Use of Electronic Anti-Fouling System to Prevent Precipitation Fouling within a Cooling System

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ABSTRACT

The objective of the present study was to investigate the validity of a new electronic anti-fouling (EAF) technology on a 2600- ton cooling system at the Rohm & Haas facility, Building #107, Bristol, PA. The EAF technology has been developed to mitigate precipitation fouling in various types of heat transfer equipment such as chillers, plate and frame heat exchangers, shell & tube heat exchangers and water-cooled air compressors, all common applications in industrial plants. The results of the present study demonstrate that the EAF technology can significantly reduce the chemical water treatment program and continue to maintain the cooling system at design conditions.

INTRODUCTION

As cooling water is heated in the condenser tubes of a chiller, dissolved mineral ions not treated by conventional chemical treatment precipitate out of the water and adhere to the tube walls. Over time, soft deposits form, and eventually, hard scale. This accumulation increases thermal resistance and increases energy costs. It is estimated that for every 1° increase in the condenser approach temperature, a 1.5% increase in the kW/ton results.

The EAF technology prevents scale fouling-by inducing dissolved mineral ions to precipitate into larger crystals, which pass through the condenser without adhering to the tube walls. The crystals are formed through solenoid-induced molecular agitation. The ED 2000 control unit sends a square-wave pulse current through a solenoid coil, which is wrapped around the condenser supply pipe. The pulse induces an oscillating electric field within the pipe.

The mineral ions passing through the solenoid coil are agitated by the continual change in the oscillating electric field and subsequently precipitate into insoluble crystals. The crystals pass through the condenser without fouling the tubes (shear) and are removed through the filtration system or kept suspended by the use of the polymers and exit through conventional blowdown

The benefits of using the EAF technology are:

- Chemical savings by reducing portions of the chemical treatment program
- Energy savings through improved chiller performance
- Reduced water and discharge costs
- Process fouling mitigation, thus reducing unscheduled downtime
- Decreases planned maintenance

This study shall address the chemical savings associated with the elimination of the scale inhibitors used in the water treatment program at this Rohm & Haas facility.

BACKGROUND

Chemical water treatment has been the most common and accepted approach to prevent precipitation fouling in cooling systems. However, the chemical treatment program has several drawbacks, including disposal and pollution problems, handling of hazardous chemicals, and cost. Hence, if there can be a non-chemical method to effectively prevent or mitigate fouling, such a method will be beneficial to not only industry but to the environment. Many articles have recently been published on the use of non-chemical treatment methods (Attachment A, 1-14). Most have addressed the effects of heat transfer with and without the EAF technology. This paper will address the substitution of the scale inhibiting chemicals with the EAF technology. In this study, the EAF technology is used as an enhancement to the water treatment service program and not as a replacement.

THE OPERATING PRINCIPAL OF EAF TECHNOLOGY

The technology uses a square wave pulsing current, which creates an induced electric field within the feed pipe to the heat exchanger. This is known as "Faraday's Law." This induced oscillating electric field provides the necessary molecular agitation to charged ions and causes the excess mineral ions to undergo a precipitation. This precipitation is deliberately initiated by the molecular agitation away from the heat exchanger surface and is called "Controlled Precipitation." A snowball effect begins resulting in larger insoluble crystals being formed.

As a result, when supersaturated water is treated by the EAF technology, dissolved mineral ions are converted to insoluble mineral crystals and are suspended in water and remain in the water without sticking to the heat exchanger surface. "Controlled Precipitation" reduces the number of dissolved mineral ions in the water and subsequently eliminates fouling.

Fouling is one problem that continues to frustrate industrial and commercial uses and costs industry millions of dollars in chemical clean up, downtime, process duplication and reduced capacity each year. Proven solutions will certainly change the face of the heat transfer industry today.

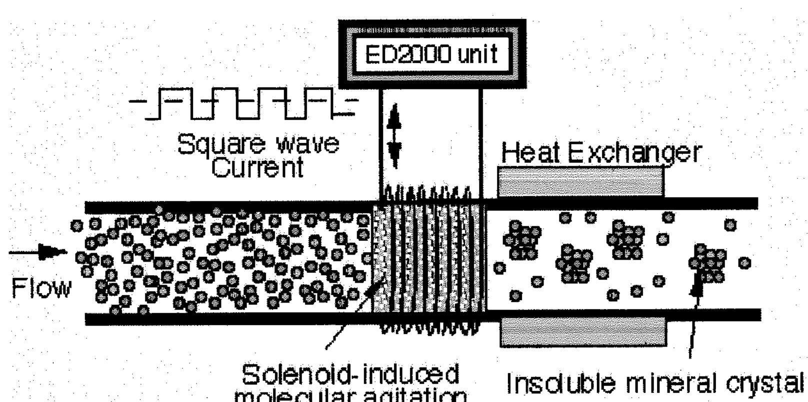

Figure 1 Sketch *of the operating principle of EAF Technology*

EXPERIMENTAL SETUP

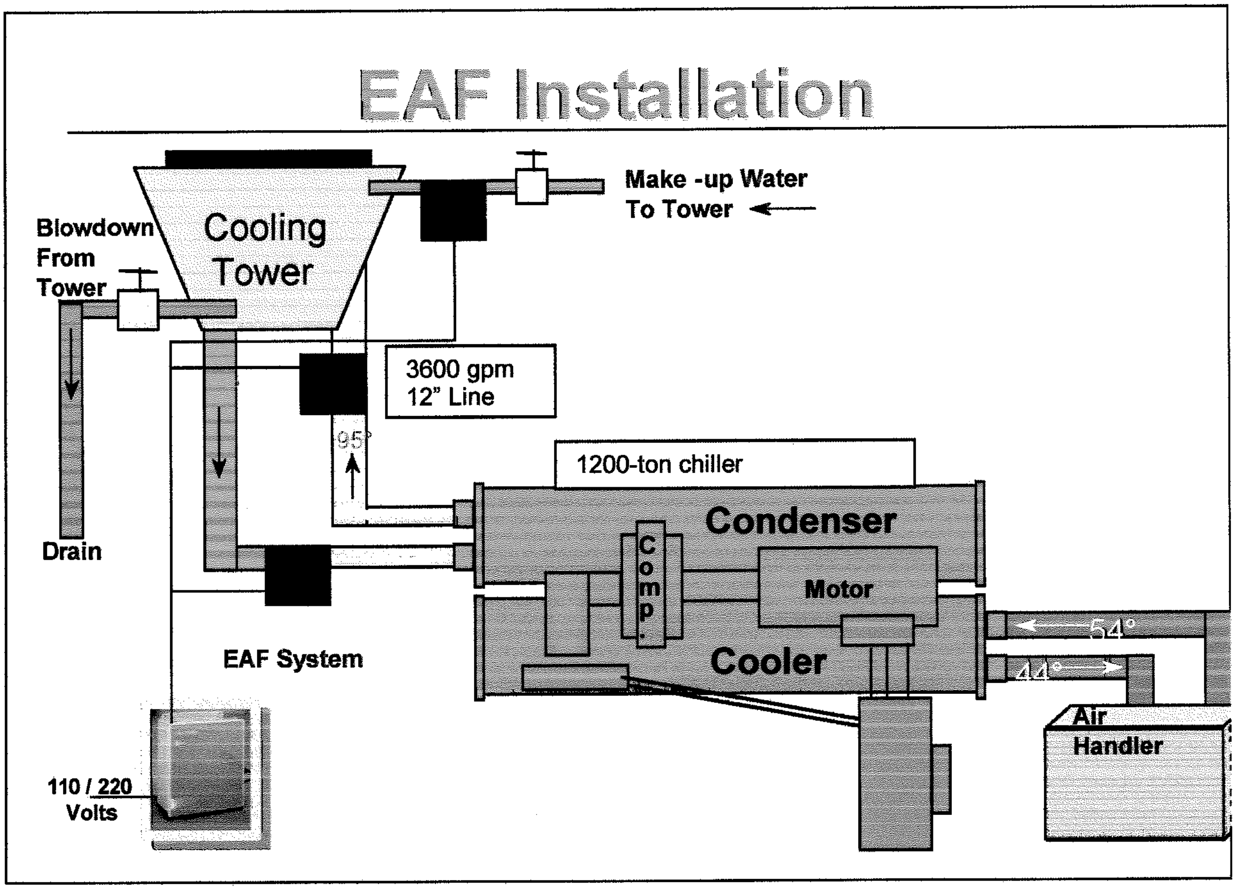

Figure 2 shows a schematic diagram of the suggested installation of an EAF System on a cooling loop. A solenoid coil is positioned on the condenser supply line, condenser return line and the tower make-up water line. A coil is to be placed on the discharge side of the condenser pump and within 50 feet from the control unit The control unit is mounted within close proximity of the chiller.

Cooling System at Rohm & Haas Building #107, Bristol, PA

- 1400-ton Trane Centrivac Model CVHF910 (estimated kW/ton 0.68)
- 1200-ton Trane Centrivac Model CVHE126 (estimated kW/ton 0.68)
- Three 1500-ton Marley cooling towers

Operating Characteristics & Assumptions

- Average 700 tons of cooling
- 24/7 running hours
- Average 5 cycles of concentration
- Make-up water cost $1.40 per 1000 gallons
- No sewer costs

Actual Chemical Treatment Expense

	1999 with Nalco	2000 with Betz	2001 Projected
Scale & Corrosion Inhibitors	$20,363	$10,239	$5,000

Projected Water Treatment Expense based on suggested Chemical Feed Rates

	Feed Rate	Control Rate	Cost per Lbs.	Cost per Day	Annual Cost
1	200 ppm		$3.94	$49.77	$18,166
2	125 ppm	13 ppm	$3.06	$24.09	$8,795
3	100 ppm	10 ppm	$2.94	$18.52	$6,760
4	50 ppm	2 ppm	$3.67	$11.56	$4,220

1. Nalco Program
   Scale and Corrosion Inhibitor #8325 at 160 ppm feed rate
   Dispersant #7302 at 40 ppm feed rate
2. Betz Program without ED 2000 Electronic Anti-Fouling System
   Complete program with scale and corrosion inhibitors.
3. Betz Program without scale inhibitors, but with dispersant, molybdate (tracer for polymer dispersant), azole (copper corrosion inhibitor) and ED 2000.
4. Betz Program with azole only and ED 2000.

All programs included an oxidizing biocide and corrosion coupons.

Estimated Annual Energy Expense

- 8753 running hours @ 700 tons
- $137,877 per year

Estimated Annual Water Expense

- $1.40 per 1000 gallons of make-up, no sewer charges
- 700 tons of cooling

Cycles of Concentration	Estimated Annual Cost
4	$20,603
5	$19,316
6	$18,543

7	$18,028
8	$17,660

Nalco Water Analysis Report (August 25, 1999)

	City Water	Tower Water	Cycles of Concentration
pH	7.7	9.3	Na
Total Hardness	86	440	5.1
Calcium Hardness	64	280	4.3
M Alkalinity	38	170	4.4
Chlorides			
	280	1400	5
LSI Saturation Index		2.23	

Betz Water Analysis Report (August 7, 2000)

	City Water	Tower Water	Cycles of Concentration
PH	6.53	8.49	Na
Total Hardness	65	528	8.12
Calcium Hardness	50	350	7.0
M Alkalinity	34	246	10.1
Chlorides			
Conductivity	193	1465	7.5
LSI Saturation Index		1.68	

Water Analysis Report (May 14, 2001)

	City Water	Tower Water	Cycles of Concentration
PH	7.0	8.7	Na
Total Hardness	77	485	6.2
Calcium Hardness	57	314	5.5
M Alkalinity	42	202	4.8
Chlorides			
Conductivity	244	1452	5.9
LSI Saturation Index		1.54	

A review of each of the monthly water analysis indicate the cooling system was operating at approximately 5 cycles of concentration for each year.

Discussion

In 2000 a project was initiated to determine if the cost of operating the cooling system at Building 107 could be reduced. A review of the chemical costs, energy costs and water expenses were analyzed. The following is a discussion of the findings.

Chemical Savings

In 2000, the current chemical treatment vendor was replaced and the annual costs were reduced by 50%. Operating conditions remained the same and the cost was only the difference in the treatment costs. The program consisted of a scale and corrosion inhibitor, dispersant and biocide. These costs were reduced from $20,363 to $10,239.

Concurrently, the new chemical treatment program was modified in a two-step process in 2000 and 2001. Initially, the scale inhibitors were first eliminated and then the dispersant. The remaining program includes a copper corrosion inhibitor and biocide only. This step generated a further reduction in the cost of the program from $10,239 to $5,000.

Chemical	**Before EAF (full treatment program)**	**with EAF in 2000**	**EAF in 2001**
Scale Inhibitor	Betz AEC 8-10 ppm	None	None
Copper Corrosion	Betz HRA 1-2 ppm	Same	Same
Polymer	Betz HPSI 13 ppm	HPSI 5-10 ppm	None
Tracer	Molybdate 1-1.5ppm	Same	None
Biocide	Chlorobromohydantion	Same	Same
Filtration	Yes	Yes	Yes

Energy Savings

The cost of operating 700 tons of cooling for a year equal $137,877 per year. A 3° increase in the condenser approach temperature would increase these costs by 5% or more. A review of the condenser approach temperature over the test period indicated no loss of performance as a result of these treatment modifications.

Water Savings

The cost of water in this particular case was not a strong impetus for this evaluation. The cost of make-up water is $1.00 per 1000 gallons and currently there is no cost for discharge at this facility. This is not the case in other facilities. Any increase in cycles of concentration may warrant the use of the EAF technology with filtration.

Summary

The EAF Technology has successfully reduced the chemical water treatment expense at Building #107 by 50% This was accomplished by using an existing side stream filtration system to remove the precipitated mineral crystals formed by the EAF technology. The cost of the EAF system provided an 18-24 month payback in this particular case. This cost savings does not include the environmental benefits associated with using this type of treatment program.

Suggested Program for Future Sites

The EAF technology may be utilized to reduce the cost of a chemical treatment program by as much as 50% based on make-up water quality and the cost of water. Filtration is suggested if the cost of water can support the use of filtration and cycles of concentration are to be optimized. A dispersant in the program may mitigate the need for filtration.

For example:

Chemical treatment program with EAF technology and with a side stream filtration system	Biocide Copper Corrosion Corrosion Coupons	50% Reduction
Chemical treatment program with EAF technology and no side stream filtration system	Biocide Copper Corrosion Dispersant Corrosion Coupons	25% Savings

	Date	Leaving Condenser	Discharge Temperature	Condenser Approach	KW	tons	kW/ton
1	7/21/00	87	93	6	498	791	0.630
2	7/24/00	81	93	12	388	484	0.802
3	7/25/00	81	91	10	388	577	0.672
4	7/27/00	82	91	9	494	797	0.620
5	8/2/00	93	105	12	953	1224	0.779
6	8/4/00	86	93	7	509	791	0.643
7	8/14/00	80	90	10		579	
8	8/16/00	90	98	8		800	
9	8/25/00	80	90	10	424	671	0.632
10	8/28/00	88	95	7	539	811	0.665
11	8/29/00	86	90	4	472	800	0.590
12	8/31/00	91	100	9	793	1240	0.640
13	9/5/00	78	87	9	333	433	0.769
14	9/6/00	80	87	7	369	476	0.775
15	9/18/00	80	91	11	412	592	0.696
16	9/19/00	81	90	9	408	590	0.692
17	9/20/00	83	93	10	522	815	0.640
18	9/21/00	82	91	9	467	692	0.675
19	9/22/00	80	90	10	303	385	0.787
20	9/26/00	79	91	12	408	528	0.773
21	9/28/00	79	87	8	300	387	0.775
22	10/9/00	73	83	10	223	252	0.885
23	10/11/00	84	91	7	344	448	0.768
24	10/12/00	81	91	10	354	474	0.747
25	10/13/00	84	91	7	290	364	0.797
26	4/5/01	85	90	5	296	309	0.958
27	4/6/01	79	83	4	256	307	0.834
28	4/18/01	74	83	9	185	186	0.995
29	4/20/01	81	85	4	225	279	0.806
30	5/1/01	84	90	6	455	613	0.742
31	5/3/01	84	93	9	438	648	0.676
32	5/8/01	84	93	9	350	465	0.753
33	5/10/01	85	93	8	324		
34	5/22/01	83	93	10	365	513	0.712
35	5/24/01	85	93	8	381	512	0.744
36	6/4/01	82	90	8	305	393	0.776
37	6/5/01	82	90	8	342	503	0.680
38	6/8/01	87	96	9	487	679	0.717
39	6/11/01	83	91	8	435	710	0.613
40	6/12/01	86	93	7	415	590	0.703
41	6/14/01	85	97	12	486	612	0.794
42	6/15/01	89	97	8	554	871	0.636
43	6/18/01	89	96	7	518	703	0.737
44	7/6/01	78	84	6	295	428	0.689
45	7/10/01	92	96	4	532	697	0.763
46	7/19/01	88	97	9	403	543	0.742
47	7/27/01	91	97	6	573	801	0.715
48	7/30/01	88	96	8	420	620	0.677
49	8/1/01	88	99	11	597	863	0.692

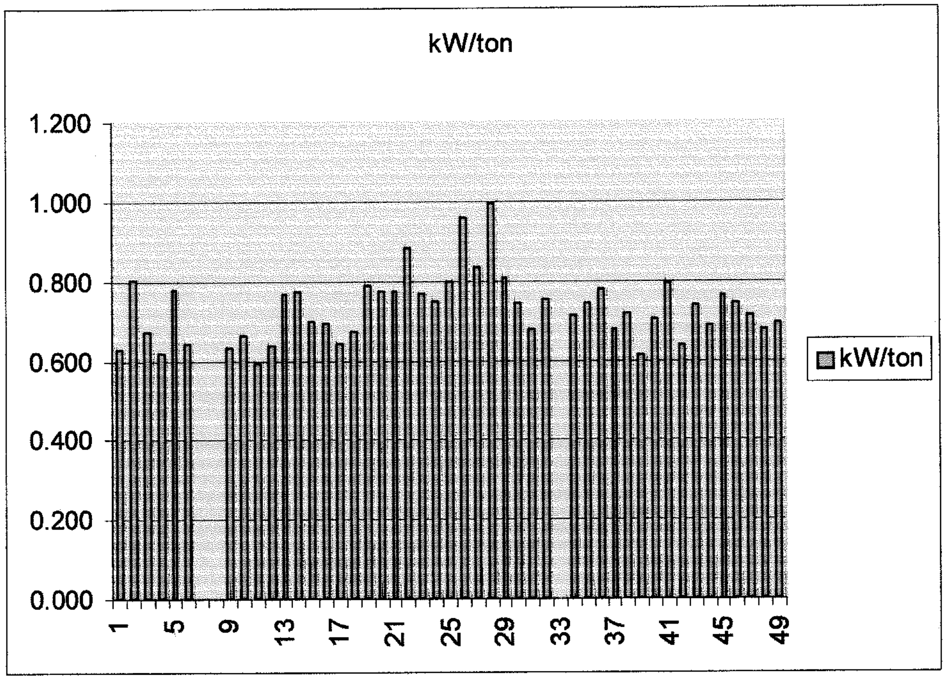

Figure 4 represents a graph of the kW/ton rating of the 1200-ton chiller over past one year period.

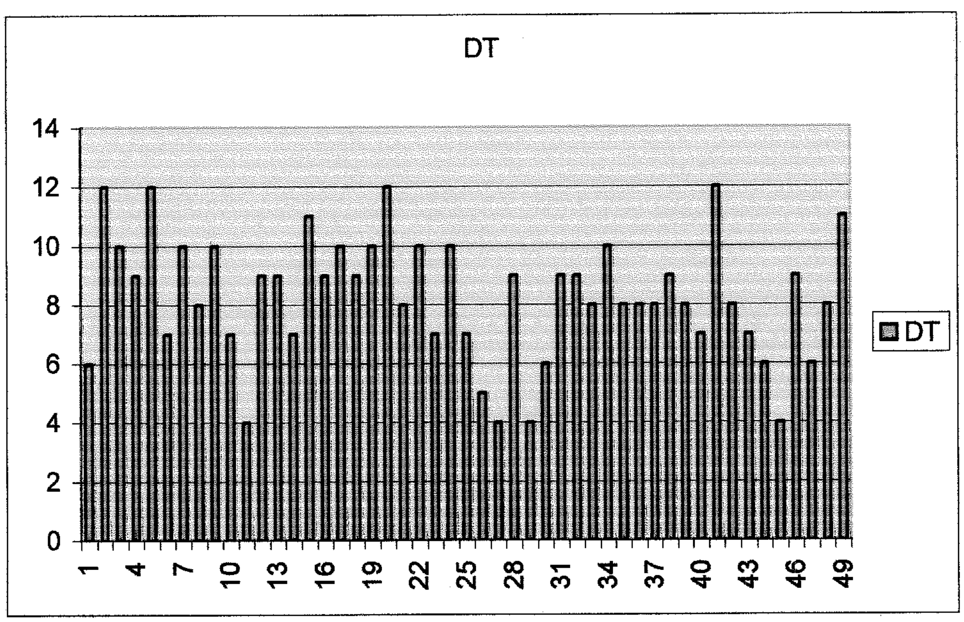

Figure 5 represents the delta t or condenser approach temperature over the past one year period.

Photographs were taken of the chiller after the test period and are attached.

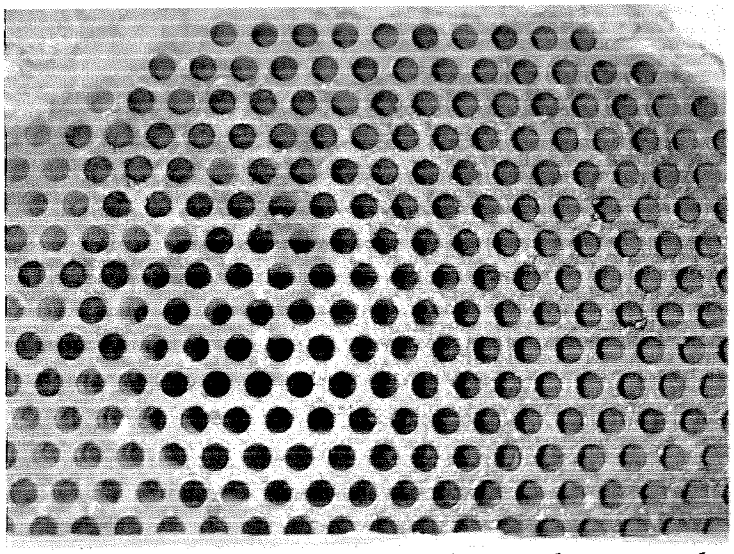

Figure 6 *Photograph taken after the initial test period.*

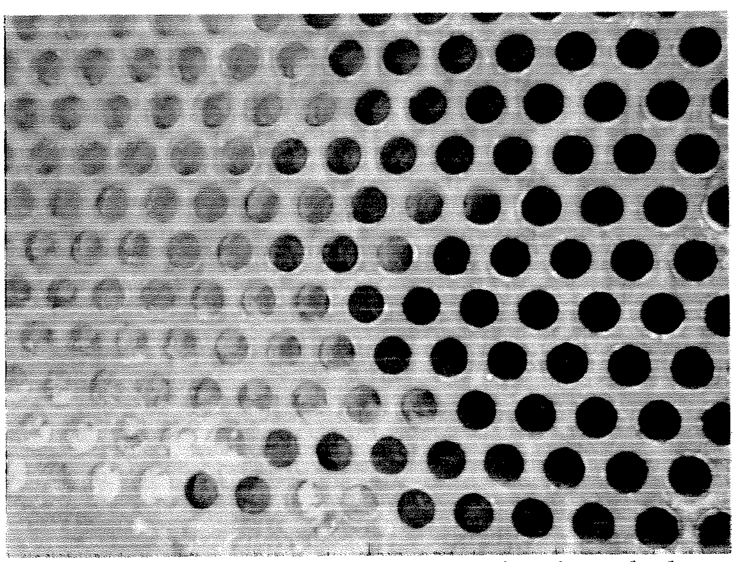

Figure 7 *There were small amounts of scale in the lower left hand corner of the chiller. This was build-up from a prior period. .*

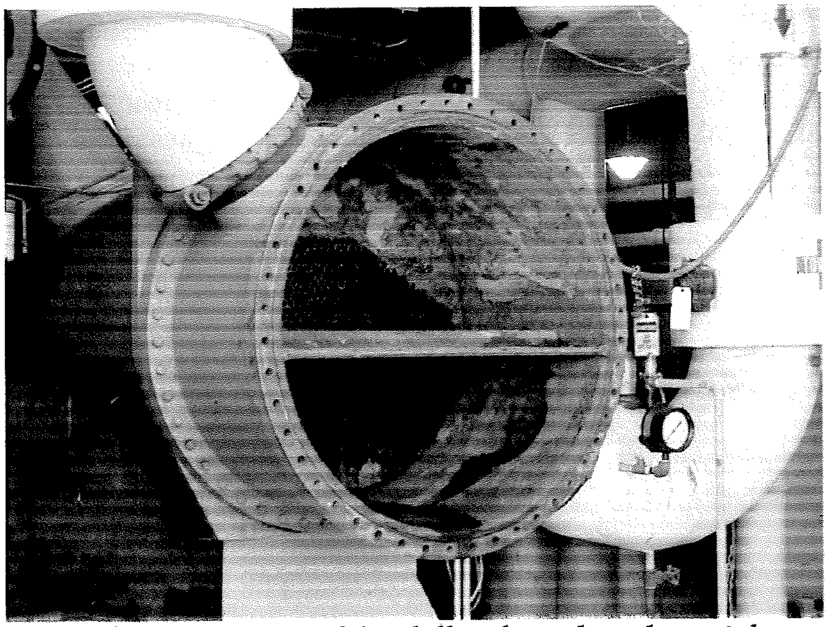

Figure 8 An *inspection of the chiller showed a substantial amount of iron deposits being removed from the channel box and tube sheet A deposit analysis indicated 98% iron deposits. This appears to be build-up from prior treatment periods.*

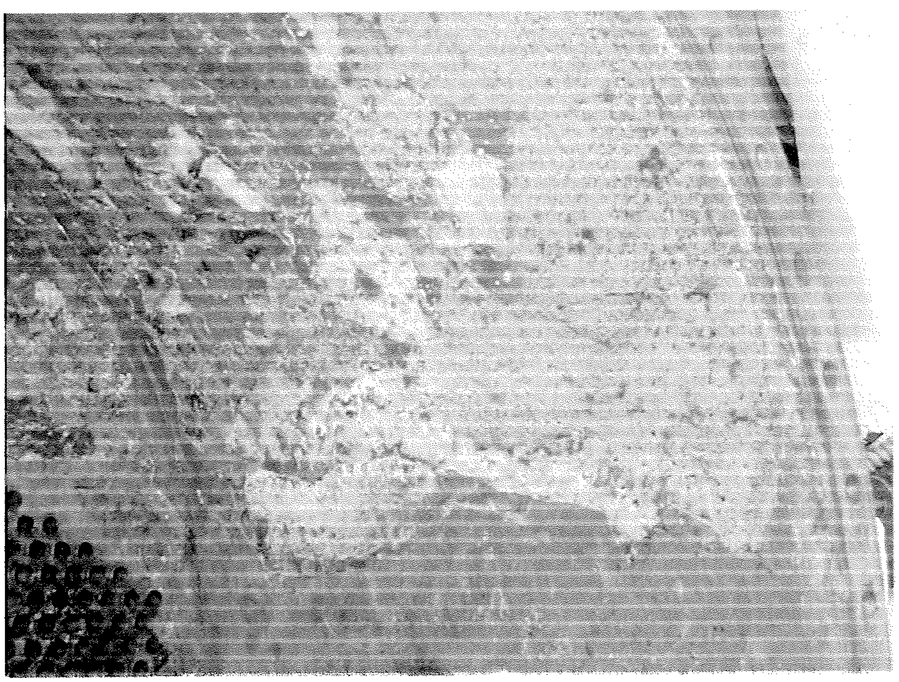

Figure 9