

•OUTSIDE RESOURCES ARE NECESSARY TODAY BECAUSE:

- Many companies today do not have the technical staff to handle water treatment responsibilities, and those that do often don't have the time needed to keep up with advances in technology.
- The application of the newer "Environmentally Acceptable" chemicals is much more difficult, and major failures can result from improper application of the "Right" chemical.

•YOU BENEFIT BY USING WATER MANAGEMENT SERVICES BECAUSE:

- You get the expertise and technology you need - without the need for hiring additional technical staff.
- You make better decisions because you now have the "missing details" you need!
- You maintain control and avoid unexpected problems.
- You save money by controlling operating costs.

•YOU CAN JUSTIFY USING OUR SERVICES BECAUSE: We protect the heart and life blood of your plant - your multi-million dollar process systems that depend upon properly treated water.

Other areas of your company use outside resources to help them do a better job. Why can't you do the same thing? You can also benefit from outside expertise in water treatment, and your payback will far exceed your investment in the cost of our services.

=====*"We Treat the Problem - Not Just the Water"*=====

PERSONAL WORK EXPERIENCE INCLUDES THESE SYSTEMS:

•PRE-TREATMENT

- Lime softeners (hot & cold)
- Demineralizers & RO, UF
- Zeolites (hot & cold)
- Iron & Manganese Removal

•STEAM GENERATION

- Boiler Feedwater
- Boilers
- Condensate Systems

•WASTE TREATMENT

- Clarifiers and Thickeners
- Waste Oil Recovery
- Sludge Dewatering
- Oily Waste Water Treatment
- Bio-oxidation Systems

•PROCESS WATERS

- Pasteurizers
- Can Cookers
- Paint Spray Booths
- Metal Finishing Operations
- Metal Working Fluids
- Wet scrubbers

•COOLING WATER

- Cooling Towers
- Evaporative Condensers
- Spray Ponds and Lakes

- Closed Systems: Diesel Cooling, Jacket, Chill, and Hot Water

•DRINKING WATER

- Corrosion control & monitoring
- Scale control
- Clarification and Iron removal

PERSONAL WORK EXPERIENCE INCLUDES THESE SYSTEMS

•PROCESS AND MANUFACTURING

- Oil Refining
- Petrochemical
- Steel and Heavy Metals
- Aluminum
- Paper
- Phosphate/Ammonia/Nitric Acid
- Breweries
- Beverage Containers
- Automotive & Aerospace
- Tire and Rubber
- Food Processing and Canning

•ELECTRIC UTILITIES

- Nuclear
- Fossil

•BUILDING COOLING/HEATING

- Hospitals
- Offices & Complexes
- Colleges & Universities
- Government and Military
- Institutions
- Recreational Facilities
- Hotels

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PARTIAL LISTING OF CLIENTS (11/96)

- Albemarle (formerly Ethyl Corp)
- American Cyanamid
- Anheuser Busch
- Arkansas Nuclear One (Nuclear Utility)
- Ashley Furniture
- Barber-Colman (valve manufacturer)
- BASF Corporation
- Binks Manufacturing
- Borden Industrial Products
- Brooks & Associates (design engineers)
- Central Illinois Public Services
- Chemtron Corporation
- Christian Hospital Northeast (St. Louis)
- Chrysler Corporation
- Clark Refining
- Continental Research
- Coors Ceramics
- Cray Research, Inc. (Super Computers)
- Diversey Water Technologies, Inc.
- Ecolab
- Energy Systems Corporation
- Ford Motor Company
- Fulton Boiler Works
- General Electric
- Goodyear Tire & Rubber
- Hamilton Standard Division - United Technologies
- Ingersoll-Rand
- Illinois Power (Clinton Nuclear Station)
- Jack Daniels
- LaRoche Industries
- Lockheed Martin Idaho, Inc. (Nuclear Reactor Test Facility, formerly EG&G Idaho)
- Mallinckrodt Chemical
- McDonnell Douglas Corporation
- McGraw Hill
- Metal Container Corporation
- Michaud, Cooley, Erickson & Assoc.
- Monsanto Chemical
- Northrop Grumman Corporation
- Paragon Group
- Peabody & Brown
- Pfizer, Inc.
- Polysar Rubber Division/ Miles Corp
- Pratt & Whitney (aircraft engines)
- Quaker Chemical
- Renaissance Hotel
- Reinhardt, Boerner, VanDeuren, Norris & Rieselbach
- Ross & Baruzzini Consulting Engineers
- Saturn division of General Motors
- Teltech Technical Knowledge Service
- Texaco Refining & Marketing
- Trigen-St. Louis Energy Corp
- University of Missouri
- U.S. Navy
- Vortex Labs

— "We Treat the Problem - Not Just the Water" —

Metallurgical Evaluation

METALLURGICAL EVALUATION

The sample of chill water piping that was taken from the discharge section of the recirculating line was sent to Dr. Tiner for evaluation.

The sample had a deposit that was covering the entire surface of the pipe. The deposition had the appearance of iron oxides that had formed a complex lattice structure.

The analysis was performed with the intention of determining if the constituents of the cleaning solution had become entrained in the deposit complex, and to determine the extent of corrosion damage to the longevity of the system.

The results of the analysis do indeed exhibit the presence of the cleaning solution in the deposit matrix. This is the result of the deposit forming during the three month time period when the cleaning solution was being recirculated through the piping system.

The presence of the cleaning solution in the matrix indicates the ability of the solution to disperse the solubilized particulates was exhausted. Thereby allowing the suspended matter to redeposit on the pipe surface.

This condition promoted underdeposit corrosion and produced the high iron levels in the water, and contaminated the systems that were being introduced into the core piping.

The calculated loss of metal from the pipe surface by Dr. Tiner is 6%. This figure should not be considered finite, as the more quantitative measure would be generated through the use of a corrosimeter, and would require extensive field evaluation.

MICROPROCESS LABORATORY INC.

AQUATEC
1500 W. El Camino Ave.
Sacramento, CA 95833
Attn: Michael Burns

October 29, 1996

RE: CHILL WATER PIPE CORROSION

I- INTRODUCTION

A plug steel test sample was submitted by Aquatec for perusal. It was removed from the chill water pipe from the Metropolitan Transportation Authority Building in Los Angeles. The system was in operation for one year and was cleaned with a solution which remained in the pipe for two months(not drained and flushed during this time). Make up and circulating water samples were analyzed by Aquatec (see Appendix I). This report summarizes our test data and observations.

II- TEST METHODS AND RESULTS

The steel plug test sample was about 3/8 in. thick (Extra strength XS Schedule 80 for 5 in. nominal size steel pipe). It showed rust deposit on the I. D. Surface(see Figure 1) The following observations were made:

1. -Chemical Analysis of Steel

	Test Sample	SAE 1022
Carbon	0.19 %	0.18-0.23 %
Manganese	0.89	0.70-1.00
Silicon	0.31	0.15-0.35
Sulfur	0.023	0.050 max.
Phosphorus	0.009	0.040 max.
Copper	0.01	
Chromium	0.04	
Iron	Balance	Balance

It was low carbon steel SAE 1022 within the chemical requirement of ASTM A53 Grade A steel pipe used for water lines.

2. Metallographic Examination

- (a) Hardness measurements indicated 62 Rockwell B.
- (b) Cross section examined under the microscope showed the structure consisted of ferrite and pearlite. Ferrite grains were very fine and pearlite showed banding, typical hot rolled steel.
- (c) Corrosion attack was by grain dissolution forming pits generally about 0.0005in. deep. Some pits were 0.0020 in. deep (see Figures 2&3). The rust overlay on the pitted surface varied from 0.0005 to 0.0015 in.

3. Analysis of Rust Deposit

Figure 4 shows scanning electron micrograph of the rust deposit. Semi qualitative analysis by microprobe using energy dispersive X-ray spectroscopy of this deposit is shown in Graphs I&II, and summarized below.

	Test # II	Test # I
Iron	83.9%	81.4%
Silicon	2.3	2.2
Phosphorus	3.0	5.0
Calcium	7.3	9.4
Copper	0.3	1.0

The rust deposit contained primarily iron, and silicon and relatively high calcium and phosphorus. Phosphorus appeared high in some pitted areas (see Test # I).

III- CONCLUDING REMARKS

The steel pipe was made of low carbon steel type SAE 1022 within the chemical requirement of ASTM A53 or A120 generally used for water pipes. The wall thickness of the pipe was 0.375 in. extra strong (schedule 80 for 5 in. nominal pipe diameter).

In general, the corrosion rate of a steel pipe exposed to water varies with temperature, flow rate, pH, oxygen content, electrical resistivity of water or its conductivity, and so on. At low pH (less than 7.0), the evolution of hydrogen eliminates protective film formation on steel surface and corrosion continues. At high pH (7.5 or higher), calcium carbonate can form a protective film and reduces the corrosion rate.

The analysis of water made by Aquatec (see Appendix I) indicates pH was 9.4, hardness 192.3 mg/l (relatively hard), conductivity 1930 micromho/cm, with 5.2 mg/l iron content. The calculated Langlier Index 2.15 predicts heavy scale formation, and 5.10 Ryznar Stability Index suggests mildly aggressive water characteristics. In order to properly estimate the corrosion rate in circulating water, it would be desirable to conduct further tests with a corrosimeter.

High phosphorus content shown by microprobe analysis suggested the use of solutions containing phosphoric acid or phosphate. The corrosion pit depth measurement showed 0.0005 to 0.0020 in. For a steel pipe with 0.375 in. wall thickness, this corresponds to a reduction of the life span of the piping system of about 6.0% or somewhat higher. The corrosion that may have occurred after the cleaning process by the circulating water must be measured by corrosimeter test to better estimate the reduction of the life span of the piping system only due to the cleaning process.

Respectfully submitted,


Nathan A. Tiner, PH.D.

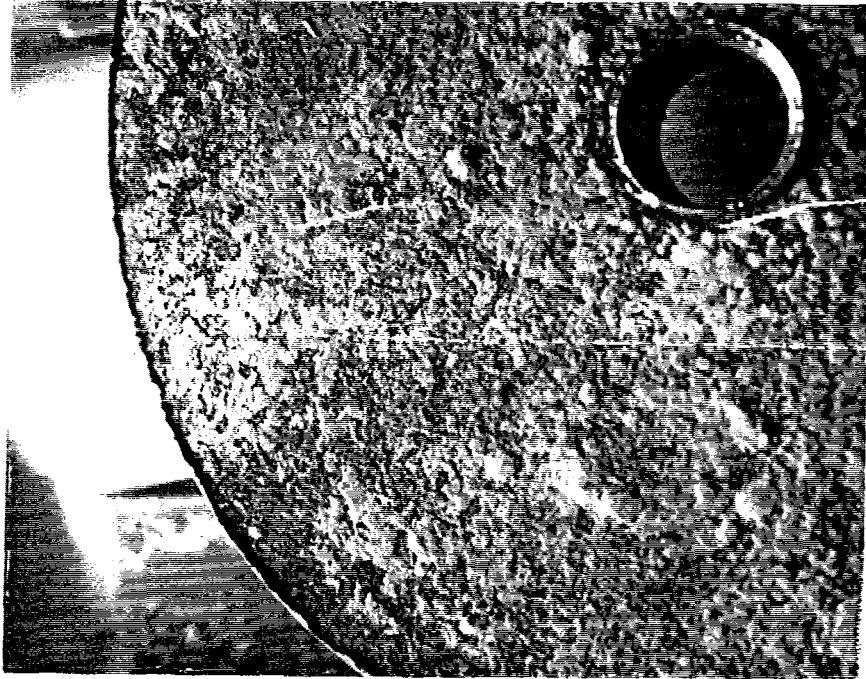
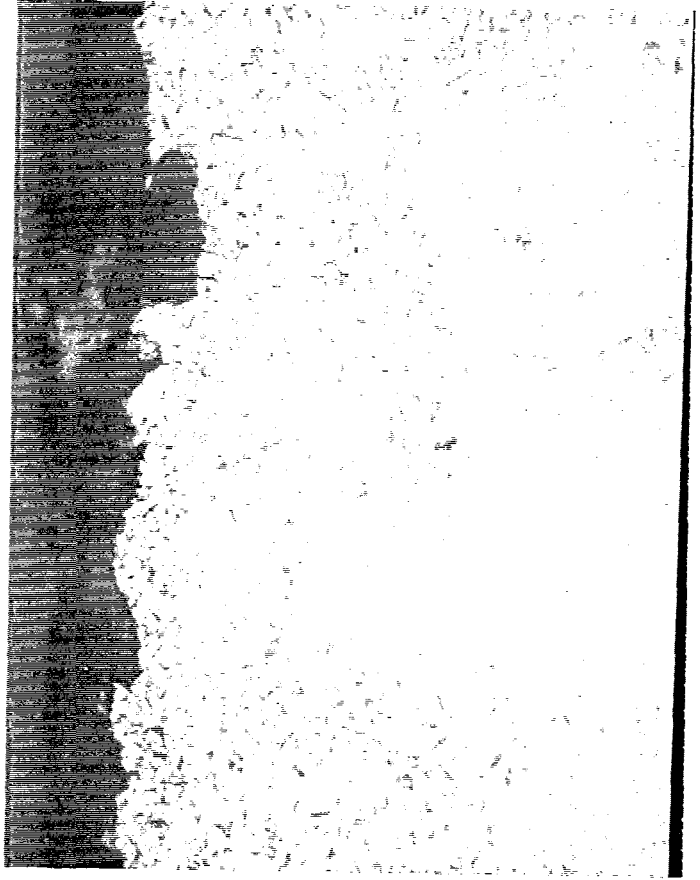
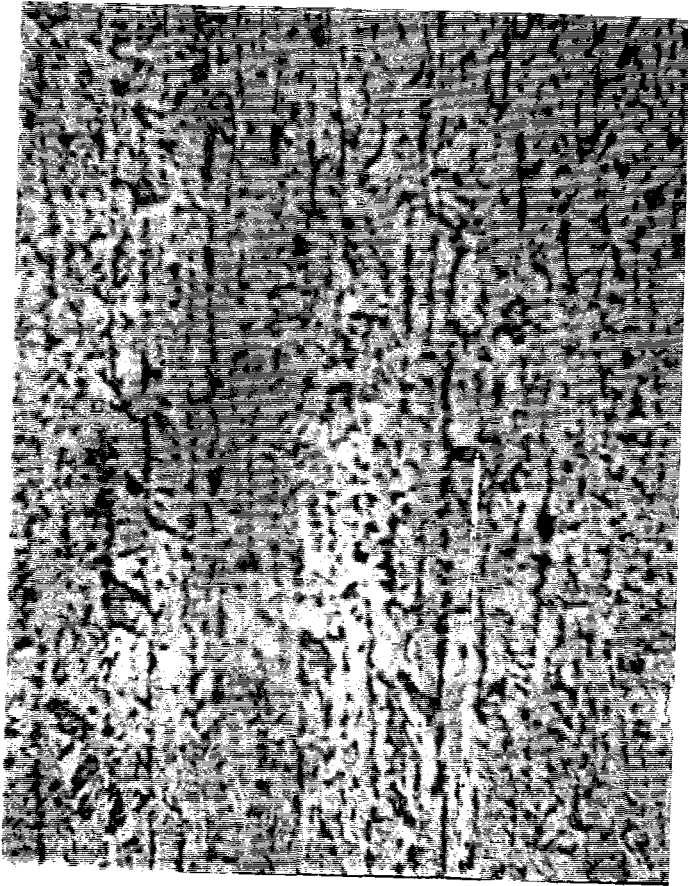


Figure 1- Photograph showing the corroded surface of the steel plug sample as received.



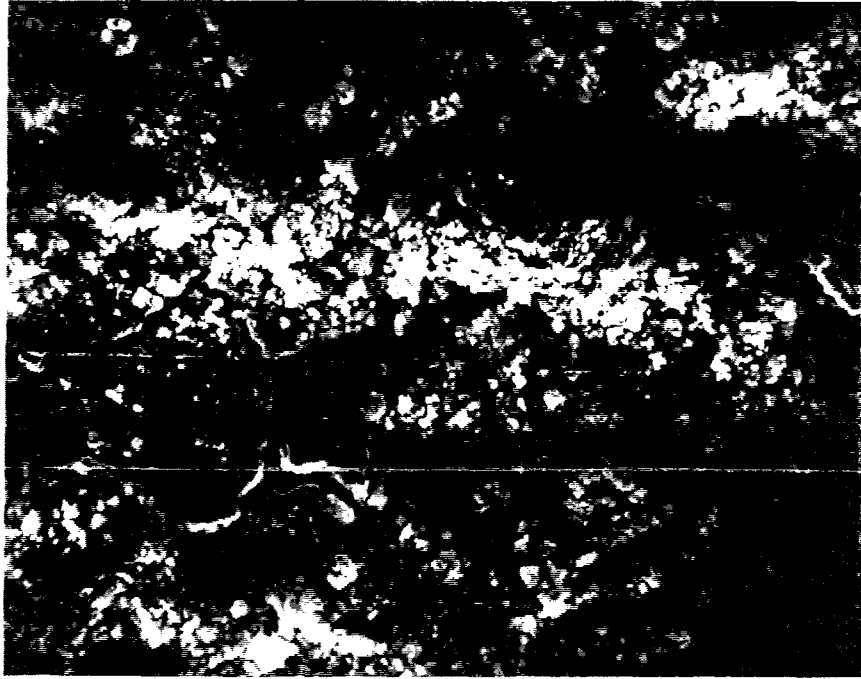
(a)Mid-section-Magnification 200X (b)Edge-Magnification 200X

Figure 2- (a) The structure at the center had very fine ferrite grains and pearlite banding.
(b) Corroded surface profile showed grain dissolution and general pitting.



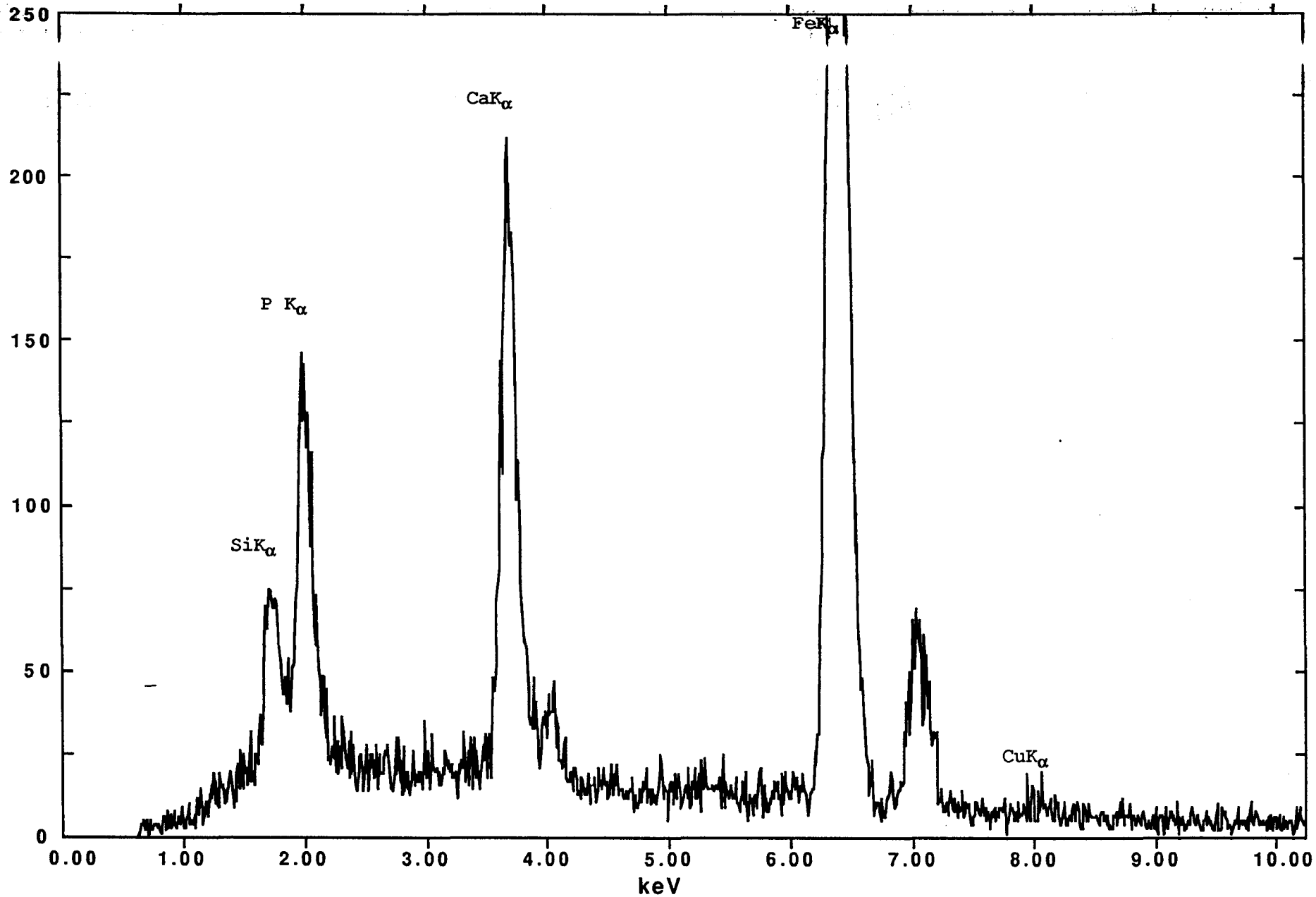
Magnification 800X

Figure 3- Magnified view of the structure showing partial spheroidization of pealite islands.



Magnification 300X

Figure 4- Scanning electron micrograph showing corrosion residue.



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STEEL PLUG SCALE #1

Analyst: JON keV: 18.10 Current: 1.00 Live Time: 100.00 eV/Channel= 10.00

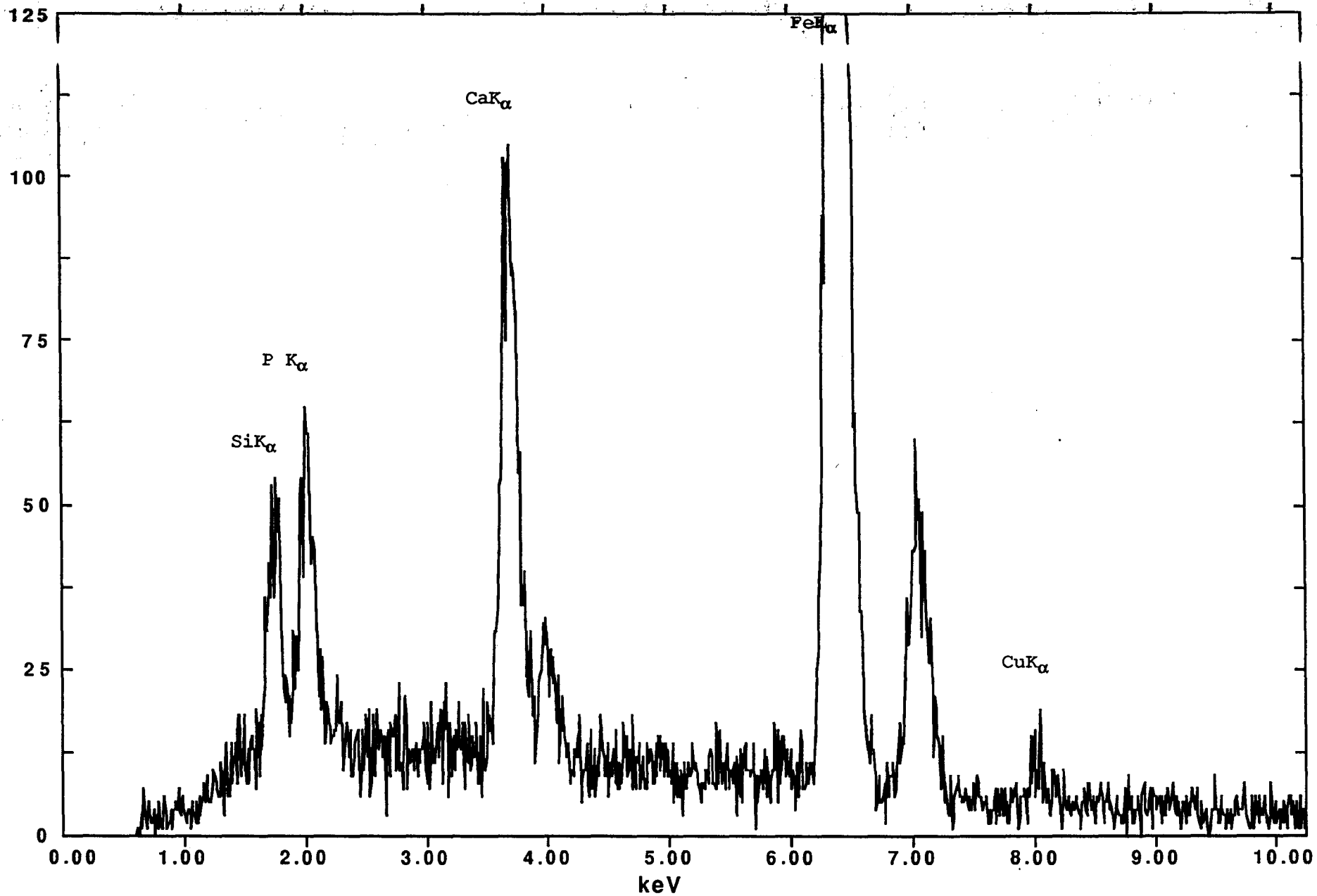
Detector Resolution: 180.00 eV Take-off angle= 40.00

Spectrum Label: STEEL PLUG SCALE #1

Number of elements: 5

Elem & Line	k-Value	Conc.	AtNo Fact.	Absorp Fact	Fluor Fact.
SiKA1	0.0001	0.0225	0.9006	0.5341	0.0037
P KA1	0.0002	0.0537	0.9323	0.6346	0.0035
CaKA1	0.0004	0.0947	0.9271	0.9301	0.0341
FeKA1	0.0031	0.8141	1.0201	0.9900	0.0014
CuKA1	0.0001	0.0150	1.0563	0.9369	0.0000

Analysis Total is 1.0000



MICROPROCESS

STEEL PLUG SCALE #2

Analyst: JON keV: 18.10 Current: 1.00 Live Time: 100.00 eV/Channel= 10.00

Detector Resolution: 180.00 eV Take-off angle= 40.00

Spectrum Label: STEEL PLUG SCALE #2

Number of elements: 5

Elem & Line	k-Value	Conc.	AtNo Fact.	Absorp Fact	Fluor Fact.
SiKA1	0.0000	0.0238	0.8966	0.5208	0.0027
P KA1	0.0001	0.0303	0.9281	0.6218	0.0032
CaKA1	0.0003	0.0732	0.9226	0.9307	0.0364
FeKA1	0.0024	0.8399	1.0146	0.9923	0.0031
CuKA1	0.0001	0.0328	1.0503	0.9360	0.0000

Analysis Total is 1.0000

Cleaning Procedure

CLEANING PROCEDURE

Conceptual;

The most effective method to remove the existing corrosion products from the three closed system recirculating waters is by using a chemical treatment regime that will solubilize the iron oxides and remove the suspended particles to drain.

The iron oxides that have precipitated on the metal surfaces can be solubilized by lowering the pH. This can be accomplished through the use of sodium citrate.

This chemical is iron specific and will not impact the metal surfaces, control devices, or packing glands in the system. The crystal lattice structure of the iron oxides will be reduced to a smaller matrix that dissociates in the presence of the sodium citrate.

The citrate has the ability to disperse the solubilized particles. This permits for the removal either in filtration or in the discharge.

The efficiency of removal can be enhanced by the bag filters that are presently being used by the building engineers. The milipore size should be reduced to 10 micron and then to 5 micron as the cleaning progresses.

Once the iron oxides have been captured in the bag filters or discharged in the blowdown, the now cleaned metal surfaces will be passivated by using tetrapotassium pyrophosphate.

The reversion of this product to orthophosphate will form the gamma iron complex that is the protective film on the metal surface.

There is also an additional iron removal product that will be used periodically to polish the water of any iron that remains in areas of low flow or areas where there are large volumes of buildup. Diphosphonic acid when used in conjunction with the sodium citrate will accelerate the solubilization of the oxides, and will also aid in the removal of any mineral salts.

Once the iron oxides have been removed and the pyrophosphate has passivated the metal surfaces, a copper corrosion inhibitor will be added, tolytriazole. This will protect the surface of the tubes in the chillers, and the heating and cooling coils.

The corrosion inhibitor sodium nitrite and sodium borate will then be added to the recirculating waters to maintain the passive film on the mild steel.

The protective film is dynamic in the sense that the molecules are leaving the surface of the metals and redepositing periodically. The maintenance treatment must be present when gaps or holes occur in the passive film.

The maintenance treatment is paramount to a successful chemical treatment program. Once the gaps or holes develop the potential for corrosion exists. The inhibitor must be present to fill the gaps and maintain the integrity of the protective film.

Routine testing for these types of closed systems should occur daily. The data should be entered into a statistical process control program for review.

Once the daily data is within the desired control parameters the testing can then be reduced based on the number of data points within the range.

Procedure;

Each of the three closed systems will be treated with sodium citrate to depress the pH and solubilized the iron. This additions will be completed over a two day period.

The water chemistry will be monitored to verify the correct concentration.

Once the addition of the citrate has been completed the systems will be partially drained to accommodate the high volume of iron present.

As the city water is added to the system the diphosphonic acid will be added to insure corrosion protection during the refilling. These volumes of water will be minor and will not require excessive amounts of the acid.

The iron level will increase during the addition of the citrate. When the iron level no longer increases after the addition of the citrate the system will then be drained and flushed.

This is an on-line process and will not impact the operation of the systems.

The filtration becomes very important at this point in the operation. High volumes of dissolved iron and mineral salts must be removed from the system. The bag filters must be check every 4 hours, cleaned and or replaced if necessary.

Once equilibrium has been established the tetrapotassium pyrophosphate will be set up at the water meters to be injected based on the volume of water being added to each system.

This will allow for the discharge of the highly concentrated iron and refill with city make up water. The city water will then be treated with corrosion inhibitor every 100 gallons.

The presence of the pyrophosphate with the citrate and the high levels of iron will not impact the formation of the gamma iron complex. The water chemistry conditions will enhance this mechanism.

During the flushing of the citrate and iron, the pyrophosphate will be injected into the make up water. Additional citrate will be added to evaluate the effectiveness of the cleaning.

At this time the diphosphonic acid will be used to assist in the removal of any iron oxides that have not dissolved.

The cleaning and treating of the system will require 2 weeks, based on the discharge and refilling of each of the closed loops.

Once the iron level has been reduced to less than 1.0 ppm and the water chemistry approaches that of the city water, the discharge and the treatment with the pyrophosphate will be discontinued.

The maintenance corrosion inhibitor, sodium nitrite, will be added to establish the concentration of 800 ppm to 1200 ppm for the chill water and the closed condenser water. The hot water control range will be 1000 to 1500 ppm.

The use of the proportional feed system will permit the discharge and refilling of the system with corrosion inhibitor present. All waters entering the system will be treated.

Once the inhibitor has been added and the system has stabilized, a biocide will be added to each of the three closed systems to prevent any biological contamination.

This final step will complete the cleaning and treating of the chill water, hot water, and closed condenser water systems.

Project Cost;

The cost for this project will include the necessary chemical treatments;

sodium citrate	tolyltriazole
diphosphonic acid	biocide
pyrophosphate	sodium nitrite

The chemical pumps that will provide the proportional addition.

The labor to administer the cleaning chemicals, corrosion inhibitors, and the biocidal treatments.

Analytical documentation of the treatment and the final analysis at the completion of the project.

The cost for the treatments, labor, and analytical will be \$14,625.00.

The filtration units will be an integral part of this process and should be changed and cleaned periodically throughout the process. The size of the bag filters should be reduced during the process.

Initially the 25 micron filters will be adequate. Once the draining and flushing begins the bag size should be reduced to 10 micron, then to 5 micron, and finally to 1 micron when the cleaning and treating has been completed.

One of the most important factors in this process is the opening of the control valves and bypass valves during the cleaning.

Manual or automatic manipulation of the equipment is instrumental in the success of the procedure.

The cleaning solution must come in contact with all sections of the piping system and flow must be evident to provide the contact time and flow velocity to achieve the desired effect.

Please allow 7 to 10 days for delivery of the chemical pumps, and the chemical treatments.

Feel free to call on me at anytime to review this process.

Respectfully submitted;

A handwritten signature in black ink, appearing to read "M. Burns". The signature is fluid and cursive, with the first letter "M" being particularly large and stylized.

Michael Burns
General Manager