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PAPER 9 **THE MAGNETIC TREATMENT OF WATER FOR SCALING, CORROSION AND BIOLOGICAL CONTROL - FACT OR FICTION**

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THE MAGNETIC TREATMENT OF WATER FOR SCALING, CORROSION AND BIOLOGICAL CONTROL - FACT OR FICTION

By J M Lobley

The Maintenance Engineer of the last decade of the Twentieth Century is faced with constraints and parameters like no other before. The need to extend plant life, to maintain operating effectiveness, reduce operating costs and to ensure burgeoning environmental and maintenance conditions are incorporated in their various modus operandii make life for the Maintenance Engineer a very challenging one.

Tried and accepted methods must be challenged. Some challenges will be unacceptable and fail - others will be imaginative, thought provoking, controversial and will have a degree of success and in time become an acceptable alternative to past practice. The magnetic treatment of fluids and the use of magnetic treatment device's (MTD's) is in the latter category.

What is it about this fluid treatment that on one side of the globe manufacturers can be involved in lawsuits by state attorneys general initiating consumer protection litigations against them and their MTD's and at the same time on the other side of the globe MTD's are being hailed as saving the national economy "millions of roubles per annum". (29)

Somewhere in this spectrum of opinion is a balanced scientific engineering conclusion that explains what many have observed - the magnetic treatment of a fluid does have an effect that can be of advantage to the fluid system and plant operation.

Authors Note: I have broadened this paper to include fluids as a result of research reports recently released.

HISTORICAL BACKGROUND OF THE MAGNETIC TREATMENT OF FLUIDS

Since 1890 the subject of the magnetic treatment of fluids has been extremely controversial, it has been labeled '.gadgetry", "not sustainable under scientific scrutiny" (9), (29) & (30). In the Eastern Bloc Countries, particularly Russia, the investigation and application of magnetic treatment of fluids has become an art form since the second world war (4), (6), (7), (8) & (23). It has been slow to gain acceptance in the West, however it has a growing number of adherents based on actual industrial applications where it works (2), (3), (5), (13), (14), (15), (16) and (17).

Successful claims have been made for the control of scaling, sludging, corrosion, algae and bacteria.

How does the process work? To provide an explanation of the phenomenon the following concepts are considered:

> The basic geometry of the system is water in a pipe passing through a magnetic field, the field being provided by either permanent magnets or electromagnets placed in the pipe or on the exterior surface of the pipe.
>
> Recent publication of five papers on how MTD's work have shed great light on what was a mystery. Up to 1986 Western criticism of MTD's was centred around non replication of tests, test conducted in a non professional way, including the selective analysis of results, non response of fluid systems to MTD's when installed, spurious claims on what MTD's could do, misinformation etc. These latter papers have been the product of scientific method of the late 1980's and have had their gestation at reputable research establishments.

The research of Donaldson and Grimes at City University, London:

Their research has been much publicised and their findings are extremely important. In a recent symposia – October 1989 in England (27) – Professor Donaldson highlighted these points when discussing the scale reducing phenomena.

Firstly the depostion or precipitation of scale depended on two factors "solubility and nucleation" and to control scaling successfully these factors had to be controlled.

Current chemical treatments have this as their objective. Donaldson found that the magnetic treatment of a fluid could change:

- particle size
- crystallinity
- crystal morphology
- crystal phase
- solubility
- rate of precipitation

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Secondly the key to these changes occurred at the boundary between crystal and solution. Implications in this process were charge differentials on the face of the growing crystals and the effects on anions and cations.

Doctor Grimes at the same symposia (28) presented a paper on the magnetic effect on field-dipole interactions, ion pair formations, polymerisation reactions, the effect of magnetic fields on solvated ions, nuclei, nuclei and ion clusters and free radicals.

All these factors point to the precipitation process to occur in solution rather than on the walls of the pipes or containing vessels.

In 1986 research by Busch, Busch, Parker, Darling and McAtee Jnr (10) found that when a fluid flowed through a MTD currents of voltages were set up and they proposed that "precipitation initiators" were produced resulting in the precipitation of scale in solution rather than on the pipes and containment vessels. They also postulated that these current and voltage effects created corrosion in the housing of the MTD.

In 1989 Herzog, Qihong Shi, Patil and Katz of the John Hopkins University, Baltimore presented their findings on investigating the calcium carbonate crystallisation processes (11).

They found the production of Fe 2+ "strongly inhibites calcite growth but not aragonite growth", it also inhibits the transformation of aragonite into calcite and Fe 3+ has a similar but lesser effect.

Previous to this Doctor K J Kronenberg of California State University in 1985 (25) (26) visualised the effect of foreign particles (neucleating centres) in the water being surrounded by "loosely bound H_20 Molecules" and the magnetic field effect breaks up this protective cover allowing seeding of the crystal to commence.

All these papers consider complex electro-chemical reactions in some detail and are beyond the scope of this paper, however, it is recommended that those interested in this subject study them.

It is of consequence that all these researchers call for and/or are undertaking further research on the complexities that they have exposed when studying this fluid treatment.

THE AUTHORS EXPERIENCE WITH MTD'S

In 1988 a MTD was installed on an air conditioning system that consistently required condenser cleaning twice per year. (see Figs 1 & 2 for a typical A.C. condenser in a fouled condition).

The system comprised an open, water cooled condensing unit for cooling and electric finned duct heaters for heating. Supplementary plant consists of a condenser water cooling tower mounted on the plant room roof, a condenser water circulating pump and a draw-through central station multi-zone air conditioner in the plant room.

The air is circulated by centrifugal fans in the air conditioner, and is distributed to the various rooms in each of the six zones via fibreglass and flexible ducting located above ceiling, after having been heated or cooled according to the demands of the thermostats.

The air is supplied into the rooms from ceiling diffusers, and is then returned through door grilles and via the passages to the plant room, where it is then mixed with a proportion of filtered outside air.

The air mixture is then filtered prior to re-entry into the air conditioner for a repeat of the process.

The controls are basically electric, but the damper control motors have proportional electronic and potentiometric functions. The system is designed to function completely on automatic control.

The plant is fully automatic in operation and is switched on and off each day by the action of a timeswitch. Items of plant which require other plant to run simultaneously for their proper operation are interlocked electrically, and all items of plant have thermal and overload protection devices inbuilt.

During its operating period a return air temperature of 23^{o}C is required to keep the unit running. The daily "off" time cycle is from 2230 hours to 0600 hours, i.e. seven hours**,** thirty minutes.

The condenser of the A.C. system is water cooled with a closed circuit of cooling tower and pump circulating the water**.**

The condenser experienced fouling requiring cleaning on an average of twice per year.

Consistent with the Victorian Health Department requirements this water was treated with a biocide and corrosion inhibitor
(chromate based).

The system used was P.S. Australian Promotions Pty Ltd (trading as **Magnetic Technology**) magnets clamped externally to the pipe supplying the water cooled condenser. The factors influencing the selection of clamp-on magnet system were:

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virtually no installation costs.

Was non-intrusive in that it did not require "cutting-in" to the water system.

no power supply required.
it treated the complete water flow and not a “by- pass" system.

During the course of the trial the ph varied between 8.9 to 7.1. The system was in place on 12th August 1988 and regularly inspected and photographed up to June 1990. During this period of nearly two years the condenser has not required cleaning - scaling and sludging have been non existent. The inhibitor dosing has been suspended and revenue savings are calculated at $1100/annum.
(see figures 3, 4, 5 & 6)

Some attempt was made to evaluate the performance of the MTD in controlling corrosion during the trial period.

Claims have been made that this process will reduce corrosion (3), (17). The process is not clear, but the presence of iron in the water was cited by Busch, et al "that MTD operation may simply accelerate an already spontaneous process that in essence is no more than the corrosion of iron". (10)

They stated further "the question of the involvement of iron is complicated by the fact that the solution chemistry of iron is not completely understood and involves complex ionic equilibria that change the nature of the species present in the solution over time. Moreover, none of the reported systems using MTD's has ever been designed for operation in the complete absence of iron; thus, the importance of iron in the anti-scaling effect cannot be rigorously determined because of a lack of control experiments. Consequently, the role of iron in magnetic water treatment remains unclear."(10)

Similarly, Herzog, et al found: "Our experimental observations may explain the reported action of magnetic water treatment devices as scale preventives. Magnetic water treatment devices could induce the liberation of iron into the water, and scale growth thus could be inhibited. This mechanism is both physically reasonable and consistent with all observations made in the field. However, whether & how passage of water through a magnetic water treatment device can result in liberation of the necessary iron to inhibit scale growth is still an open question." (11)

During the trial period the iron content of the water was measured. From the point of cooling tower management and control of water borne bacteria the reduction of iron in solution is very important. One of the environmental parameters for the proliferation of Legionnaires Disease is iron in solution (1), (21). Any reduction of iron levels and corrosion is advantageous.

The test showed an initial increase in iron levels (Note: The flame atomic absorption septroscopy method used does not distinguish the form of the iron in solution) during the September/October 1988 period of the test rising to a maximum of 1.55mg/1 and dropping to below 0.2mg/1 for the remaining months (see Figure7).

It was also noted a small series of corrosion blister appeared during the April, May, June 1989 period. Until that time the corrosion pattern on the cast iron end plate of the condenser was unchanged. This was not the case pre MTD treatment when chemical treatment was applied.

The April, May, June 1989 period was a period where the Air Conditioning System did not operate as the heating cycle was required. Consequently the chiller would be out of service and hence no circulation of the water through the magnetic field for that period of time.

This of course is no indication that the magnetic field will prevent corrosion but is does indicate that for that system significant corrosion arrestation may have been achieved by the effect of the magnetic field for the first 6 months of operation.

THE BIOLOGICAL EFFECT

It has been shown that mixing water containing bacteria and viruses with magnetite and passing the resultant mixture through a magnetic field will see the bacteria and virus adhere to the magnetite and be extracted from the water - a form of magnetic filtration. (19), (20)
(This also is the principle on which the very successful CSIRO process CIROFLOC is based.)

One Australian company has world patent rights on the treatment of water for algae control. Algarid of Box Hill, Melbourne has marketed their MTD's for many years for the treatment of drinking and swimming pool water.

Their Managing Director describes a very simple experiment to demonstrate the effectiveness of the treatment, ie - pass ordinary tap water through a MTD and leave a glassful along with a glassful of untreated water from the same source in sunlight. After a period of time the untreated water will exhibite a far greater algal bloom than the treated water.

Recently Dr. Lloyd of Dynamag Australia, announced positive results using a MTD to control a Legionnaires Disease Bacteria -Legionella Pneumophila. The results of this work was announced in Maintenance Australia (22) and the National Press. However in the opinion of this Author the results of research carried out by Fassbinder, Stanjek and Vali of Munich (18) may have the most significant impact on this area of MTD operation. Their research indicated that certain soil-borne bacteria either ingest or produce magnetite and hence became subject to earth's magnetic field.

This has implications for the same bacteria being subject to applied magnetic fields. The question now posed is, "what other bacteria has this ability to ingest or form magnetite"? Fassbinder (et . al) found the bacteria Aquaspirillum magnetotacticium contained magnetite crystals and it would be pertinent to the MTD control of Legionella, Naeglaria and Acanthamaoeba if they were found to exhibit the same magnetic characteristics as Aquaspirillum - The research opportunities are unlimited.

The method of bacteriological, viral and algae control (ie . killing) by MTD is still being investigated, however, the positive actions of MTD's in controlling or limiting the populations of such micro organisms whether directly or indirectly - is documented.

THE CURRENT USE OF MTD's IN AUSTRALIAN INDUSTRY

The general skepticism of the use of MTD's in the past has meant that they have taken a very low profile in Australian Industry, however, some notable installations are:

Photographic Industry - to treat water before film processing to reduce biofouling of sensitive developing equipment (see ref. (14) for the American experience).

Boiler Applications - Alan Cosgrifts' experience with a boiler installation at Aararat (Vic) to reduce scaling. Reported in Maintenance Australia (13).

Vehicle Manufacture - Ford Australia, Homebush (N.S.W.), the magnetic treatment of zinc phosphate to reduce spray nozzle and heat exchange blocking in pre-coating of car bodies.

Anti Scaling and Fouling Applications – Sydney Hospital. The MTD's are fitted to:

Athertons Amertican Cyclomatic Sterilizer electric heat self generating steam unit

Hitachi Electron Microscope (the coding system)

Lucas 80 kW electric steam generators all these applications are working satisfactorily (24) .

Cooling or recirculating water applications including systems with cooling towers.

Domestic applications, drinking water improvements, swimming pool algae treatment.

Undoubtably there are failures in MTD applications but the fact of the matter is that there is successes.

WHAT ARE THE CONSIDERATIONS IN SELECTING A MTD

The Russian experience with water treatment after the Second World War was one in which we could learn from. They didn't have access to the chemical industry capacity that was in the West and they had limited reconstruction capital to develop such an industry anyway, so they developed an alternative, it may not have been as good as chemical water treatment but it was effective and cheap. They could not understand

how it worked but it worked, consequently the use of MTD's flourished and a variety of applications were developed.

Maintenance engineers are faced with a simi1iar situation today not withstanding the financial issues, environmental issues are extremely powerful ones in the eyes of the community and are in turn translated into legislative action by Governments. This is particularly so in the use of chemicals and their residuals or effluents and hence pressure to change the existing systems emerges. The questions the Maintenance Manager needs to ask as he considers using MTD's are:

Is the current treatment or process effective?

Would the use of an MTD give efficiencies over the current treatments?

Would I lose some efficiencies but have an overall gain environmentally?

What is the overall effect of an MTD on plant life expectancy and life cycle costing?

Can I use an MTD in conjunction with my existing chemical process or operation to enhance its effectiveness thereby increasing efficiencies and improve its environmental acceptability?

Anyway will a MTD work on this system or process?

Having made a decision to proceed with a MTD installation these next set of questions and parameters need to be considered:

What is the fluid circuit geometry?

- pipe diameters

- pipe lengths

What limitations does this geometry place on MTD operation?

What materials are in the fluid circuitry that may adversally affect MTD operation?

What is the best place for the MTD to be installed in the circuit?

What are the fluid constituents?

chemical composition

pH

TDS

What is the operating temperature range of the fluid?

What is the fluid velocity at the point of MTD installation?

Should I use permanent magnets or electromagnets?

If I select an electromagnet what are my power supply requirements?

Should I use a "clamp-on" or a "cut-in" MTD.

Does the fluid circulate all the time or is additional circuitry required to ensure the fluid moves through the MTD at all times?

Do I have to install a low velocity point in the system to trap the debris and clean it out?

Are there any laws, regulations or codes that prevent me from using a MTD for this application?

What is the magnetic field pattern of the MTD being considered?

How is the MTD supplier going to "tune" the MTD to the fluid circuit?

What if the MTD doesn't work for my application can I negotiate a trial period or "buy-back"?

The answers to these questions will either be supplied by the Maintenance Manager or the MTD Supplier. No guarantee can be given that an MTD will work on a particular system, but the Maintenance Manager should expect from the MTD Supplier:

A full explanation of how his system operates and its relativity to the problem at hand.

Examples of where his MTD's are currently successful - and unsuccessful.

A willingness to "tune" or adjust the Magnetic device to give a reasonable opportunity for it to operate.

Having an appreciation of these issues will enable the Maintenance Manager to make more than educated guess on the application and performance of the MTD.

Prior to the trial or initial stages of operation, some agreement to what tests and reports that will be provided by the MTD Supplier should have been agreed upon and should be analysed critically.

Then when these things are in place it is a case of wait and see, don't expect quick, spectacular results a fair trial could extend up to 6 months.

Be prepared to clean the system of sludge initially on an increased frequency as the desludging/descaling effect takes hold. As the treatment proceeds this cleaning - at the low velocity point - will reduce in frequency.

THE FUTURE

Both Dr Grimes and Dr Kronenberg indicate that we should raise our vision in considering MTD application. Dr Grimes in her paper (28) indicated inorganic and organic fluid applications that are being investigated; such topics as:

Water Based Acrylic Dye Applications

Clays and Cement Slurries

Polymers (the Russians have done extensive research in this area).

Dr Kronenberg (26)

Oil Industry applications

Cleaning detergent applications

Changes in water surface tension and viscosity with a consequential effect on a range of mixtures where powdery materials are used.

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In a paper by Maatta and Tabakov (16) the use of magnetic fields enhanced the removal of a number of pesticide effluent constituencies from water and the process reduced the time taken by conventional extraction methods.

The future is an invigorating one for MTD's and their greatest benefit will be to work in concert with chemical technology to enhance and create efficiencies in current chemical practices and usage and if necessary provide non-chemical alternatives to meet environmental standards.

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REFERENCES

(1) Standards Australia AS 3666
"Air Handling and Water Systems of Buildings Microbial Control" Page 4

(2) Hibben, SG
"Magnetic Treatment of Water"
US Air Force Office of Scientific Research - Advanced Research Projects Agency, 30 January 1973

3) Raisen, E
"The Control of Scale and Corrosion in Water Systems Using Magnetic Fields"
Paper 1 17
Corrosion'84 2-6 April 1984 NewOrleans, Louisiana US.

(4) Belova, V
"Magnetic Treatment of Water"
Soviet Science Review, May 1972.

(5) Vermeiren, T
"MagneticTreatment of Liquids for Scale and Corrosion Prevention"
Corrosion Technology, July 1958.

(6) Klassen, VI
"Magnetic Water: Between Scylla and Charybdis"
Khimiya i zhizn', (Russian) No 9, September 1969.
PP 24-27
Institute of Mineral Fuels of the USSR Academy of Sciences, Moscow.

(7) Kul'skii LA, Zochmarskii VZ and Krivtsov VV
"Calculation of the Efficiency of the Antiscale Action of Crystallisation Nuclei in Waters of the Carbonate Class"
Khimiya i Tekhnologiya Vody, Vol 4, No 2, PP 115- 120, 1982.

(8) Kul'skii LA,Zochmarskii VZ and Krivtsov VV
"Magnetothermal Methodof Antiscale Water Treatment"
Khimiya i Tekhnologiya Vody, Vol 4, No 4, PP 308-311, 1982 .

(9) Eliassen R, Skrinde RT and Davis WEI
"Experimental Performance of'Miracle' Water Conditions"
Journal AW1WA, Vol 50, No10, PP 1371-1384, 1958.

(10) Busch KW, Busch MA, Parker RE, Darling RE and McAtee(Jr)JL
"Studies of a Water Treatment Device that uses Magnetic Fields"
Corrosion - Nace, Vol 42, No 4, PP 211-221, April 1986.

(11) Herzog RE, Shi Q, Patil JN and Katz JIL
"Magnetic Water Treatment: The Effect of Iron on Calcium Carbonate Nucleation and Growth"
The American Chemical Society, 9 February 1989.

(12) Donaldson J and Grimes 5
"Lifting Scales from our Pipes"
New Scientist, PP 43-46, 18 February 1988.

(13) Cosgrift AA
"The Application of Electro Magnetic Boiler Water Treatment"
Maintenance Australia, PP 40-44. June/July 1989.

(14) Ishihara FY and Bradley SM
"Magnetic Water Conditioning for Control of Scaling and Biogrowth"
Journal of Imaging Technology, Vol 14, No 6, December 1988.

(15) Donaldson J and Grimes S
"Scale Prevention in Steel Pretreatment by Magnetic Treatment"
Steel Times International, PP 44 & 45, December 1987.

(16) Maatta R and Tabakov D
"Possibilities for Purification of Effluents from Pesticide Production using Magnetic Treatment and Electrocoagulation"
Apua Fennica, Vol 17, No 2, PP 239-244, 1987.

(17) Grutsch JF and McClintock JW
"Corrosion and Deposit Control in Alkaline Cooling Water Using Magnetic Water Treatment a.t AMOCO's Largest Refinery"
Paper No 330, National Association of Corrosion Engineers, 1984.

(18) Fassbinder JWE, Stanjek H and Vali H
"Occurence of Magnetic Bacteria in Soil"
Nature, Vol 343, 11 January 1990.

(19) Bitton G, Gifford GE and Pancorbo OC
"Removal of Viruses from Water by Magnetic Filtration"
Water Resources Research Centre-Publication No 40 Department of Environmental Eng. Sciences, University of Florida, October 1976.

(20) Bitton G, Fox JL and Strickland HG
"Removal of Algae from Florida Lakes by Magnetic Filtration"
Applied Microbiology, Vol 30, No 6, PP 905-905
December 1975.

(21) Quinn FS and Weinberg ED
"Susceptibility of Legionella Pneumophila to Iron Binding Agents"
Legionella - Proceedings of the 2nd International Symposium, 1984.

(22) Lloyd D
"The Treatment of Legionella Bacteria with Magneto Hydrodynamics"
Maintenance Australia, January 1990.

(23) Fedotkin IM
"Application of Magnetically Treated Water for Preventing Scaling of Turbine Cooling System Condensers"
Energetika i Elektrifikatsiya, No 5, PP 42-43, 1972 .

(24) Department of Minerals and Energy - NSW
"Hospital Cuts Chemical and Energy Costs with New Magnetic Feed Water Treatment"
Energy Focus, No 24, April 1990.

(25) Kronenberg KJ
"Experimental Evidence for Effects of Magnetic Fields on Moving Water"
IEEE Transactions on Magnetics, Vol-Mag, No 5, September 1985.

(26) Kronenberg KJ
"Magnetic Water Treatment De-Mystified"
Magnets Magazine.

(27) Donaldson JD
"The Magnetic Treatment of Fluids"
HDL Fluid Dynamics Limited Symposia
London and Harwell, October 1989.

(28) Grimes SM
"Magnetic Treatment of Fluids and Field Charge Interactions"
HDL Fluid Dynamics Limited Symposia
London and Harwell, October 1989.

(29) Chowdbury J and Tanzosh FJ
"Magnetic Units: Views Are Still Poles Apart"
Chemical Engineering, January 1984.

(30) Limpert GJC and Raber JL
"Tests of Non-Chemical Scale Control Devices in a Once-Through System"
Corrosion 1985, Paper 250, March 1985.

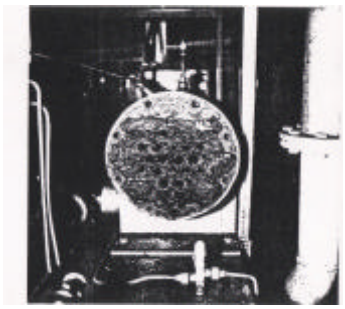

FIGURE 1
A TYPICAL AIR CONDITIONING CONDENSER
SHOWING TUBE FOULING.
(12 MONTHS DUTY)

FIGURE 2
A TYPICAL AIR CONDITIONING CONDENSER
END-PLATE SHOWING
FOULING AND CORROSION (12 MONTHS DUTY)

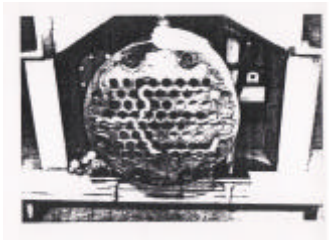

FIGURE 3
TEST AIR CONDITIONING CONDENSER
SEPT 1988 SHOWING TUBE CONDITION
AT BEGINNING OF TEST.

FIGURE 4
TEST AIR CONDITIONING CONDENSER
SEPT 1988 SHOWING END PLATE CORROSION PATTERN
AT BEGINNING OF TEST.

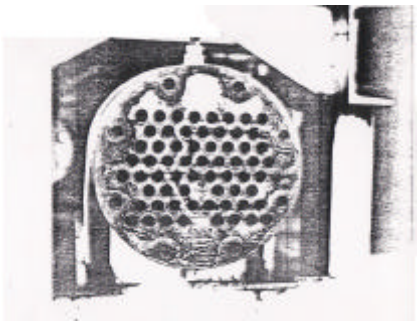

FIGURE 5
TEST AIR CONDITIONING CONDENSER
.JULY 1990 SHOWING TUBE CONDITION
NOTE: NO CLEANING DURING TEST PERI0D
(23MONTHS)

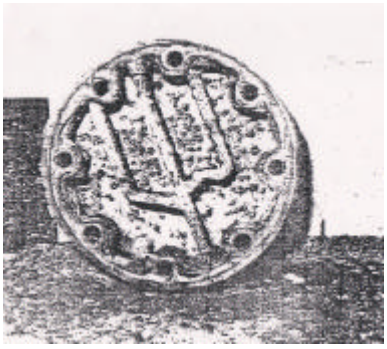

FIGURE 6,
TEST AIR CONDITIONING CONDENSER
JULY 1990 SHOWING END PLATE CONDITION
NOTE: NO CLEANING DURING TEST PERIOD (23 MONTHS)

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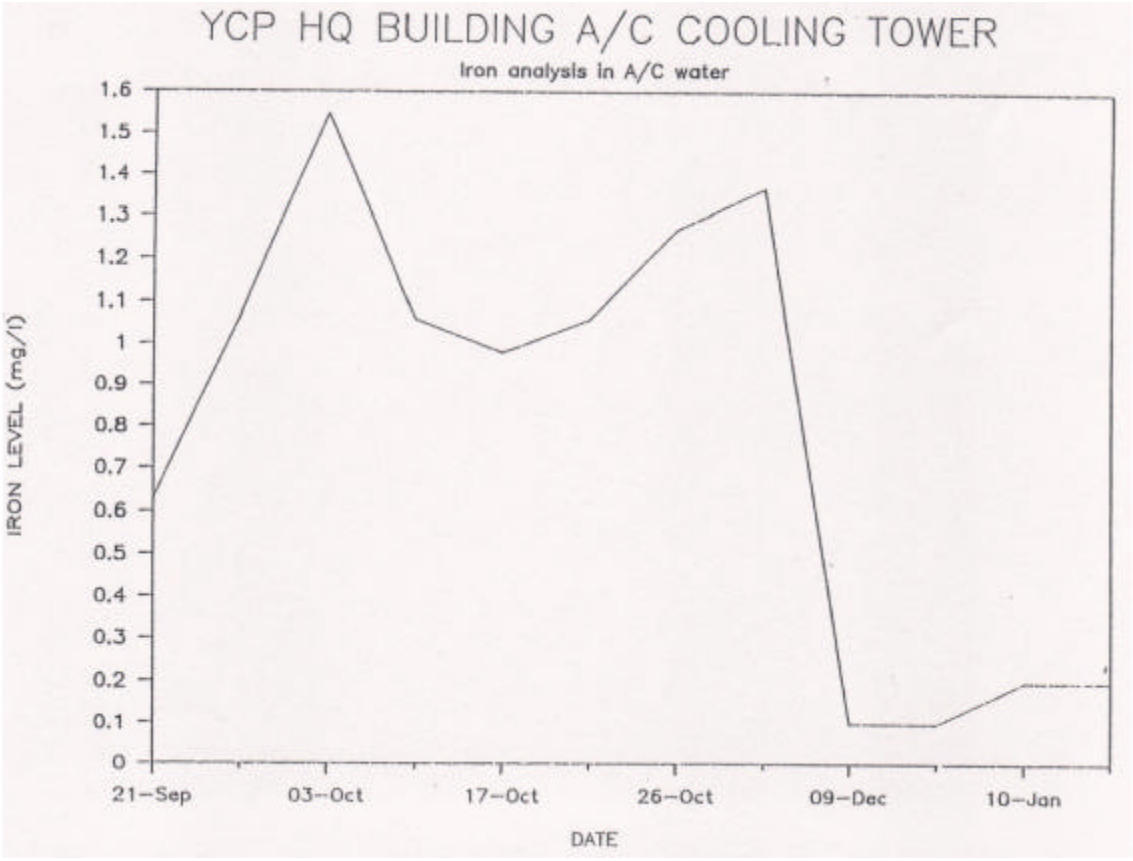
YCP HQ BUILDING A/C COOLING TOWER
Iron analysis in A/C water
IRON LEVEL (mg/l)
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
21-Sep
03-Oct
17-Oct
26-Oct
09-Dec
10-Jan
DATE

FIGURE 7