

## TREATMENT OF COOLING WATER WITH SODIUM HYPOCHLORITE

AT THE VERMONT YANKEE NUCLEAR POWER STATION, VERNON, VERMONT - MAY 1973

### Closed Cycle Operation

#### INTRODUCTION

The studies were conducted to define the concentration-time relationships of free and combined chlorine (1) at the cooling tower inlet (forebay), (2) at the cooling tower outlet, (i.e. afterbay and blowdown) and (3) in the immediate receiving water area (Vernon Pond of the Connecticut River). The study reported here was conducted during May 1973.

During this period (and since commercial operation began in September 1972) the plant has been operated entirely in the closed cycle mode, hence, cooling water discharged to Vernon Pond was limited to blowdown. Since the first chlorination on March 27, 1973, to date, the plant has operated at 75% of full power (i.e. 405 MWe). The point of hypochlorite injection to the cooling water system is between the trash racks and vertical traveling screens in the intake structure. Chlorine was injected in the form of 12% sodium hypochlorite solution.

#### METHODOLOGY

Chlorination was performed by the Vermont Yankee Chemistry and Health Physics Staff and sampling and analyses were performed both by plant staff and the chemistry staff of Aquatec, Inc. of South Burlington, Vermont. Both plant staff and Aquatec staff had the opportunity to consult personally with Dr. Joseph E. Draley, Environmental Statement Project, Argonne National Laboratory. On May 3-4, 1973, Dr. Draley visited the plant, and personally ran several analyses for free and combined residual chlorine with the Vermont Yankee and Aquatec staff in attendance.

For the remainder of the program in May grab samples were collected in the forebay and afterbay of the discharge structure by lowering a weighted plastic bottle on a rope into the bays. Grab samples of the blowdown were collected from the blowdown discharge pipe on the apron of the discharge structure. Samples of river water were collected in the river within 100 feet of the river edge of the discharge structure.

Background chlorine residuals were measured before chlorination. After initiation of chlorination at the intake structure, cooling water samples were collected in the forebay every one to two minutes and titrated for total chlorine residual. When the maximum total chlorine concentration was approached titrations for free chlorine residual were also performed. When the maximum residual in the forebay was reached, sampling of the afterbay and/or the blowdown was begun. Sampling and titration for total and free chlorine was continued until the pattern of decay of chlorine concentration was established. Sampling of the river was begun after the maximum chlorine residual was detected in the blowdown samples.

In addition to these studies, on May 17, 1973, the blowdown was sampled exclusively during one chlorination run to obtain more complete concentration-time data on the plant discharge.

The analyses for total and free available chlorine were done by the

Amperometric Titration Method, Section 114B, Standard Methods for the Examination of Water and Wastewater, 13th Edition. The analyses were performed with a Wallace and Tiernan Amperometric Titrator, Series A790.

Tabulations of all experimental results are attached (pages 1-19). The results have been summarized graphically on experimental runs in which the quantity of data was sufficient to justify such a presentation. Maxima on these graphs were obtained by extrapolation.

A graphical presentation of data on pages 19-24 follows the tabular data summary on pages 1-19.

#### SUMMARY

1. Data presented (pages 1-24) on the results of test cooling water chlorination are confined to plant operation under the following specific conditions.

a. Complete closed-cycle operation utilizing both mechanical-draft wet-type cooling towers (11 cells each tower).

b. Data from one month (May).

c. Operation only at 75% of full power (i.e. 405 MWe).

2. During the test period in May, total residual chlorine concentrations were, except for one case observed, below the 0.1 mg/l regulation limit (0.08 mg/l) in the afterbay and blowdown (cooling tower outlet) (pages 22-23) while maximum total residual chlorine in the forebay condenser outlet-cooling tower inlet was recorded once as 0.64 mg/l (pages 11 and 21). Throughout May, hypochlorite was regularly injected 6 days per week at 50 gallons per day in one 10-minute slug each day.

3. Chlorination data are not developed for open cycle-operation and/or operation at other times of the year, viz. summer months when bacterial, fungal and algal growths can be expected to be maximum within the cooling water systems and the cooling towers. For these reasons, the herein reported test should not be regarded as conclusive as to what steps might be necessary to prevent biological fouling of the cooling water hardware at (a) 100% of power, (b) summer months and other times of the year, (c) open-cycle operation.

4. Under the conditions of the present test, the chlorination protocol adopted experimentally has been adequate to keep the condenser system per se in a reasonable state of cleanliness. It has, however, not resulted in adequate control of bacterial slime growth in the cooling towers. Apparently a great deal of residual chlorine is evaporated in cooling tower water vapor and drift. This slime build-up is seen by Vermont Yankee staff to be potentially a serious problem to plant operation particularly in the summer months when increased ambient river temperatures occur. Ambient river temperature in May (present test) ranged from approximately 50-65°F while Vernon Pond river temperature in July and August can be expected to reach as high as 75-80°F based on historical data.

5. At no time did the total residual chlorine concentration in the river at a point 100 feet from the discharge point exceed 0.01 mg/l. For the majority of analyses, no measurable total residual chlorine was detected in the river.

6. If and when the plant is allowed once-through cooling (open-cycle operation) a new test period for cooling water chlorination will probably be necessary since

the results of the present chlorination testing on closed-cycle operation should not be extrapolated (or if so, with great care) to (a) open-cycle operation and/or (b) operation at 100% power, and/or (c) operation in summer and winter months.

For these three reasons, it is recommended that Vermont Yankee be permitted additional testing periods under varying conditions (supra) based solely on need (condenser-cooling tower cleanliness) with the present upper total residual chlorine concentration limit for testing (RE: Non-Radiological Technical Specifications Section 1.0.B.2, page 3) of 0.5 mg/l at the point of discharge to the river (afterbay/blowdown).

CHLORINE RESIDUALS  
IN  
DISCHARGE STRUCTURE FOREBAY

<u>Date</u>	<u>Run</u>	<u>Gallons of Hypochlorite Added</u>	<u>Total Chlorine Residuals</u>		<u>Free Chlorine Residuals</u>	
			<u>Observed</u>	<u>Extrapolated</u>	<u>Observed</u>	<u>Extrapolated</u>
5/14/73	I	50	0.06	0.06	0.02	0.03
	II	150	0.20	0.24	0.04	0.09
	III	50	0.18	0.18	<.01	--
5/15/73	I	50	0.10	0.16	0.04	0.06
	II	50	0.27	0.35	0.06	0.08
	III	50	0.35	0.38	0.12	0.13
	IV	50	0.28	0.40	0.12	0.18

CHLORINE RESIDUALS  
IN  
DISCHARGE STRUCTURE AFTERBAY

<u>Date</u>	<u>Run</u>	<u>Gallons of Hypochlorite Added</u>	<u>Total Chlorine Residuals</u>		<u>Free Chlorine Residuals</u>	
			<u>Observed</u>	<u>Extrapolated</u>	<u>Observed</u>	<u>Extrapolated</u>
5/14/73	I	50	0.02	--	--	--
	II	150	0.05	--	<.01	--
	III	50	0.08	--	<.01	--
5/15/73	I	50	0.02	--	--	--
	II	50	0.05	--	>.01	--
	III	50	0.08	--	>.01	--
	IV	50	0.05	--	>.01	--

VERMONT YANKEE CHLORINATION STUDY

Date: 5/4/73

Run: I

Gallons of Hypochlorite Added: --

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1132	--	--	--	--	--	--	--	--
1136	--	0.00	--	--	--	--	--	--
1137	--	0.00	--	--	--	--	--	--
1139	--	0.10	--	--	--	--	--	--
1141	0.00	0.08	--	--	--	--	--	--
1145	0.02	0.12	--	--	--	--	--	--
1148	--	--	0.00	0.06	--	--	--	--
1150	--	--	0.00	0.03	--	--	--	--
1152	0.00	0.06	--	--	--	--	--	--
1158	0.00	0.05	--	--	--	--	--	--
1204	--	--	--	0.04	--	--	--	0.00
1209	--	--	--	--	--	--	--	--
1214	0.00	0.00	--	--	--	--	--	--
1219	--	--	0.00	0.01	--	--	--	--
1231	--	--	--	0.01	--	--	--	--

VERMONT YANKEE CHLORINATION STUDY

Date: 5/14/73

Run: I

Gallons of Hypochlorite Added: 50

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1116	--	<.01	--	<.01	--	--	--	<.01
1118	--	<.01	--	--	--	--	--	--
1120	--	<.01	--	--	--	--	--	--
1123	--	.01	--	--	--	--	--	--
1124	--	.03	--	--	--	--	--	--
1126	--	.06	--	--	--	--	--	--
1129	.02	--	--	--	--	--	--	--
1131	--	--	--	.02	--	--	--	--
1134	--	<.01	--	--	--	--	--	--
1136	--	--	--	<.01	--	--	--	--
1203	--	<.01	--	--	--	--	--	--
1207	--	--	--	--	--	--	<.01	--
1213	--	--	--	<.01	--	--	--	--

VERMONT YANKEE CHLORINATION STUDY

Date: 5/14/73

Run: II

Gallons of Hypochlorite Added: ≤ 150 gallons

Time	Forebay		Afterbay		Slowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1350	--	<.01	--	<.01	--	--	--	<.01
1352	--	<.01	--	--	--	--	--	--
1354	--	<.01	--	--	--	--	--	--
1355	--	.09	--	--	--	--	--	--
1357	.01	--	--	--	--	--	--	--
1359	--	.20	--	--	--	--	--	--
1403	--	--	--	.05	--	--	--	--
1406	.04	--	--	--	--	--	--	--
1408	--	--	--	<.01	--	--	--	--
1412	--	.04	--	--	--	--	--	--
1415	--	--	--	.05	--	--	--	--
1417	.05	--	--	--	--	--	--	--
1420	--	--	--	--	--	--	--	.03
1423	--	--	--	--	--	--	--	<.01
1425	<.01	.03	--	--	--	--	--	--
1428	--	--	<.01	.03	--	--	--	--

VERMONT YANKEE CHLORINATION STUDY

Date: 5/14/73

Run: III

Gallons of Hypochlorite Added: 50

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1515	--	<.01	--	--	--	--	--	--
1517	--	<.01	--	--	--	--	--	--
1519	--	.01	--	--	--	--	--	--
1521	--	.18	--	--	--	--	--	--
1523	--	--	--	.08	--	--	--	--
1529	<.01	--	--	--	--	--	--	--
1532	--	--	<.01	.08	--	--	--	--
1534	--	.05	--	--	--	--	--	--
1538	--	--	--	.05	--	--	--	--

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# VERMONT YANKEE CHLORINATION STUDY

Date: 5/15/73

Run: I

Gallons of Hypochlorite Added: 50

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
0801	--	<.01	--	--	--	--	--	--
0803	--	--	--	<.01	--	--	--	--
0810	--	<.01	--	--	--	--	--	--
0812	--	<.01	--	--	--	--	--	--
0814	--	<.01	--	--	--	--	--	--
0816	--	<.01	--	--	--	--	--	--
0818	--	.03	--	--	--	--	--	--
0819	--	.08	--	--	--	--	--	--
0823	.04	.10	--	--	--	--	--	--
0828	--	<.01	--	--	--	--	--	--
0830	--	--	--	.01	--	--	--	--
0832	--	.01	--	--	--	--	--	--
0834	--	--	--	.01	--	--	--	--
0836	--	.02	--	--	--	--	--	--
0838	--	--	--	.02	--	--	--	--
0840	--	.01	--	--	--	--	--	--
0842	--	--	--	.01	--	--	--	--
0843	--	.01	--	--	--	--	--	--
0846	--	--	--	<.01	--	--	--	--
0847	--	.01	--	--	--	--	--	--
0849	--	--	--	.01	--	--	--	--
0851	--	.01	--	--	--	--	--	--

# VERMONT YANKEE CHLORINATION STUDY

Date: 5/15/73

Run: II

Gallons of Hypochlorite Added: 50

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1001	--	<.01	--	--	--	--	--	--
1002	--	<.01	--	--	--	--	--	--
1003	--	<.01	--	--	--	--	--	--
1004	--	<.01	--	--	--	--	--	--
1006	--	<.01	--	--	--	--	--	--
1007	--	.03	--	--	--	--	--	--
1008	.02	.13	--	--	--	--	--	--
1013	.06	.27	--	--	--	--	--	--
1017	--	.07	--	--	--	--	--	--
1019	--	--	<.01	.05	--	--	--	--
1022	--	.05	--	--	--	--	--	--
1024	--	--	--	.04	--	--	--	--
1026	--	--	--	.05	--	--	--	--
1027	--	--	--	.04	--	--	--	--
1029	--	--	--	--	--	--	--	--
1033	--	.03	--	--	--	--	--	>.01
1034	--	--	--	.02	--	--	--	--
1036	--	.03	--	--	--	--	--	--
1038	--	--	--	.03	--	--	--	--
1040	--	.01	--	--	--	--	--	--
1043	--	--	--	.02	--	--	--	--
1044	--	.02	--	--	--	--	--	--
1046	--	--	--	.02	--	--	--	--

VERMONT YANKEE CHLORINATION STUDY

Date: 5/15/73

Run: III

Gallons of Hypochlorite Added: 50

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1243	--	>.01	--	--	--	--	--	--
1244	--	--	--	>.01	--	--	--	--
1245	--	>.01	--	--	--	--	--	--
1247	--	--	--	>.01	--	--	--	--
1248	--	.02	--	--	--	--	--	--
1249	--	--	--	>.01	--	--	--	--
1251	.11	.30	--	--	--	--	--	--
1254	.12	.35	--	--	--	--	--	--
1300	--	--	>.01	.08	--	--	--	--
1303	--	.07	--	--	--	--	--	--
1306	--	--	--	--	--	--	--	>.01
1307	--	.04	--	--	--	--	--	--
1308	--	--	--	.04	--	--	--	--
1310	--	.03	--	--	--	--	--	--
1312	--	--	--	.03	--	--	--	--
1314	--	.02	--	--	--	--	--	--
1315	--	--	--	.03	--	--	--	--
1317	--	--	--	.02	--	--	--	--
1318	--	.02	--	--	--	--	--	--
1320	--	--	--	.03	--	--	--	--
1322	--	.02	--	--	--	--	--	--
1324	--	--	--	.02	--	--	--	--

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# VERMONT YANKEE CHLORINATION STUDY

Date: 5/15/73

Run: IV

Gallons of Hypochlorite Added: 50

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1509	--	>.01	--	--	--	--	--	--
1511	--	--	--	>.01	--	--	--	--
1512	--	--	--	--	--	--	--	--
1513	--	>.01	--	--	--	--	--	--
1514	--	>.01	--	--	--	--	--	--
1515	--	>.01	--	--	--	--	--	--
1516	--	>.01	--	--	--	--	--	--
1518	--	.03	--	--	--	--	--	--
1519	--	.18	--	--	--	--	--	--
1520	--	--	--	--	--	--	--	--
1523	.12	.28	--	--	--	--	--	--
1527	--	.05	--	--	--	--	--	--
1529	--	--	--	.05	--	--	--	--
1533	--	.07	--	--	--	--	--	--
1534	--	--	--	.04	--	--	--	--
1535	--	.04	--	--	--	--	--	--
1537	--	--	>.01	.05	--	--	--	--
1540	--	.03	--	--	--	--	--	--

VERMONT YANKEE CHLORINATION STUDY

Date: 5/17/73

Run: I

Gallons of Hypochlorite Added: 25 (New Lot)

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1029	--	>.01	--	>.01	--	--	--	--
1031	--	>.01	--	--	--	--	--	--
1032	--	>.01	--	--	--	--	--	--
1033	--	>.01	--	--	--	--	--	--
1034	--	.01	--	--	--	--	--	--
1036	--	.20	--	--	--	--	--	--
1038	--	.60	--	--	--	--	--	--
1044	--	--	--	.05	--	--	--	--
1049	--	.02	--	--	--	--	--	--
1051	--	--	--	>.01	--	--	--	--
1053	--	.01	--	--	--	--	--	--
1054	--	.04	--	--	--	--	--	--
1055	--	--	--	.02	--	--	--	--
1057	--	.01	--	--	--	--	--	--
1059	--	--	--	.02	--	--	--	--
1101	--	>.01	--	--	--	--	--	--
1103	--	--	--	.03	--	--	--	--
1105	--	.02	--	--	--	--	--	--
1107	--	--	--	.01	--	--	--	--
1109	--	>.01	--	--	--	--	--	--

VERMONT YANKEE CHLORINATION STUDY

Date: 5/17/73

Run: II

Gallons of Hypochlorite Added: 30

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1302	--	<.01	--	<.01	--	<.01	--	--
1304	--	--	--	<.01	--	--	--	--
1305	--	<.01	--	--	--	--	--	--
1306	--	.01	--	--	--	--	--	--
1307	--	<.01	--	--	--	--	--	--
1308	--	.15	--	--	--	--	--	--
1310	.51	--	--	--	--	--	--	--
1311	--	.64	--	--	--	--	--	--
1316	--	--	--	--	--	.15	--	--
1318	--	>.01	--	--	--	--	--	--
1320	--	--	--	.02	--	--	--	--
1322	--	.04	--	--	--	--	--	--
1323	--	--	--	--	>.01	>.01	--	--
1326	--	--	--	.03	--	--	--	--
1328	--	.02	--	--	--	--	--	--
1329	--	.01	--	--	--	--	--	--
1331	--	--	--	--	--	.02	--	--
1333	--	--	--	.01	--	--	--	--
1334	--	.02	--	--	--	--	--	--
1335	--	--	--	.02	--	--	--	--

VERMONT YANKEE CHLORINATION STUDY

Date: 5/17/73

Run: III

Gallons of Hypochlorite Added: 25

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1502	--	--	--	--	--	>.01	--	--
1503	--	--	--	--	--	>.01	--	--
1505	--	--	--	--	--	>.01	--	--
1506	--	--	--	--	--	>.01	--	--
1507	--	--	--	--	--	>.01	--	--
1508	--	--	--	--	--	>.01	--	--
1509	--	--	--	--	--	>.01	--	--
1510	--	--	--	--	--	>.01	--	--
1511	--	--	--	--	--	>.01	--	--
1512	--	--	--	--	--	.08	--	--
1513	--	--	--	--	.08	.12	--	--
1516	--	--	--	--	--	--	--	>.01
1518	--	.02	--	--	--	--	--	--
1519	--	--	--	--	--	.03	--	--
1520	--	--	--	--	--	.01	--	--
1522	--	--	--	--	--	.01	--	--

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# VERMONT YANKEE CHLORINATION STUDY

Date: 5/18/73

Run: I

Gallons of Hypochlorite Added:

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
0953	--	>.01	--	--	--	--	--	--
0958	--	>.01	--	--	--	--	--	--
1006	--	>.01	--	--	--	--	--	--
1007	--	>.01	--	--	--	--	--	--
1008	--	>.01	--	--	--	--	--	--
1010	--	>.01	--	--	--	--	--	--
1011	--	.03	--	--	--	--	--	--
1012	--	.30	--	--	--	--	--	--
1014	.06	--	--	--	--	--	--	--
1015	.38	--	--	--	--	--	--	--
1016	--	--	--	--	.02	.12	--	--
1021	--	--	--	--	--	>.01	--	--
1026	--	.02	--	--	--	--	--	--
1030	--	--	--	.02	--	--	--	--



VERMONT YANKEE CHLORINATION STUDY

Date: 5/18/73

Run: II

Gallons of Hypochlorite Added:

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1327	--	>.01	--	--	--	--	--	--
1343	--	.02	--	--	--	--	--	--
1344	--	>.01	--	--	--	--	--	--
1346	--	.04	--	--	--	--	--	--
1347	--	.82	--	--	--	--	--	--
1349	--	.46	--	--	--	--	--	--
1353	--	--	--	--	.08	.14	--	--
1359	--	.07	--	--	--	--	--	--
1402	--	--	--	--	--	.02	--	>.01

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VERMONT YANKEE CHLORINATION STUDY

Date: 5/29/73

Run: I

Gallons of Hypochlorite Added: 25

Time	Forebay		Afterbay		Slowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1048	--	--	--	--	0	0	--	--
1053	--	--	--	--	--	0	--	--
1055	--	--	--	--	--	0	--	--
1058	--	--	--	--	--	0	--	--
1100	--	--	--	--	--	0.02	--	--
1102	--	--	--	--	--	0.02	--	--
1104	--	--	--	--	--	0	--	--
1106	--	--	--	--	--	0	--	--
1108	--	--	--	--	--	0	--	--

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VERMONT VANKEE CHLORINATION STUDY

Date: 5/25/73

Run: I

Gallons of Hypochlorite Added:

Time	Forebay		Afterbay		Slowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1020	--	--	--	--	0	0	--	--
1050	--	--	--	--	0	0	--	--
1055	--	--	--	--	0	0	--	--
1105	--	--	--	--	0	0	--	--
1110	--	--	--	--	0	0	--	--

356 144

VERMONT YANKEE CHLORINATION STUDY

Date: 5/25/73

Run: II

Gallons of P per ilorite Added: 50

Time	Forebay		Afterbay		Blowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1509	--	--	--	--	0	0	--	--
1511	--	--	--	--	--	0	--	--
1513	--	--	--	--	--	0	--	--
1516	--	--	--	--	--	0	--	--
1519	--	--	--	--	--	0.05	--	--
1521	--	--	--	--	0.02	0.06	--	--
1523	--	--	--	--	0	0	--	--
1527	--	--	--	--	--	--	0	0
1531	--	--	--	--	--	--	--	0
1535	--	--	--	--	--	0	--	--

356 145

VERMONT YANKS CHLORINATION STUDY

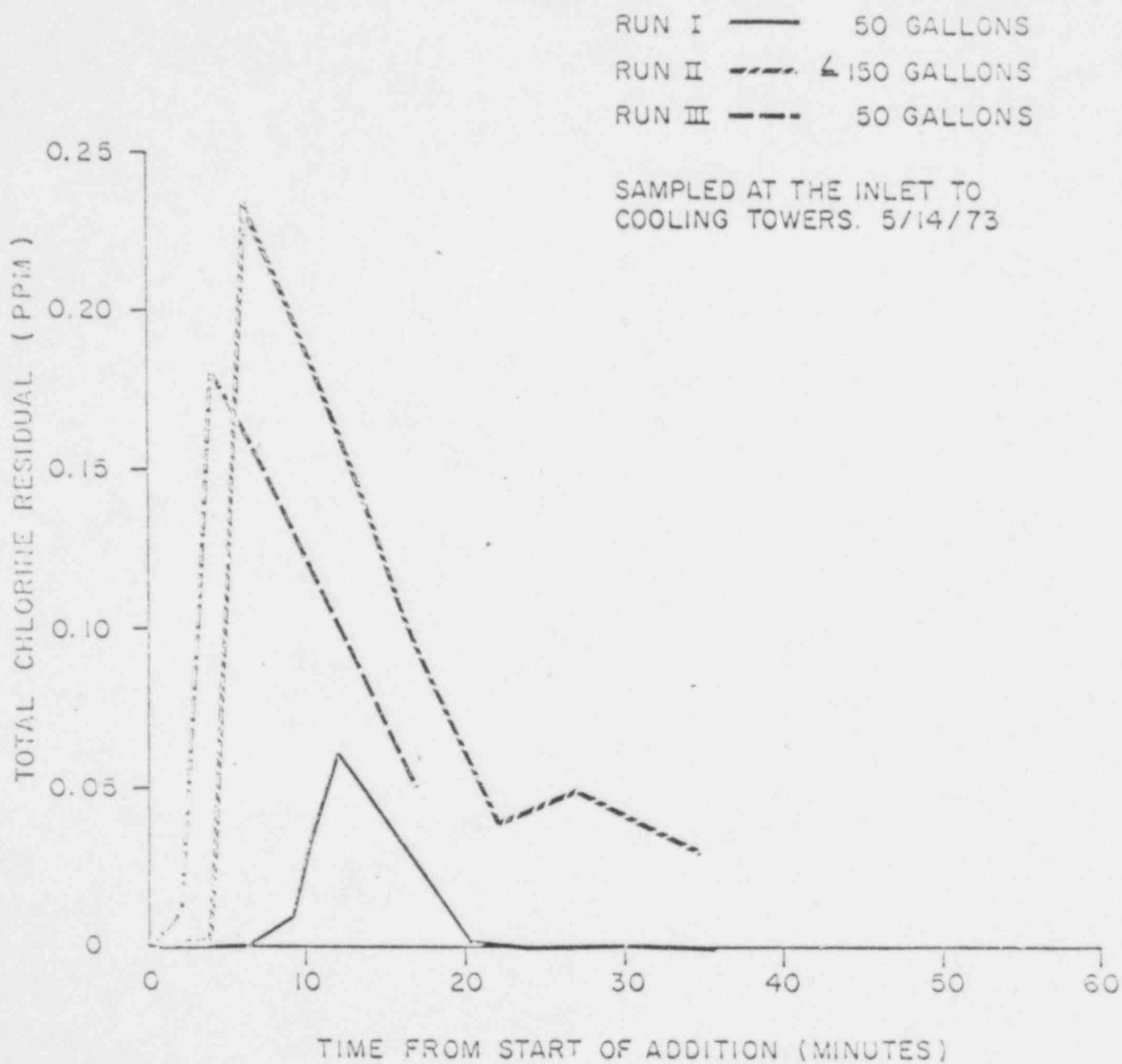
Date: 5/29/73

Run: II

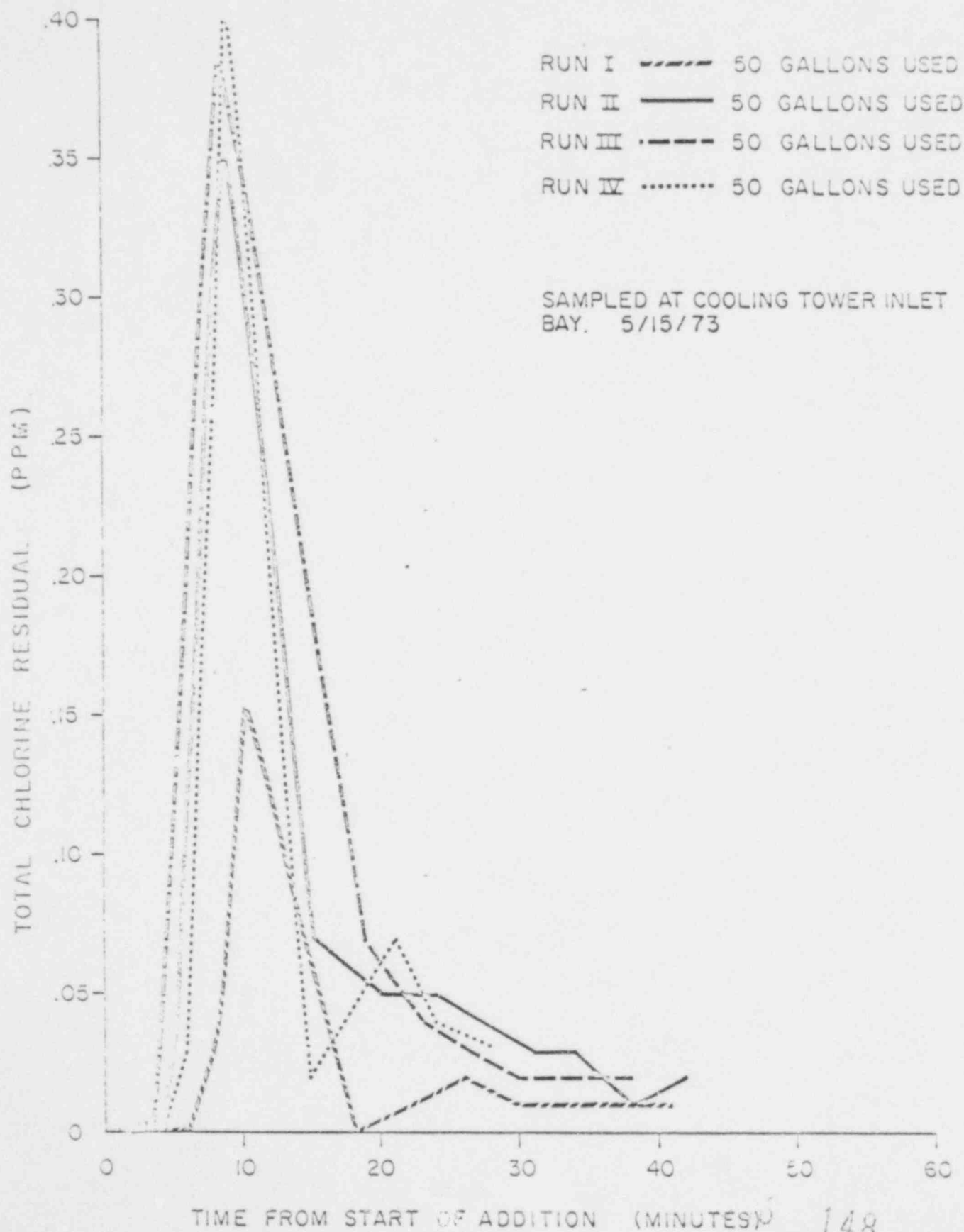
Gallons of Hypochlorite Added: 25

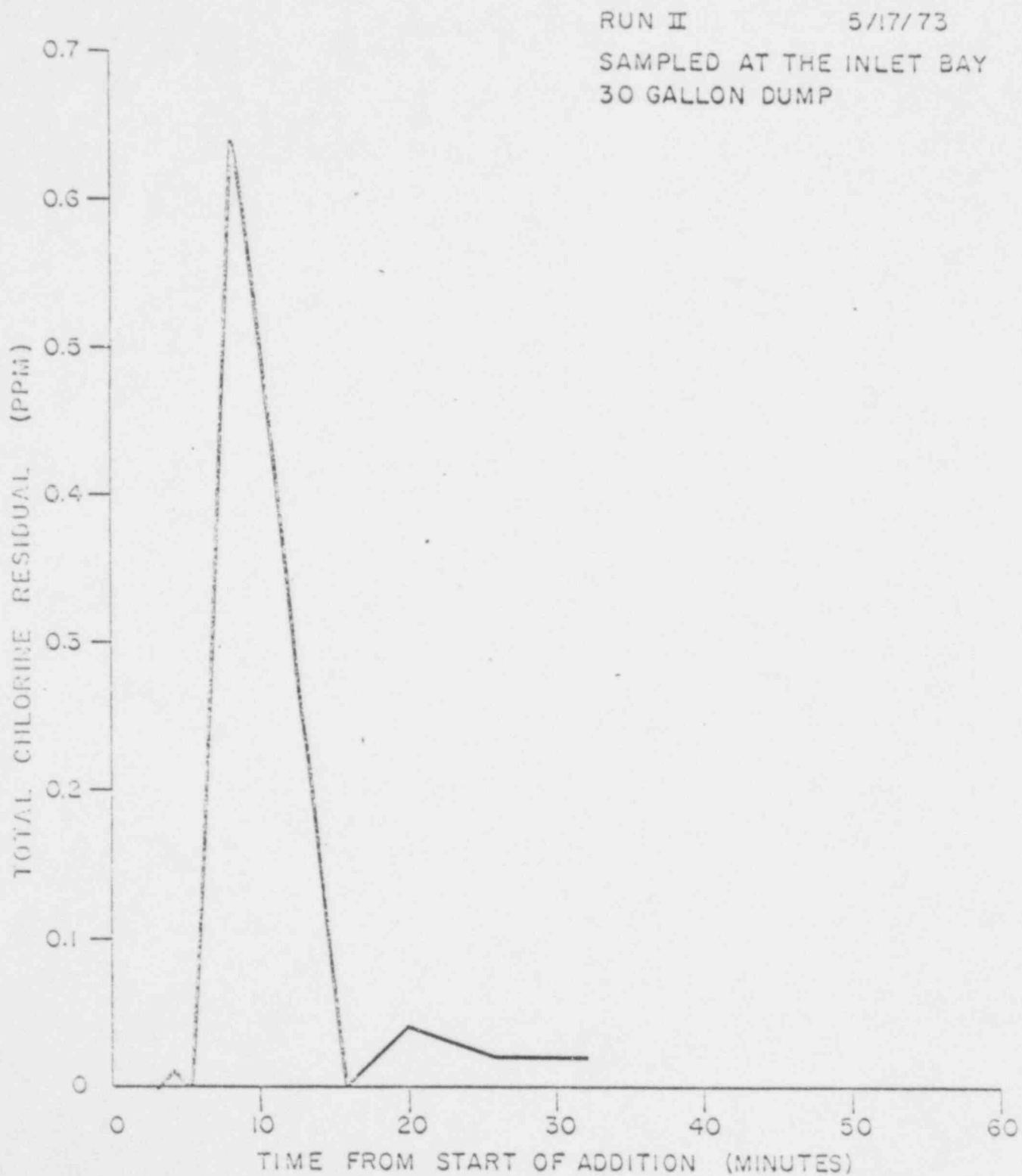
Time	Forebay		Afterbay		Slowdown		River	
	Free	Total	Free	Total	Free	Total	Free	Total
1413	--	--	--	--	--	0.02	--	--
1414	--	--	--	--	--	0.03	--	--
1415	--	--	--	--	--	0.03	--	--
1417	--	--	--	--	--	0.00	--	--
1418	--	--	--	--	--	--	--	0.00
1420	--	--	--	--	--	--	--	0.00

356 146

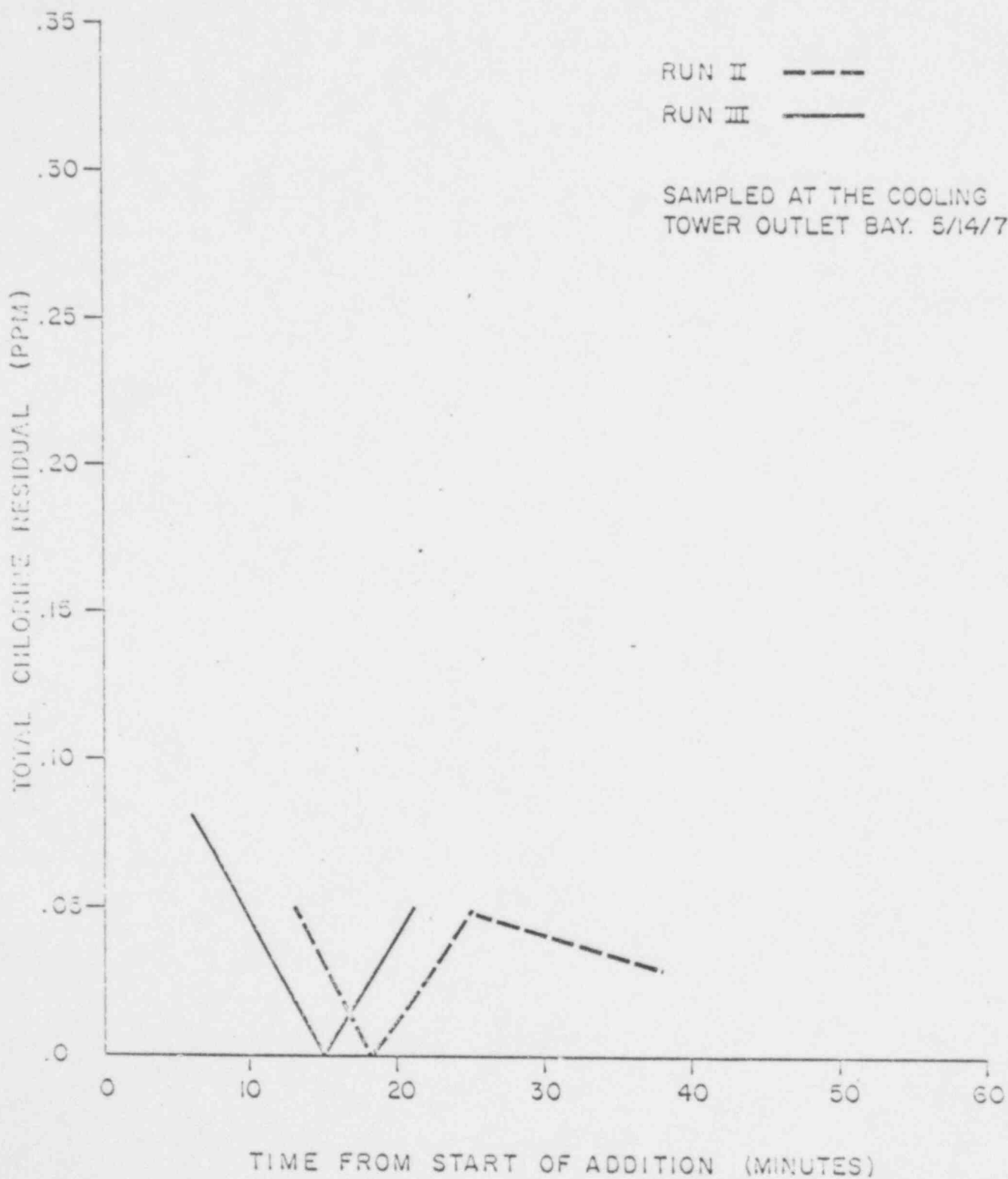


356 147

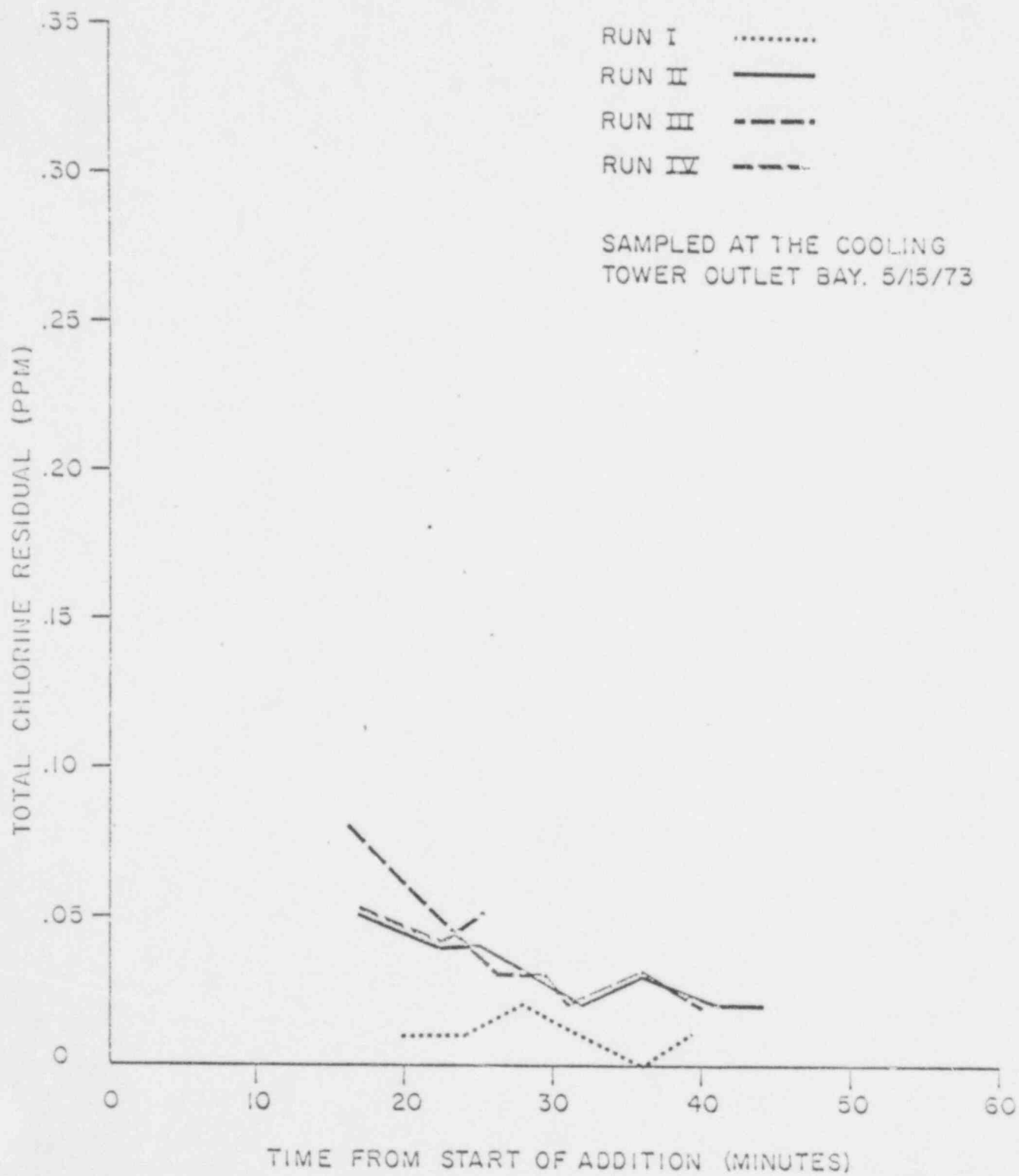








356 150

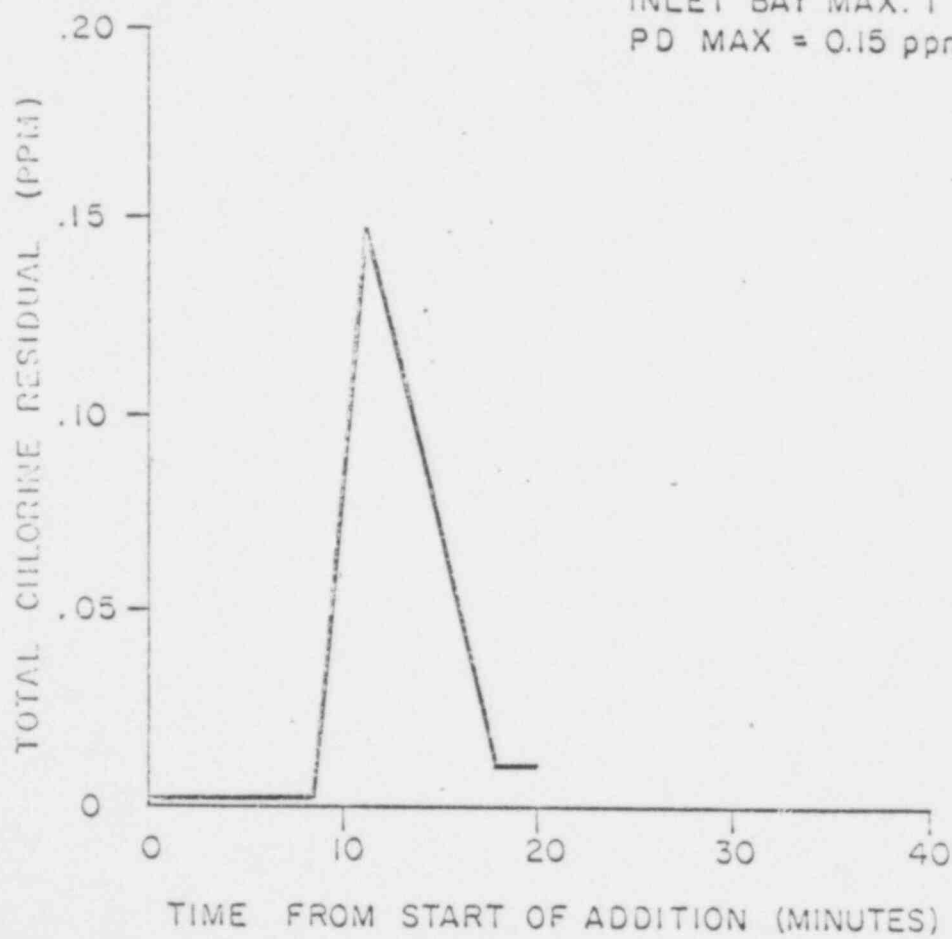


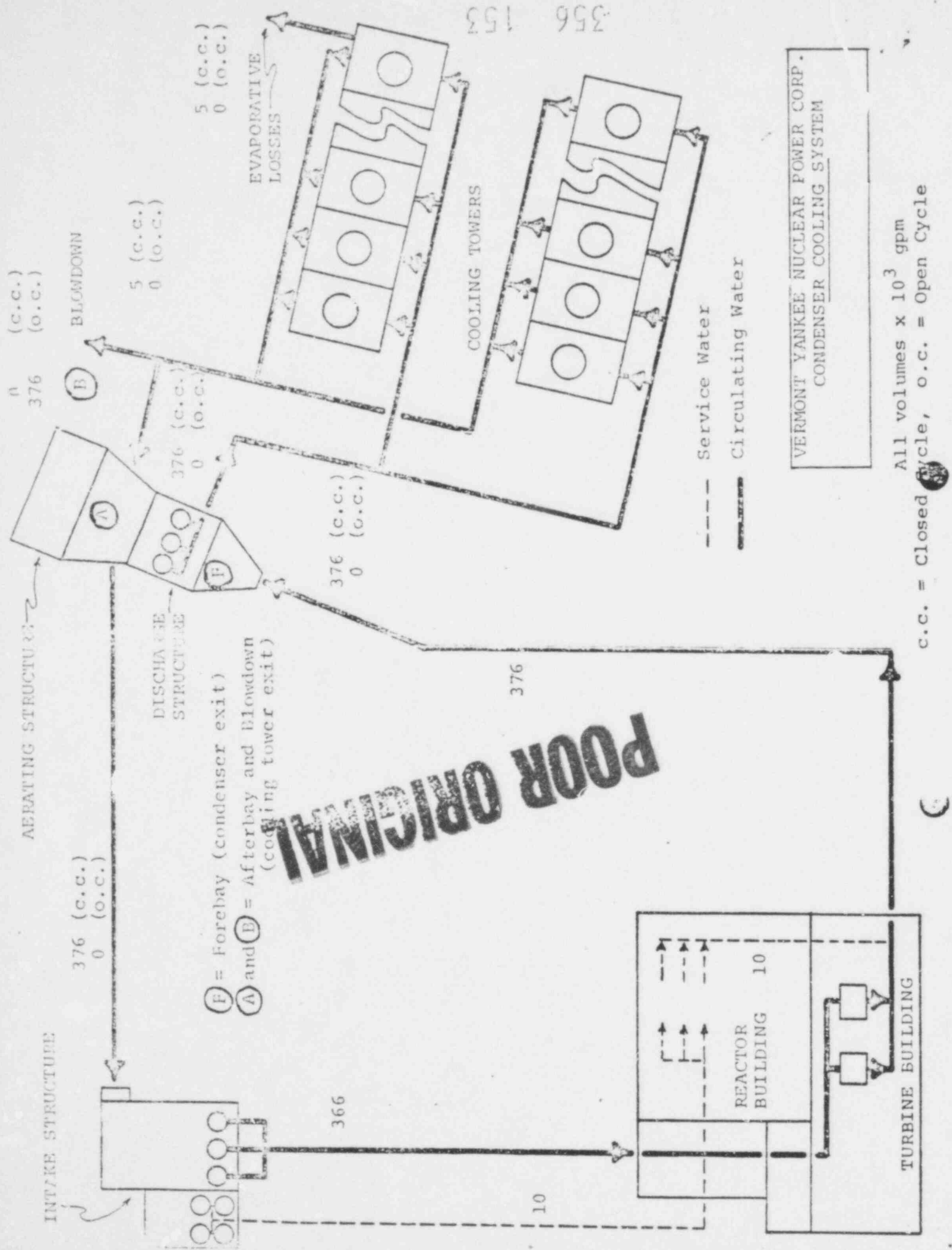
356 151

RUN III

5/17/73

SAMPLED AT PLANT DISCHARGE  
25 GALLON DUMP  
INLET BAY MAX. 1 ppm  
PD MAX = 0.15 ppm





POOR ORIGINAL

356 153