PACIFIC GAS AND ELECTRIC COMPANY

PG&E 77 BEALE STREET • SAN FRANCISCO, CALIFORNIA 94106 • (415) 972-2733 • TWX 910-372-6587

H. M. HOWE
CHIEF SITING ENGINEER

June 12, 1985

Mr. Kenneth R. Jones
Executive Officer
California Regional Water Quality
Control Board
1102-A Laurel Lane
San Luis Obispo, CA 93401

Dear Mr. Jones:

Subject: Submittal of Diablo Canyon Nuclear Power Plant NPDES Permit (No. CA0003751) Provision D.6 Report

Provision D.6 of the Diablo Canyon Nuclear Power Plant (DCNPP) National Pollutant Discharge Elimination System (NPDES) permit requires Pacific Gas and Electric Company (PGandE) to evaluate alternative demusseling programs and propose to the Board its method to reduce heat treatment at the point of discharge to 86 degrees F, prior to Unit 2 commercial operation. The attached report is submitted in fulfillment of this requirement and of the additional directives included in State Water Resources Board Order No. WQ 83-1. Analysis of a wide variety of procedures for the control of biofouling has led to the conclusion that heat treatment would be the most efficient option for the Diablo Canyon Power Plant. This method is estimated to reduce discharge temperatures to 86 F or less 99 percent of the time. As indicated in the report, PGandE will continue monitoring the biological effects of demusseling on Diablo Canyon.

If you have any questions concerning this report, please contact either Craig Walton at (415) 972-6903 or Dave Sommerville at (805) 595-7373.

Sincerely,

H.M. Howe

50-275
323

IE25
1/1

cc: Marine Resources Region
California Department of Fish and Game
350 Golden Shore
Long Beach, CA 90802

Regional Administrator, Region IX
Environmental Protection Agency
215 Fremont Street
San Francisco, CA 94105

Regional Administrator
U. S. Nuclear Regulatory Commission
Region 5
1450 Maria Lane, Suite 210
Walnut Creek, CA 94596-5368

Mr. Ronald L. Ballard, Chief
Environmental and Hydrologic Engineering Branch
Division of Engineering
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Chief, Marine Resources Branch
California Department of Fish and Game
Resources Building
1419 9th Street
Sacramento, CA 95814

DIABLO CANYON POWER PLANT
ALTERNATE DEMUSSELING PROGRAM EVALUATION
AND
HEAT TREATMENT OPTIMIZATION STUDIES

Submitted to the

Central Coast Regional Water Quality Control Board

by

Pacific Gas and Electric Company

June 1985

INTRODUCTION

Provision D.6 of the current NPDES Permit for the Diablo Canyon Power Plant (DCPP) requires an assessment of alternative demusseling programs prior to operation of Unit 2. The demusseling program proposed for DCPP prior to the commercial operation of Unit 1 was based on operating experience at other PGandE ocean sited power plants. Demusseling was to be accomplished by heat treatment. The proposed procedure consisted of raising the internal temperature of the cooling water flow to 110 degrees F over a period of two to four hours, holding the demusseling temperature for one hour, and cooling to ambient temperature over one to two hours. Due to the potential seven hour duration, separate condenser halves would have been demusseled on alternate weeks, resulting in an average of 48 heat treatments per year for the two units.

Pursuant to the requirements of the NPDES Permit, PGandE has undertaken engineering and biological studies of demusseling procedures to evaluate alternate biofouling control strategies, to develop an optimal heat treatment program within the constraints of the existing system, and to protect beneficial uses of the receiving water by minimizing the temperature of the heat treatment discharge. The results of these studies have been integrated to develop an optimal heat treatment strategy which is specific to DCPP. The proposed heat treatment program will maximize biofouling control while minimizing the duration and frequency of the demusseling procedure.

ALTERNATE DEMUSSELING PROGRAMS

The evaluation of alternative demusseling programs centered around a feasibility assessment of other methods for effective biofouling control, and engineering studies of methods which would simultaneously optimize the application of heat treatment and reduce the temperature of the heat treatment discharge.

The purpose of these investigations was to provide an objective evaluation of alternative methods for controlling the growth of marine organisms within the cooling water systems of the Diablo Canyon Power Plant (DCPP). The evaluation of each demusseling method was made relative to the planned method of control, i.e., periodic heat treatment. Possible control measures were identified without regard to their effectiveness, cost or applicability to DCPP and screened on the basis of potential effectiveness and compatibility with the existing conditions at DCPP and regulatory constraints. Technically feasible alternatives that were then evaluated in greater detail to determine the engineering modifications, if any, that would be required to implement them at DCPP and to establish the effects the alternatives would have on the plant's operation. From this analysis, estimates and probable impacts on the environment were determined.

A total of 17 possible macrofouling control methods were identified for consideration. Of these, six (including heat treatment) were determined to be technically feasible for use at DCPP

(Attachment 1). The capital cost for implementing the various alternatives ranged from nothing to approximately $340 million. The operational costs ranged from nothing to approximately $240 million annually. None of the alternatives compared favorably with heat treatment as the primary macrofouling control approach considering all the factors of proven effectiveness, predictable environmental impacts and total cost.

Additional engineering studies were designed to investigate methods to reduce the temperature of the heat treatment discharge. After initial screening of several alternatives, it was determined that the most promising method appeared to be modification of the discharge structure. In the existing discharge structure (Attachment 2), the flow of the two units was separated by a center wall. If the two flows could be blended prior to discharge, the mixing of the heat treatment effluent from one unit with the normal operation discharge from the other unit would result in a reduced temperature at the point of discharge.

A 1:20 scale physical model of the discharge structure was constructed and a number of design modifications were tested. The study determined the optimal size and placement of cutouts in the discharge center wall which would maximize passive mixing of the two flows.

Crossflow tests on the physical model indicated a high degree of mixing through the cutouts and across the gap at the base of the system. During a simulated heat treatment of one unit with the other in normal operation, the crossflow was measured as 42 percent of the difference between the two flows. Since the heat treatment discharge is 500 cfs and the normal operation discharge 2,000 cfs, approximately 630 cfs of the normal operation discharge would mix with the reduced flow of the heat treated unit. Based on results of the model studies, the discharge structure was modified. Two crossover ports 10 feet high, 7.5 feet wide, were cut in the discharge septum. An 11.5 foot high weir was also constructed at the base of the discharge to force mixing across the gap at the base of the existing system (Attachment 3). Results of model studies were confirmed by dye studies at the power plant after the design modification was completed.

The first opportunity to test the heat treatment procedure and assess the effects of the discharge structure modification came during startup testing of Unit 1 on December 26, 1984. The purpose of this test was to determine the maximum operating temperatures maintainable during demusseling, and to collect temperature data at various points throughout the system. The startup test produced several important results. Since the Unit 2 circulating water pumps were run with no plant load, the resultant combined discharge temperature was measured at 71 degrees F. The synoptic internal temperature of the demusseled conduit was 104 degrees F, and the temperature of the water exiting the Unit 1 condenser was 95.8 degrees F. Attachments 4 and 5 present a graphical comparison of internal and discharge temperatures in normal operation and heat treatment configurations. Data from the actual heat treatment were subsequently used in a predictive mathematical model which forecasts mixed discharge temperatures as a function of ambient temperature.

These projections are based on over 67,000 data points from nine years of monitoring data which includes two years of El Nino temperatures. The model predicts discharge temperatures from ambient conditions, since the heat treatment discharge delta T is not constant, but is a function of ambient temperature due to blending at the point of intake in recirculation mode (see Attachment 5). With one unit operating at a normal operation delta T of 22 degrees and the other discharging heat treatment effluent, the model predicts that the discharge temperature would be 86 degrees or less 98.5 percent of the time (Attachment 6).

An additional modification of the heat treatment procedure evolved from the initial operational demusseling test which will result in shortening the duration of heat treatment. Based on the modified procedure, it may be possible to demussel both condenser halves on the same day. This change may reduce the annual frequency of heat treatment by a factor of two.

HEAT TREATMENT OPTIMIZATION

A four phase Heat Treatment Optimization Study was initiated in early 1983. The goal of the study was to develop an optimal heat treatment methodology which would effectively control biofouling organisms within the power plant's cooling system while minimizing the potential for environmental impacts. Phase I of the study was designed to determine the heat tolerance of major fouling organisms through laboratory experiments. In Phase II, actual fouling communities were cultured in a sidestream of the power plant cooling water flow. These fouling organisms were then subjected to laboratory conducted heat treatment simulations, developed from results of Phase I experiments. Physical modeling studies were conducted in Phase III to determine the probable extent and distribution of the DCPP discharge plume during various heat treatment scenarios. This information was then combined with results of biological studies in order to predict the environmental consequences of different heat treatment regimes under a variety of oceanic conditions. In the final phase of the study, Phase IV, power plant heat treatment operations are monitored to determine their effectiveness and environmental influence.

The bay mussel (Mytilus edulis) was chosen as the test organism for Phase I thermal tolerance studies because of its common occurrence as a marine fouling organism and its well documented tolerance to elevated temperatures. Previous studies have shown M. edulis to be the most heat tolerant of all fouling organisms tested. Therefore, any heat treatment regime that successfully controls fouling by this species should also be effective in controlling other species. Experiments were conducted to determine combinations of temperature and duration which effectively kill 95 percent of the test organisms. Test temperatures and the rates of temperature change were selected based on information in the scientific literature and the heat treatment procedures proposed for use at the Diablo Canyon Power Plant. A logarithmic relationship between temperature and duration of exposure was developed through probit analysis of mussel dose-response data (Attachment 7). At a heat treatment temperature of 105 degrees F, 95 percent mortality of mussels would occur in 12 minutes,

while at 95 degrees F, an exposure of over 8 hours is required. The time/temperature relationships developed in Phase I studies were used to design Phase II simulation studies.

Phase II of the study was designed to simulate power plant heat treatment of actual fouling communities and to simultaneously monitor peak seasonal periods in settlement and growth of major fouling species. Heat treatment simulations were conducted on fouling communities cultured in a sidestream of the plant's cooling water to determine the minimum treatment frequency required and to evaluate the effectiveness of temperature-duration combinations (Attachment 8). Results of this study indicate that, during most of the year, heat treatments could be effectively conducted at eight to twelve week intervals.

The purpose of Phase III of the study was to assess the environmental consequences of heat treatment regimes selected from Phase I under various combinations of physical environmental conditions. This analysis is focused upon thermal plume data generated by U. C. Berkeley physical model, the known distributions of important species in the receiving water body, and laboratory thermal tolerance data on the important species. The objective is to predict for each species, the degree of exposure to the plume during heat treatment and to determine the potential environmental consequences of such exposure. The location and degree of "risk" for each species is compared with that predicted from the plume during normal operation, to determine the reduction, equality, or increase in risk resulting from heat treatment operations.

A number of test cases involving various environmental and plant operational conditions were performed on the physical model which provided the distribution of predicted temperatures in Diablo Cove. The distribution of temperatures (delta T degrees F above ambient seawater) on the bottom of Diablo Cove during normal operation of both units (Attachment 10) can be compared with the most extreme case, wherein one unit is heat treating while there is no flow in the other unit (Attachment 11). The position of the 10 degrees F isotherm is approximately the same in both cases. In the heat treatment case, higher isotherms, particularly those above 20 degrees F, are shown to be limited to a small area immediately adjacent to the discharge structure, a major portion of which includes the high velocity zone. This plume is more pronouncedly surface borne than that during normal operation for two reasons: the reduction in flow during heat treatment to about one-fourth the normal flow, and the greater buoyancy of the warmer water being discharged. The other major operational case considered, heat treating one unit while the other is operated normally, resulted in lower discharge temperatures because of the crossflows within the modified discharge structure. The physical model results demonstrated that, in the most extreme case, the distribution of heat treatment plume temperatures would be approximately equivalent to those of the normal operation plume. The major difference would be the occurrence of warmer temperatures in a small area in the immediate vicinity of the discharge structure.

The physical effects of the high water velocities that occur during normal operation were predicted to reduce the ability of benthic organisms to remain attached in an area seaward of the

discharge structure. The probabl[illegible] of organisms from this high velocity zone reduces significantly the possible extent of contact with the warmer temperature portion of the plume and, in particular, eliminates the possible contact of organisms with the warmest temperatures.

Laboratory thermal tolerance data were obtained on intertidal and subtidal organisms by mimicing the discharge temperature curve during heat treatment and exposing the organisms to a range of temperatures. The results (Attachment 12) show that most species exhibited no mortality in the range of temperatures under consideration (75 to 85 degrees F). Those species that did exhibit mortality within this temperature range were primarily subtidal, so that little if any of their populations will occur within the area of Diablo Cove under consideration. Thus, this phase of the study indicated that heat treatment operation presents little, if any, risk to the indigenous communities of Diablo Cove beyond that resulting from normal operation.

Phase IV of the study, initiated following commercial operation of Unit 1, is a heat treatment monitoring program which was designed to assess the effectiveness of the experimentally determined heat treatment program. Results of the optimization program can be used to institute a fixed interval heat treatment regime, or monitoring of fouling and growth rates in the sidestream system can be used to predict the need for demusseling. The procedure currently in place will schedule heat treatment at eight week intervals. Monitoring of specially dedicated fouling plates in the sidestream system is reported regularly to operations personnel in order to shorten or lengthen the interval between demusseling, as dictated by the measured rate of fouling. Potential environmental effects of heat treatment will be monitored in Diablo Cove in conjunction with the ongoing Thermal Effects Monitoring Program.

CONCLUSIONS

The results of the optimization program have been integrated to develop a site specific demusseling procedure which maximizes biofouling control and minimizes the temperature at the point of discharge. The internal demusseling temperature proposed is 105 degrees F, maintained for 30 minutes. Both condenser halves of a single unit will normally be demusseled on the same day. The projected frequency of demusseling will average six times annually per unit. With the alternate unit operating at full load, the crossover ports will result in a mixed temperature at the point of discharge of 86 degrees F or less nearly 99 percent the time. If operational, the pumps of the alternate unit will be run during heat treatment. During the lifetime of the power plant, there may be instances when the pumps of the alternate unit cannot be operated. Under these conditions the volume of the discharge would be reduced by a factor of four, and the discharge temperature would average approximately 96 degrees F. During demusseling, the discharge plume would differ little from the plume of the operating plant. The major reasons for this are: the in-plant dilution, crossflows and mixing that reduce the discharged seawater temperature; the reduced flow of the heat treatment discharge which reduces the size of the warmest

portion of the plume; the buoyant nature of the warmer water, which limits its contact with the bottom. Predictions made from laboratory data indicate no adverse effects on receiving water species from short term exposures to the resultant receiving water temperatures. The net effect of the proposed DCPP demusseling program is to reduce the number of required heat treatments of both units from 48 to 12 per year, and to reduce the discharge temperature from approximately 100 degrees F to 86 degrees F.

ATTACHMENT I

TABLE 5-I

COMPARATIVE ANALYSIS OF TECHNICALLY FEASIBLE MACROFOULING CONTROL ALTERNATIVES

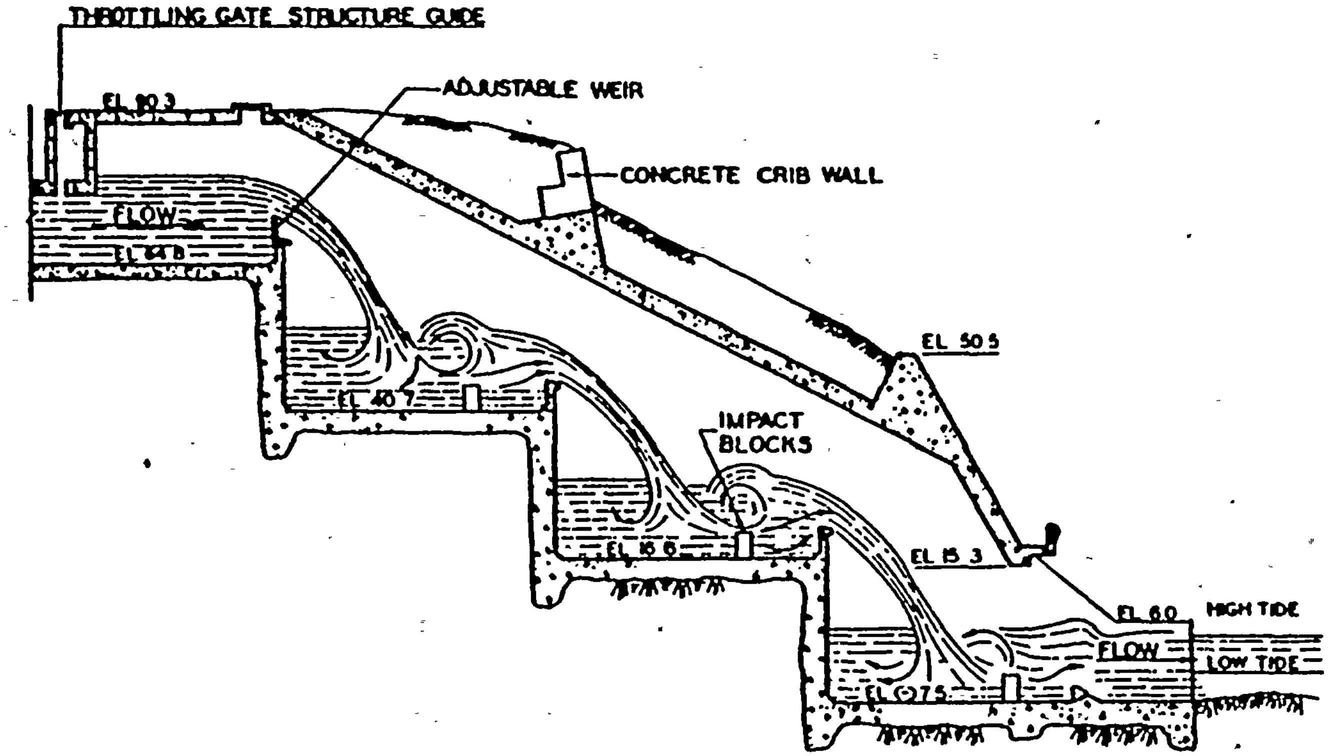
Treatment Effectiveness	Technical Compatibility	Cost	Environmental Effects
Alternative 1. Chlorination			
The application of continuous low levels of chlorine to cooling water systems has been shown to be successful in controlling fouling for some hard-shelled organisms. Intermittent chlorination has been shown to be either unsuccessful or to aggravate the fouling problem.	The DCPP has a chlorination system which could be increased in capacity to permit continuous chlorination.	The total costs of improvements to the existing chlorination system of the DCPP would be approximately $370,000. The increase in annual costs for energy production at the plant would range from $338,600 to $455,800.	The use of this alternative would increase the mortality of organisms entrained into the cooling water system of the plant and could lead to mortality of organisms in the receiving water body.
Alternative 2. Ozonation			
The use of ozone for the control of fouling has been demonstrated in pilot scale tests at power plants. However, little application or experience has been gained in full scale operations.	Ozonation facilities could be constructed on the DCPP site, but would require significant modifications to existing facilities. The effects of increased corrosion of cooling water system components from residual ozone are not predictable from existing studies and experience.	The capital cost of an ozone system at the DCPP estimated to be approximately $6.6 million. The increase in annual energy production costs at the plant would be about $3.3 million.	The use of this alternative would increase the mortality of organisms entrained into the cooling water system of the plant.
Alternative 3. Anti-fouling Coatings			
Demonstration testing with anti-fouling coatings at power plants in the U.S. has shown that such coatings can provide effective macrofouling control in cooling water system applications. The period of effectiveness can be as long as 5-7 years.	Anti-fouling coatings in the form of organotin paint could be employed at the DCPP with no major modifications to existing systems.	The cost of installation of an organotin based paint coating system at the DCPP would be about $3.7 million. Costs for subsequent recoatings at a 5 to 7 year frequency would also be incurred through the 30 year life of the facility. The total increase in annual costs of energy production at the DCPP from the initial coating installation would be about $1 million.	The active compounds in the most effective coatings have been shown to be toxic to nontarget species through leaching. Sedimentary deposition and bioaccumulation have also been demonstrated. The long-term effects of discharges containing chemical residuals from organotin compounds are unknown. Also, it is not known what the effects would be of starting up the cooling system after a period of stagnation.

ATTACHMENT I

TABLE 5-1

COMPARATIVE ANALYSIS OF TECHNICALLY FEASIBLE MACROFOULING CONTROL ALTERNATIVES (CONTINUED)

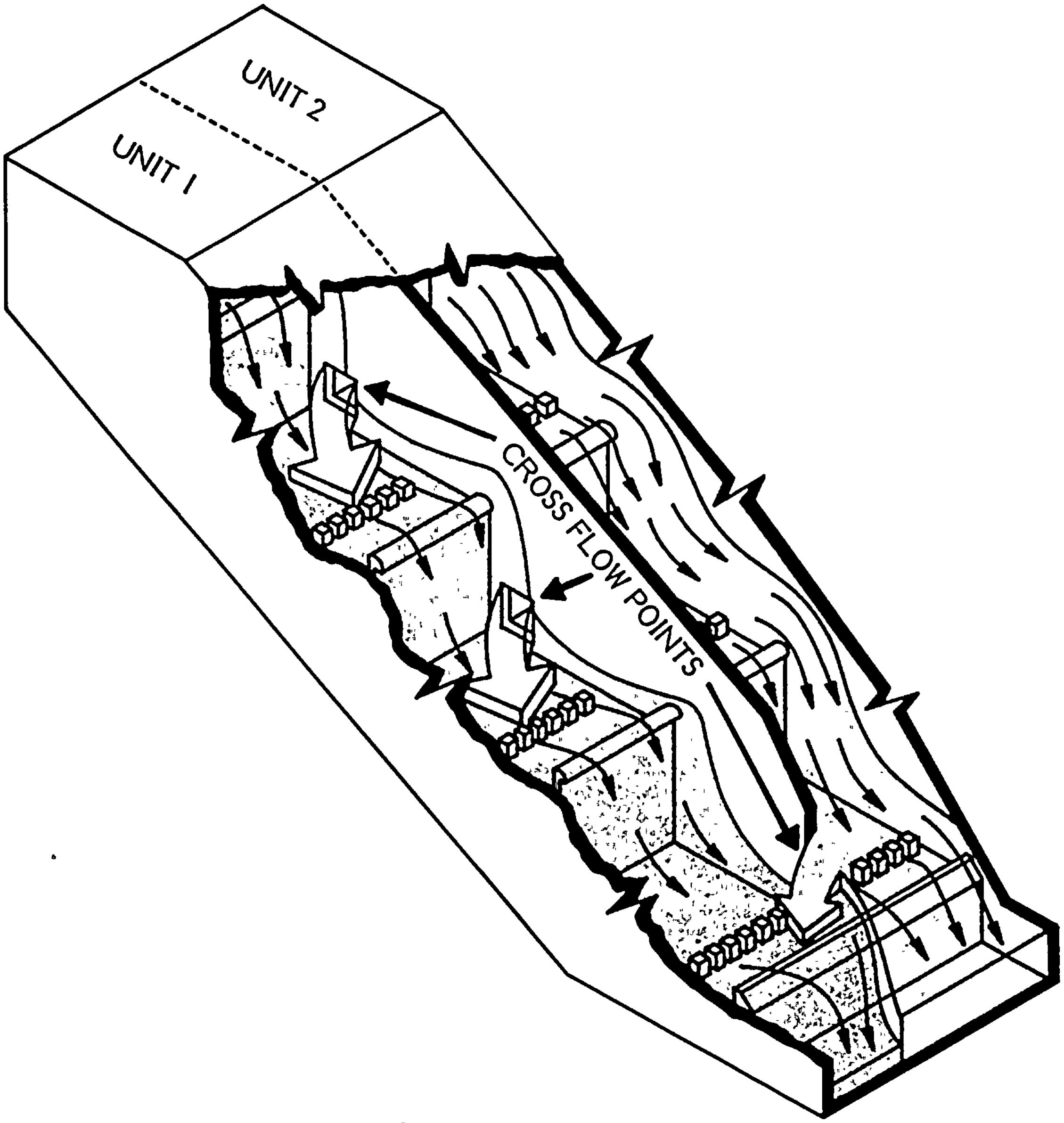
Treatment Effectiveness	Technical Compatibility	Cost	Environmental Effects
	Alternative 4. Manual Cleaning		
The manual cleaning of cooling water system components can be nearly 100 percent effective in controlling macrofouling.	Manual cleaning has been done at the DCPP and is technically compatible with the facility. Some modifications would, however, be required to employ manual cleaning as the primary control method.	Capital cost of improved access to the conduits: \$128,000. Total direct cost of cleaning (based on four cleanings per year): \$540,000/year. Cost of replacement energy: \$242 million/year.	No significant environmental effects.
	Alternative 5. Shellfish Filter		
A shellfish or debris filter is ineffective as a primary method for macrofouling control. It is employed as a secondary method in combination with other technologies to mitigate the effects of macrofouling on condensor/heat exchanger operation.	The installation of the shellfish filter at the DCPP is impractical. The units could not be optimally located, and would require extensive modifications to the plant.	Total capital cost: \$30 million. Replacement energy cost during installation: \$155-\$310 million. Annual costs: \$14.1 million.	No significant environmental effects
	Alternative 6. Thermal Treatment		
Thermal treatment is expected to be completely effective as a method for macrofouling control at the DCPP. The frequency required for effective control is being investigated at this time. However, it is expected that heat treatment will be required between 4 and 12 times per year.	The DCPP is now configured and constructed to employ thermal treatment.	Capital costs: None. Annual costs for heat treatment are estimated to range from \$4.6 million to \$19.3 million due to replacement energy costs.	The best treatment alternatives involving reduced discharge flow, in plant dilution and strong bouyant character of the heated discharge produce no significant environmental effects beyond those of the discharge during normal operation.



ATTACHMENT 2

DCPP DISCHARGE STRUCTURE
PRIOR TO MODIFICATION

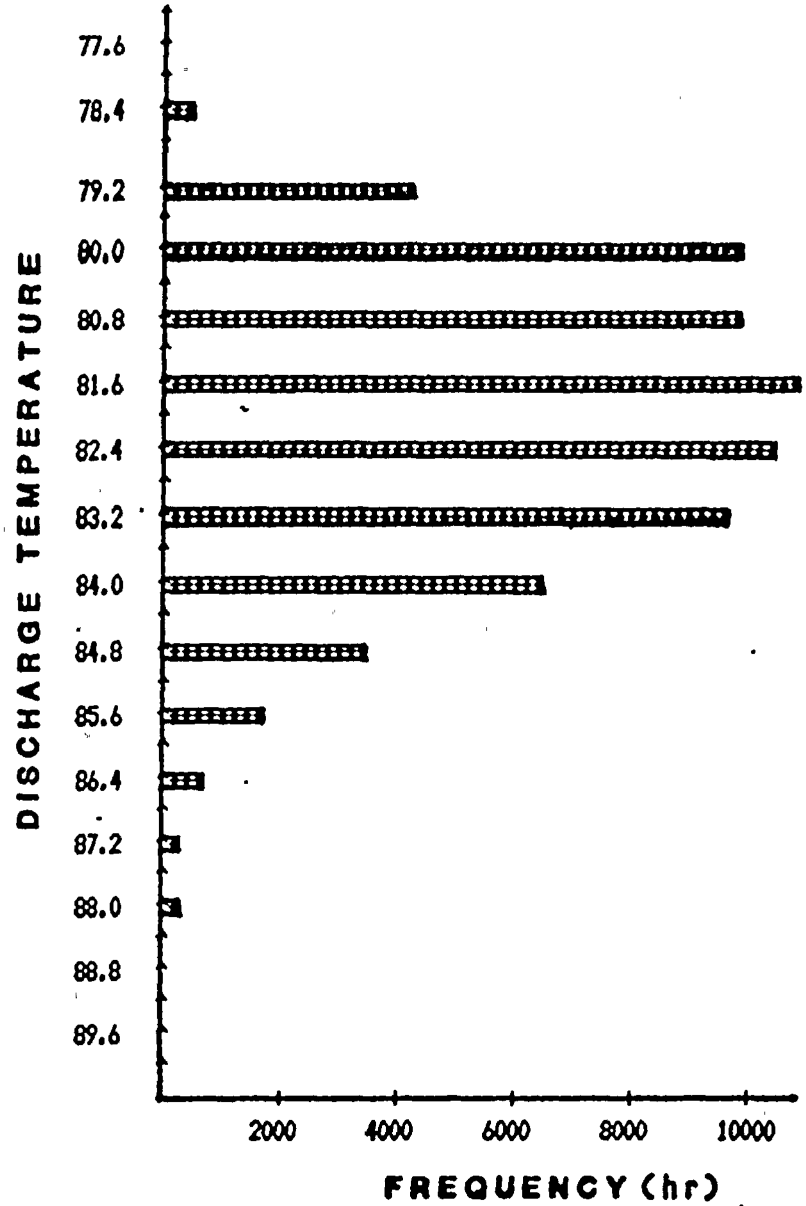
ATTACHMENT 3



NOT TO SCALE

FIGURE 1-6

SCHEMATIC DRAWING OF DCPP DISCHARGE STRUCTURE
SHOWING EFFECT OF CUTOUTS



	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
77.6	0	0	0.00	0.00
78.4	381	381	0.57	0.57
79.2	4153	4534	6.17	6.73
80.0	9806	14340	14.56	21.30
80.8	9754	24094	14.49	35.79
81.6	10811	34905	16.06	51.84
82.4	10443	45348	15.51	67.35
83.2	9671	55019	14.36	81.72
84.0	6306	61325	9.37	91.09
84.8	3385	64710	5.03	96.11
85.6	1587	66297	2.36	98.47
86.4	657	66954	0.98	99.45
87.2	250	67204	0.37	99.82
88.0	115	67319	0.17	99.99
88.8	8	67327	0.01	100.00
89.6	0	67327	0.00	100.00

FREQUENCY OF OCCURRENCE OF COMBINED TWO UNIT DISCHARGE TEMPERATURES
ONE UNIT IN HEAT TREATMENT, ONE UNIT IN NORMAL OPERATION

ATTACHMENT 6

MYTILUS EDULIS – Exposure Required for 95% Mortality

(2.5 hr ramp to target temp, 1 hr ramp down)

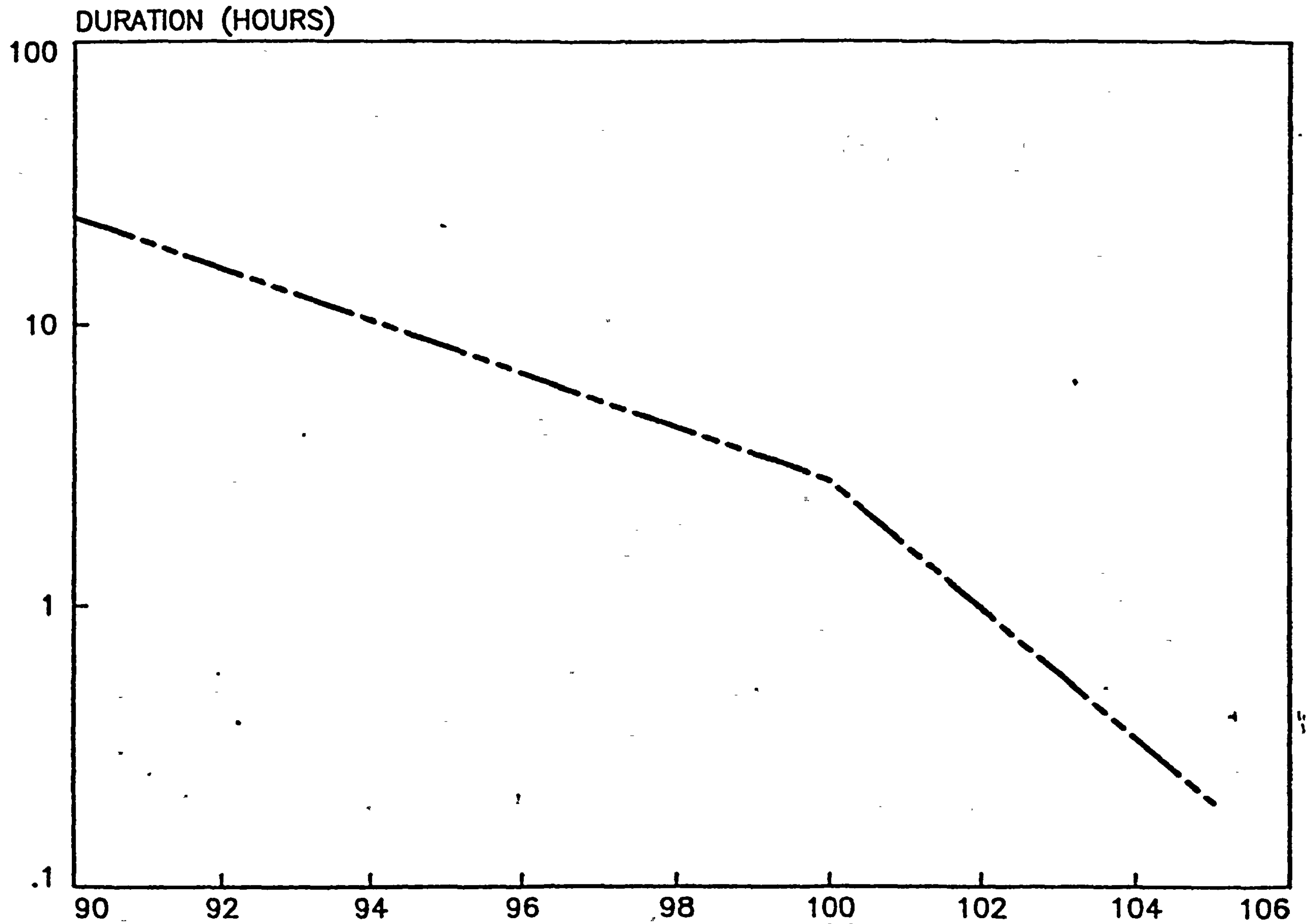
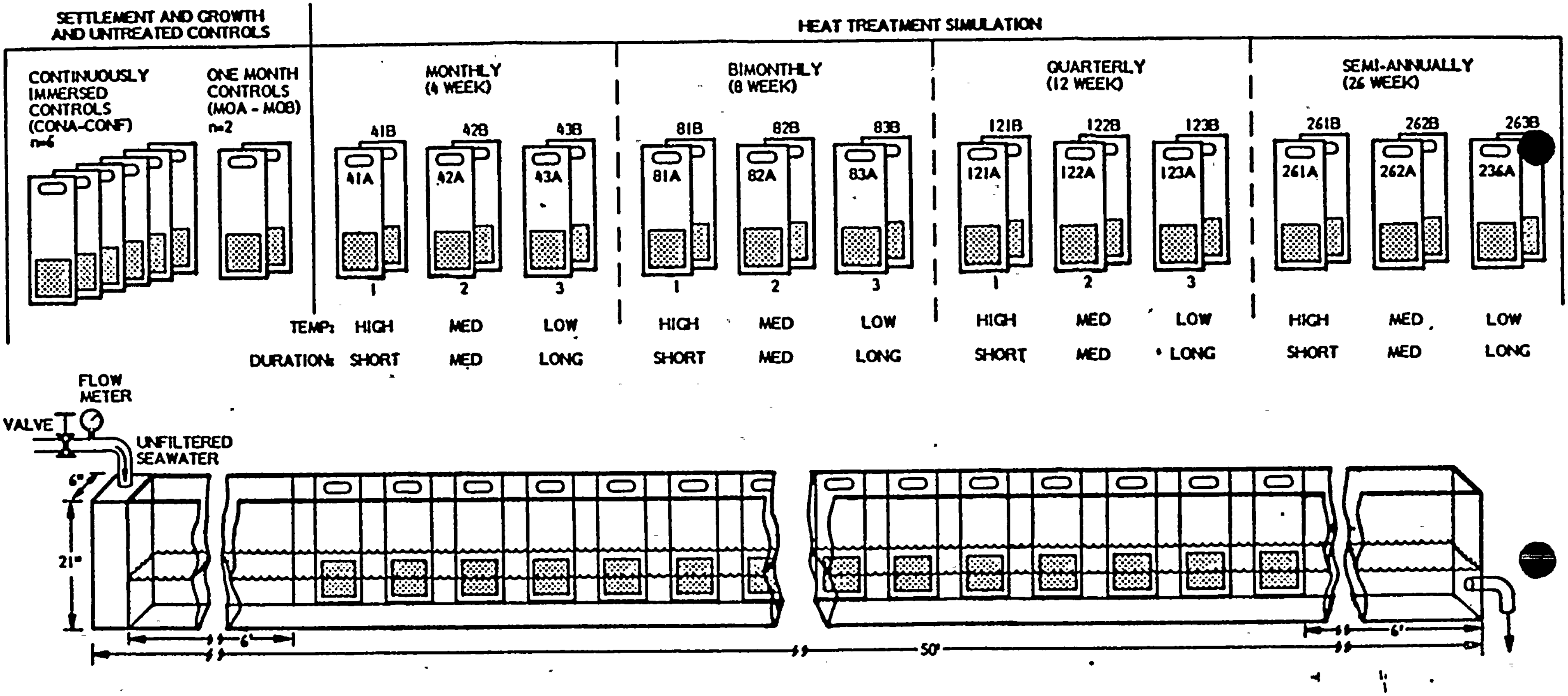


FIGURE 1

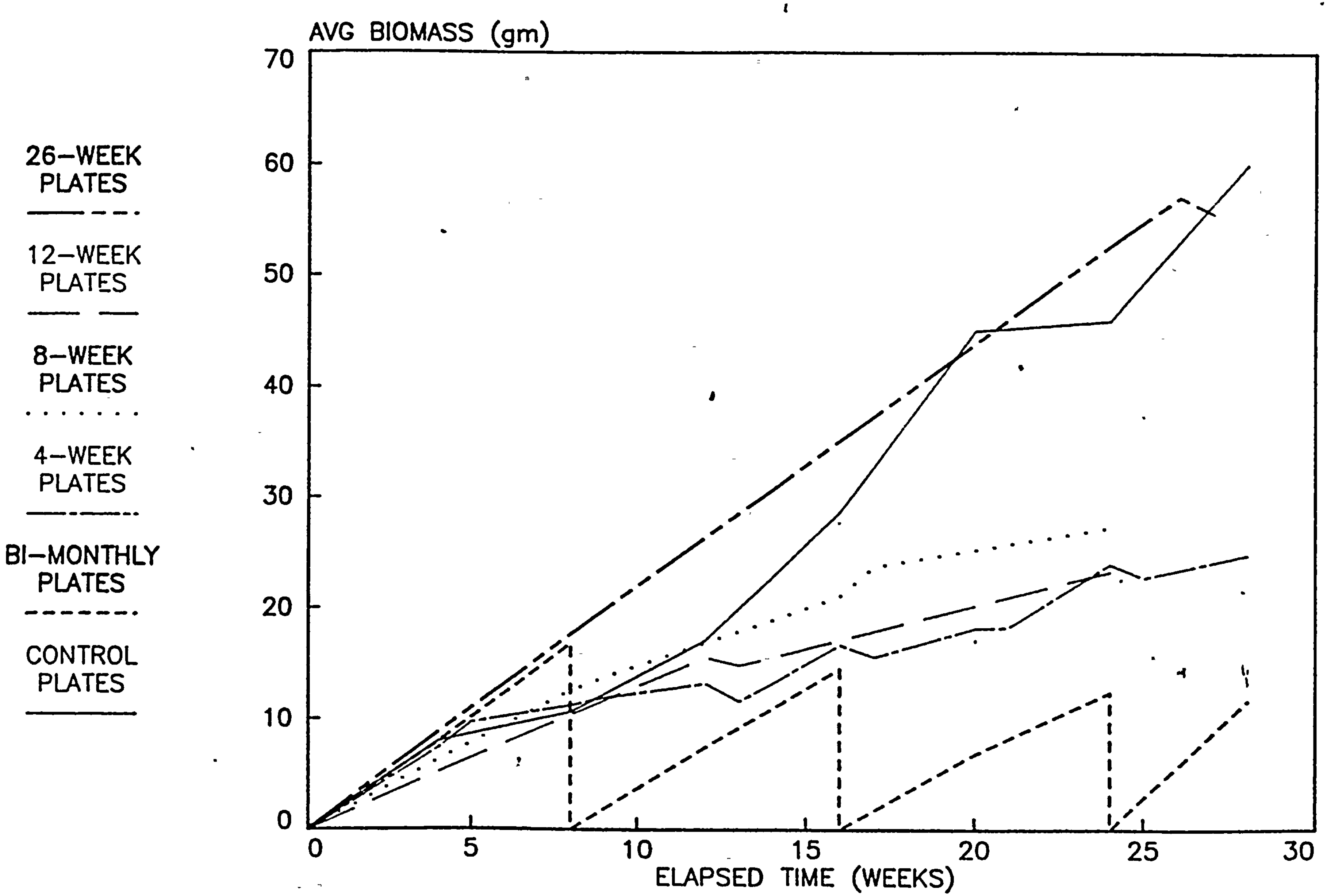
ATTACHMENT 7



DIAGRAMMATIC REPRESENTATION OF PHASE II CONDUIT SIMULATION STUDY

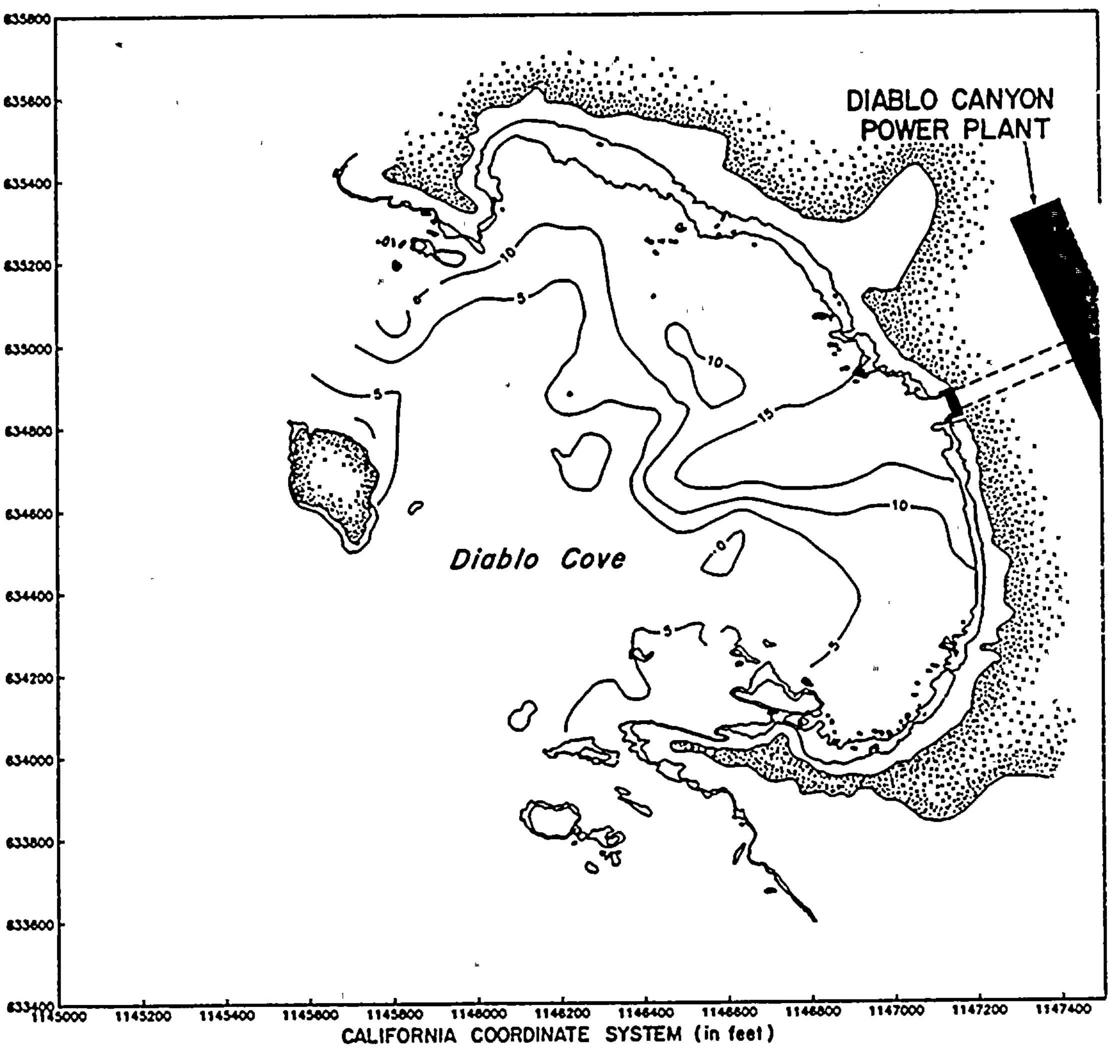
ATTACHMENT 8

DCPP SETTLING PLATES
Average Biomass vs Elapsed Time



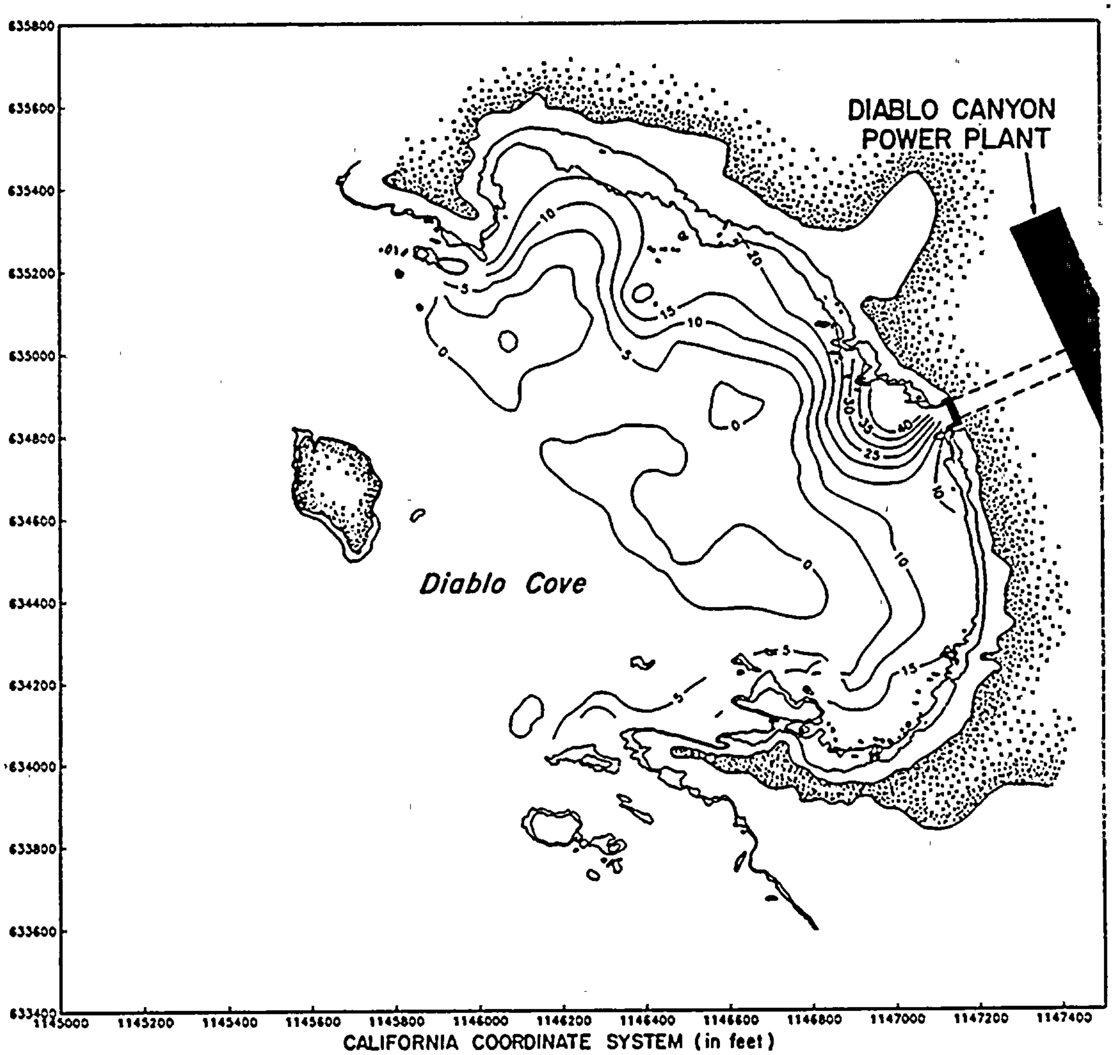
ATTACHMENT 9

ATTACHMENT 10



PACIFIC GAS and ELECTRIC COMPANY DIABLO CANYON POWER PLANT	
THERMAL DISCHARGE PHYSICAL MODEL UNIVERSITY OF CALIFORNIA AT BERKELEY	
DELTA T °F BOTTOM CONTOURS MODEL CONDITIONS: MSL, NO WAVES, DOWNCOAST CURRENT ASSUMED PROTOTYPE AMBIENT TEMPERATURE = 55°F	
UNIT 1 DELTA T = 19°F FLOW = 2000CFS	UNIT 2 DELTA T = 19°F FLOW = 2000CFS
TEST NUMBER: HT0701	

ATTACHMENT II



PACIFIC GAS and ELECTRIC COMPANY DIABLO CANYON POWER PLANT	
THERMAL DISCHARGE PHYSICAL MODEL UNIVERSITY OF CALIFORNIA AT BERKELEY	
DELTA T °F BOTTOM CONTOURS MODEL CONDITIONS: MSL, NO WAVES, DOWNCOAST CURRENT ASSUMED PROTOTYPE AMBIENT TEMPERATURE = 55°F	
UNIT I DELTA T = 42°F FLOW = 500CFS	UNIT II DELTA T = 0°F FLOW = 000CFS
TEST NUMBER: HT0601BOT	

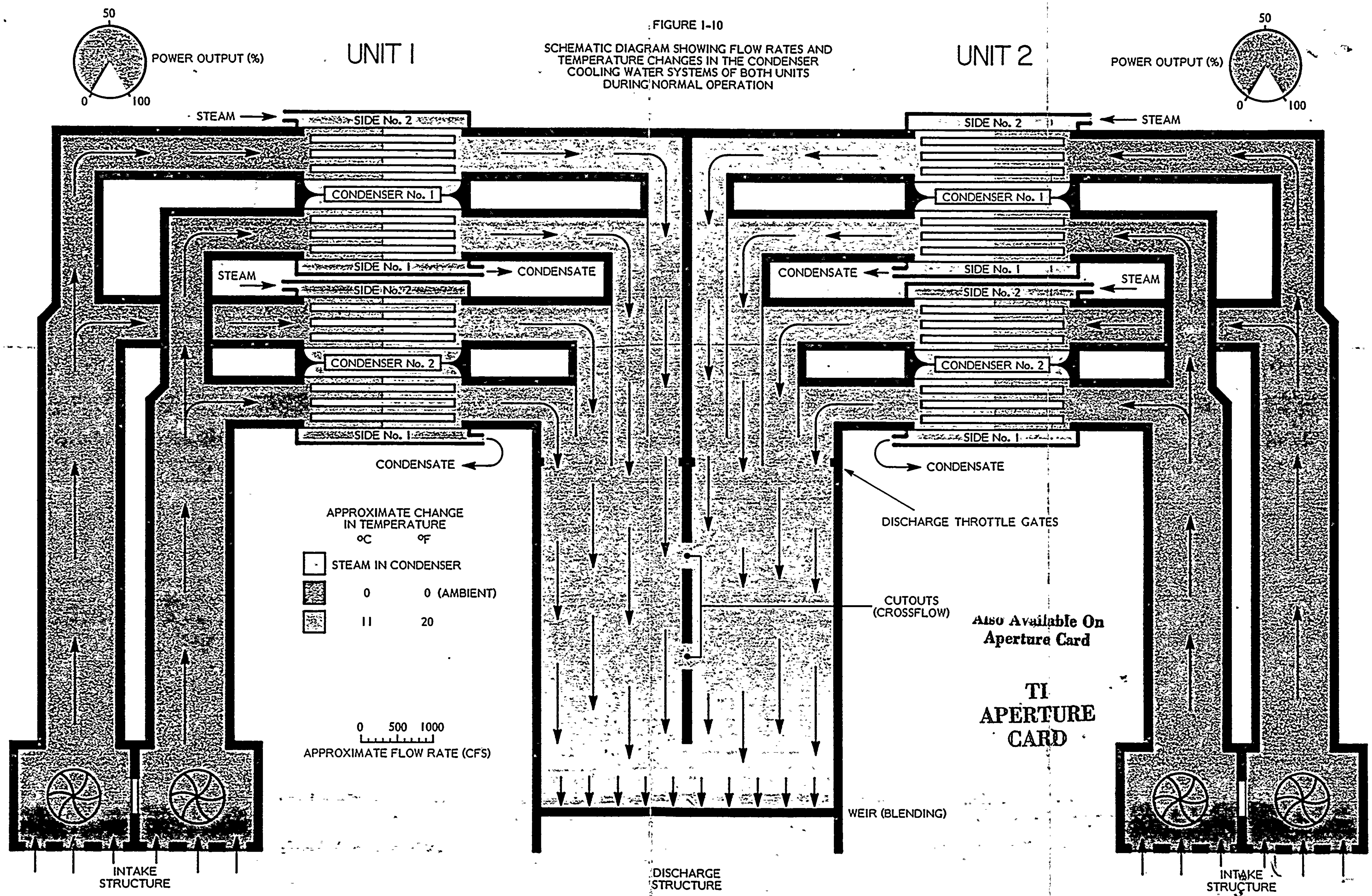
ATTACHMENT 12

Summary of Results of
Heat Treatment Simulation Experiments
on Receiving Water Organisms

Species	Temperature (F)** Highest with No Mortality	Lowest With 100% Mortality
Xiphister mucosus	79	90
Acanthina punctulata	95	--
Cancer antennarius	84	88
Haliotis cracherodii	90	95
Haliotis rufescens	79	90
Hemigrapsus nudus	95	--
Ocenebra circumtexta	90	95
Pachygrapsus crassipes	90	--
Pagurus spp.	90	95
Patiria miniata	86	95
Pisaster ochraceus	82	95
Strongylocentrotus purpuratus	79	84
Tegula brunnea	79	84
Tegula funebralis	95	--
Botryoglossum farlowianum	77	82
Cystoseira osmundacea	77	--
Gastroclonium coulteri (tips)	[90]	--
Gelidium coulteri	95	--
Gigartina canaliculata	90	--
Gigartina papillata	95	--
Iridaea flaccida	90	--
Laminaria dentigera	77	90
Nereocystis luetkeana	68	81
Pelvetia fastigiata	95	--
Pterygophora californica	77	90
Littorina planaxis	95	--
Notoacmaea scutum*	?	95
Collisella scabra	95	--
Collisella digitalis*	95	--
Collisella limatula*	95	--

*Preliminary results (excessive mortality in controls).
**Duration of exposure = 1 hour.

ATTACHMENT 4



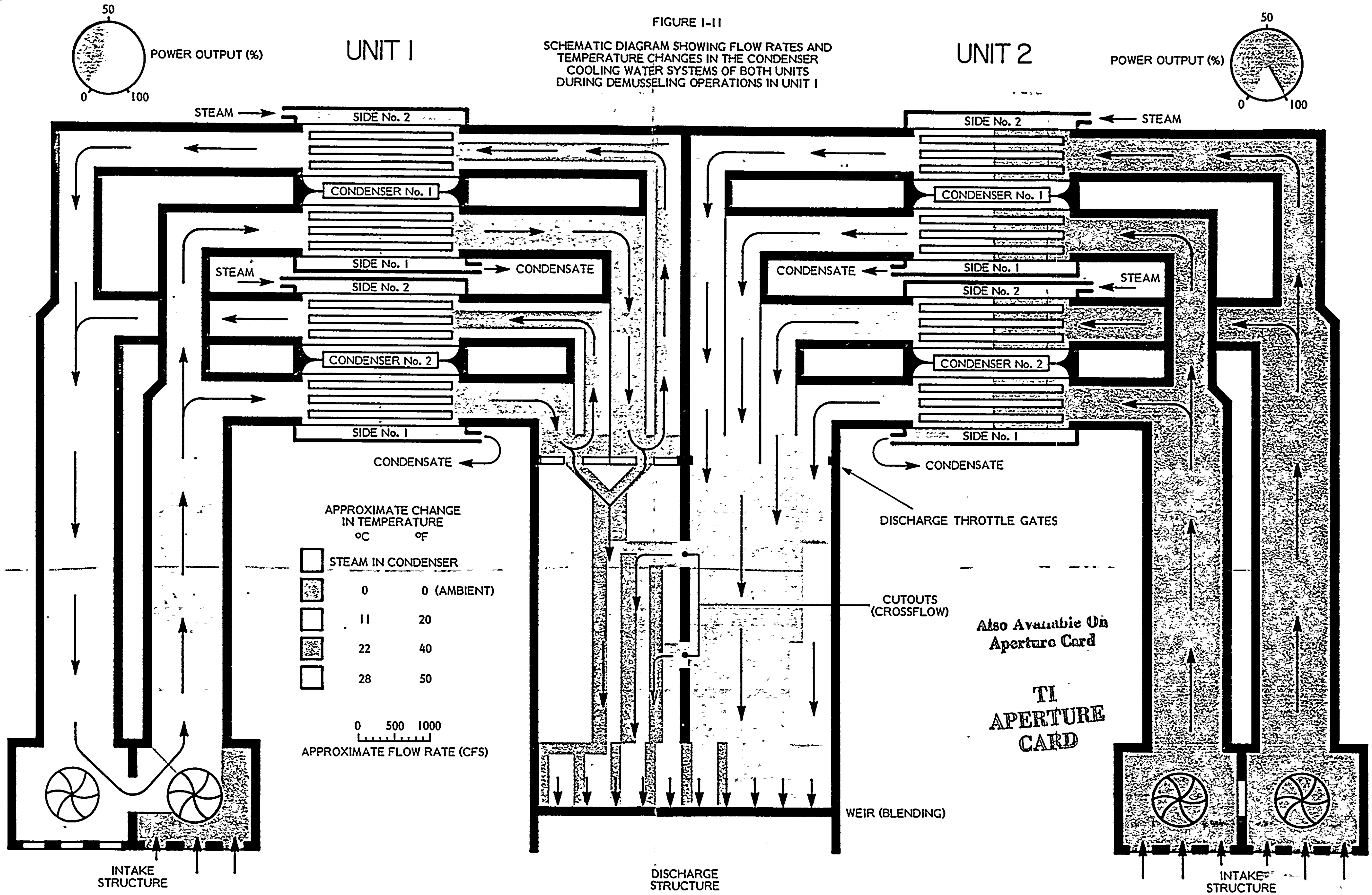
Also Available On Aperture Card

TI APERTURE CARD

8506270111-01

FIGURE I-11

SCHEMATIC DIAGRAM SHOWING FLOW RATES AND TEMPERATURE CHANGES IN THE CONDENSER COOLING WATER SYSTEMS OF BOTH UNITS DURING DEMUSSELING OPERATIONS IN UNIT I



8506270111-02