Condenser Performance Monitoring and Cleaning

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Presented by: Joseph P. Simpson
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CONDENSER PERFORMANCE MONITORING AND CLEANING

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Abstract

The main condenser at Ginna Station was retubed from admiralty brass to 316 stainless steel. A condenser performance monitoring spreadsheet was developed using EPRI guidelines after fouling was discovered. PEPSE computer models were used to determine the power loss and confirm the spreadsheet results. Cleaning of the condenser was performed using plastic scrubbers. Condenser performance improved dramatically following the cleaning. PEPSE, condenser spreadsheet performance, and actual observed plant data correlated well together. The fouling mechanism was determined to be a common lake bacteria and fungus growth which was combined with silt. Chlorination of the circulating water system at the allowable limits is keeping the biofouling under control.

Background

Ginna Station is an early Westinghouse two-loop 1520 MWTH PWR located on Lake Ontario. The original condenser had 24,004 tubes, with the majority being admiralty brass. Tube thinning at the inlet from entrained silt and sand was causing numerous leaks and frequent power reductions for tube plugging. In addition, steam generators were scheduled to be replaced in 1996. Copper is detrimental to the steam generators. Therefore, it was decided to retube the condenser in the spring of 1995 with 316 stainless steel.

Design engineering had concerns with the stainless steel's resistance to biological fouling based on experience from other plants on Lake Ontario. The brass tubes had experienced little fouling and had never been cleaned. Condenser performance was not being formally monitored by the thermal performance program prior to the fall of 1994. Discussions at the EPRI thermal performance conference in 1995 made numerous references to condenser fouling factor calculations. Hotwell temperature and condenser backpressure curves were being monitored, but a fouling calculation needed to be developed.

First Cycle Fouling

The first cycle with the new condenser showed that the new tubes were prone to biological fouling. Condenser hotwell temperatures increased during the winter of 1996, while circulating water temperatures remained constant. Fortunately, the unit was entering into the steam generator replacement outage at the end of March, 1996. Inspection of the condenser tubes revealed that a slime buildup had occurred and a cleaning would be required. Goodway scrubbers were shot through the tubes and the majority of the fouling was removed. A New York State Electric and Gas fossil unit with stainless steel tubes was contacted to determine their method of dealing with biological fouling from Lake Ontario. They were able to control the fouling through chlorination of the circulating water system.

Cleanliness Factor Calculation

A copy of "ABC's of Condenser Technology" by EPRI was reviewed in the fall of 1996 which had equations for determining cleanliness factor. A spreadsheet was created using the LMTD method of determining the measured heat transfer coefficient (Um). The measured value was then divided by the expected U and multiplied by 100 to determine the cleanliness factor in percent. Values for the expected U vary with temperature and were curve fit in the spreadsheet. Flow rates for the circulating water system were also determined using Q=M*Cp*dT. The heat load on the condenser was determined from Qreactor-Wgenerator. A printout of the spreadsheet is attachment A.

Clean, baseline data from when the condenser was retubed was input into the spreadsheet. Attachment B, condenser performance factor graph, shows the dramatic decrease in performance starting in January 1996. Performance improved to 94% after the tube cleaning in the spring of 1996. The quick drop in performance following the cleaning in June 1996 was attributed to the malfunction of the circulating water chlorination system. Once repaired, performance leveled out at 95% until November 1996 when chlorination was halted.

The Ginna hypochlorite tank is located outside the screenhouse and is not insulated. Winter chlorination of circulating water had never been performed due to weather concerns and performance of the brass tubes had not required it. Chlorination was typically halted in mid-November. As the winter of 1996-1997 progressed, condenser performance was closely monitored. Condenser cleanliness dropped rapidly from 92% in mid-January 1997 to 78% in mid-March 1997. The drop in performance was halted by the restart of the chlorination system on March 14, 1997. Only slight increases in cleanliness were observed with a two-hour per day treatment of the circulating water system at 0.2 ppm Chlorine. It became apparent that another cleaning of the condenser tubes would be required to regain lost performance.

PEPSE Performance Projections

Projections of the power loss due to condenser fouling were needed to perform a cost benefit analysis of the tube cleaning. The PEPSE thermal model of Ginna was used to generate the graphs of hotwell temperatures and gross megawatt output vs. water box inlet temperatures at varying cleanliness levels (see Attachments C & D). The condenser was placed in the design mode in the model using the revised 1995 HEI calculations for 316 stainless steel. The curves matched well with the measured values and cleanliness calculations (see Attachments E & F). Cost projections showed that if condenser cleaning was postponed until the fall refueling outage, the company would lose over $300,000 worth of generation. Projected downpower and tube cleaning expenses were estimated to be slightly over $200,000.

Station management approved the cleaning in early April. The tube cleaning power reduction was scheduled for the weekend of May 17th. Power losses would not be counted as forced in accordance with INPO and NERC standards since it was a scheduled derating.

Tube Cleaning

The power reduction and isolation of condenser water boxes went smoothly on the morning of May 17. Upon opening of the water boxes, it was clear that the blockage of tubes by debris and dead fish was not the cause of the condenser problems. The worst blockage is shown in the attached photograph of the 1A2 tubesheet. The majority of the pictured material on the inlet tube sheet are fresh water eel remains which were accumulated over the twelve months of operation. The other inlet tube sheets had significantly fewer clogged tubes.

The large bits of eels and fish were removed and the tube sheet hydrolased using a high pressure wash. Working conditions inside the water box inlet were greatly improved by performing this initial cleaning. Small amounts of slime can be seen on the stainless steel tube sheet. Initial visual inspection of the first few inches of the condenser tubes showed little slime build up. Tube scrubbers were loaded into the inlet side while eddy current inspection of the tubes was attempted on the outlet side. Eddy current probes could not be pushed very far down the tubes due to the fouling. During the testing the previous year, the probes were passed down the full length of the tubes with difficulty before they were cleaned. This was a clear indication that the fouling was worse than the previous cycle, as indicated by performance monitoring.

A camera inspection was performed inside the tubes to determine the extent of the fouling. As shown in the attached photographs, a thick layer of slime and silt was present. Tubes were then cleaned using the Goodway scrubbers. Samples of the fouling were collected for analysis. The attached photograph shows the inside surface of the cleaned tube. Large amounts of slime and silt were ejected out of the tubes as scrubbers shot out into the outlet water boxes. The duration of the cleaning process was thirty hours from the initial hold on the water box to release for the power increase.

Post Cleaning Results

Improvements in condenser performance exceeded the levels used in the cost justification analysis. Condenser cleanliness increased to 105% instead of the projected 92%. Cost savings over the summer increased to over $400,000. Daily chlorination at the allowable limits maintained condenser performance at 105%. A two week continuous chlorination at 0.1 ppm was performed in August. A two percent increase in performance was obtained as shown on the condenser performance graph, Attachment G. Graphs plotting hotwell temperatures and gross megawatt output vs. circulating water temperatures postcleaning are Attachments H & I. No cleaning of the condenser tubes is anticipated in the upcoming October refueling outage, saving $16,000.

Sample analysis revealed that the fouling was biological combined with lake silt. The species of bacteria and fungi were identified in the report from the Pure Earth Environmental Laboratory, Inc., Attachment J. Currently, the station is insulating the chlorination system for winter operation.

Conclusions

Retubing to stainless steel on the Great Lakes may require changes in chemical treatment of the circulating water. Heat balance model results appear to correlate well with observed plant data and EPRI guidelines. The cleaning experience clearly demonstrates the major impact that condenser fouling can have on plant performance. When the fouling takes place at low circulating water temperatures, the effect on station heat rate may not appear until temperatures increase in the spring. Careful planning of condenser cleaning activities is required in order to minimize the cost of the downpower maneuver.

ATTACHMENT A

Condenser

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Nuclear	Gross	A1 West	B1 West	TCWI	A1 West	A2 East	B1 West	B2 East	TCWO		TCW
2	DATE	NPQ	GROSSH	T2031	T2032		T2034	T2033	T2036	T2035			
3		Power	Output	Cond Inlet	Cond Inlet	Avg.	Cond Outlet	Cond Outlet	Cond Outlet	Cond Outlet	Avg.	dt CW	Avg.
4		%	MWE	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)
5	9/14/97	99.86	511.8	65.9	66	65.95	85.7	86.1	86.5	86.9	86.30	20.35	76.13
6	9/13/97	99.81	515.6	60.3	60.4	60.35	80.1	80.7	80.8	81.3	80.73	20.38	70.54
7	9/12/97	99.80	518.8	53.8	53.9	53.85	73.7	73.6	74.3	74.8	74.10	20.25	63.98
8	9/11/97	99.67	517.7	52.2	52.3	52.25	72.2	71.9	72.7	73.2	72.50	20.25	62.38
9	9/10/97	99.75	513.1	61.8	61.9	61.85	81.8	81.6	82.4	82.8	82.15	20.30	72.00
10	9/9/97	99.80	510.3	67.4	67.5	67.45	87.3	87.3	88.1	88.4	87.78	20.33	77.61
11	9/8/97	99.75	508.9	67.8	67.8	67.80	87.7	87.6	88.3	88.7	88.08	20.28	77.94
12	9/7/97	99.55	509.4	67.9	67.9	67.90	87.8	87.7	88.4	88.8	88.18	20.28	78.04
13	9/6/97	99.86	510.5	67.7	67.8	67.75	87.6	87.6	88.1	88.6	87.98	20.23	77.86
14	9/5/97	99.78	509.8	67.6	67.7	67.65	87.4	87.5	88	88.4	87.83	20.18	77.74
15	9/4/97	99.73	509	68.2	68.2	68.20	87.9	88	88.6	89	88.38	20.18	78.29
16	9/3/97	99.70	507.5	69.5	69.6	69.55	89.3	89.5	90	90.4	89.80	20.25	79.68
17	9/2/97	99.62	507.6	69.1	69.1	69.10	88.8	89	89.5	89.9	89.30	20.20	79.20
18	9/1/97	99.64	508.5	69.3	69.3	69.30	89	89.3	89.7	90.2	89.55	20.25	79.43
19	8/31/97	99.76	510.5	68	68	68.00	87.6	87.9	88.4	88.9	88.20	20.20	78.10
20	8/30/97	99.81	510.7	67.8	67.9	67.85	87.5	87.9	88.3	88.7	88.10	20.25	77.98
21	8/29/97	99.84	509.9	67.4	67.5	67.45	87.1	87.6	87.9	88.3	87.73	20.28	77.59
22	8/28/97	99.77	511.3	66	66	66.00	85.6	86.1	86.3	86.9	86.23	20.23	76.11
23	8/27/97	99.75	513	63.4	63.5	63.45	83	83.5	83.7	84.4	83.65	20.20	73.55
24	8/26/97	99.71	514	62.1	62.2	62.15	81.7	82.1	82.4	83	82.30	20.15	72.23
25	8/25/97	99.66	512.7	63.6	63.7	63.65	83.3	83.7	83.8	84.6	83.85	20.20	73.75
26	8/24/97	99.78	511.5	66.6	66.6	66.60	86.3	86.7	86.9	87.6	86.88	20.28	76.74
27	8/23/97	99.83	517.3	54.1	54.2	54.15	73.7	74.3	74.4	75	74.35	20.20	64.25
28	8/22/97	99.77	518.7	44.1	44.1	44.10	63.4	64.4	64.2	65.1	64.28	20.18	54.19
29	8/21/97	99.77	518.6	43.4	43.4	43.40	62.6	63.7	63.5	64.5	63.58	20.18	53.49
30	8/20/97	99.75	506.4	68.9	68.9	68.90	88.3	88.6	89.3	90	89.05	20.15	78.98

ATTACHMENT A

Condenser

	N	O	P	Q	R	S	T	U	V	W	X
1					Q to cdsrs	CW Flow	CW	LMTD	U_m	U	PF
2	T2051	T2052			Assumes1520MWth		row = 62.5				U = 655
3	TCOND-N	TCOND-S	TCOND	PCOND-C	C = 3.413		Approx		A=252616		$U_m/U * 100$
4	(F)	(F)	(F)	(psi)	(MBTU/H)	(Mlbm/hr)	(GPM)		(Ft^2)		(Btu/Hr/F/ft^2)
5	101.1	101.9	101.50	0.94	3433.72	168.73	336566.8	23.95	567.5146	528.5545	107.3711
6	96.4	97.2	96.80	0.82	3418.16	167.76	334630.2	24.89	543.6830	511.1179	106.3713
7	91.2	92	91.60	0.71	3406.72	168.23	335568.9	26.34	511.9822	488.7820	104.7465
8	89.9	90.6	90.25	0.68	3403.73	168.09	335274.4	26.60	506.4866	482.9887	104.8651
9	97.7	98.5	98.10	0.85	3423.58	168.65	336399.1	24.73	548.0953	515.8118	106.2588
10	102.4	103.2	102.80	0.98	3435.73	169.04	337177.7	23.76	572.5183	532.9809	107.4182
11	102.7	103.5	103.10	0.99	3437.91	169.56	338224.1	23.74	573.3450	533.9367	107.3807
12	102.8	103.6	103.20	0.99	3425.83	168.97	337035.5	23.74	571.3301	534.2299	106.9446
13	102.7	103.4	103.05	0.99	3438.16	170.00	339084.5	23.77	572.5678	533.7164	107.2794
14	102.5	103.3	102.90	0.98	3436.40	170.33	339750.8	23.75	572.7371	533.3489	107.3851
15	103	103.8	103.40	1.00	3436.54	170.34	339764.3	23.70	574.0429	534.9615	107.3055
16	104.2	105.1	104.65	1.03	3440.10	169.88	338856.9	23.54	578.4752	538.9798	107.3278
17	103.9	104.7	104.30	1.02	3435.61	170.08	339252.1	23.68	574.2987	537.6121	106.8240
18	104.1	104.9	104.50	1.03	3433.57	169.56	338214.1	23.65	574.7826	538.2610	106.7851
19	103	103.8	103.40	1.00	3432.97	169.95	338991.9	23.89	568.7592	534.4131	106.4269
20	102.9	103.7	103.30	0.99	3434.88	169.62	338343.2	23.91	568.6184	534.0467	106.4735
21	102.6	103.4	103.00	0.98	3439.17	169.63	338347.7	24.00	567.2125	532.9072	106.4374
22	101.3	102.1	101.70	0.95	3430.76	169.63	338354.8	24.19	561.3167	528.5170	106.2060
23	99.1	99.9	99.50	0.89	3423.92	169.50	338098.1	24.58	551.3714	520.6836	105.8937
24	98	98.8	98.40	0.86	3418.43	169.65	338393.8	24.83	545.0591	516.5255	105.5241
25	99.1	100.1	99.60	0.89	3420.28	169.32	337738.2	24.48	553.1647	521.3048	106.1116
26	101.6	102.6	102.10	0.96	3430.60	169.20	337504.2	23.95	567.0518	530.3875	106.9127
27	91.5	92.4	91.95	0.71	3413.40	168.98	337058.8	26.43	511.3291	489.7631	104.4034
28	83.6	84.5	84.05	0.56	3405.51	168.80	336696.3	28.69	469.8853	450.8031	104.2329
29	83.1	84	83.55	0.55	3405.85	168.82	336730.0	28.90	466.5448	447.8291	104.1792
30	103.8	104.7	104.25	1.02	3446.45	171.04	341166.9	23.87	571.4514	536.9614	106.4232

ATTACHMENT B

Condenser Performance Factor

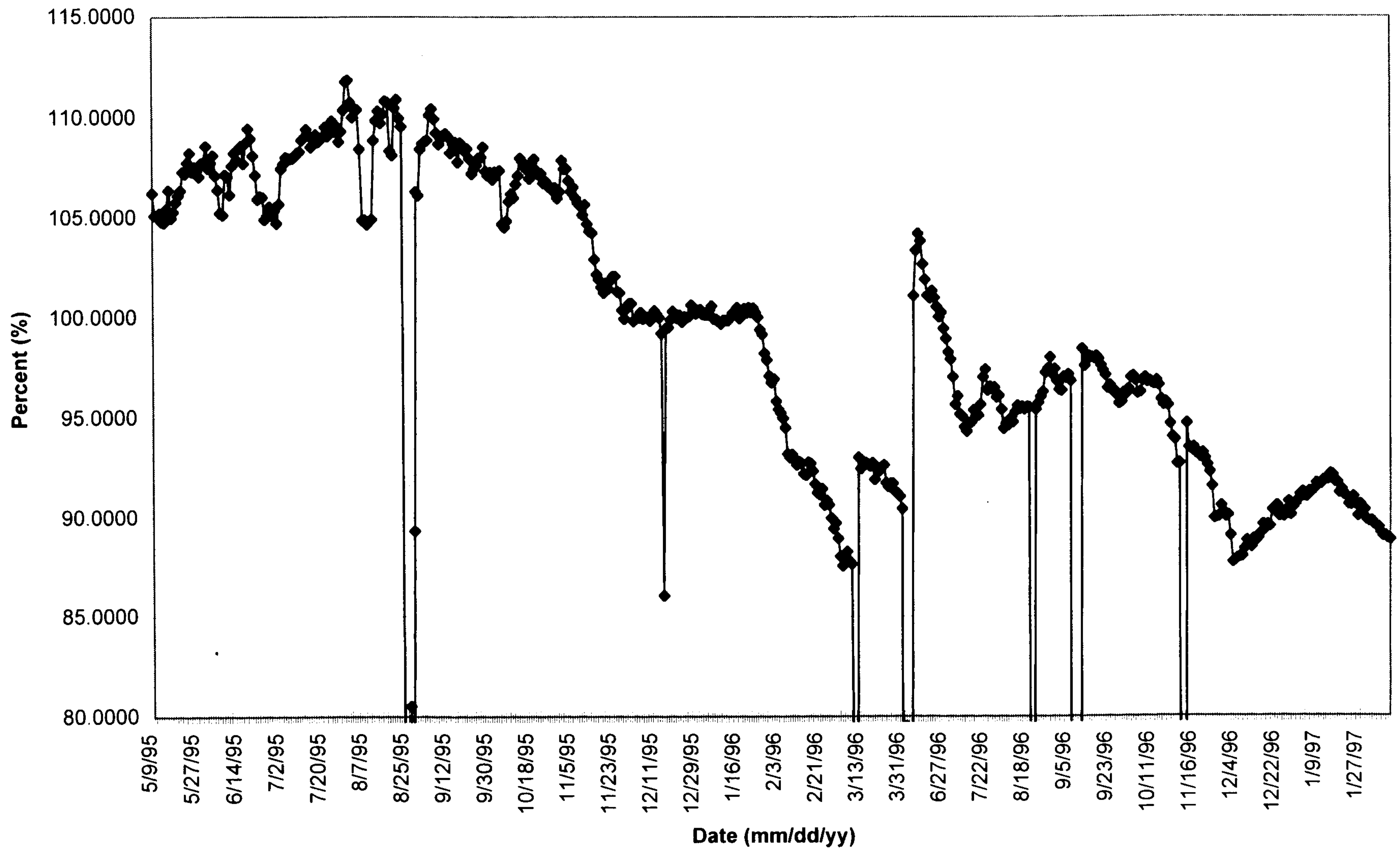


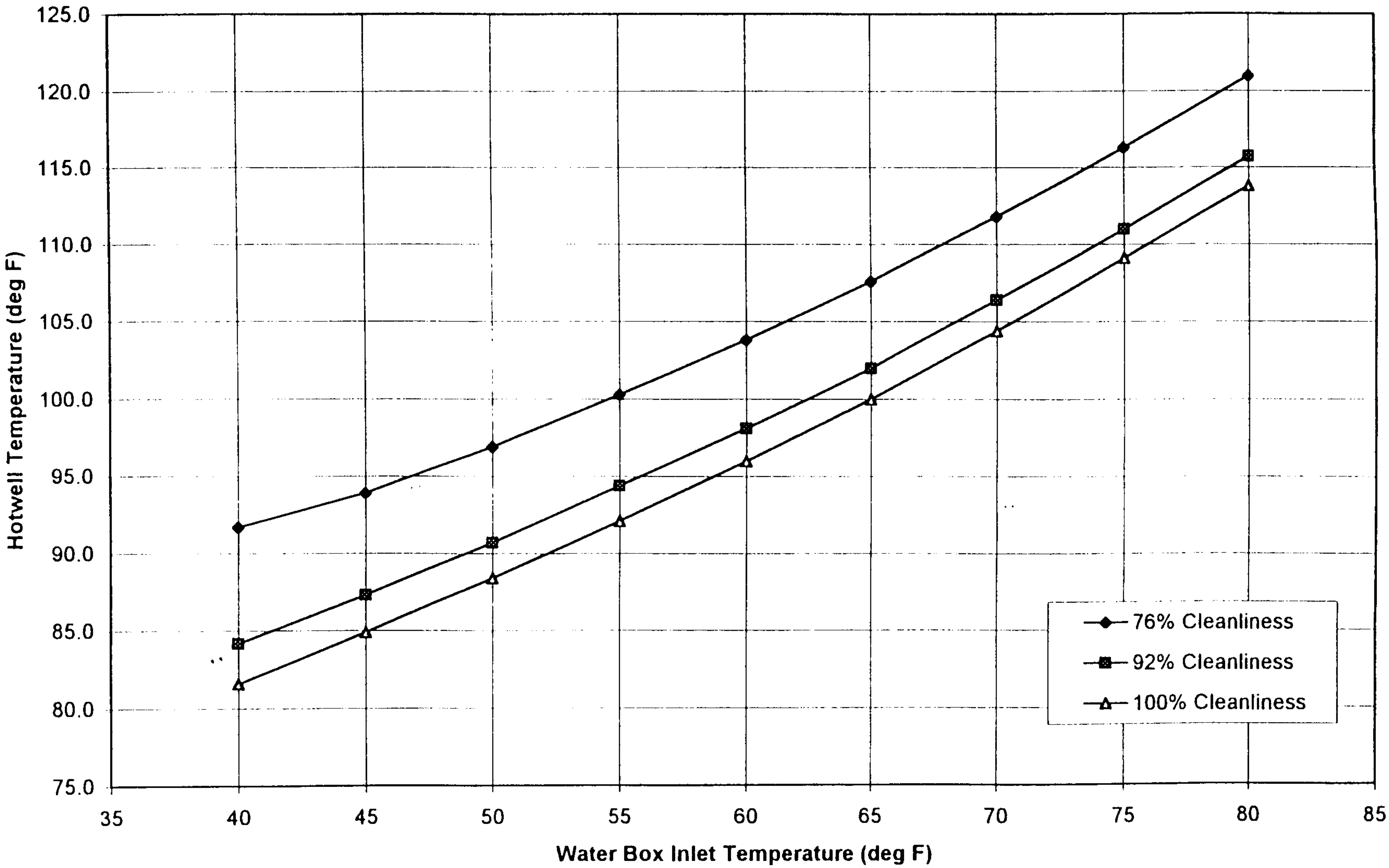
Fig. 1

ATTACHMENT C

Hotwell Temps

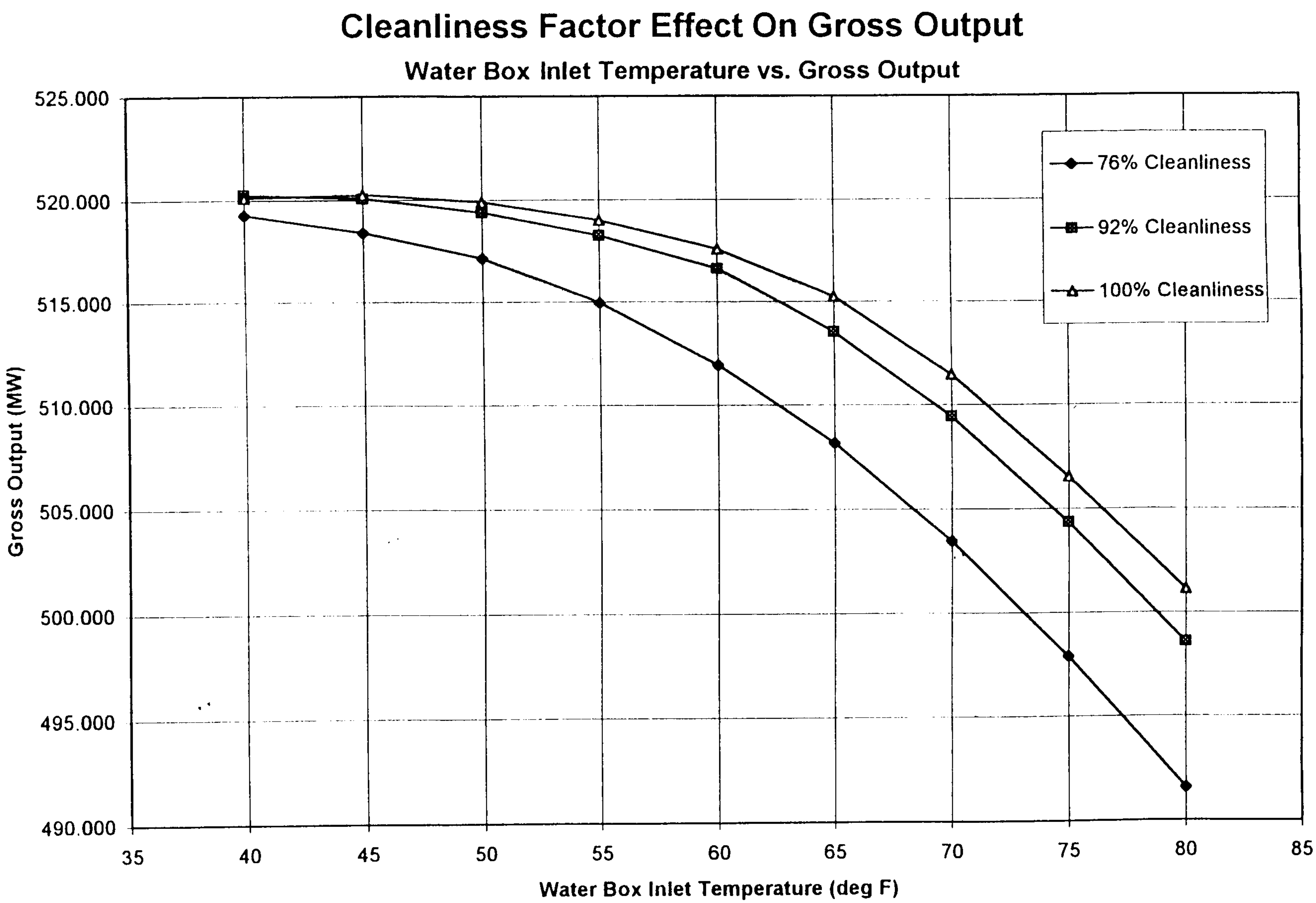
Cleanliness Factor Effect on Hotwell Temperatures

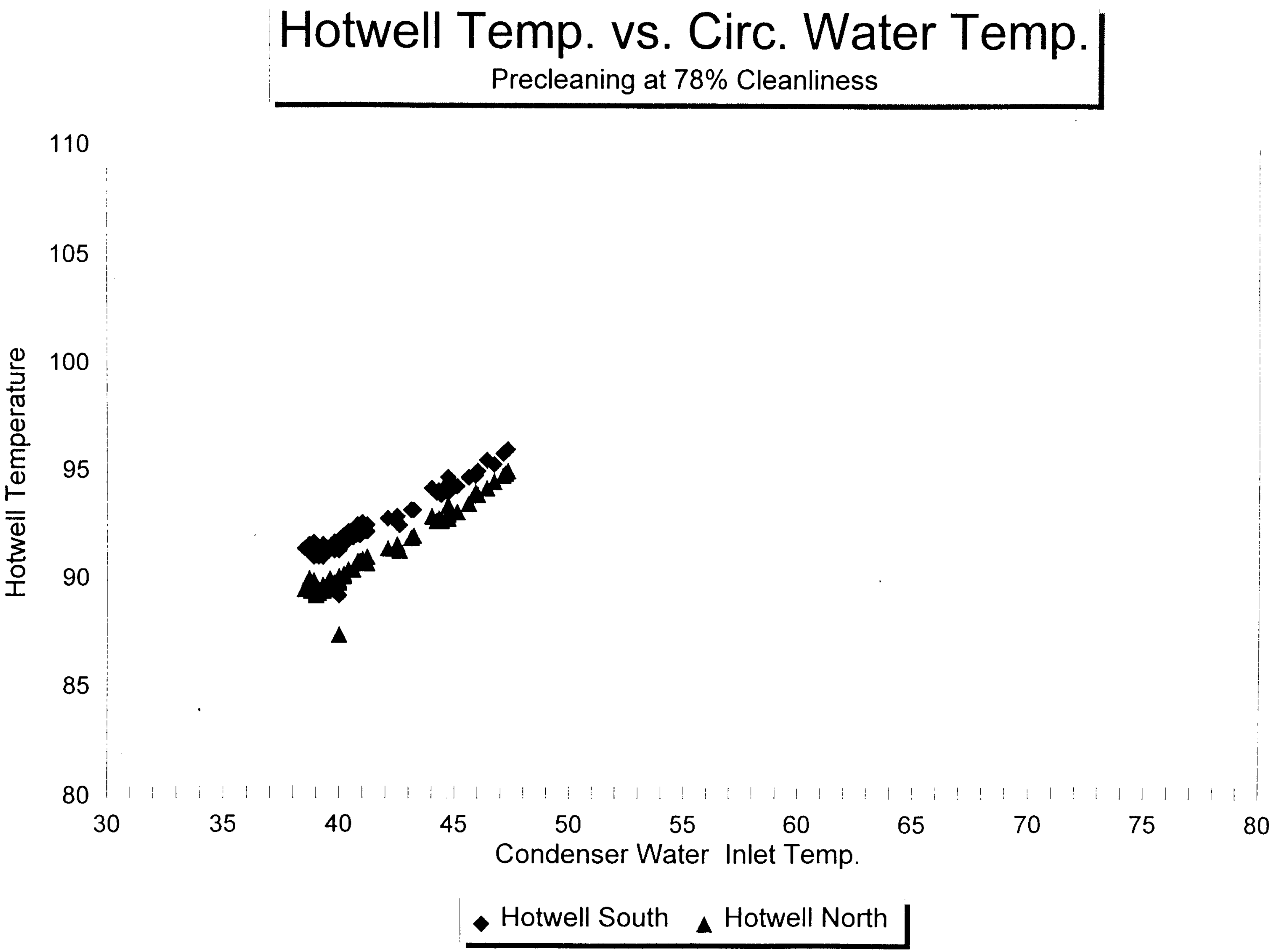
Water Box Inlet Temperature vs. Hotwell Temperature

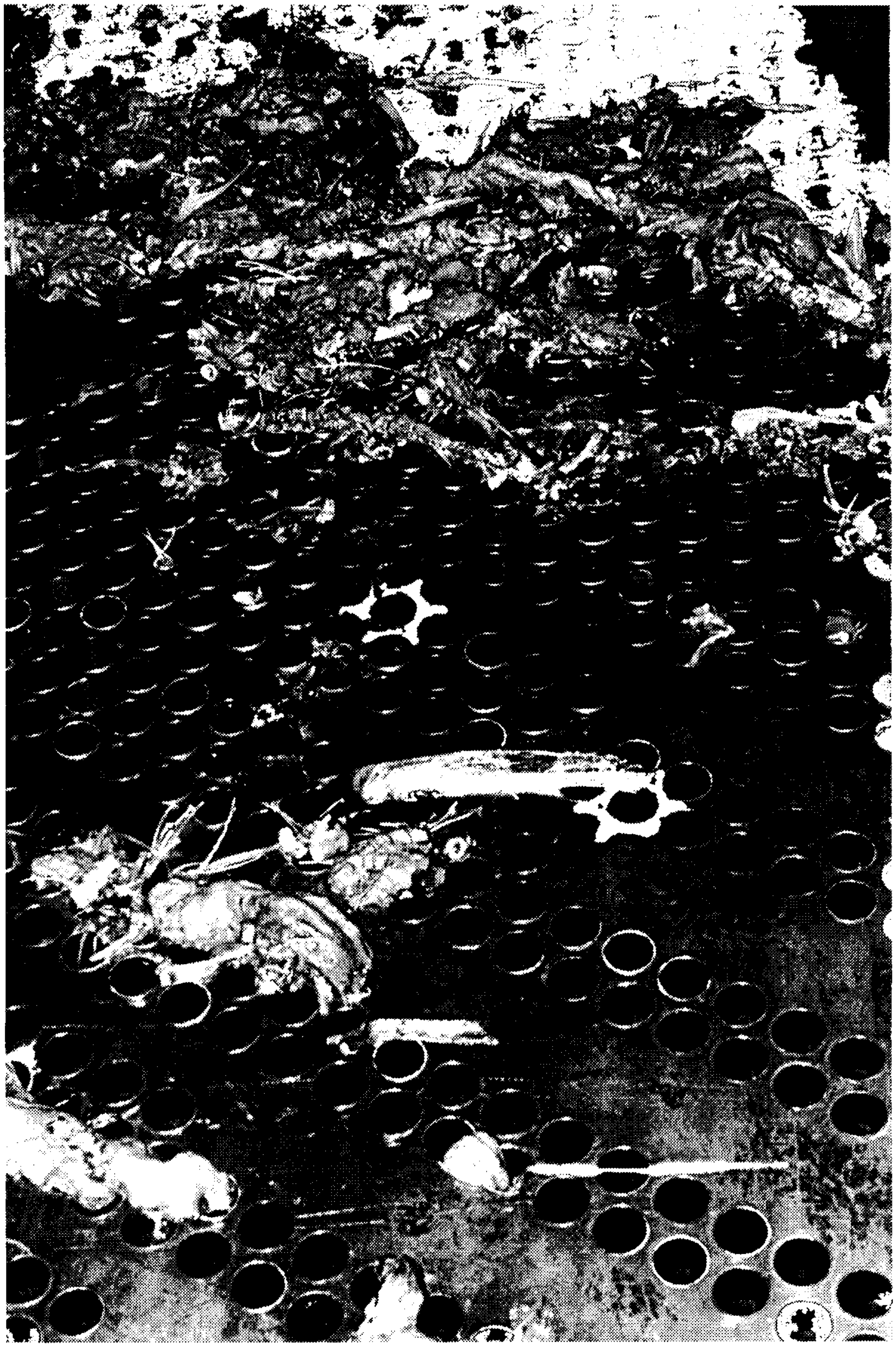


ATTACHMENT D

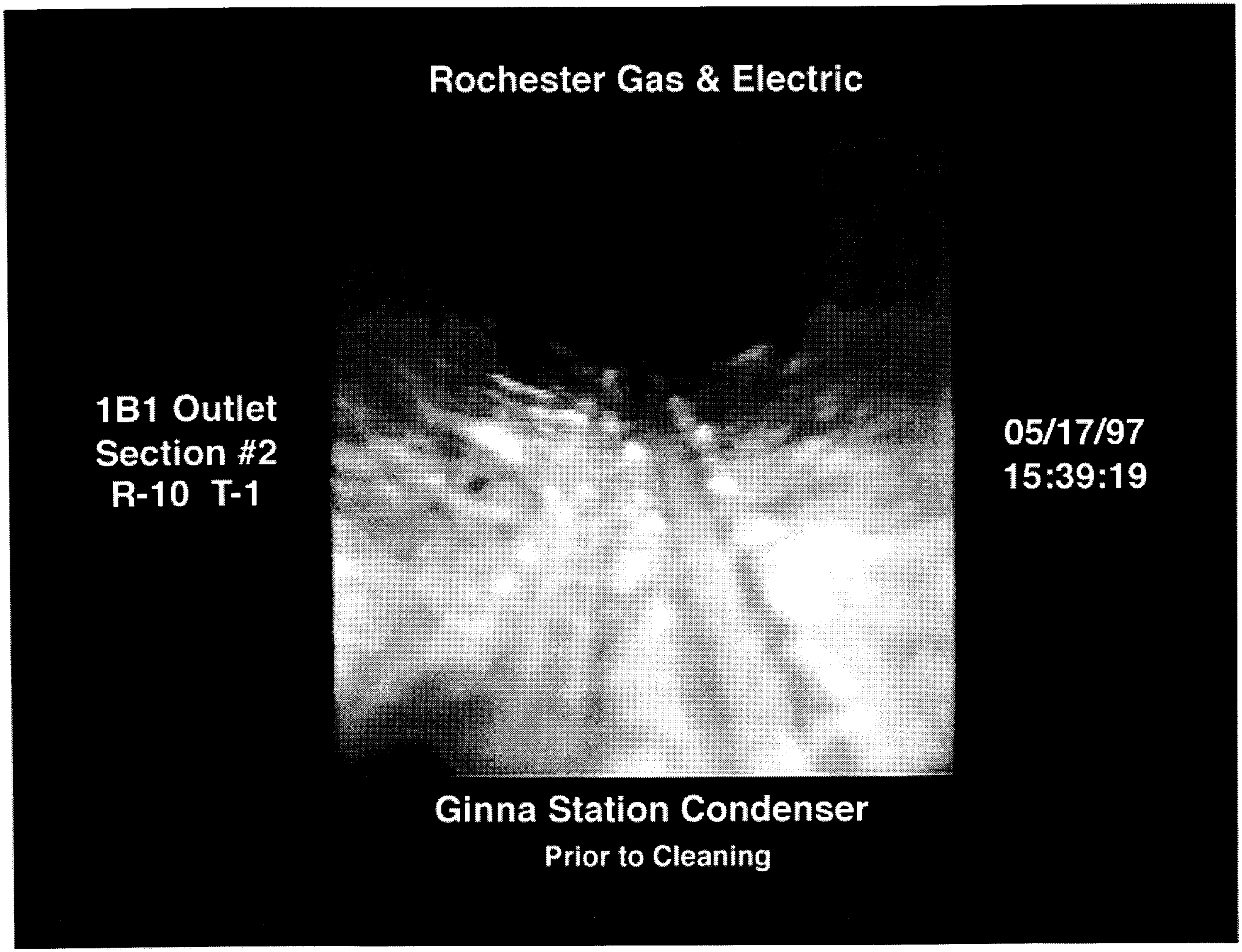
MegaWatt Output

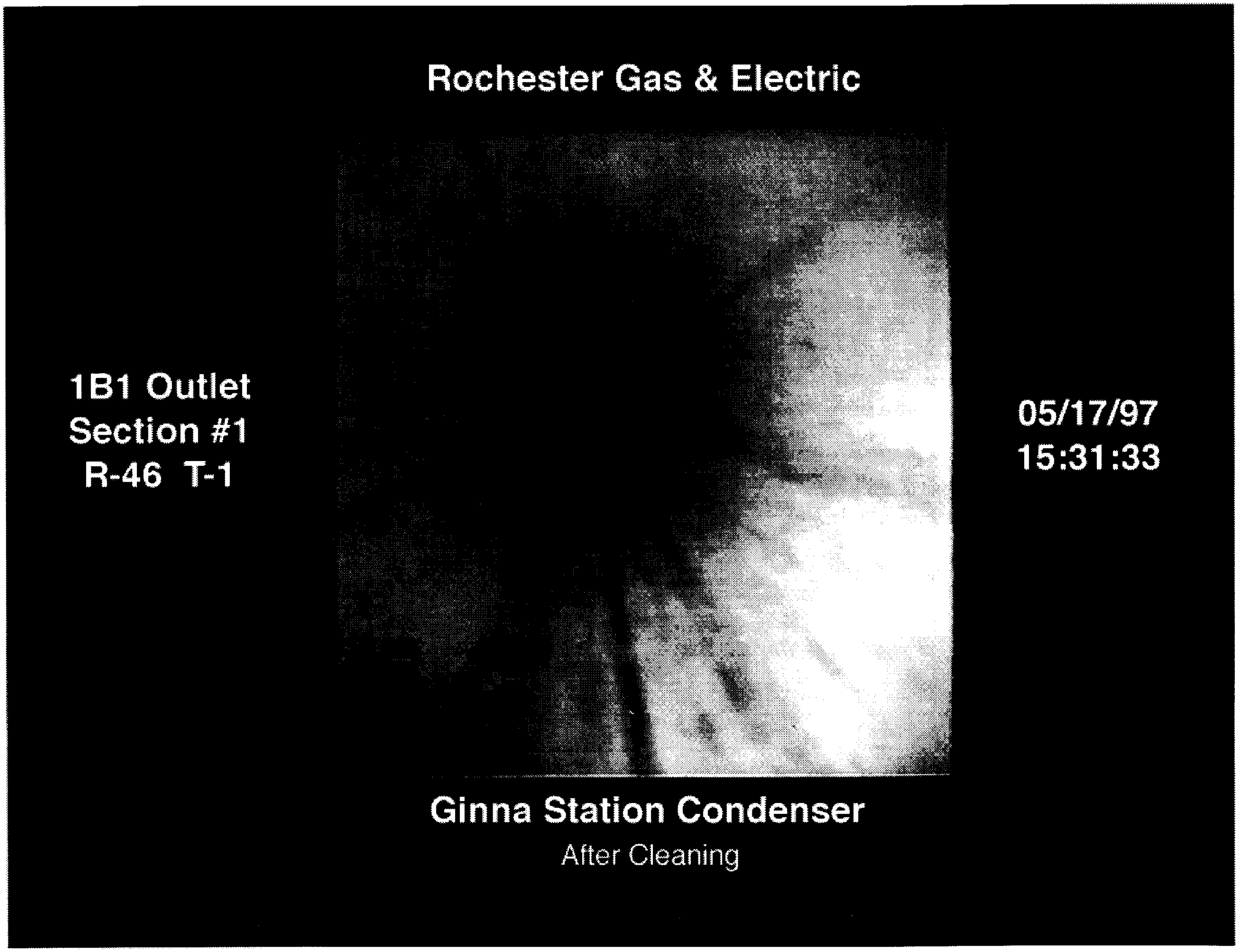


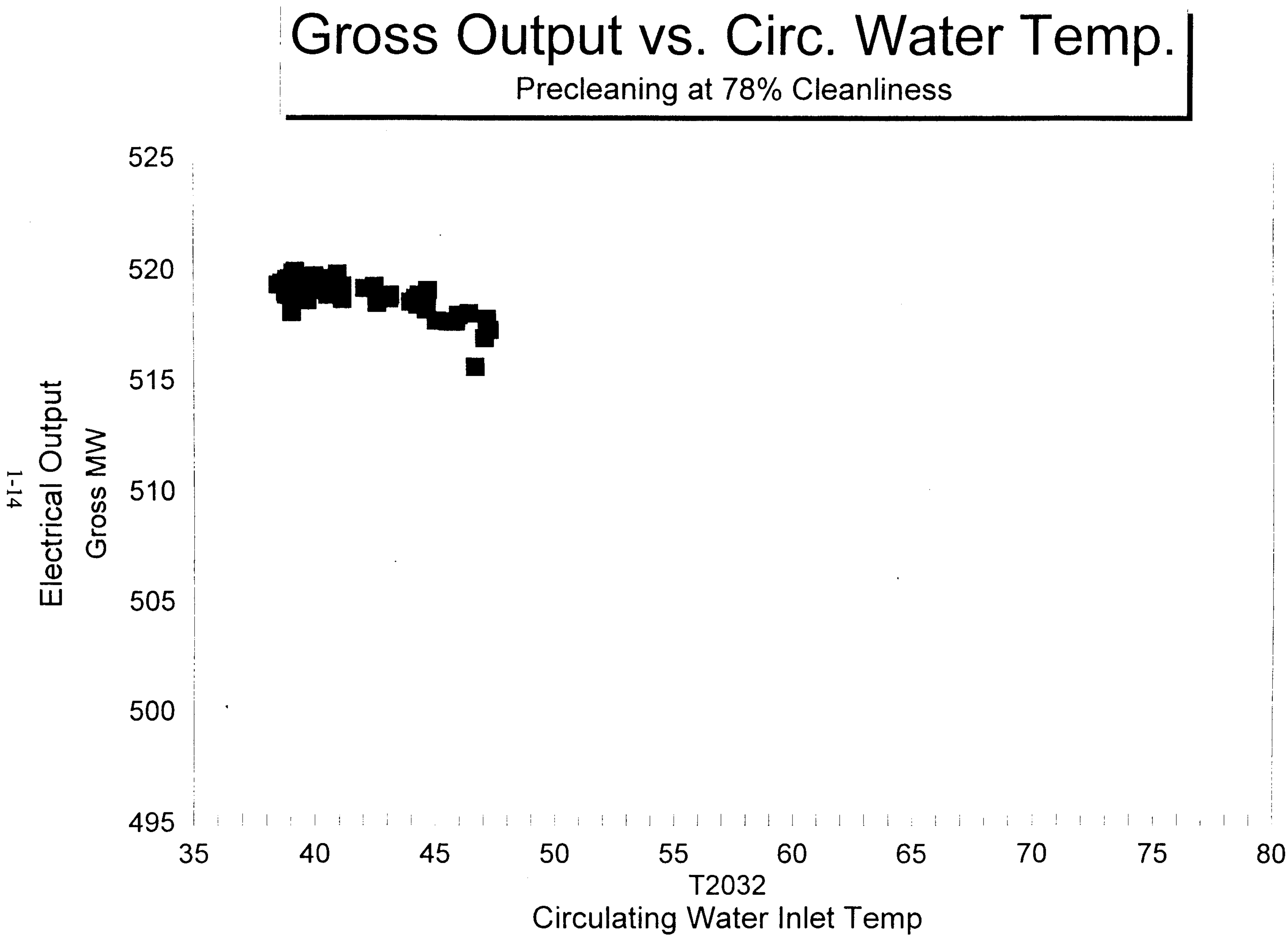

Hotwell Temp. vs. Circ. Water Temp.
Precleaning at 78% Cleanliness
Hotwell Temperature
110
105
100
95
90
85
80
30
35
40
45
50
55
60
65
70
75
80
Condenser Water Inlet Temp.
Hotwell South
Hotwell North



1A2 Condenser Inlet Tube Sheet

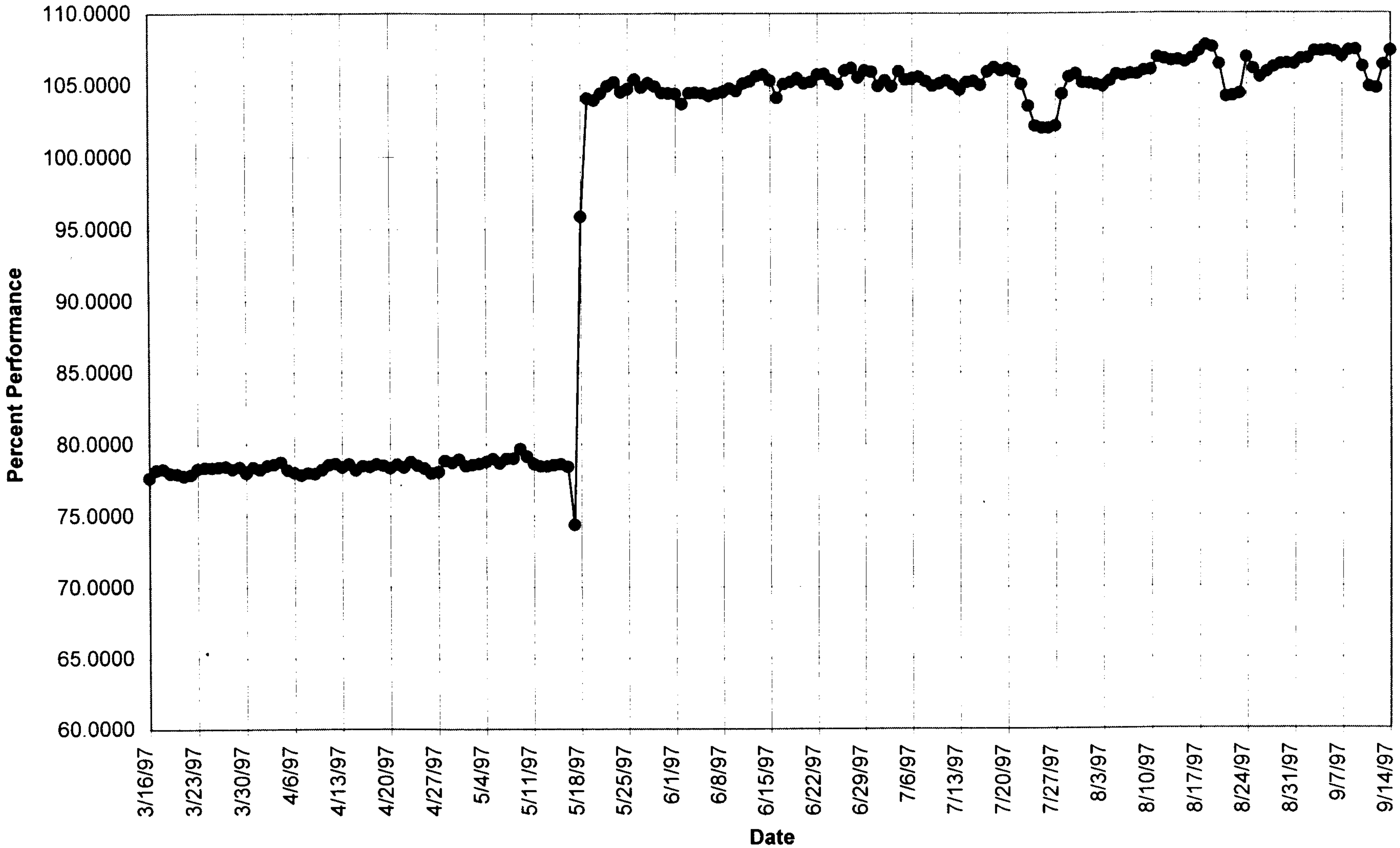

Rochester Gas & Electric
1B1 Outlet
Section #2
R-10 T-1
05/17/97
15:39:19
Ginna Station Condenser
Prior to Cleaning

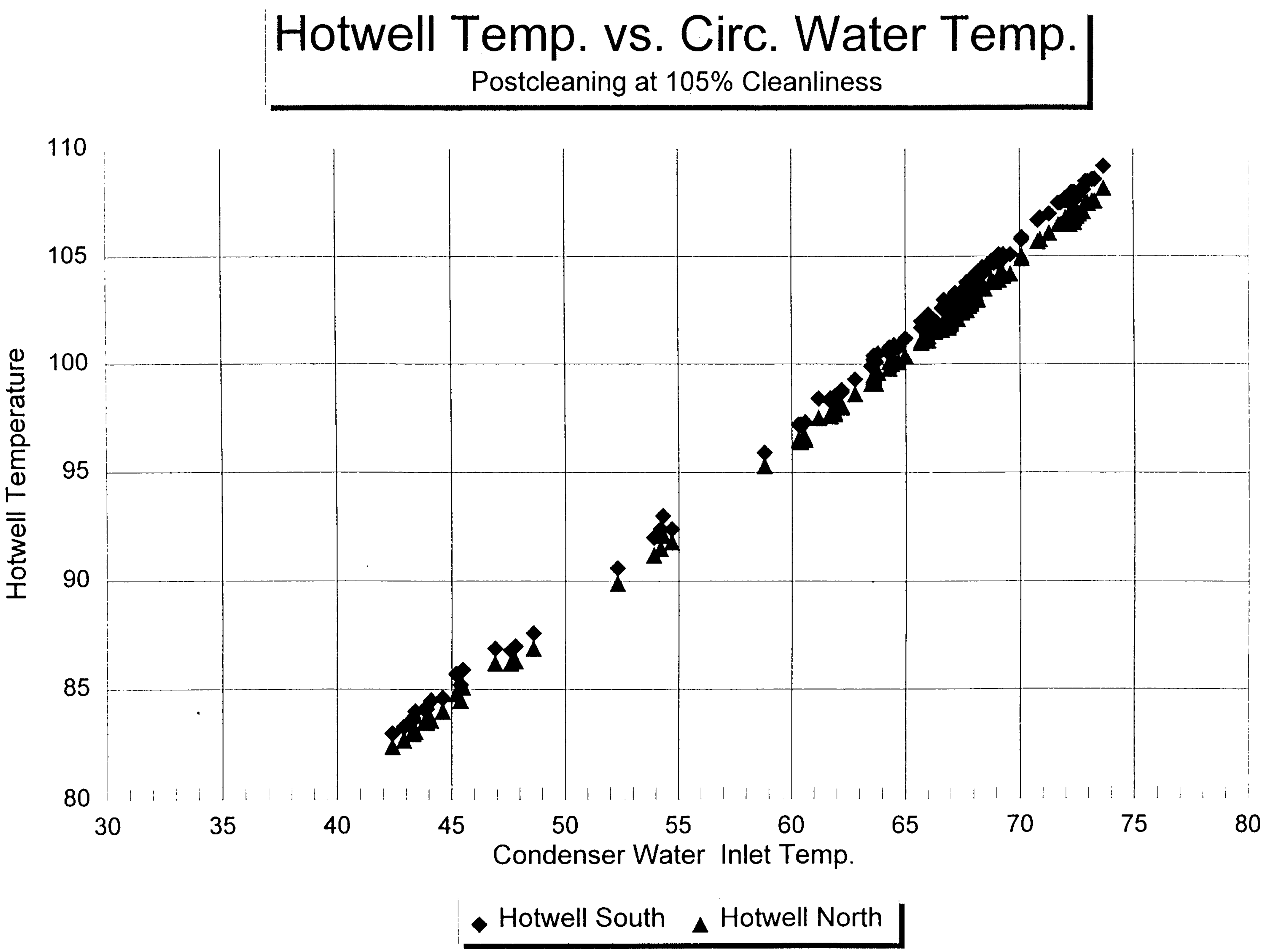

Rochester Gas & Electric
1B1 Outlet
Section #1
R-46 T-1
05/17/97
15:31:33
Ginna Station Condenser
After Cleaning


Gross Output vs. Circ. Water Temp.
Precleaning at 78% Cleanliness
525
520
515
510
505
500
495
Electrical Output
Gross MW
35
40
45
50
55
60
65
70
75
80
T2032
Circulating Water Inlet Temp

ATTACHMENT G

Condenser Performance




Hotwell Temp. vs. Circ. Water Temp.
Postcleaning at 105% Cleanliness
110
105
100
95
90
85
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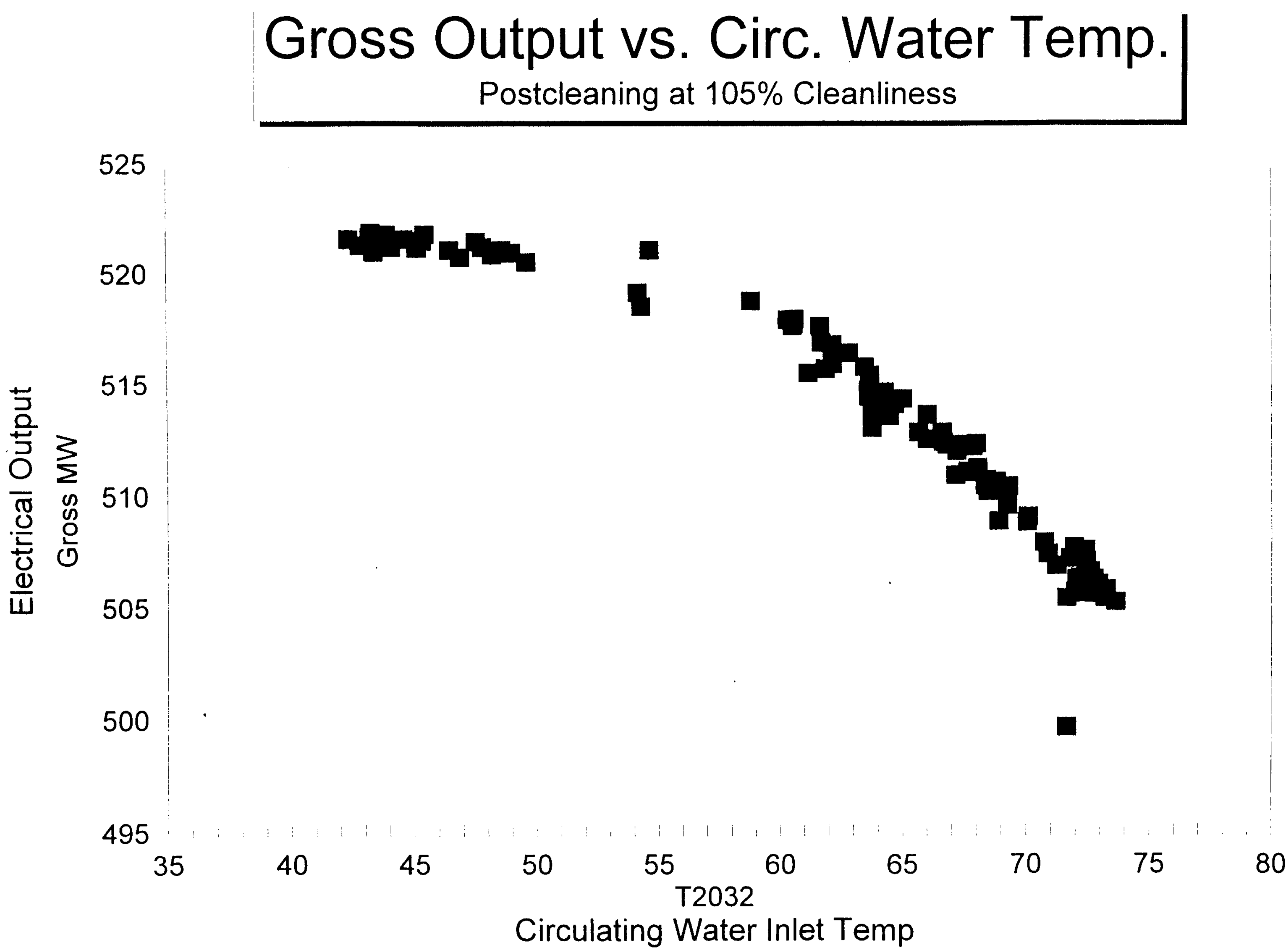
Hotwell Temperature
30
35
40
45
50
55
60
65
70
75
80
Condenser Water Inlet Temp.
Hotwell South
Hotwell North



Gross Output vs. Circ. Water Temp.
Postcleaning at 105% Cleanliness
Electrical Output
Gross MW
525
520
515
510
505
500
495
35
40
45
50
55
60
65
70
75
80
T2032
Circulating Water Inlet Temp

PURE EARTH ENVIRONMENTAL LABORATORY, INC.

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Rochester Gas & Electric
ATTN: Wendy Schneider
89 East Avenue
Rochester, NY 14649

June 3, 1997

SITE: Ginna Station

Dear Ms. Schneider,

The microbiological analysis of the bulk sample collected by Rochester Gas & Electric on 5/21/97 and submitted to Pure Earth Environmental Laboratory on 5/22/97 has been completed. The sample was evaluated for total count and identification of bacteria and fungi.

The results are presented in the enclosed data. This sample showed bacterial concentrations of 4.0×10^6 CFU/ml of 100% of *Xanthomonas maltophilia*. The fungal concentration was 39,000 CFU/ml of 97% *Penicillium* sp. and 3% of *Aspergillus niger*.

If you have any questions, please do not hesitate to call. Thank you.

Sincerely,

Theodore J. Passon Jr., PhD., SM(AAM), BCLD
Laboratory Director