Final Report
Biofouling Control Studies at
Pilgrim Nuclear Power Station
April 1981 - A ril 1982

February 2, 1983

Marine Research, Inc.

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Introduction

This report describes biofouling control studies conducted by Marine Research, Inc. at the Pilgrim Nuclear Power Station for Boston Edison Company under BECO Purchase Order No. 69306. These studies involved five separate tasks:

Task 1 - weekly monitoring of the intake cooling water for concentrations of mussel larvae.

Task 2 - evaluation of continuous chlorine concentrations required to prevent mussel fouling.

Task 3 - evaluation of treatment cycles required to maintain system cleanliness.

Task 4 - bimonthly evaluation of fouling severity to determine seasonal needs for chlorination.

Task 5 - evaluation of scaling severity in heat exchange tubes under the proposed chlorination regimes.

Materials and Methods

Task 1 larval monitoring was performed weekly by passing 250 liters of ambient intake water through a #30 mesh plankton net and preserving with glutaraldehyde the strained sample. These samples were returned to the laboratory and concentrated to an appropriate volume using a 325 mesh sieve (pore size = 45 μm). Three 1 ml aliquots were withdrawn from the sample, placed on Sedgwick-Rafter cells, and observed under the microscope. All bivalve larvae were counted in each aliquot and separated into *Mytilus edulis* and other bivalves. The *M. edulis* larvae were measured for length, width, and length of straight hinge where appropriate, and further separated into straight hinge, early umbonate, and late unbonate larvae.

Tasks 2 - 5 were conducted utilizing a specially designed test facility (Figures 1 and 2) which combined the requirements for each task into an integrated experimental system. Seawater was provided by a 200 gpm Flygt submersible pump located in the intake basin of PNPS. Ambient intake seawater was pumped through a 3" PVC pipe to a 500 gallon constant level head tank located approximately 15' above the test facility. Thirteen separate valved 1½" PVC feed lines delivered desired volumes of seawater from the head tank to each of 13 concrete/asbestos test pipes. End caps threaded to accept 1½" PVC feed lines were attached to each concrete test pipe via removable rubber couplings (Figure 3). Three test pipes were used as untreated controls and the remaining ten were paired to evaluate the effectiveness of different treatments in duplicate. Each test pipe (measuring 5' long x 4" I.D.) was inclined slightly at the discharge end to reduce internal air space, and water flow through each test pipe section was regulated at 10 gpm to maintain a velocity of 0.25 fps. For the purpose of determining scaling severity as required by Task 5, one-foot long sections of titanium condenser (heat exchange) tubes were attached to the downstream end of one test pipe of each of the five pairs of test pipes and to one of the three control sections using Tygon tubing (see Figures 4 and 5).

The five pairs of treated test lines were chlorinated by injecting sodium hypochlorite at the base of 18" PVC static mixers located directly before each test pipe (Figure 6). The mixers assured thorough dispersion of hypochlorite with ambient intake seawater before entering test pipes. Chlorine feed rates were controlled by variable speed precision feed pumps (Figure 7). Chlorine treatment levels, μg/l TRO (Total Residual Oxidant), were measured and recorded daily at the discharge end of each test line using a digital chlorine flux monitor or an amperometric titrator. Deviations from desired concentrations were corrected by adjusting the feed pumps. Intermittent treatments were controlled manually or by timers connected to the feed pumps. To minimize

chlorine decay, feed solutions were prepared daily and pumped from flasks stored within a light-tight box (Figure 8).

The replicate chlorine concentrations which were delivered continuously during Task 2 were as follows: 50 µg/l, 100 µg/l, 250 µg/l, 500 µg/l, and 1000 µg/l, (TRO). The three untreated lines were used as controls under Task 2, the treatments being continued until fouling was apparent in at least two of these. All test pipes were then disconnected, washed lightly, cut open and photographed. The contents of each pipe were removed by scraping and preserved in formalin for later analysis. Prior to the commencement of Task 3, the head tank and feed lines were cleaned and thirteen new concrete/asbestos test pipes installed.

Task 3 involved the evaluation of five replicate chlorine treatment cycles delivering 250 µg/l TRO in the following schedules: continuous; 12 hrs on, 12 hrs off; 12 on, 24 off; 24 on, 24 off; 24 on, 48 off. The three untreated lines again served as controls. After two months the test pipes were not sufficiently fouled to warrant termination of Task 3. (However, at that time one of the control test pipes was removed and analyzed in accordance with Task 4 requirements.) When sufficient fouling had finally occurred, the remaining twelve test pipes were removed, washed down, cut open and photographed. Each pipe was then scraped and the contents preserved in formalin.

Analysis of these as well as the fouling samples from Tasks 2 and 4 was conducted at MRI's laboratory in Sandwich, Massachusetts. The samples were first sieved using 0.33 mm square mesh to remove sediment and wet weighed. Fifty randomly selected mussels (Mytilus edulis) were measured to determine the average length. If the sample size was so large as to preclude complete enumeration, it was sieved onto 2 mm, 1 mm, and 0.33 mm square meshes. Each fraction was then wet weighed and the volume of the 0.33 mm fraction measured. Three aliquots selected at random from each fraction were wet weighed and the

dominant bivalves identified and counted. General condition of the sample was noted and any marine fauna observed were identified.

Ambient intake seawater was analyzed weekly during the Task 2 and 3 studies to determine conductivity, pH, dissolved oxygen, and ammonia values (Table 1); intake water temperature was measured daily and these values are shown in Figure 9.

Task 5 was performed in conjunction with Tasks 2 and 3 by placing 12" sections of condenser tube at the discharge end of the test pipes (see Figure 4) resulting in exposure to each of the chlorine treatments. When the tasks were completed, the 12" tube sections were removed, sealed, and submitted to the General Testing Division of BECO for analysis of scale deposition (Appendix B).

Results and Discussion

Task 1: Weekly monitoring of the intake cooling water for concentrations of mussel larvae.

Sampling began on April 13, 1981, and was continued on a weekly basis through April of 1982. Only one sample was taken during the months of January and February 1982 owing to the extremely cold weather which caused sampling lines to freeze. A graphical presentation of mussel larval concentrations observed during this sampling period, as well as the data for the same period in 1979, are shown in Figure 10. A more detailed analysis of the 1981-1982 samples is also included in Appendix A.

Data for 1979 showed two distinct major spawnings, one in early July and a second larger one in September. In 1981 the only major spawning was observed during early October. It is interesting to note that, for the fall spawning in both years and the spring spawning in 1979, water temperatures were almost identical (approximately 14°C) even though the major fall peaks of larvae were three weeks apart.

Larval concentrations for the major fall spawning in 1979 and 1981 were of similar magnitude, averaging about 5000-6000 larvae/m^3. In addition to the spawning peaks small numbers of mussel larvae were present in the water column almost continuously from April through November. This suggests that some small level of spawning activity occurs throughout the spring and summer with greatest peaks occurring as water temperatures pass through the 14°C barrier in the fall and occasionally in the early summer.

Tasks 2 and 3: Evaluation of continuous and intermittent chlorine concentrations to prevent mussel fouling.

Task 2 evaluations were initiated on July 7, 1981, and continued for 45 days through August 21, 1981, at which time all treated tubes were opened and analyzed. Table 2 and Figure 11 summarize the antifouling effectiveness of chlorine applied continuously at various TRO concentrations; Table 3 shows the actual weekly average TRO values. As concentrations increased, both numbers of attached mussels and wet weight of all fouling decreased. It was also interesting to note that with increasing TRO concentrations the average size of the mussels decreased until, at concentrations of 250 ppb TRO, size remained fairly constant. From the above data, it is apparent that levels above 100 ppb TRO are required on a continuous basis to noticeably retard Mytilus fouling at PNPS. It was therefore concluded that a level of 250 ppb TRO, although not 100% effective, would be the lowest treatment level to significantly reduce macrofouling and still keep the possible effects of continuous chlorination to a minimum.

This level was used in Task 3 studies to determine if intermittent treatment might also significantly reduce fouling and further minimize the amount of chlorine needed. Task 3 studies were initiated immediately following the Task 2 studies and continued until November 25, 1981, at which time the tubes

were opened and their contents analyzed. The results are summarized in Tables 4 and 5 and Figure 12.

The data show that the continuous exposure to 250 ppb TRO was the most effective although less so than observed in the Task 2 studies. The reasons for this are not fully understood but may be due to the length of the Task 3 studies (86 days) versus 45 days for Task 2, or it may be the result of reduced water temperatures during Task 3 versus Task 2. This same phenomenon was observed in previous studies at PNPS during 1979, further suggesting that temperature or seasonality may be important to the effectiveness of chlorine for biofouling control.

Further analysis of the data suggests that the duration of chlorine injection is more important than the cycle time; that is, 12 hours of chlorine feed whether every 12 hours or every 24 hours is less effective than 24 hours of chlorine feed whether applied every 24 hours or 48 hours. It would be interesting to determine at what feed duration cycle the effectiveness might approach that of continuous feed as a means of further reducing chlorine volumes, i.e., possibly 48 hours on, 48 hours off, might be as effective as a continuous application but use half the amount of chlorine. Some further testing of short duration cycle times (5 minutes on, 5 minutes off) might also be warranted to determine whether such a scenario might be effective.

Task 4: Bimonthly evaluation of fouling severity to determine seasonal needs for chlorination.

Starting in July 1981, a clean concrete/asbestos tube (identical to those used for Task 2 and 3 studies) was exposed to 0.25 fps of untreated ambient intake seawater. The tube was allowed to foul over a two-month period, was then removed and fouling analyzed, and a new clean tube was installed. This procedure was followed throughout the yearly period.

The results of the bimonthly sampling are given in Table 6. The two periods of heaviest fouling are those with the warmest water temperatures - 7/7-8/21/81 and 5/5-7/6/82. Fouling during the warm-water periods is ten to thirty times greater than the rest of the year. This is shown by the increase per day in wet weight during the warm periods versus the cold. Even during the late winter (2/2-3/4/82) when water temperatures averaged below 2°C and no larvae were present in the water column, a small number of mussels were found, probably from the fall set, which had been dislodged from outside the intake and were transported by water currents into our system where they reattached.

This may also happen to some extent within the operating unit which cautions one from drawing the conclusion that, since no larvae are in the water column, mussel fouling cannot occur. These small mussels do not grow during the winter months and, if one assumes that only small mussels can be transported by water currents, then they could be ignored and removed before growth resumes in the spring. Since there is uncertainty regarding this possibility, it is suggested that inspection dives be conducted during the winter months to determine whether mussel reattachment is occurring and that both heat treatments and chlorination during the winter be continued until this process is fully understood.

Task 5: Evaluation of scaling severity in heat exchange tubes under tested chlorination regimes.

Task 5 studies were conducted in conjunction with Task 2 and 3 experiments. The titanium condenser tube sections placed on the discharge end of the fouling tube sections received the identical chlorine treatments as the concrete/asbestos sections. Upon termination of testing, the condenser tube sections were analyzed for buildup of manganese, iron, and silica scale. Table 7 summarizes these measurements. With no chlorination, manganese,

iron, and silica values are relatively high, suggesting that the biofilm growing on the tube walls is high in these elements. With the addition of chlorine this biofilm is destroyed, but at and above 250 ppb TRO manganese levels increase tremendously. This could be seen within the concrete tube sections as well as in the Tygon tubing holding the condenser tube sections (see Figure 5). This increase is a result of scale deposition. The manganese scale formation appears to be an almost-all-or-none phenomenon occurring at the chlorine concentrations needed to prevent mussel fouling, i.e., between 100 and 250 ppb TRO. Above 250 ppb TRO, the scale formation remains fairly constant but does appear to be temperature sensitive. During Task 2 studies water temperatures averaged 18.4°C, producing a manganese concentration of 4.48 ppm over a 45-day period when exposed continuously to 250 ppb TRO. The same treatment over an 86-day period, when temperatures averaged only 13.3°C, produced only 0.79 ppm of manganese.

Continuous chlorination at levels required to maintain system cleanliness will produce a manganese dioxide scale which may retard heat transfer. This retardation should be evaluated in detail before any continuous chlorination treatment is utilized since the advantages gained from macrofouling control may be overridden from heat exchange or condenser heat transfer loss.

Conclusions

1. Pilgrim Nuclear Power Station has a potentially serious macrofouling problem, the dominant organism being the blue mussel, *Mytilus edulis*.

2. Mussel larvae are present in the intake water from April through November with major spawning periods occurring during the fall as water temperatures drop below 14°C. A second important spawning occasionally occurs during the spring as temperatures approach 14°C.

3. Heaviest fouling including mussel attachment and growth occurs during the warm-water periods (May-September). However, some fouling and attachment of mussels occur throughout the entire year. The attachments observed during the winter result from mussels which become detached outside the intake and are transported by currents to the intake area where they reattach.

4. Continuous chlorination at concentrations of 250 ppb TRO and above significantly reduces all fouling.

5. Of the intermittent treatment levels tested using 250 ppb TRO, those of the longer duration appeared best, i.e., 24 hours on was better than 12 hours on. However, no intermittent level tried was as effective as continuous chlorination.

6. Continuous chlorination at 250 ppb TRO will produce a manganese scale, its buildup appearing to be related to water temperature.

Recommendations

1. It is recommended that to maintain cleanliness within the salt service water system a continuous treatment of 250 ppb TRO be utilized. This should be continued throughout the year.

2. Side-stream evaluation of stopping chlorination during the winter and starting in the spring should be evaluated as a further possible cost saving.

3. Side-stream testing of the thermal resistance of the manganese dioxide scale should be performed to determine the possible effects on the heat transfer of heat exchangers exposed to continuous chlorination.

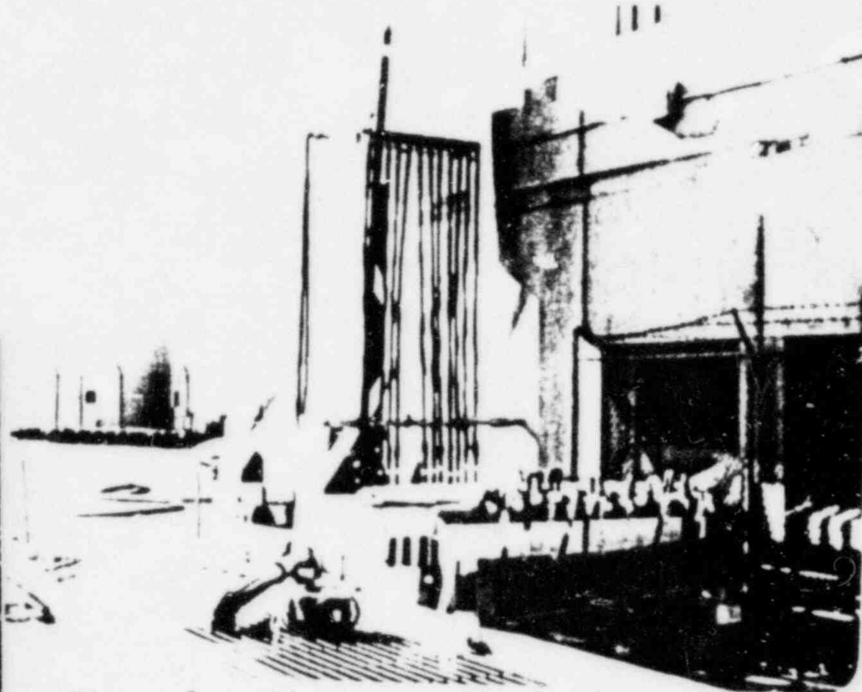


Figure 1. Side-stream test facility.

Figure 2. Side-stream test facility.

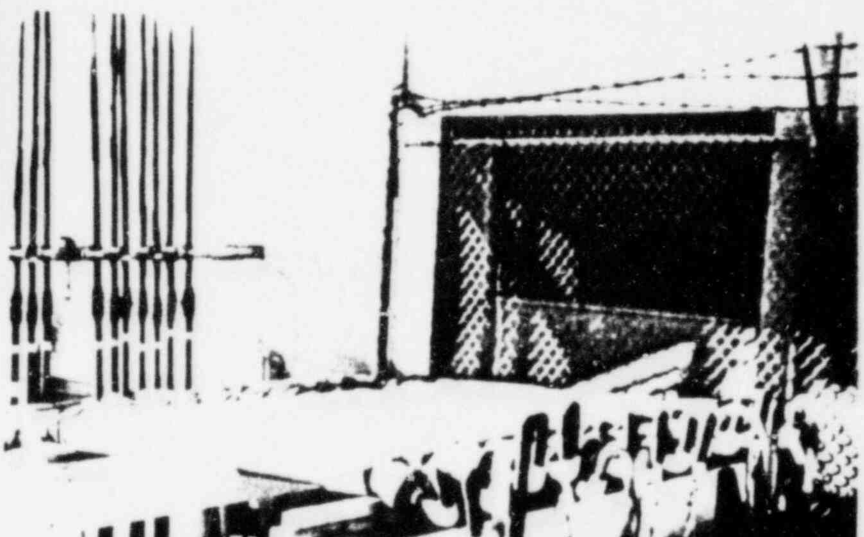


Figure 3. Concrete/asbestos test pipe sections.

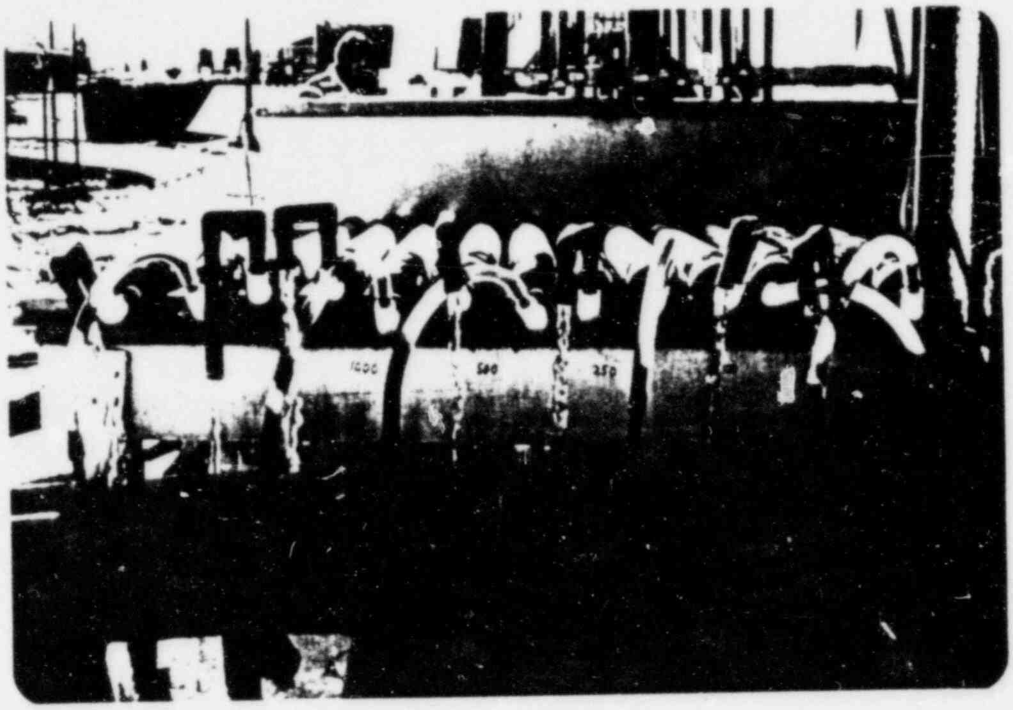


Figure 4. Discharge end of test pipe sections showing Tygon tubing connected to titanium condenser tube sections.

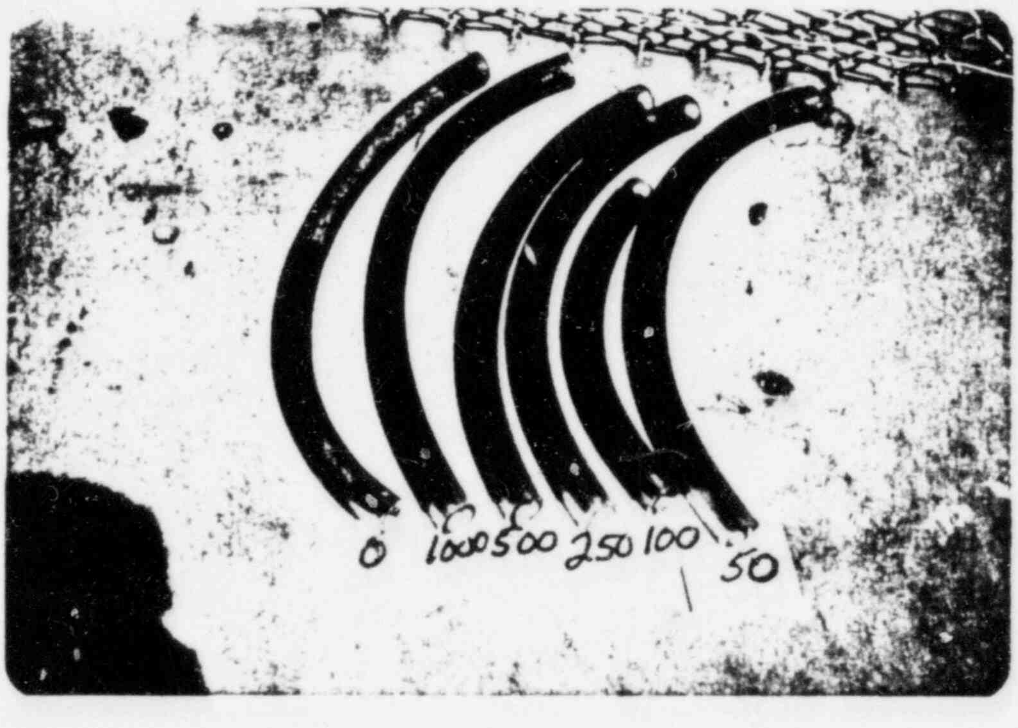


Figure 5. Tygon tube sections after 45 days of continuous treatment (the numbers indicate TBT levels in ppb).

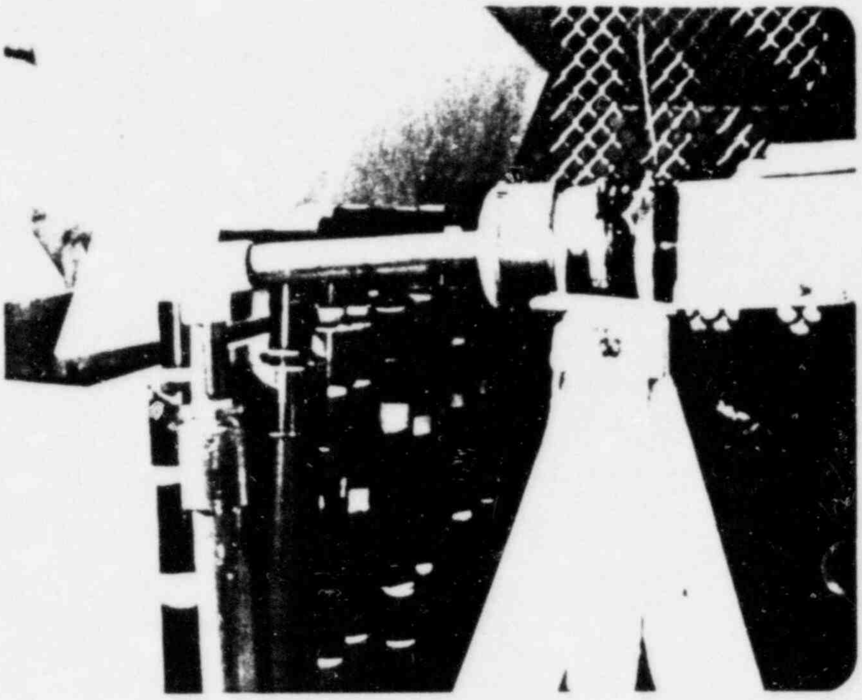
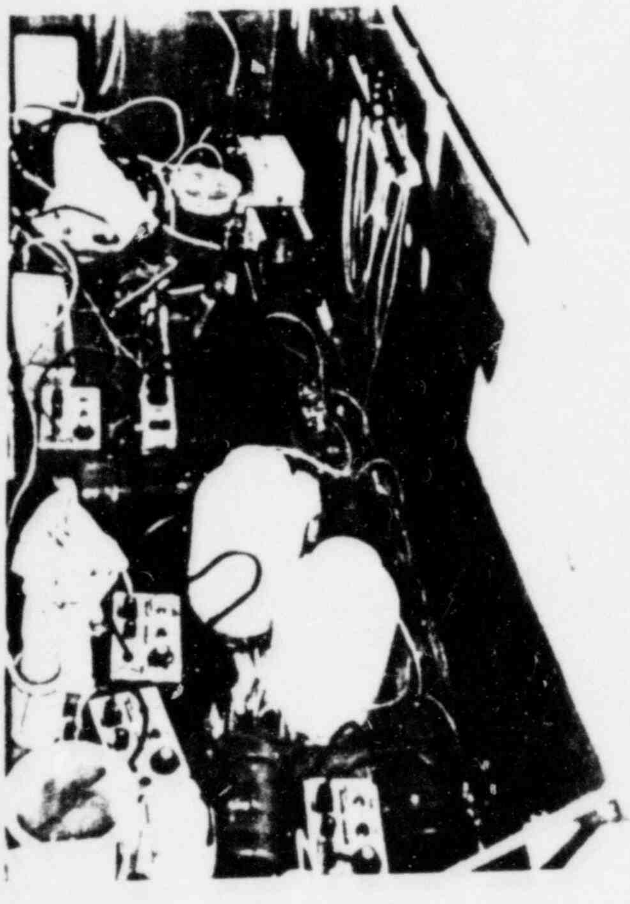


Figure 6. Static mixers.



[illegible] 7. [illegible] feed pumps.

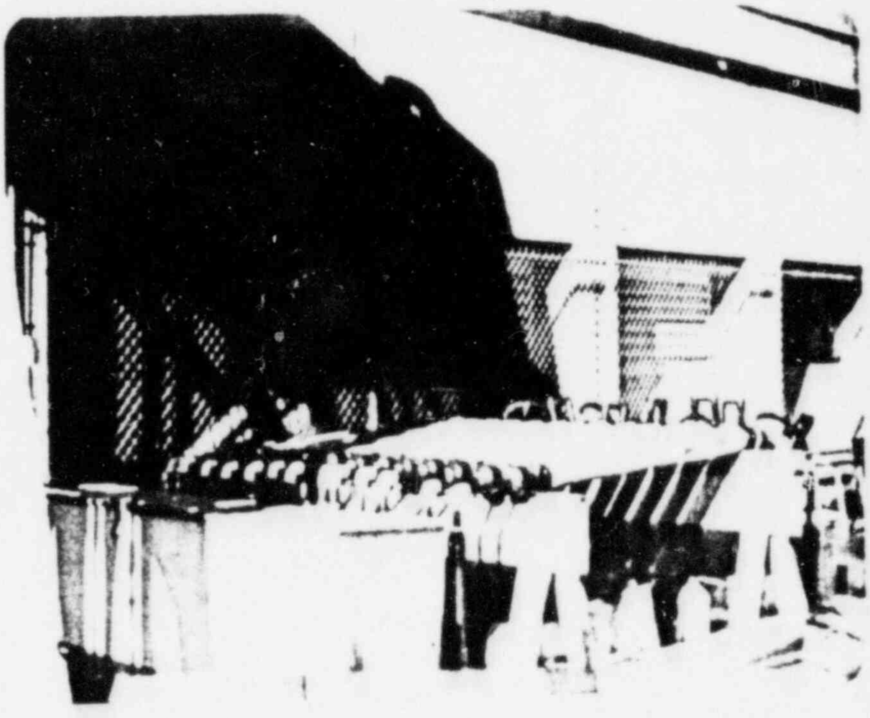


Figure 8. Test facility [illegible]
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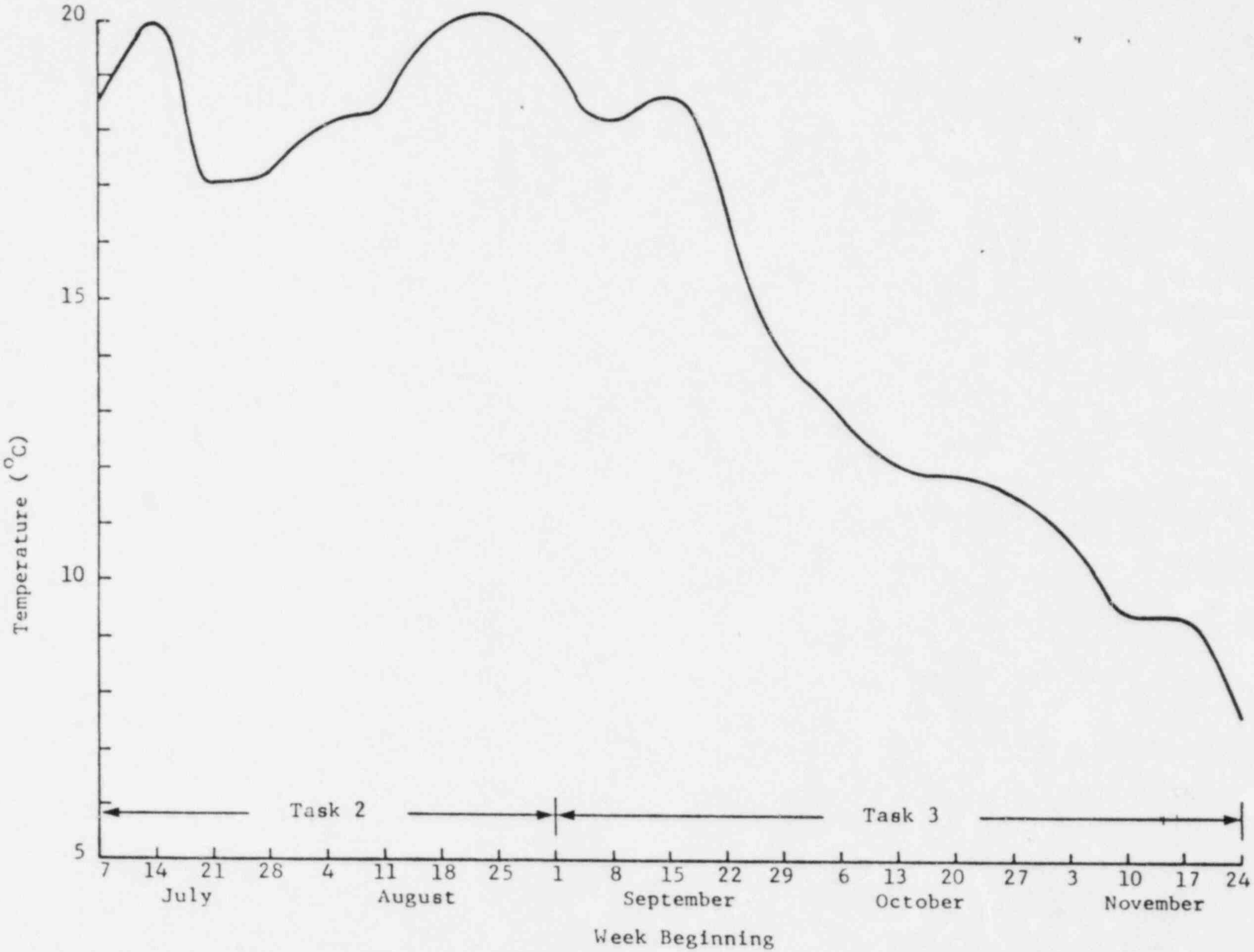


Figure 9. Average weekly temperature profile during Tasks 2 and 3 evaluation.

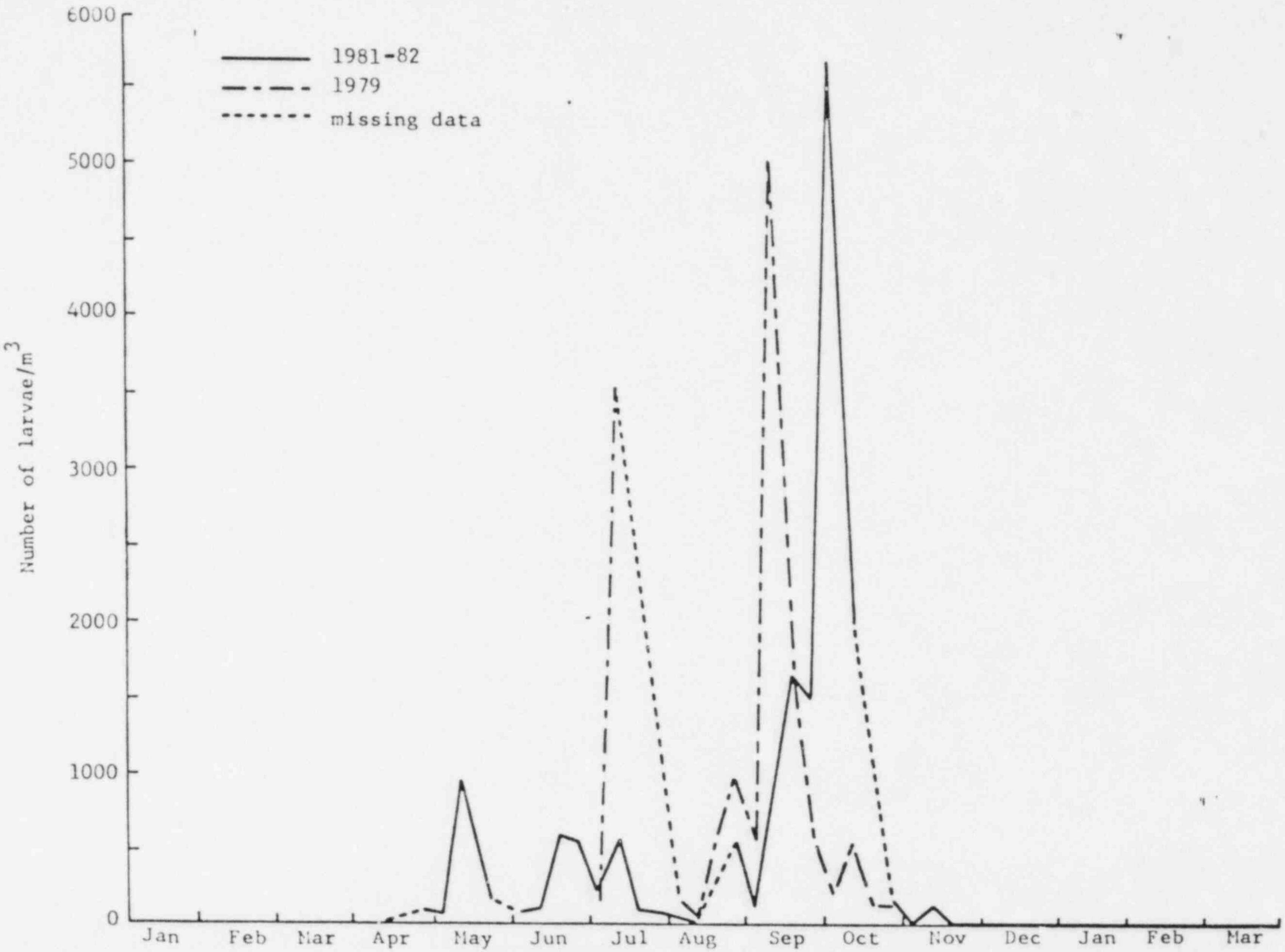


Figure 10. The monthly concentration of mussel (Mytilus edulis) larvae/m^3 sampled from PNPS intake waters during 1979 and 1981-82.

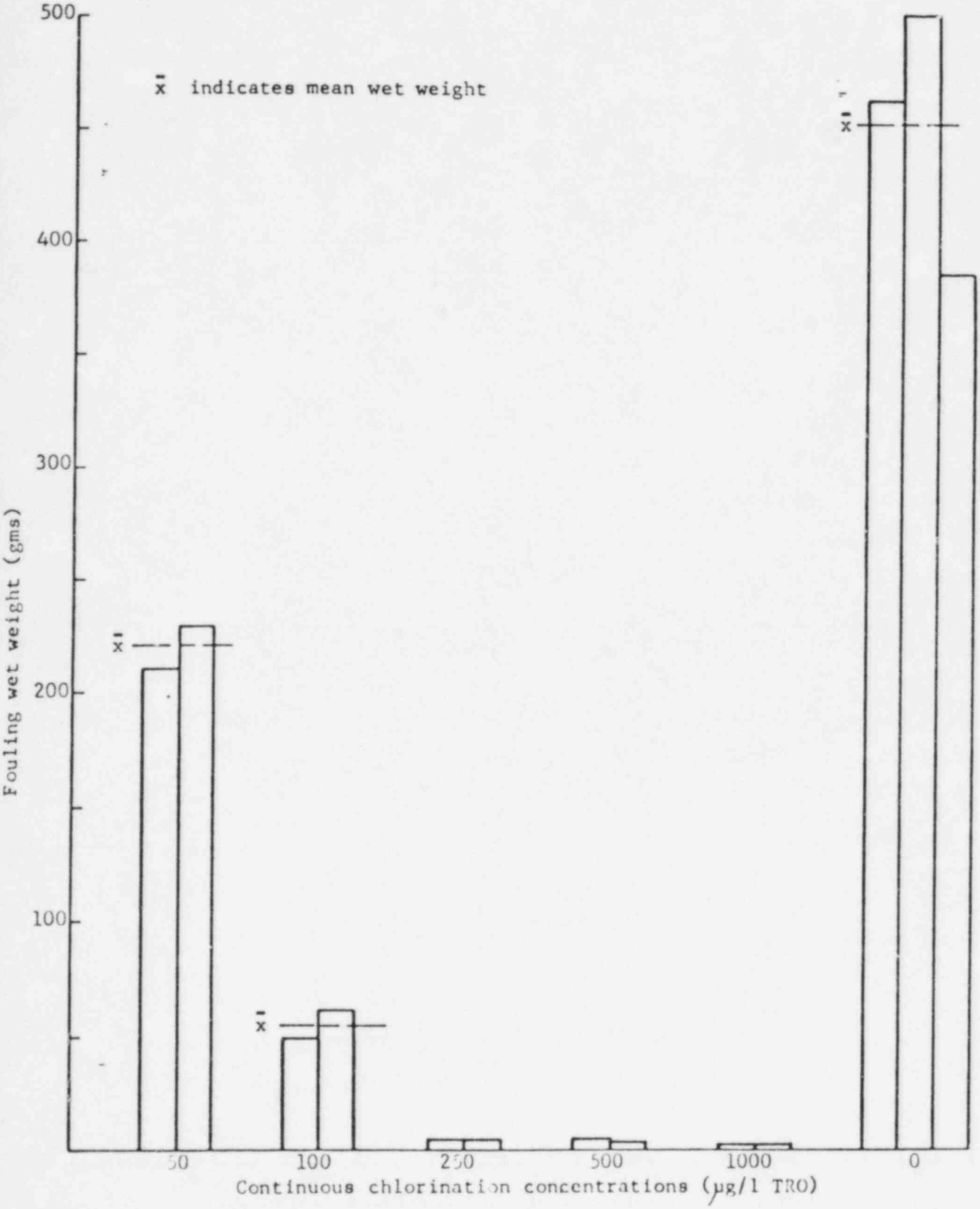


Figure 11. The effectiveness of various continuous chlorination levels on fouling biomass.

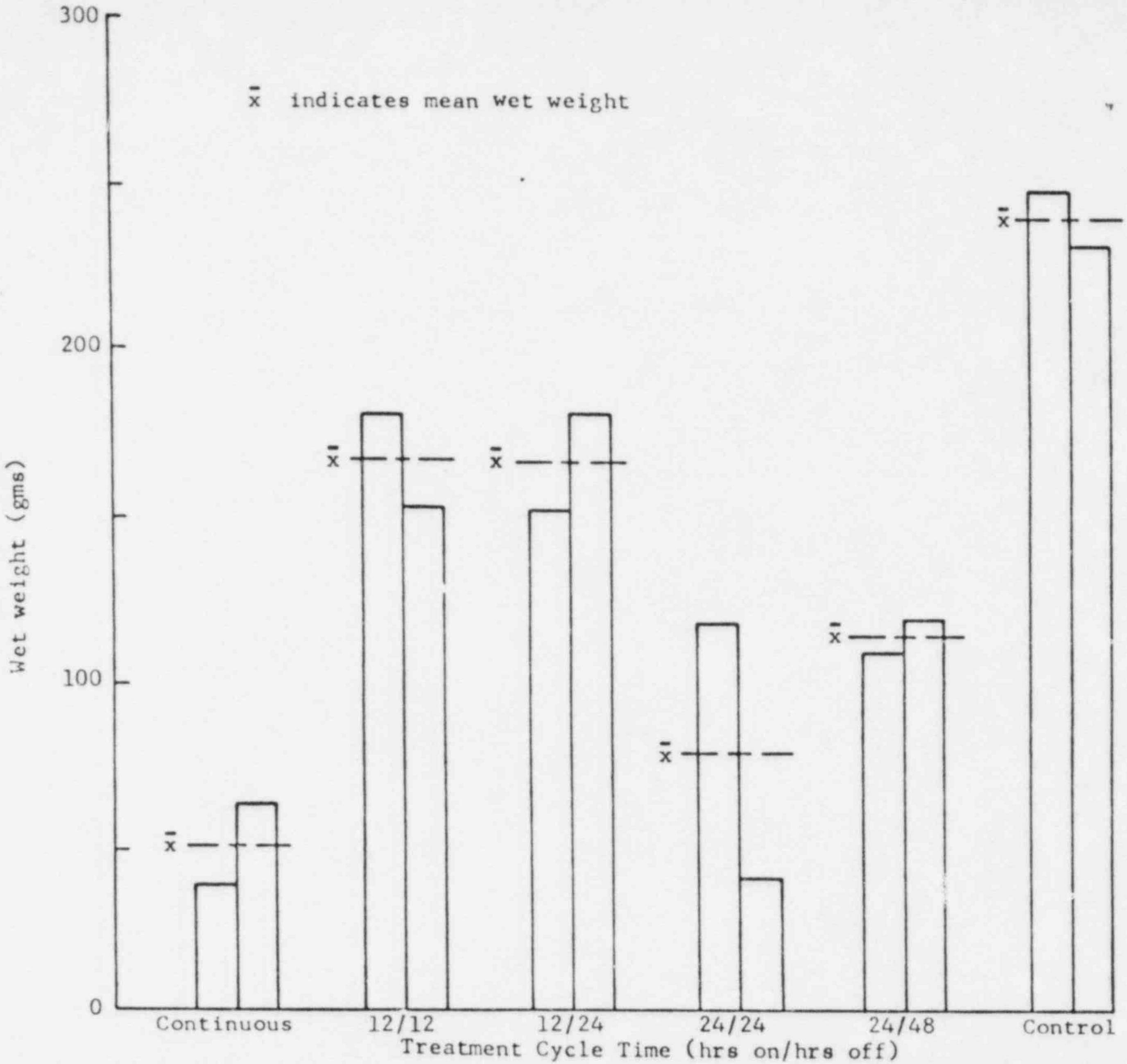


Figure 12. The effectiveness of various intermittent chlorine treatments at 250 ppb TRO on fouling biomass.

Table 1. PNPS hydrographic data.

Date	Time	Temperature (°C)	pH	Dissolved oxygen (mg/l)	Salinity (o/oo)	Ammonia (ugatN)
7/7/81	1100	15.7	7.8	7.7	31.4	2.37
7/14	1145					2.19
7/21		16.4	8.1	7.4	31.2	1.98
7/28	1030	18.8	7.8	7.7	31.4	3.90
8/5	0900	17.8	7.8	7.8	31.3	
8/12	0900	18.3	7.8	8.0	31.3	2.67
8/21	0830	20.7	7.9	7.2	29.9	3.20
9/1	1300	19.2	8.2	7.7	31.3	2.15
9/9	1530	18.6	8.2	7.8	30.9	0.86
9/19	1115	19.7	8.2	7.0	30.8	
9/26	0915	16.0	8.4	7.9	31.5	4.63
10/3	0950	13.6	8.2	7.8	31.4	
10/11	1000	11.8	8.2	8.1	31.6	
10/18	1000	12.0	8.0	8.2	31.1	
10/24	1030	11.3	8.0	8.0	31.8	
10/31	1000	10.7	7.8	8.5	31.4	2.88
11/7	1030	10.3	8.0	7.9	31.9	4.04
11/14		8.3	8.3	9.0	31.9	
11/25	1000	6.4	7.8	10.3	31.9	2.86

Table 2. The effectiveness of various continuous chlorination concentrations on the fouling of concrete/asbestos pipe sections over a 45-day period (Task 2, July 7 - August 21, 1981).

Line	Total wet Weight (grams)	Total Number Mytilus	Mytilus (grams wet wgt)	TRO (µg/l)	Percent of Control		Average Length	Average TRO
					Number	Weight		
1	211.2	3084	14.6	50	5.4	46.9	3.1	50
2	229.7	1994	8.7		3.5	51.0	2.5	51
x̄	220.5	2539	11.7		4.5	49.0	2.8	51
3	48.4	1533	31.7	100	2.7	10.7	2.8	100
4	61.3	2610	42.6		4.6	13.6	2.3	103
x̄	54.9	2072	37.2		3.7	12.2	2.6	102
5	4.3	447	104.0	250	0.8	0.95	1.7	251
6	4.3	940	218.6		1.6	0.95	1.1	254
x̄	4.3	694	161.3		1.2	0.95	1.4	253
7	4.0	202	50.5	500	0.4	0.89	1.3	496
8	3.6	195	54.2		0.3	0.80	1.3	508
x̄	3.8	199	52.4		0.35	0.85	1.3	502
9	2.0	86	43.0	1000	0.2	0.44	1.5	985
10	2.1	91	43.3		0.2	0.47	1.3	952
x̄	2.1	89	43.2		0.2	0.46	1.4	969
11	463.8	54800	118.2	Control	-	-	3.4	-
12	501.2	69491	138.6		-	-	3.3	-
13	386.5	46878	121.3		-	-	3.1	-
x̄	450.5	57056	126.0		-	-	3.3	0

Table 3. The weekly average chlorine residual (TRO) measured daily at the discharge end of the treatment lines during Task 2 studies.

	Average Line Concentration (ppb)									
Week of	1	2	3	4	5	6	7	8	9	10
July 7	58	59	104	101	241	258	545	536	1019	974
July 14	56	59	102	106	263	254	498	477	999	893
July 21	57	58	106	109	255	258	516	511	1007	921
July 28	40	50	99	103	253	240	494	487	951	928
Aug 4	54	48	100	101	259	269	493	502	958	950
Aug 11	41	38	102	105	253	266	491	519	955	993
Aug 18	46	49	93	99	239	236	435	523	1004	996
Desired Cl_2 concentration (ppb)	50		100		250		500		1000	

Table 4. The effectiveness of various intermittent treatments of 250 ppb (TRO) on fouling of identical concrete/asbestos test lines over an 86-day period (Task 3, August 31-November 25, 1981).

Line	Total wet Weight (grams)	Total Number Mytilus	Mytilus (grams wet wgt)	Chlorine (hrs/day)	Time Cycle	Percent of Control Number	Percent of Control Weight	Average Length	Average TRO
1	39.0	1733	44.4	24	24/0	13.2	16.3	1.1	244
2	63.5	2137	33.7			16.2	26.6	1.1	236
x̄	51.3	1935	39.1			14.7	21.5	1.1	240
3	180.0	5365	29.8	12	12/12	40.7	75.4	1.5	236
4	152.6	6776	44.4			51.4	63.9	1.3	236
x̄	166.3	6071	37.1			46.1	69.7	1.4	236
5	151.0	11316	74.9	8	12/24	85.9	63.3	2.0	234
6	179.5	6575	36.6			49.9	75.2	1.9	238
x̄	165.3	8934	55.8			67.9	69.3	1.9	236
7	117.5	9439	80.3	12	24/24	71.7	49.2	1.2	237
8	40.3	3907	96.9			29.7	16.9	1.2	241
x̄	78.9	6673	88.6			50.7	33.1	1.2	239
9	107.2	7080	66.0	8	24/48	53.8	44.9	1.6	241
10	117.8	6717	57.0			60.0	49.4	1.5	241
x̄	112.5	6899	61.5			56.9	47.2	1.5	241
11	246.8	12647	51.2	Control		-	-	3.4	-
13	230.6	13695	59.4			-	-	3.9	-
x̄	238.7	13171	55.3			-	-	3.6	0

Table 5. The weekly average chlorine residual TRO measured daily during the various intermittent treatments performed during Task 3 studies. The desired concentration (TRO) for all lines was 250 ppb TRO.

	Line #									
Week of	1	2	3	4	5	6	7	8	9	10
Aug 31	271	254	246	246	244	260	249	275	238	255
Sept 7	269	231	246	245	250	247	237	243	284	255
Sept 14	256	208	213	204	193	208	209	209	261	256
Sept 21	261	256	252	249	242	246	245	243	243	245
Sept 28	248	250	248	249	238	252	239	255	244	256
Oct 5	246	247	250	257	245	252	245	249	263	255
Oct 12	245	243	244	250	245	248	244	246	245	249
Oct 19	244	248	247	248	250	258	254	257	251	265
Oct 26	255	246	248	243	249	249	257	258	255	255
Nov 2	243	245	241	241	245	245	242	[illegible]	249	250
Nov 9	215	216	213	215	215	215	214	213	194	193
Nov 16	174	175	176	170	176	170	184	179	148	148
Nov 23	245	255	247	248	245	247	263	258	255	245

Table 6. Comparison of seasonal fouling rates.

Period	Days	Range and Mean Temperature (°C)	Wet Weight (gm)	Wet Weight Increase/day	Number of Mytilus	Mean Length (mm)
7/7/81-8/21/81	45	16 - 21 (18.4)	451	10	57000	3.3
8/31/81-11/2/81	63	11 - 19 (15.1)	46	0.7	8400	2.1
11/2/81-1/4/82	63	3 - 11 (6.6)	23	0.4	2700	3.5
2/2/82-3/4/82	30	-1 - 3 (1.8)	10	0.3	720	2.2
3/4/82-5/5/82	62	3 - 10 (6.5)	41	0.7	150	1.0
5/5/82-7/6/82	61	10 - 17 (13.0)	610	10	2100	13.0

Table 7. Analysis of scaling deposition.

Task 2 Continuous Chlorination 8/21/81			
TRO (ppb)	Mn (ppm)	Fe (ppm)	Si (ppm)
0	2.66	22.2	0.95
50	0.16	21.5	0.36
100	0.41	15.4	0.13
250	4.48	25.0	0.47
500	4.36	17.2	0.24
1000	3.78	17.5	0.43

45 days
mean temp: 18.4°C
range: 15.7-21.1°

Task 3 Treatment Cycles (@ 250 ppb TRO) 11/25/81				
Hrs on	Hrs off	Mn (ppm)	Fe (ppm)	Si (ppm)
Control		2.27	41.3	3.15
24	0	0.79	35.1	0.19
12	12	0.20	29.3	0.11
12	24	0.13	22.0	0.27
24	24	0.16	20.2	0.22
24	48	0.13	18.7	0.17

86 days
mean temp: 1[illegible].3°C
range: 7.6-19.4°

Appendix A

Counts and measurements of bivalve larvae

sampled at Pilgrim Station 4/13/81-4/8/82

Original Volume 250L

Final Volume 30mL

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1		$\bar{x}$		NO/m³	
/ Bivalve larvae	1	0	0		0.33		40	
/ Mytilus edulis larvae	0	0	0		0		0	

Time Circle ______ Station DISCHARGE Depth ______ Bottle ______ Date 13-IV-81 Project PILGRIM

Counted by: TMH Date: 7-V-81

Comments:

Original Volume 250L

Final Volume 30mls

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1		$\bar{X}$		No/m³	
MYTILUS EDULIS LARVAE	1	0	1		0.67		80	
BIVALVE LARVAE	0	0	1		0.33		40	

MYTILUS EDULIS – 1 LATE UMBO
1 STRAIGHT HINGE

Time Code ____ Station DISCHARGE Depth ____ Bottle ____ Date 28-IV-81 Project PILGRIM

Counted by: TMH Date: 11-V-81

Comments:

Original Volume 250 L

Final Volume 30 mls.

ZOOPLANKTON

Sedgwick Rafter

	*Fraction 1	1	1		$\bar{x}$		$\frac{No.}{M^3}$	
Bivalve larvae	9	9	8		8.67		1040	
Mytilus edulis larvae	0	1	0		0.33		40	
Mytilus edulis – 1 straight hinge								

Counted by: TMH Date: 11-V-81

Comments:

Time Code ___ Station DISCHARGE Depth ___ Bottle ___ Date 5-V-81 Project PILGRIM

Original Volume 250L

Final Volume 30mls.

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1		$\bar{X}$		No/M³	
/ MYTILUS EDULIS LARVAE	10	6	10		8.67		1040	
/ BIVALVE LARVAE	0	1	2		1.00		120	

MYTILUS EDULIS LARVAE WERE ALL STRAIGHT HINGE.

Counted by: TMH Date: 15-V-81

Comments:

Time Code ____ Station DISCHARGE Depth ____ Bottle ____ Date 11-V-81 Project PILGRIM BIVALVES

Original Volume 250 L

Final Volume 30 ml.

ZOOPLANKTON

Sedgwick Rafter

Time Code ______ Station DISCHARGE Depth ______ Bottle ______ Date 18-V-81 Project PILGRIM BIVALVES

*Fraction	1	1	1		$\bar{x}$	No/m³		
MYTILUS EDULIS LARVAE	1	1	3		1.67	200		
BIVALVE LARVAE	1	3	0		1.33	160		
L=150μm W=130μm S.H=80μm								
L=170μm W=140μm EARLY UMBO								
L=180μm W=140μm EARLY UMBO								
L=[illegible]μm W=[illegible]μm								
L=140μm W=100μm S.H.=90μm								

Counted by: [illegible] Date: 30-V-81

Comments:

Original Volume 250L

Final Volume 30mls.

ZOOPLANKTON

Sedgwick Rafter

Line Code ______ Station DISCHARGE Depth ______ Bottle ______ Date 2-VI-81 Project PILGRIM BIOFOULING (CHLORINE MIN.)

	*Fraction	1	1	1		$\bar{x}$	No/m³		
	MYTILUS EDULIS LARVAE	1	1	0		0.67	80		
	UNKNOWN BIVALVE LARVAE	10	4	3		5.67	680		
	140X120 EARLY UMBO								
	160X120 EARLY UMBO								

Counted by: TMH Date: 15-VI-81

Comments:

Original Volume 250L

Final Volume 30mls

ZOOPLANKTON

Sedgwick Rafter

Time Code ______ Station DISCHARGE Depth ______ Bottle ______ Date 11-VI-81 Project PILGRIM CHLORINE MINIMIZATION

*Fraction	1	1	1		$\bar{X}$	No/m^3		
MYTILUS EDULIS LARVAE	0	1	1		0.67	80		
UNKNOWN BIVALVE LARVAE	1	0	0		0.33	40		
310µm X 270µm LATE UMBO								
230µm X 210µm UMBO								

Counted by: TMH Date: 15-VI-81

Comments:

Original Volume 250L

Final Volume 30mls

ZOOPLANKTON

Sedgwick Rafter

	*Fraction	1	1	1		$\bar{X}$	No/m^3		
	MYTILUS EDULIS LARVAE	1	1	1		1.00	120		
	UNKNOWN BIVALVE LARVAE	0	1	2		1.00	120		
	320µm X 300µm LATE UMBO								
	280µm X 250µm LATE UMBO								

Time Code ______ Station DISCHARGE Depth ______ Bottle ______ Date 15-VI-81 Project PILGRIM CHLORINE MINIMIZATION

Counted by: TMH Date: 16-VI-81

Comments:

Original Volume 250 L

Final Volume 30 mls.

ZOOPLANKTON

Sedgwick Rafter

Time Code ____ Station Discharge Depth ____ Bottle ____ Date 17-VI-81 Project Pilgrim Chlorine Minimization

	*Fraction	1	1		$\bar{X}$	No/m³			
/	Mytilus edulis larvae	7	4		5.5	640			
/	Bivalve larvae	12	5		8.5	1020	-		
/									
/									
/									
/									
/									
/									
/									
/									
/	300µm X 260µm Late umbo								
/	290µm X 260µm " "								
/	290µm X 260µm " "								
/	300µm X 260µm								
/	130µm X 100µm S.H. = 70µm								
/	260µm X 220µm Late umbo								
/	270µm X 240µm Late umbo								
/	200µm X 160µm Early umbo								
/	220µm X 180µm " "								
/	280µm X 250µm Late umbo								
/	320 X 270µm Late umbo								
/									
/									
/									
/									
/									
/									
/									
/									
/									
/									
/									
/									

Counted by: TMH Date: 19-VI-81

Comments:

Original Volume 250L

Final Volume 30mls

ZOOPLANKTON

Sedgwick Rafter

Time Circle ____ Station DISCHARGE Depth ____ Bottle ____ Date 17-VI-81 Project PILGRIM CHLORINE MINIMIZATION

*Fraction	1	1	1		X̄	No/m³		
MYTILUS EDULIS LARVAE	4	5	4		4.33	520		
BIVALVE LARVAE	30	35	20		28.33	3400		
270µm X 230µm EARLY UMBO								
270µm X 230µm " " " "								
330µm X 280µm LATE UMBO								
270µm X 240µm EARLY UMBO								
340µm X 290µm LATE UMBO								
340µm X 280µm " "								
230µm X 200µm EARLY UMBO								
260µm X 230µm " " " "								
320µm X 280µm LATE UMBO								
290µm X 240µm " "								
240µm X 200µm EARLY UMBO								
270µm X 240µm " " " "								
290µm X 240µm LATE UMBO								

Counted by: TAH Date: 30-VI-81

Comments:

Original Volume 250L

Final Volume 30mls

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1		$\bar{X}$	[illegible]$/m^3$		
MYTILUS EDULIS LARVAE	7	5	4		5.33	640		
BIVALVE LARVAE	6	9	12		9.00	1050		
240µm X 210µm EARLY UMBO								
290µm X 250µm LATE " "								
300µm X 260µm " " "								
320µm X 280µm " " "								
300µm X 260µm " " "								
310µm X 270µm " " "								
300µm X 260µm " " "								
300µm X 260µm " " "								
250µm X 210µm EARLY UMBO								
280µm X 250µm LATE " "								
290µm X 260µm " " "								
270µm X 220µm " " "								
270µm X 240µm " " "								
300µm X 260µm " " "								
280µm X 240µm " " "								
290µm X 250µm								

Time Code ______ Station DISCHARGE Depth ______ Bottle ______ Date 22-VI-81 Project PILGRIM CHLORINE MINIMIZATION

Counted by: TMH Date: 1-VII-81

Comments:

Original Volume 250L

Final Volume 30ml.

ZOOPLANKTON

Sedgwick Rafter

Time Circle ______ Station DISCHARGE Depth ______ Bottle ______ Date 24-VII-81 Project PILGRIM CHLORINE MINIMIZATION

*Fraction	1	1		$\bar{X}$	No/m³		
MYTILUS EDULIS LARVAE	4	5		4.5	540		
BIVALVE LARVAE	8	12		10.0	1200		
360µm X 270µm LATE UMBO							
330µm X 290µm " "							
250µm X 210µm EARLY UMBO							
280µm X 240µm LATE UMBO							
280µm X 260µm " "							
290µm X 260µm " "							
260µm X 230µm EARLY UMBO							
230µm X 200µm " " " "							
260µm X 230µm " " " "							

Counted by: TMH Date: 1-VIII-81

Comments:

Original Volume 250 L

Final Volume 30 mls.

ZOOPLANKTON

Sedgwick Rafter

Time Code ____ Station DISCHARGE Depth ____ Bottle ____ Date 26-VI-81 Project PILGRIM CHLORINE MINIMIZATION

*Fraction	1	1		$\bar{x}$	No/m³			
/ MYTILUS EDULIS LARVAE	7	6		6.5	780			
/ BIVALVE LARVAE	14	13		13.5	1620			
/								
/								
/								
/								
/								
/								
/								
/								
/ 300µm X 260µm EARLY UMBO								
/ 280µm X 240µm " " " "								
/ 310µm X 270µm MID UMBO								
/ 330µm X 290µm LATE UMBO								
/ 290µm X 250µm EARLY UMBO								
/ 330µm X 280µm LATE UMBO								
/ 290µm X 250µm EARLY UMBO								
/ 330µm X 280µm LATE " "								
/ 290µm X 250µm EARLY " "								
/ 340µm X 300µm LATE " "								
/ 330µm X 290µm " " "								
/ 300µm X 260µm MID " "								
/ 300µm X 270µm " " "								
/								
/								
/								
/								
/								
/								
/								
/								
/								
/								

Counted by: TMH Date: 10-VIII-81

Comments:

Original Volume 250L

Final Volume 30mls

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1		$\bar{x}$	No/M.³		
/ Mytilus edulis larvae	3	4	1		2.67	320		
/ Bivalve larvae	1	2	1		1.33	160		
/ 290µm X 250µm Mid umbo								
/ 290µm X 250µm " " "								
/ 300µm X 270µm " " "								
/ 290µm X 250µm " " "								
/ 300µm X 280µm " " "								
/ 350µm X 300µm Late umbo								
/ 300µm X 250µm Mid " "								
/ 360µm X 310µm Late " "								

Time Code ____ Station DISCHARGE Depth ____ Bottle ____ Date 29-VI-81 Project PILGRIM CHLORINE MINIMIZATION

Counted by: TAH Date: -VII-81

Comments:

Original Volume 250 L

Final Volume 30 mls.

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1	1	1	1	$\bar{X}$	No/m³
MYTILUS EDULIS LARVAE	4	5	1	4	4	3	3.50	420
BIVALVE LARVAE	7	1	5				4.33	520
210µm X 170µm EARLY LARVAE								
230µm X 190µm " " "								
310µm X 280µm LATE " "								
330µm X 300µm " " "								
220µm X 180µm EARLY " "								
230µm X 190µm " " "								
310µm X 260µm LATE " "								
310µm X 270µm " " "								
300µm X 260µm " " "								
220µm X 170µm EARLY " "								

Time Code ______ Station DISCHARGE Depth ______ Bottle CANAL Date 6-VIII-81 Project PILGRIM CHLORINE MINIMIZATION

Counted by: TMH Date: 29-VII-81

Comments:

Original Volume 230 mls.

Final Volume 30 mls.

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1	1	1	1	$\bar{X}$	No/m^3
MYTILUS EDULIS LARVAE	0	1	2	3	1	0	1.17	152
BIVALVE LARVAE	3	2	2				2.33	304
130µm X 110µm S.H. = 70µm								
110µm X 90µm S.H. = 70µm								
120µm X 90µm S.H. = 70µm								

Counted by: TMH Date: 29-VIII-81

Comments:

Time Circle ______ Station DISCHARGE Depth ______ Bottle IMPOUNDMENT Date 6-VII-81 Project PILGRIM CHLORINE MINIMIZATION

Original Volume 250 L

Final Volume 30 mls.

ZOOPLANKTON

Sedgwick Rafter

		*Fraction	1	1	1		$\bar{X}$	No./m³		
MYTILUS EDULIS LARVAE			0	3	0		1	120		
BIVALVE LARVAE			2	1	2		1.67	200		
MYTILUS EDULIS LARVAE										
330 x 300 μm LATE UMBO										
300 x 260 μm LATE UMBO										
220 x 180 μm EARLY UMBO										

Counted by: TMH Date: 23-XII-81

Comments:

Time Circle ____ Station DISCHARGE Depth ____ Bottle ____ Date 9-VII-81 Project PILGRIM CHLORINE MINIMIZATION

Original Volume 250 L

Final Volume 30 mls

ZOOPLANKTON

Sedgwick Rafter

Time Code ______ Station Discharge Depth ______ Bottle ______ Date 13-VIII-81 Project Pilgrim Chlorine Minimization

*Fraction		1	1	1		$\bar{X}$	No/m³		
Mytilus edulis larvae		3	6	7		5.33	640		
Bivalve larvae		32	27	35		31.33	3760		
Mytilus edulis larvae									
120x90µm S.H.=75µm									
110x90µm S.H.=75µm									
130x100µm S.H.=80µm									
100x80µm S.H.≐80µm									
120x90µm S.H.=75µm									
110x90µm S.H.=80µm									
120x91µm S.H.=70µm									
110x80µm S.H.=75µm									
120x90µm S.H.=70µm									
180x90µm S.H.=75µm									
100x80µm S.H.=75µm									
120x80µm S.H.=70µm									
300x270µm Late umbo									
120x90µm S.H.=75µm									
300x270µm Late umbo									
300x270µm Late umbo									

Counted by: TMH Date: 23-XII-81

Comments:

Original Volume 250 l

Final Volume 30 mls #30 Mesh

ZOOPLANKTON

Sedgwick Rafter

	*Fraction	1	1	1	1	.1	1	.1	
/	Mytilus edulis	0	0	1	0	0	0		
/	Bivalve larvae	2	3	3					
/	Mytilus edulis								
/	300 x 260 late umbo								
/	3								

Counted by: B.B. Date: 31-VII-81

Comments:

Time Circle ___ Station Discharge Depth ___ Bottle #1 Date 21-VII-81 Project Pilgrim Discharge

Time Code ____ Station DISCHARGE Depth ____ Bottle 2 Date 21-VII-81 Project PILGRIM

Original Volume 250 l.

Final Volume 27 mls.

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1	1	·1	1		
MYTILUS EDULIS	2	1	1	1	0	1		
BIVALVE LARVAE	0	4	1	1	1	3		

MYTILUS EDULIS
265 × 225 UMBO
140 × 110 EARLY UMBO
165 × 130 " "
155 × 125 " "

Counted by: CF Date: July 31, 1981

Comments: # 30 MESH

Original Volume 250 l.

Final Volume 20 mls.

ZOOPLANKTON

Sedgwick Rafter

Time Code ____ Station Discharge Depth ____ Bottle # 2 Date 27.VII.81 Project Pilgrim

*Fraction	1	1	1	1	1	1			
MYTILUS EDULIS	0	1	1	0	3	1			
BIVALVE LARVAE	2	1	1	2	0	2			

MYTILUS
130 x 125
140 x 125

Counted by: LF Date: July 31, 1981

Comments: # 30 mesh

Original Volume 250 l

End Volume 30 ml

30 Mesh

ZOOPLANKTON

Sedgwick Rafter

Time Circle ______ Station Discharge Depth ______ Bottle 1 Date 27-VII-81 Project ______ Pilgrim Discharge 200

*Fraction	1	1	1	1	1	1	x	[illegible]
Unk. Bivalve	1	0	0	1	5			
Mytilus edulis	1	2	0	1	2	0		

Mytilus edulis

140 x 120 80 u
130 x 110 80 u
140 x 110 90 u
130 x 110 85 u
130 x 110 80 u
130 x 110 80 u

Counted by: B. Brooks Date: 31-VII-81

Comments:

Original Volume 250 L

Final Volume 30 mls.

ZOOPLANKTON

Sedgwick Rafter

Time Code ______ Station DISCHARGE Depth ______ Bottle ______ Date 10-VIII-81 Project PILGRIM CHLORINE MINIMIZATION

	*Fraction	1	1	1		$\bar{X}$	No/m³		
MYTILUS EDULIS LARVAE		0	0	1		0.33	40		
BIVALVE LARVAE		15	18	6		13	1560		

MYTILUS EDULIS LARVAE

90 x 160 µm EARLY UMBO

Counted by: TMH Date: 03-XII-81

Comments:

Original Volume 250 L

Final Volume 30 mls.

ZOOPLANKTON

Sedgwick Rafter

	*Fraction	1	1	1		$\bar{X}$	No/m³		
MYTILUS EDULIS LARVAE		0	0	0		0	0		
BIVALVE LARVAE		1	5	3		3	360		

Time Code ______ Station DISCHARGE Depth ______ Bottle ______ Date 17-VIII-81 Project PILGRIM CHLORINE MINIMIZATION

Counted by: TMH Date: 23-XII-81

Comments:

Original Volume 250 l

Final Volume 60 mls

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1		X̄	No/M³		
MYTILUS EDULIS LARVAE	1	0	0		0.33	80		
BIVALVE LARVAE	5	4	0		3	720		

MYTILUS EDULIS LARVAE

100 X 80 μm S.H. = 75 μm

Time Code ____ Station DISCHARGE Depth ____ Bottle ____ Date 25-VIII-81 Project PILGRIM CHLORINE MINIMIZATION

Counted by: TMH Date: 24-XII-81

Comments:

Original Volume 250 l

Final Volume 20 ml #30 Mesh

ZOOPLANKTON

Sedgwick Rafter

	*Fraction	1	1	1		$\bar{x}$	Density		
	Mytilus edulis	5	8	8		7	560		
	Unid. Bivalves	33	25	19		25.67	2053		
	160 x 120 St. hinge								
	110 x 80 " "								
	150 x 130 " "								
	120 x 90 " "								
	140 x 110 " "								
	110 x 90 " "								
	110 x 80 " "								
	110 x 90 " "								
	150 x 130 " "								
	110 x 90 " "								
	110 x 80 " "								
	140 x 130 " "								
	110 x 80 " "								
	110 x 80 " "								
	110 x 80 " "								
	110 x 80 " "								
	110 x 90 " "								
	120 x 90 " "								
	110 x 90 " "								
	110 x 90 " "								

Counted by: B Brooks Date: 6-X-81

Comments:

Time Circle ______ Station ______ Discharge Depth ______ Bottle ______ Date 31-VIII-81 Project Pilgrim Chlorine Minimization

Original Volume 250 l

Final Volume 40 ml

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1			X̄	Dens/m³
Mytilus edulis larvae	1	0	1			0.67	107
Bivalve larvae	5	6	3			4.67	747
112 x 80 st. hinge							
120 x 80 " "							

Pilgrim Disch
500
8-IX-81
#30 mesh 250L

Time Code ___ Station Discharge ___ Depth ___ Bottle ___ Units 8-IX-81 Project Pilgrim Chlorine Minimization

Counted by: B. Brooks Date: 3-X-81

Comments: Heavy with Detritus

Time Code ______ Station [illegible] Depth ______ Bottle ______ Date 17-IX-81 Project PILGRIM CHLORINE MINIMIZATION

Original Volume 250 l.

Final Volume 78 mls.

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1			$\bar{X}$	Dens/m³	
MYTILUS EDULIS LARVAE	3	2	3			2.67	832	
BIVALVE LARVAE	7	10	6			7.67	2392	
145×110 µ S.H.								
115×85 µ SH								
110×85 µ S.H.								
135×115 µ SH								
135×100 SH								
110×85 SH								
70×55 SH								
105×70 SH								

Counted by: LF Date: Oct. 6, 1981

Comments:

Original Volume 250 l

Final Volume 25 mls

#30 Mesh

ZOOPLANKTON

Sedgwick Rafter

	*Fraction	1	1	1			$\bar{X}$	Density
	Mytilus edulis larvae	7	4	5			5.33	1664
	Bivalve larvae	11	9	6			8.67	2704
	120 x 80 st. hinge							
	120 x 90 " "							
	120 x 90 " "							
	120 x 90 " "							
	120 x 90 " "							
	120 x 90 " "							
	120 x 90 " "							
	120 x 90 " "							
	120 x 90 " "							
	120 x 80 " "							
	120 x 90 " "							
	120 x 90 " "							
	120 x 80 " "							
	120 x 90 " "							
	120 x 90 " "							
	120 x 90 " "							

Pilgrim DISCH
Zoo
23-IX-81
#30 mesh 250 L

F.V.=25ml
3-X-81

Time ___ Station Discharge Depth ___ Bottle ___ Date 23-IX-81 Project Pilgrim Chlorine Minimization

Counted by: B Brooks Date: 3-X-81

Comments: Time on Tag = 1520

Original Volume 250 l.

Final Volume 45 mls.

ZOOPLANKTON

Sedgwick Rafter

Station: DISCHARGE

Date: 30-IX-81

Project: PILGRIM CHLORINE MINIMIZATION

		*Fraction	1	1	1			X̄	DENSITY	
1.		MYTILUS EDULIS LARVAE	8	10	6			8.00	1440	
2.		BIVALVE LARVAE	3	5	7			5.00	900	
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										
11.										
12.										
13.										
14.										
15.										
16.		110 × 80 SH								
17.		110 × 70 SH								
18.		110 × 80 SH								
19.		115 × 85 SH								
20.		110 × 75 SH								
21.		115 × 85 SH								
22.		110 × 75 SH								
23.		110 × 75 SH								
24.		110 × 90 SH								
25.		110 × 75 SH								
26.		105 × 75 SH								
27.		200 × 190 UMBO								
28.		110 × 85 SH								
29.		115 × 80 SH								
30.		105 × 70 SH								
31.		110 × 80 SH								
32.		290 × 265 UMBO								
33.		100 × 70 SH								
34.		105 × 70 SH								
35.		100 × 70 SH								

Counted by: LF Date: OCT. 6, 1981

Comments:

Original Volume 250 l

Final Volume 80 mls

ZOOPLANKTON

Sedgwick Rafter

	*Fraction	1	1	1			$\bar{x}$	Density
/	Mytilus edulis	16	13	24			17.67	5653
/	Unk bivalve	4	3	4			3.67	1173
/	110 x 80 u ST hinge							
/	110 x 80 " "							
/	110 x 80 " "							
/	110 x 90 " "							
/	120 x 90 " "							
/	110 x 90 " "							
/	110 x 90 " "							
/	110 x 80 " "							
/	110 x 80 " "							
/	100 x 75 " "							
/	110 x 90 " "							
/	110 x 80 " "							
/	110 x 80 " "							
/	110 x 90 " "							
/	110 x 80 " "							
/	110 x 90 " "							
/	110 x 80 " "							
/	110 x 80 " "							
/	110 x 80 " "							
/	230 x 200 Early Umbo							
/	270 x 270 Late Umbo							
/								

Counted by: B Brooks Date: 5 - X - 81

Comments:

Time Circle ______ Station Discharge Depth ______ Bottle ______ Date 5-X-81 Project Pilgrim Chlorine Minimization

Original Volume 250 l

Final Volume 13 ml

ZOOPLANKTON

Sedgwick Rafter Density

	*Fraction	1	1	1	Σ	$\bar{X}$	x F.V	x 4	
/	Mytilus edulis	38	39	43		40		2,080	
/	Unk. Bivalve	4	8	2		4.67		243	

Line Code ______ Station [illegible] Depth ______ Bottle ______ Date 10-12-81 Project # Fil. Zoo

Counted by: B. Brooks Date: 24 - XI - 81

Comments:

Z-1

Mytilus edulis

Slide #1

L × W	hinge
110 x 90µ	80
110 x 70	70
110 x 70	70
110 x 70	70
110 x 70	70
110 x 70	70
110 x 70	70
120 x 70	70
110 x 70	70
110 x 70	70
100 x 70	70
100 x 60	70
100 x 70	70
110 x 80	80
110 x 70	70
110 x 70	70
110 x 70	80
100 x 70	75
100 x 70	70
110 x 80	80
110 x 70	80
110 x 70	80
110 x 70	80
100 x 60	70
100 x 70	75
110 x 70	70
110 x 70	70
110 x 80	70
110 x 70	80
110 x 80	70
110 x 80	70
110 x 70	70
110 x 80	70

L × W	hinge
110 x 70µ	70
110 x 70	70
110 x 80	80
110 x 70	70
110 x 70	70

Slide #2

L × W	hinge
110 x 70µ	70
110 x 70	70
110 x 80	80
110 x 60	70
110 x 70	70
100 x 70	70
110 x 70	80
110 x 80	70
100 x 70	70
110 x 80	70

Slide #3

L × W	hinge
110 x 70µ	70
100 x 70	70
110 x 70	70
110 x 80	70
110 x 70	70
110 x 70	80
110 x 70	70
100 x 70	70
100 x 70	70
110 x 70	70

Original Volume 250 l

Final Volume 30ml

ZOOPLANKTON

Sedgwick Rafter

		*Fraction	1	1	1					
Mytilus edulis			0	0	0					
Unk. Bivalve			1	0	1					

PILGRIM
INTAKE
ZOO SAMPLE
23 - X - 81
250 lt.

Time Code ______ Station Intake Depth ______ Bottle ______ Date 23-X-81 Project Pilgrim Intake

Counted by: B. Brooks Date: 6 - IV - 82

Comments:

Original Volume 250 L

Final Volume 30 mls

ZOOPLANKTON

Sedgwick Rafter

*Fraction		1	1	1		$\bar{X}$	N_o/m^3		
MYTILUS EDULIS LARVAE		0	1	4		1.67	200		
BIVALVE LARVAE		0	3	1		1.33	160		
MYTILUS EDULIS LARVAE									
90x60µm S.H.=75µm									
90x60µm S.H.=75µm									
90x60µm S.H.=75µm									
90x60µm S.H.=80µm									
90x60µm S.H.=80µm									

Time Code ____ Station DISCHARGE Depth ____ Bottle ____ Date 31-X-81 Project PILGRIM CHLORINE MINIMIZATION

Counted by: TMH Date: 24-XII-81

Comments:

Original Volume 250 l

Final Volume 36 ml

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1	1				
Bivalves	0	0	0	0				

Pilgrim
ZOOPLANKTON
7-XI-81
250 lt.
form.

Time Code ______ Station INTAKE Depth ______ Bottle ______ Date ______ Project B. Pilgrim

Counted by: B. Brooks Date: 25-XI-81

Comments: No bivalves in concentrated subsample.

Original Volume 250L

Final Volume 30mls

ZOOPLANKTON

Sedgwick Rafter

Time Code ______ Station INTAKE Depth ______ Bottle ______ Date 13-XI-81 Project PILGRIM CHLORINE MINIMIZATION

	*Fraction	1	1	1		$\bar{X}$	No/m³		
MYTILUS EDULIS LARVAE		0	2	1		1	120		
BIVALVE LARVAE		2	2	1		1.67	200		

MYTILUS EDULIS

150 x 130µm S.H. = 80µm

300x240µm LATE UMBO

190x160µm EARLY UMBO

Counted by: JMH Date: 22-XII-81

Comments:

Original Volume 250 l

Final Volume 35 ml

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1	1				
/ Bivalves	0	0	0	0				

Pilgrim
INTAKE ZOO SAMPLE
20-XI-81
250 lt
Comm.

Time Circle ______ Station Intake ______ Depth ______ Bottle ______ Date 20-XI-81 Project Intake Zoo Sample

Counted by: B Brooks Date: 24-XI-81

Comments: Even concentrated Subsamples showed No Bivalves

Original Volume 250 L

Final Volume 30 mls

ZOOPLANKTON

Sedgwick Rafter

		*Fraction	1	1	1		$\bar{x}$	No/m³		
MYTILUS EDULIS LARVAE			0	0	0		0	0		
BIVALVE LARVAE			1	0	0		0.33	.40		

Time Code ____ Station DISCHARGE Depth ____ Bottle ____ Date 4-XII-81 Project PILGRIM CHLORINE MINIMIZATION

Counted by: TMH Date: 28-XII-81

Comments:

Original Volume 250 l

Final Volume 30 ml

ZOOPLANKTON

Sedgwick Rafter

Time Code ____ Station Intake Depth ____ Bottle ____ Date 11-XII-81 Project Pilgrim Intake

*Fraction		1	1	1					
Mytilus edulis		0	0	0					
Bivalve larvae		0	0	1					

Pilgrim Intake
ZOO SAMPLE
11 - XII - 81
250 lt

Counted by: B. Brooks Date: 6-IV-82

Comments:

Original Volume 250 L

Final Volume 30 mls.

ZOOPLANKTON

Sedgwick Rafter

*Fraction	1	1	1
Mytilus edulis larvae	0	0	0
Modiolus spp. larvae	0	0	0
Unknown bivalve larvae	0	0	0

Time Code ______ Station Pilgrim Depth ______ Bottle Intake Date 28-XII-81 Project Pilgrim Chlorine Minimization

Counted by: TMH Date: 17-VIII-82

Comments:

ZOOPLANKTON
Sedgwick Rafter

Final Volume 30 ml

Time Code ____ Station ____ Depth ____ Bottle ____ Date 5-I-82 Project Pilgrim Intake Zoo

	*Fraction	1	1	1					
F Mytilus edulis		0	0	0					
F Unk. Bivalve		0	0	0					

Pilgrim Intake Zoo
5-I-82
250 liters

Counted by: B Brooks Date: 23-IV-82

Comments:

Original Volume 250 L

Final Volume 30 ml.

ZOOPLANKTON

Sedgwick Rafter

		*Fraction	1	1	1					
MYTILUS EDULIS LARVAE			0	0	0					
UNKNOWN BIVALVE LARVAE			0	0	0					

Time Code ______ Station INTAKE Depth ______ Bottle ______ Date 22-II-82 Project PILGRIM CHLORINE MINIMIZATION

Counted by: TMH Date: 11-V-82

Comments:

Original Volume 250l

Final Volume 30mls.

ZOOPLANKTON

Sedgwick Rafter

		*Fraction	1	1	1		$\bar{X}$	No/m³		
Mytilus edulis larvae			0	0	0					
Modiolus spp. larvae			0	0	0					
Unknown bivalve larvae			0	1	1		0.67	80		

Time Code ____ Station Pilgrim Depth ____ Bottle Intake Date 5-III-82 Project Pilgrim Chlorine Minimization

Counted by: TMH Date: 18-VIII-82

Comments:

[illegible]al Volume 250 L

[illegible] Volume 30 mls.

ZOOPLANKTON

Sedgwick Rafter

	*Fraction	1	1	1					
[M]YTILUS EDULIS LARVAE		0	0	0					
[M]ODIOLUS SPP. LARVAE		0	0	0					
[UN]KNOWN BIVALVE LARVAE		0	0	0					

Time Code ____ Station PILGRIM Depth ____ Bottle INTAKE Date 11-III-82 Project PILGRIM CHLORINE MINIMIZATION

Counted by: TMH Date: 18-VIII-82

Comments:

…inal Volume 250 L

…d Volume 30 mls

ZOOPLANKTON

Sedgwick Rafter

	*Fraction	1	1	1		$\bar{x}$	No/m³		
…TILUS EDULIS LARVAE		0	0	0					
…DIOLUS SPP. LARVAE		0	0	0					
…KNOWN BIVALVE LARVAE		1	2	1		1.33	160		

…ounted by: TMH Date: 18-VIII-82

…omments:

Time Code ____ Station PILGRIM Depth ____ Bottle INTAKE Date 17-III-82 Project PILGRIM CHLORINE MINIMIZATION

Original Volume 250L

Final Volume 30mls.

ZOOPLANKTON

Sedgwick Rafter

Time Code ____ Station PILGRIM Depth ____ Bottle INTAKE Date 25-III-82 Project PILGRIM CHLORINE MINIMIZATION

		*Fraction	1	1	1					
MYTILUS EDULIS LARVAE			0	0	0					
MODIOLUS SPP. LARVAE			0	0	0					
UNKNOWN BIVALVE LARVAE			0	0	0					

Counted by: TMH Date: 23-VIII-82

Comments:

ZOOPLANKTON

Sedgwick Rafter

ial Volume 250 L

d Volume 30 mls.

		*Fraction	1	1	1					
TILUS EDULIS LARVAE			0	0	0					
DIOLUS SPP. LARVAE			0	0	0					
KNOWN BIVALVE LARVAE			0	0	0					

Time Code ______ Station PILGRIM Depth ______ Bottle INTAKE Date 1-IV-82 Project PILGRIM CHLORINE MINIMIZATION

Counted by: TMH Date: 23-VIII-82

Comments:

[Orig]inal Volume 250 L

[Fina]l Volume 30 ml

ZOOPLANKTON

Sedgwick Rafter

Time Code ____ Station PILGRIM Depth ____ Bottle INTAKE Date 8-IV-82 Project PILGRIM CHLORINE MINIMIZATION

	*Fraction	1	1	1					
[M]YTILUS EDULIS LARVAE		0	0	0					
[M]ODIOLUS SPP. LARVAE		0	0	0					
[U]NKNOWN BIVALVE LARVAE		0	0	0					

Counted by: TMH Date: 23-VIII-82

Comments:

Appendix B

BECO General Testing Division Reports

Results of Scale Examination

OFFICE MEMORANDUM

FORM 73? BOSTON EDISON COMPANY

FILE

TO Mr. A. V. Morris

FROM Mr. R. F. Standring

DATE 10/1/81

MAIL Waltham PHONE 3654

CONDENSER TUBES - PILGRIM STATION

The General Test Division has completed the analysis of six (6) condenser tubes from Pilgrim Station. A request was received from Mr. L. N. Scotton, Nuclear Operations, to determine the manganese, iron and silicon content of the deposit contained on the interior surface of the condenser tubes. In addition, Mr. L. N. Scotton requested that the actual thickness of the interior deposit and/or the relative thickness of the interior deposit be determined.

The condenser tubes are part of a continuing chlorine minimization study being conducted by Marine Research Inc. at Pilgrim Station. The study is being performed to determine the effect that various trace amounts of chlorine have on the integrity of interior surface of the condenser tubes.

The parameter, manganese is being measured to determine whether or not manganese is being concentrated by the biological organisms onto the interior surface of the tubes. Therefore theoretically the manganese level should be inversely proportional to the amount of chlorine.

The other two, metals, iron and silicon, would be indicative of the nature of the deposit, while the thickness of the deposit would be indicative of the level of chlorine necessary to prevent a deposit build-up.

The results of the analysis are inconclusive. There is no observable trend based upon the amount of chlorine added to the tubes with respect to the trace metal parameters.

The GTD investigated a technique whereby the actual thickness would be determine by microscopically measuring the thickness of the tubes cross-section both before and after removal of the deposit. This technique proved to be beyond the scope of our present equipment. A professional microscopist, Mr. C. M. Spooner, Ph D of BB&N Inc., was consulted by telephone. He confirmed that the technique was beyond our capabilities and added it was beyond his capability. He stated that he would be very skeptical about any results obtained in such a manner since the variability of the thickness of the deposit would be far greater than the accuracy of the analytical technique. He suggested an alternate technique for determining the relative thickness of the deposit (contained in attached table).

The results of this suggested technique indicated that the tube with 0 ppB chlorine added is 8-10 times higher in deposit than the remaining chlorine treated tubes. (See attached photograph).

The results of the analysis were reported by telephone on an "as obtained" basis to Mr. L. N. Scotton.

The analytical results and complete sample identification are contained in the attached table: (See Attached).

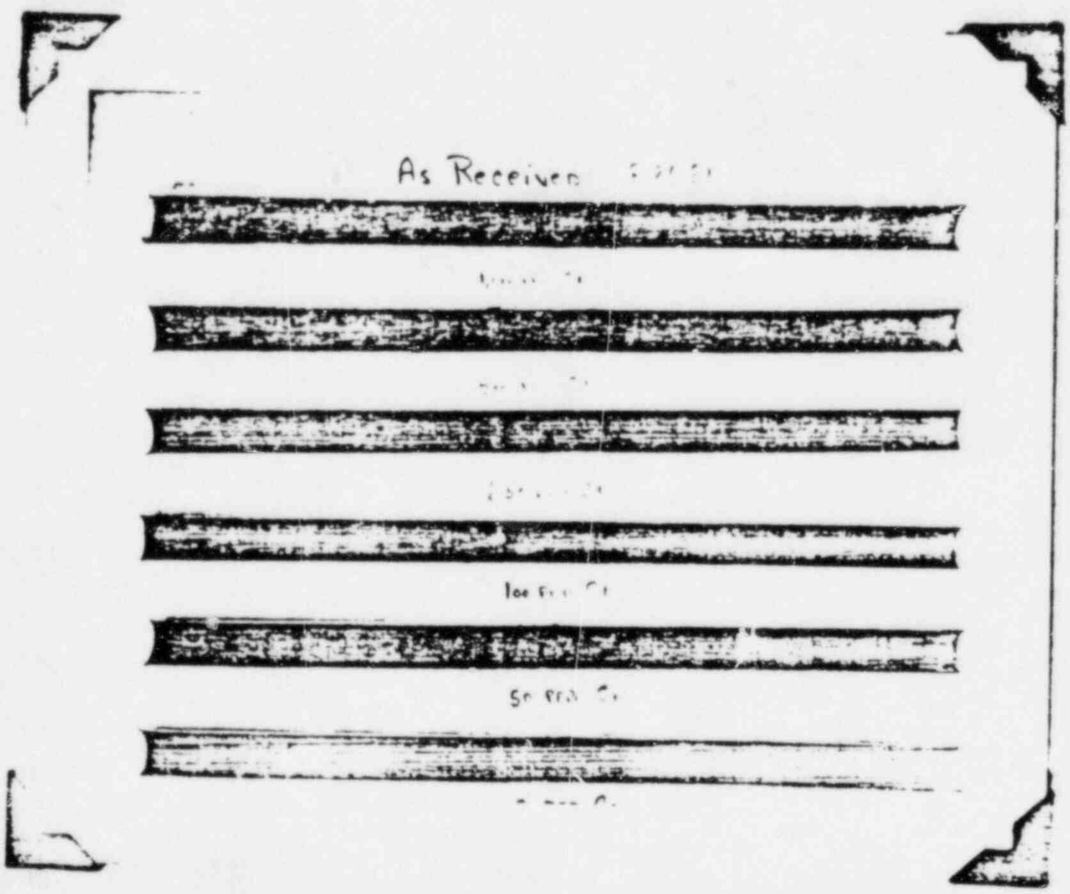
RFS/dp

x.c. Mr. L. N. Scotton
Mr. V. J. Merritt

I.D. Sample #195-	Date	ppB Chlorine Added	Results ppm* Mn	Fe	Si	ug/cm* Thickness
1009-1	8/21/81	0	2.66	22.2	0.95	3,880
1009-2	"	50	0.16	21.5	0.36	538
1009-3	"	100	0.41	15.4	0.13	250
1009-4	"	250	4.43	25.0	0.47	344
1009-5	"	500	4.36	17.2	0.24	441
1009-6	"	1,000	3.78	17.5	0.43	263

Results ppm* - Tubes split lengthwise. 1 half treated with Dil. HNO3 for trace metal analysis. Results in relative parts per million.

sults ug/cm* - Second half of split tubes. Dried, weighed, interior cleaned, redried, reweighed. Difference equals amount of deposit. Length of split tubes determined. Difference divided by length.



OFFICE MEMORANDUM

Boston Edison Company

To: Mr. A. V. Morris From: Mr. H. F. Standring Date: February 2, 1982
Mail: Watertown Phone: 3654

CONDENSER TUBES - PILGRIM STATION

The General Test Division has completed the analysis of six (6) condenser tubes from Pilgrim Station. A request was receivea from Mr. L. N. Scotton, Nuclear Operations, to determine the manganese, iron and silicon content of the deposit located on the interior surface of the condenser tubes. In addition he requested that the relative amount of deposit per unit length be determined.

The condenser tubes were Phase II of a chlorine minimization study that was conducted by Marine Research Inc., at Pilgrim Station. The study was performed to determine the effect that various trace amcunts of chlorine had on the integrity of the interior surface of the condenser tubes. This bundle of tubes is the final installment from the study.

The results of the analyses indicate that the parameters Mn. Si. and relative ug/cm are 10 times higher in tube 0 than the remaining 5 tubes, while the parameter Fe has no discernable pattern.

An explanation of why and how the parameters were tested is contained in a memo from Mr. H. F. Standring to Mr. A. V. Morris, dated 10/1/81. (Attached).

The complete sample identifications and analytical results are contained in the following table:

ID					Results*	
Sample #195	Date	Line #	Mn	Fe	Si	ug/cm*
1138-1	11/25/81	0	2.27	41.3	3.15	9,168
1138-2	11/25/81	2	0.79	35.1	0.19	805
1138-3	11/25/81	4	0.20	29.3	0.11	885
1138-4	11/25/81	6	0.13	22.0	0.27	904
1138-5	11/25/81	8	0.16	20.2	0.22	724
1138-6	11/25/81	10	0.13	±8.7	0.17	791

Results - Tubes split lengthwise .1 half treated with 20% HNO_3 for trace metal analysis. Results in relative parts per million.

ug/cm - Second half of split tubes were dried, weighed, cleaned, redried and reweighed. Difference in weight equals amount of deposit. Difference was divided by length of tubes.

The results of the analysis were reported to Mr. L. N. Scotton on January 22, 1982.

RFD/jq3L
xc: Mr. L. N. Scotton
Mr. W. J. Merritt

I.D. Sample #195-	Date	PPB Chlorine Added	Results ppm* Mn	Fe	Si	ug/cm* Thickness
1009-1	8/21/81	0	2.66	22.2	0.95	3,880
1009-2	"	50	0.16	21.5	0.36	538
1009-3	"	100	0.41	15.4	0.13	250
1009-4	"	250	4.48	25.0	0.47	344
1009-5	"	500	4.36	17.2	0.24	441
1009-6	"	1,000	3.78	17.5	0.43	263

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