CONSIDERATION OF OTHER HUDSON RIVER POWER PLANTS

AEC Regulatory Staff

February 12, 1973

Enclosure No. 1

Preliminary Study of the Expected Temperature Distribution in the Hudson River as a Result of Operation of Danskammer, Roseton, Indian Point Units 1 and 2, Lovett, and Bowline Power Stations

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February 8, 1973

Introduction

On December 15, 1972, the Atomic Safety and Licensing Board requested an evaluation of the effect of other power plants, in addition to Indian Point, on the Hudson River. In order to study the effect of heat discharge from power plants in the Hudson River and Estuary, a time dependent three-dimensional model is required. The applicant has presented in the environmental report (Ref. 1, 2) a very simplified steady state one-dimensional model. The staff has presented its reservations about this model (Ref. 3) but agreed that a time dependent three-dimensional model is not available at the present time. The need for using an extensive parametric study to evaluate various possible assumptions has been also emphasized by the staff (Ref. 3). The applicant's thermal model cannot be used for the prediction of such multiplant effects. The staff has performed a preliminary study of that problem by developing a truly time dependent one-dimensional thermal model (cross sectional averaged). The development of this model was started at about the time when the AEC Final Environmental Statement on Indian Point Unit 2 was published and is still in process of completion. The results presented here should be looked at as preliminary. Additional study is required for reaching final conclusions. However, the staff believes that the results presented here are, for the most part, correct so that general conclusions can be derived.

The Model and Results

The model presented here is a one-dimensional truly time dependent model which was developed for predicting the cross sectional average temperatures along the Hudson River. Single as well as multiplant heat discharges may be simulated by the model. The water physical properties, the river geometry and the heat exchange to the atmosphere are considered to be constants along the length of the river. The longitudinal dispersion coefficient can vary along the length so that the apparent increase in mixing capability at the salt intrusion zone can be indirectly taken into account. The river water velocity is taken as truly instantaneous, but constant along the river, i.e.,

$$U(t) = U_F + U_T \sin 2\pi(t/T_d) \ , \qquad (1)$$

where

$U(t)$ = actual instantaneous velocity,

U_F = downstream fresh water velocity,

U_T = maximum tidal velocity,

t = time,

T_d = tidal period.

Equation 1 above assumes a sinusoidal variation of velocity with time which is reasonably correct at Indian Point site but not necessarily so at other locations.

The differential equation on which the model is based is

$$\frac{\partial T}{\partial t} + U(t)\,\frac{\partial T}{\partial X} = \frac{\partial}{\partial X}\left[E_L(X)\,\frac{\partial T}{\partial X}\right] - \frac{\overline{K}T}{\rho C_p H} + \frac{Q}{\rho C_p A \Delta X} \ , \qquad (2)$$

where

T = temperature,

E_L = longitudinal dispersion coefficient,

$\overline{K}$ = surface heat exchange coefficient,

Q = power plant heat discharge,

H = river depth,

X = distance along the river,

the zone of salt intrusion some increase in the effective dispersion coefficient might be needed in order to take into account the density induced flow which cannot be simulated in a one-dimensional model. The applicant is using a value of 12 sq miles/day (about 3850 ft^2/sec) in his steady state one-dimensional model (Ref. 1). The method used by the applicant to derive the dispersion coefficient is based on tidal average salinity data substituted into a steady state concentration equation. The staff does not believe that this is a valid approach since the case cannot be analyzed on steady state basis nor does Reynolds analogy between salt intrusion mechanism and dispersion of polluted discharge, especially heat, hold for the case at hand. The argument behind this opinion is too lengthy to be discussed here. In any case, the specific dispersion coefficient to be used is not exactly known at the present time. Field data taken from time dependent dye discharge studies might be more realistic, although not ideal, for that purpose. Additional studies, both analytical and experimental, are needed for establishing the correct dispersion coefficient to be used. Nevertheless, the staff has decided, for the purpose of getting an approximate analysis of the multiplant effect, to use the longitudinal dispersion coefficients reported by the applicant's consultant in the study made for New York State on the Hudson River (Ref. 4). These values are duplicated here in Fig. 2 for a fresh water flow of 3000 cfs. The staff does not adopt these values as being correct but rather believes that they are too optimistic. Based on Fig. 2 the dispersion coefficient at Indian Point is about 8 sq miles/day. This value is about 2/3 of the value used by the applicant in his environmental report (Refs. 1, 2). It is slightly higher than the value of 7.5 sq miles/day recently reported by Prof. Harleman from MIT (Refs. 5, 6). All those values are considered by the staff to be too optimistic for a real time model like the one presented here.

The set of conditions presently investigated is the one considered by the applicant in Table 6 of Ref. 2 as "Drought-Fall Conditions" which imply a fresh water flow of 4000 cfs and a surface heat exchange coefficient of 90 Btu/ft^2·°F·day. The value of the longitudinal dispersion coefficient, however, was changed as indicated before. Figures 3-9 show the results of the present analysis in four different combinations of power plants operations: (1) no power plant in operation, (2) only Indian Point Units 1 and 2 are in operation, (3) five power plants (Danskammer, Roseton, Indian Point 1 and 2, Lovett, and Bowline) are in operation, (4) same as case 3 but without Indian Point Units 1 and 2.

This kind of presentation allows one to see the effect of Indian Point alone or its incremental effect as well as its combined effect when the other four power plants are in operation. Figure 3 shows the cross sectional average temperature as a function of time at Indian Point site for each of the four cases.

The table below summarizes the tidal maximum, average, and minimum temperatures which occur at Indian Point site under the various combinations of plants operation.

		At Indian Point Site			Other Max. Temp.	
Case		Max. Temp, °F	Avg. Temp, °F	Min. Temp, °F	Max. Temp, °F	Location
1	No. power plants	79.59	79.00	79.36	79.95	Troy
2	I.P. 1 and 2 only	82.39	82.26	82.10	82.39	I.P.
3	Danskammer, Roseton, I.P. 1 & 2, Lovett, and Bowline	85.73	85.40	85.05	85.73	I.P.
4	Danskammer, Roseton, Lovett, and Bowline	82.67	82.53	82.38	83.30	Roseton
5	Incremental effect of I.P. 1 & 2 based on no power plant	2.80	2.76	2.74	---	--
6	Incremental effect of I.P. 1 & 2 based on all five power plants	3.06	2.87	2.43	---	--

The preceding table also shows that the maximum temperature occurs at the Indian Point site except in the case when Indian Point Units 1 and 2 are not in operation (Case 4). In this case the maximum temperature occurs at Roseton Power Plant site. Figures 4, 5, and 6 show the instantaneous temperatures as functions of distance from Troy at three different quarterly tidal periods for Indian Point only (Fig. 4), for four power plants (Fig. 5), and for five power plants (Fig. 6) with the case of no power plants given as a background. The movements of the peak temperature with the tide can be seen clearly in the figures with the distance of movement being equal to the tidal excursion length. The effect of ocean intrusion into the estuary can also be seen clearly in those three figures.

Figures 7, 8, and 9 show the tidal maximum, average, and minimum temperatures along the river for Indian Point only, four power plants, and five power plants, respectively. This is not a truly existing situation but rather the tidal maximum, average, and minimum temperatures which occurred at any point during the entire time range of the case and after reaching quasi steady state equilibrium.

It is interesting to indicate at that point that the time required to reach thermal quasi steady state equilibrium (that is, all tidal periods having similar behavior) is relatively long. It changes with various assumptions of longitudinal dispersion coefficient or initial conditions but its order of magnitude is between 80 and 100 tidal periods. This means that to have any meaningful temperature measurements one must wait some 6-12 weeks after startup operation begins.

Since some possibility exist that the correct dispersion coefficient might be as low as 0.2 sq miles/day the staff has run two additional cases using the above value in order to get an idea of the possible upper bound to the maximum predicted cross sectional excess temperature. The maximum excess temperature at Indian Point site was 7.5°F for only Indian Point Units 1 and 2 in operation and 11.57°F when all five power plants are in operation. Those values should certainly be considered as upper limits to vary pessimistic conditions.

Conclusions

Although the above study is considered preliminary, the following conclusions can be derived.

1. Both tidal average temperatures and tidal maximum temperatures as well as the ratio between them are strong functions of the longitudinal dispersion coefficient.

2. The staff believes that the correct values to be used for the longitudinal dispersion coefficients are not yet established and that the values reported by the applicant are biased to the high side.

3. For the purpose of approximate analysis the staff has used the longitudinal dispersion coefficients reported by the applicant's consultant in Ref. 4. It must be emphasized again that those values for dispersion coefficient are considered by the staff to be too high and therefore the maximum temperatures can be even higher than predicted here.

4. The staff preliminary estimate of the expected tidal maximum excess temperature averaged over the cross sectional area at Indian Point site is about 2.80°F when only Indian Point Units 1 and 2 are in operation and about 6.14°F when Danskammer, Roseton, Indian Point Units 1 and 2, Lovett, and Bowline Power Plants are in operation. It can be seen that

the effect of the other two power plants is considerable. The corresponding tidal average excess temperatures are 2.76°F and 5.90°F. By comparison the value reported by the applicant for the tidal average excess temperature for Indian Point Units 1 and 2 only is about 1.65°F (Ref. 2).

5. The above results are for cross sectional average temperature. In the opinion of the staff, the analytical prediction of the extent of the 4°F excess temperature isotherms is not possible with the presently available models. A parametric study, as proposed by the staff in the Final Environmental Statement (Ref. 3), is still possible and necessary. Such a parametric study with the present results can only strengthen the staff conclusions already stated in the FES.

6. Considering the fact that the cross sectional average temperature at Indian Point site when all five power plants are in operation can be about 6.14°F, the staff is also concerned that recirculation of heated water into the intake may be much higher than considered before. Such recirculation can effect directly the near field temperature distribution including the maximum surface temperature that can occur at the center of the surfacing submerged jet. The staff believes that the 90°F maximum surface temperature cirteria might still be met but the confidence in this prediction is reduced considerably when the effect of the other power plants are also taken into account. Additional studies are needed on this point.

7. The staff is concerned that the temperature distribution at Indian Point site will be well above the values reported by the applicant even for the operation of Indian Point Units 1 and 2 only. This is certainly true when the effect of the other power plants is also taken into account.

In the Final Environmental Statement (Ref. 3) the staff has expressed its concern that the New York State thermal criteria for the 4°F excess temperature on the river surface will be violated. This is definitely true when the results of the present study are considered.

References

1. Quirk, Lawler and Matusky Engineers, "Effect of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution," Appendix K in Consolidated Edison Corporation's Environmental Report on Indian Point Unit 2.

2. Testimony of John P. Lawler, PhD, Quirk, Lawler and Matusky Engineers, "On the Effect of Indian Point Units 1 and 2 Cooling Water Discharge on the Hudson River Temperature Distribution," April 5, 1972.

3. AEC Final Environmental Statement on Indian Point Units 1 and 2, September 1972.

4. Quirk, Lawler, and Matusky Engineers, "Hudson River Water Quality and Waste Assimilative Capacity Study," report to State of New York Department of Environmental Conservation, December, 1970.

5. T. M. Llewellyn, D. R. F. Harleman, "A Mathematical Model for the Prediction of Unsteady Salinity Intrusion," Report No. 144, Ralph M. Parsons Laboratory of Water Resources and Hydrodynamics, MIT, February 1972.

6. J. E. Dailey, D. R. F. Harleman, "Numerical Model for the Prediction of Transient Water Quality in Estuary Networks," Report No. 158, Ralph M. Parsons Laboratory of Water Resources and Hydrodynamics, MIT, October 1972.

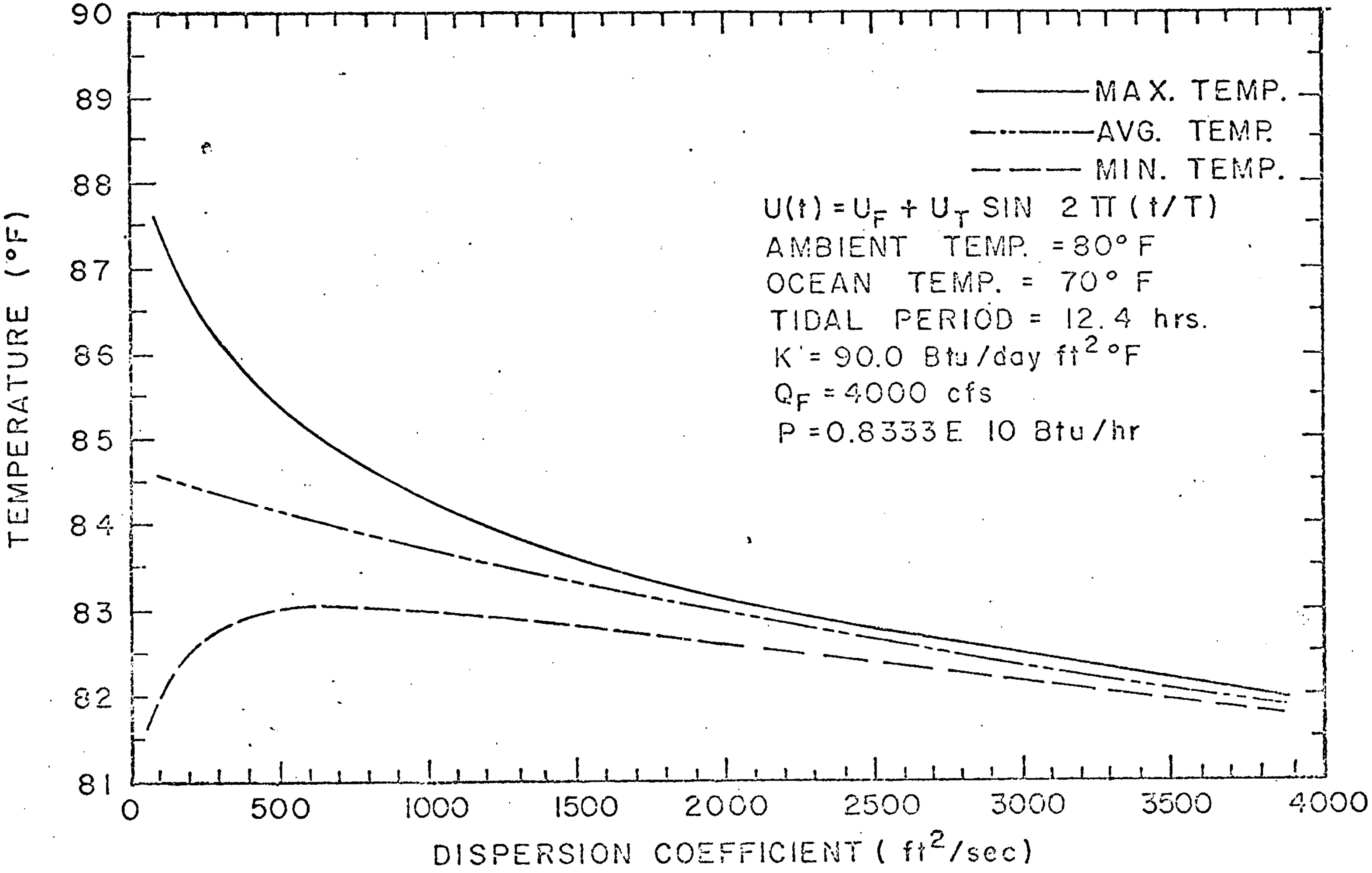


Fig. 1 Tidal Maximum, Average and Minimum Temperatures as a Function of Longitudinal Dispersion Coefficient for Indian Point, Units 1 & 2 Only.

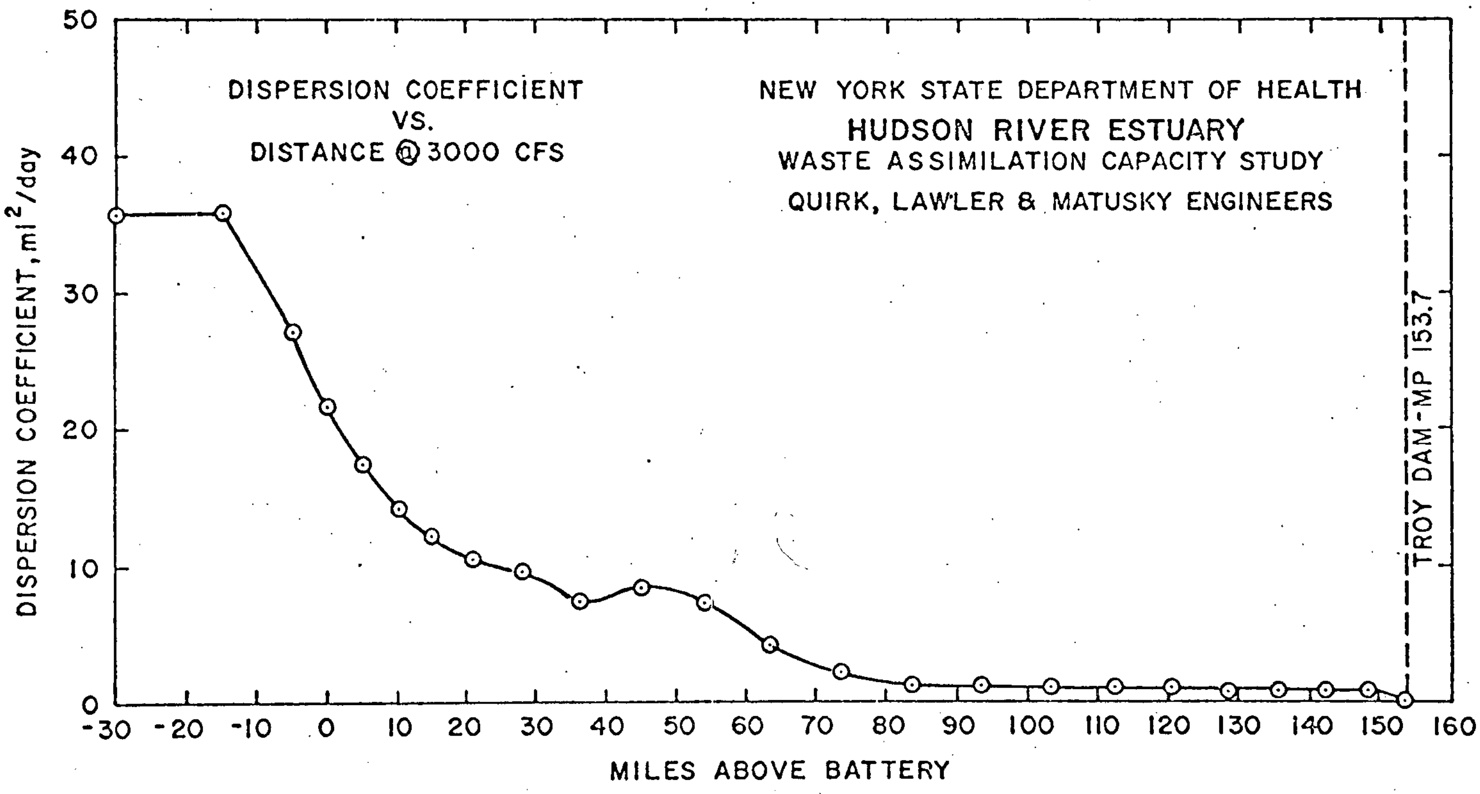


Fig. 2. Effective Despersion Coefficient as a Function of Distance in the Hudson River (Ref. 4)

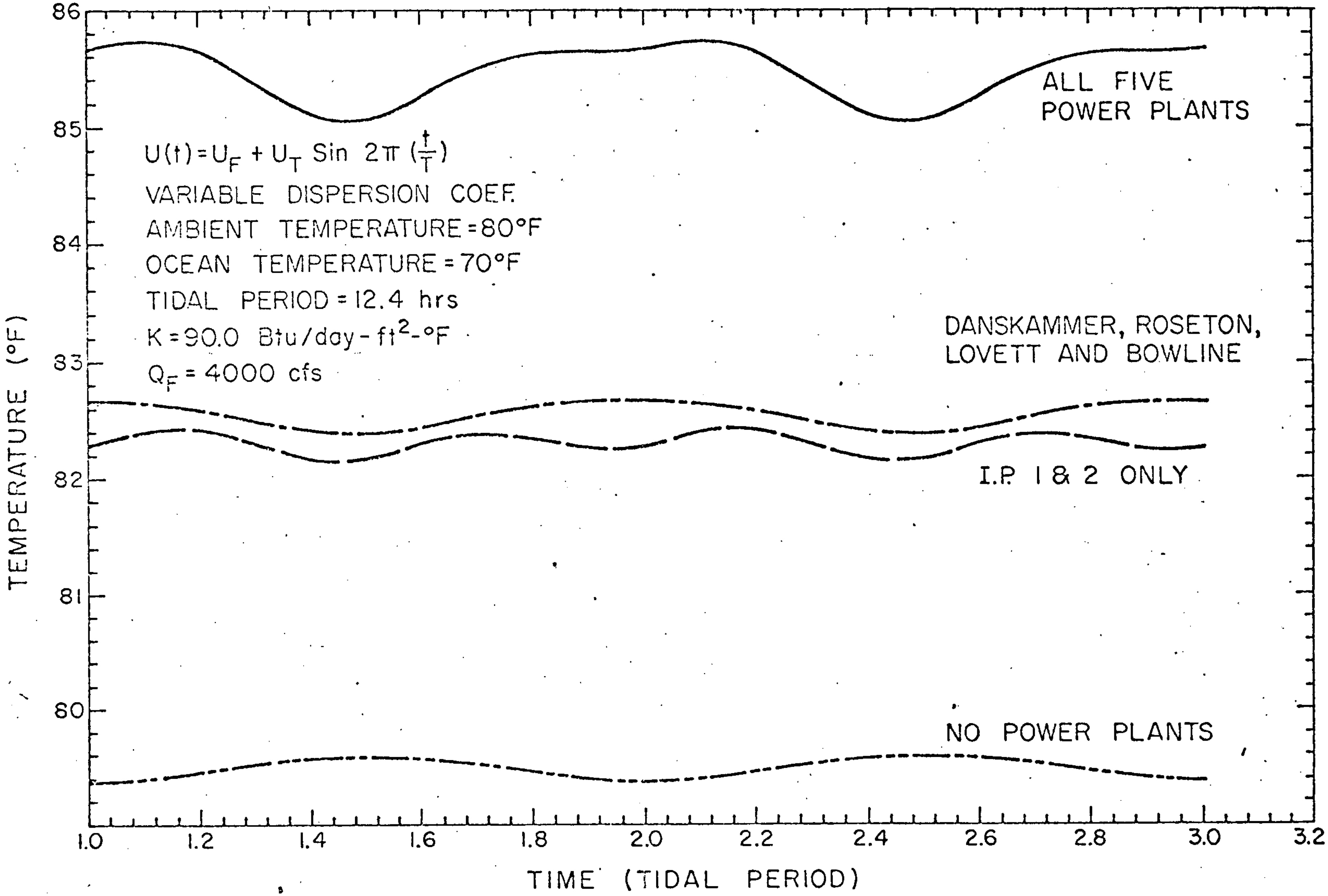


Fig. 3 TEMPERATURE AT INDIAN POINT SITE AS A FUNCTION OF TIME DURING TWO TIDAL CYCLES FOR FOUR COMBINATIONS OF POWER PLANTS OPERATION.

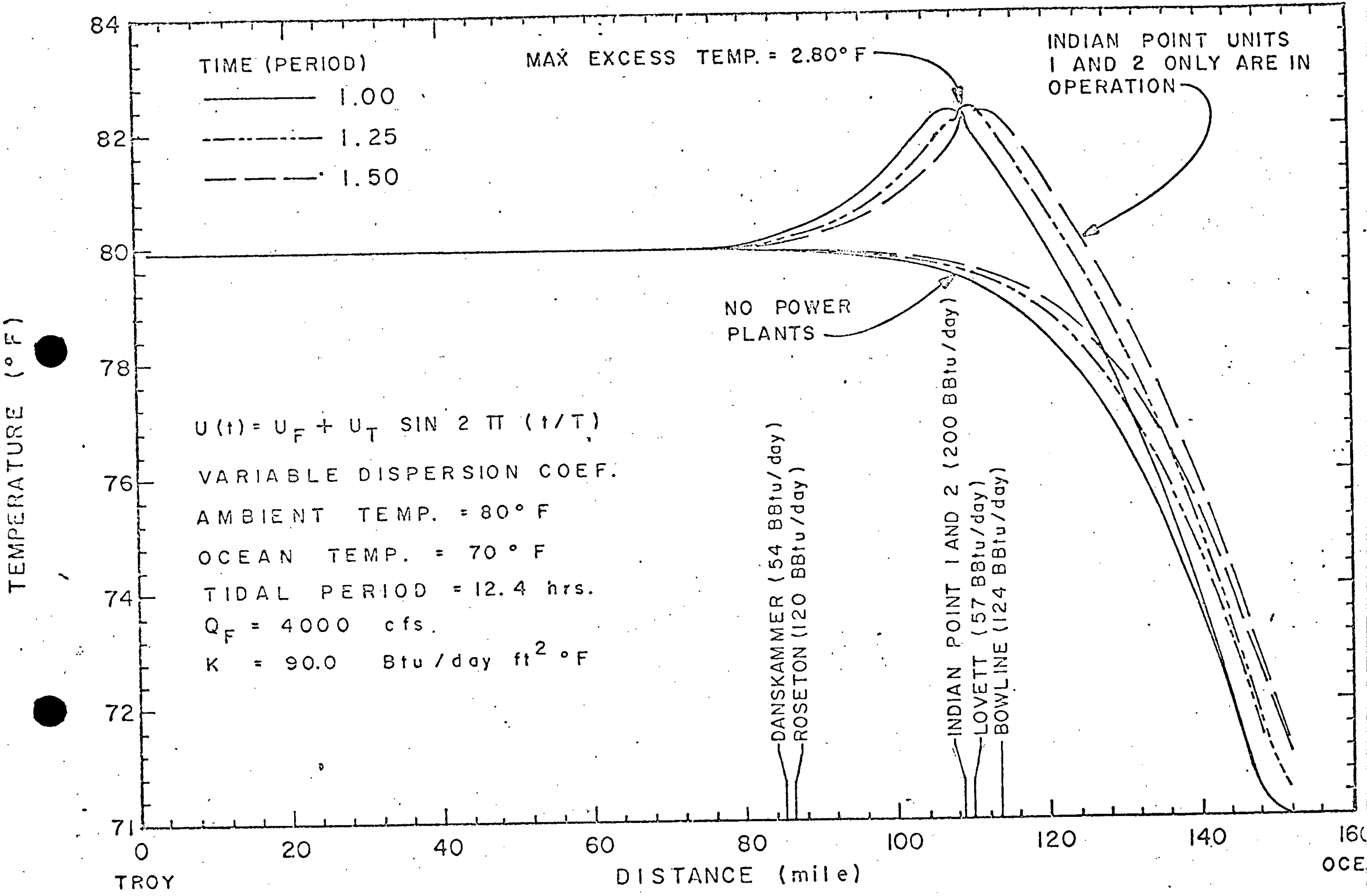


Fig. 4 ACTUAL TEMPERATURE AS A FUNCTION OF DISTANCE FROM TROY, N.Y. AT THREE TID
TIMES WHEN ONLY INDIAN POINT UNITS I AND 2 ARE IN OPERATION.

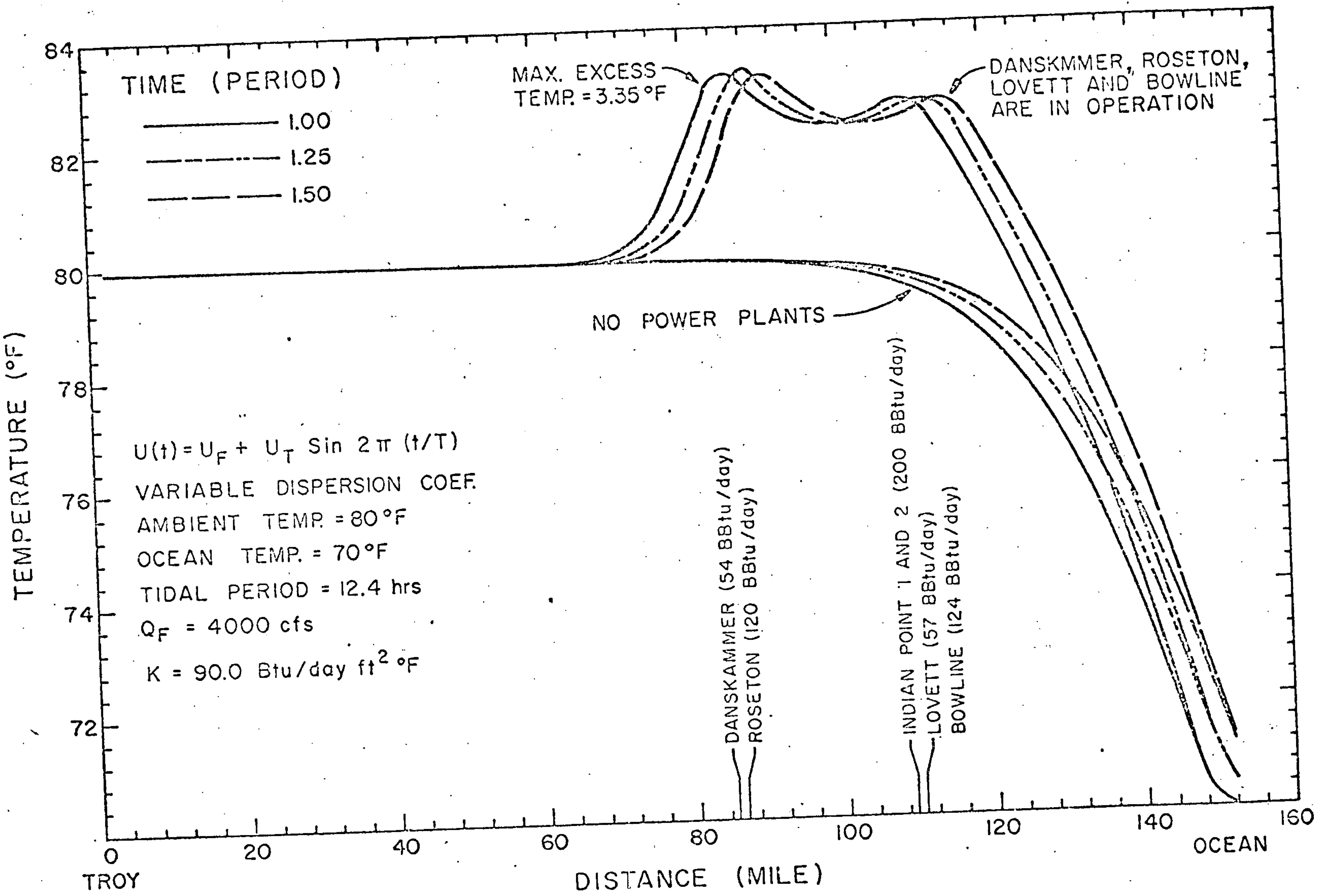


Fig. 5 ACTUAL TEMPERATURE AS A FUNCTION OF DISTANCE FROM TROY N.Y. AT THREE TIDAL TIMES, WHEN DANSKAMMER, ROSETON, LOVETT AND BOWLINE POWER PLANTS ARE IN FULL OPERATION.

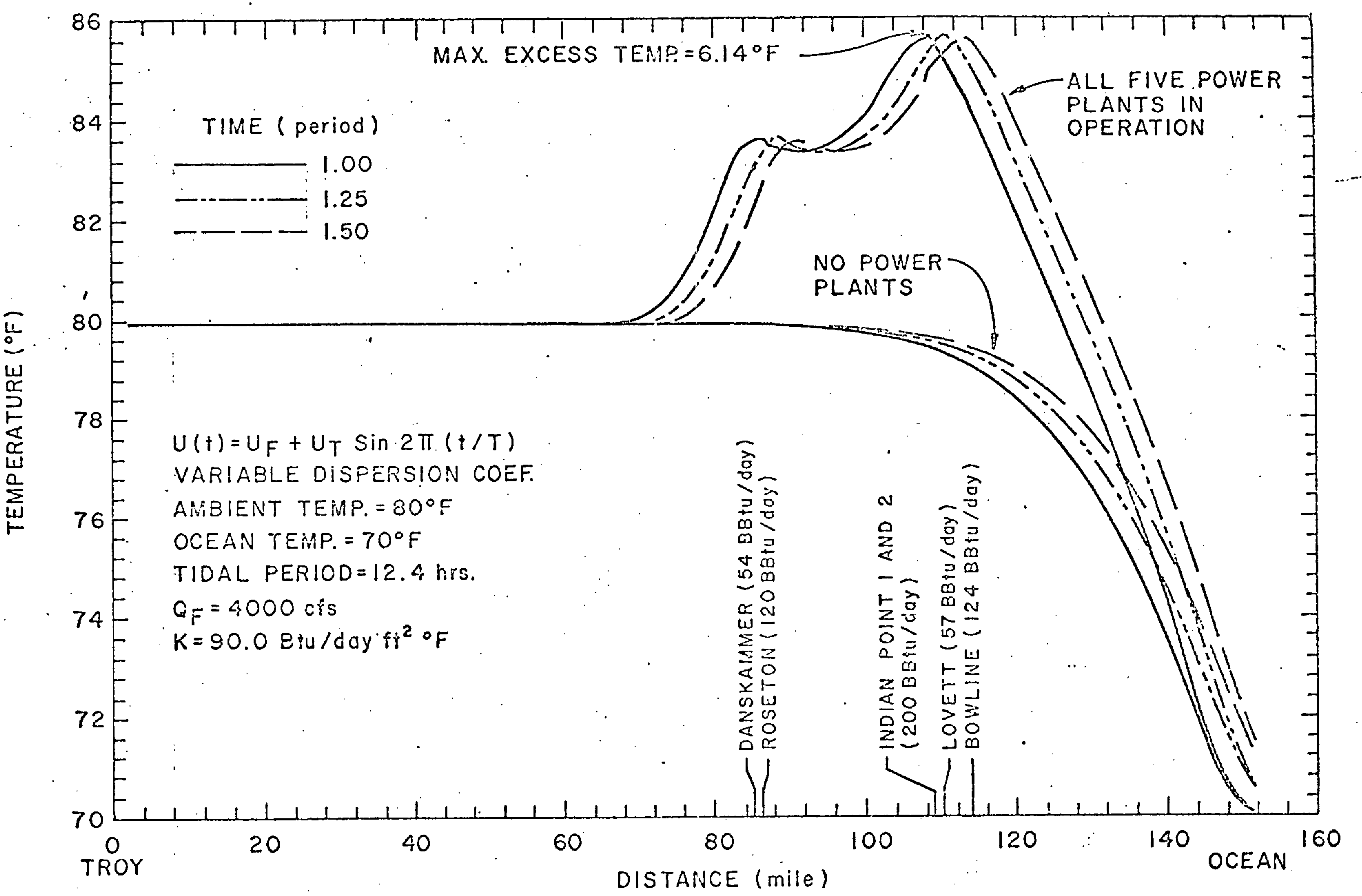
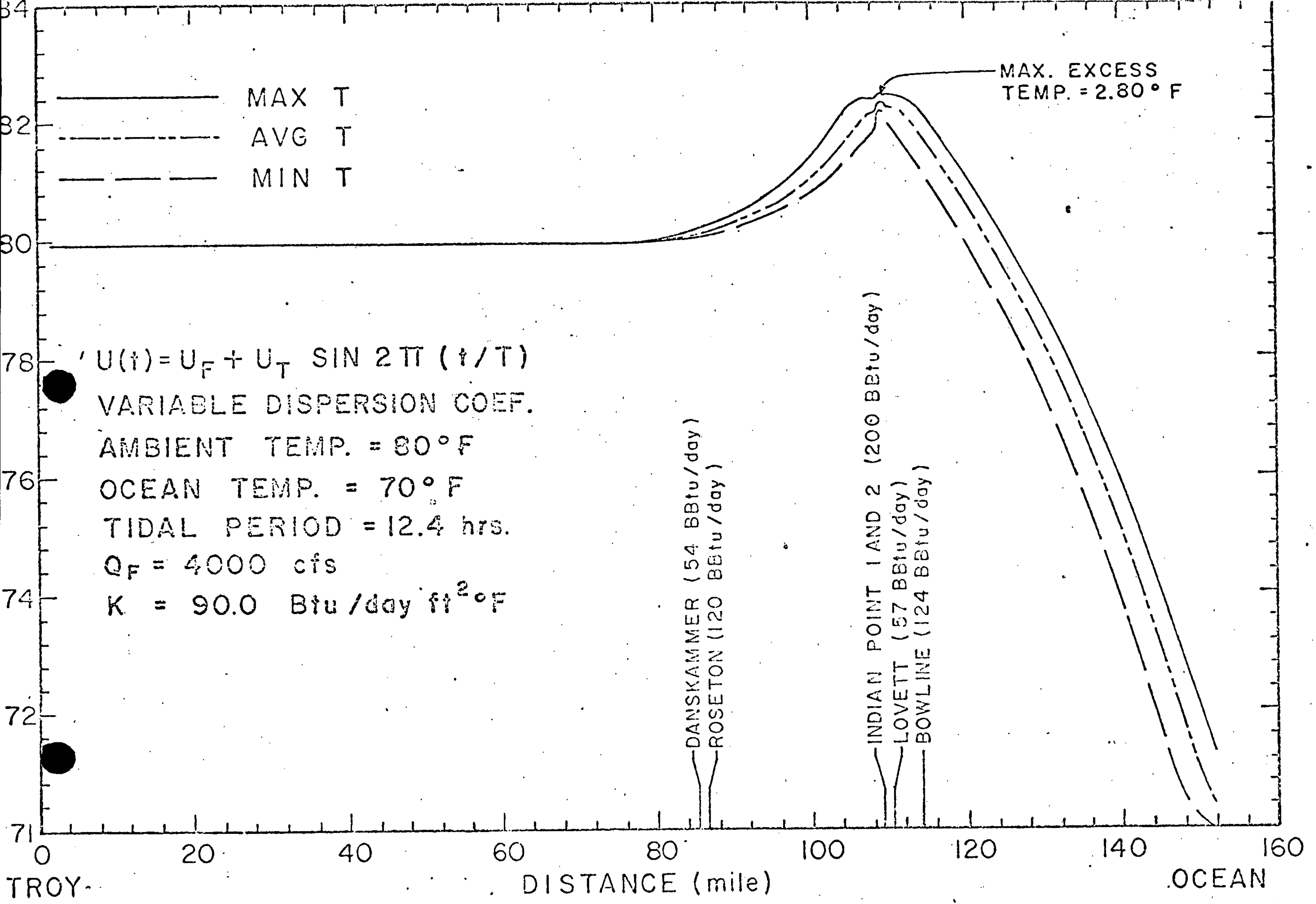


Fig. 6, ACTUAL TEMPERATURE AS A FUNCTION OF DISTANCE FROM TROY, N.Y. AT THREE TIDAL TIMES WHEN ALL FIVE POWER PLANTS ARE IN FULL OPERATION.



ig. 7. TIDAL MAXIMUM, AVERAGE AND MINIMUM TEMPERATURES AS FUNCTION OF DISTANCE FROM TROY, N.Y. WHEN ONLY INDIAN POINT NITS 1 AND 2 ARE IN FULL OPERATION.

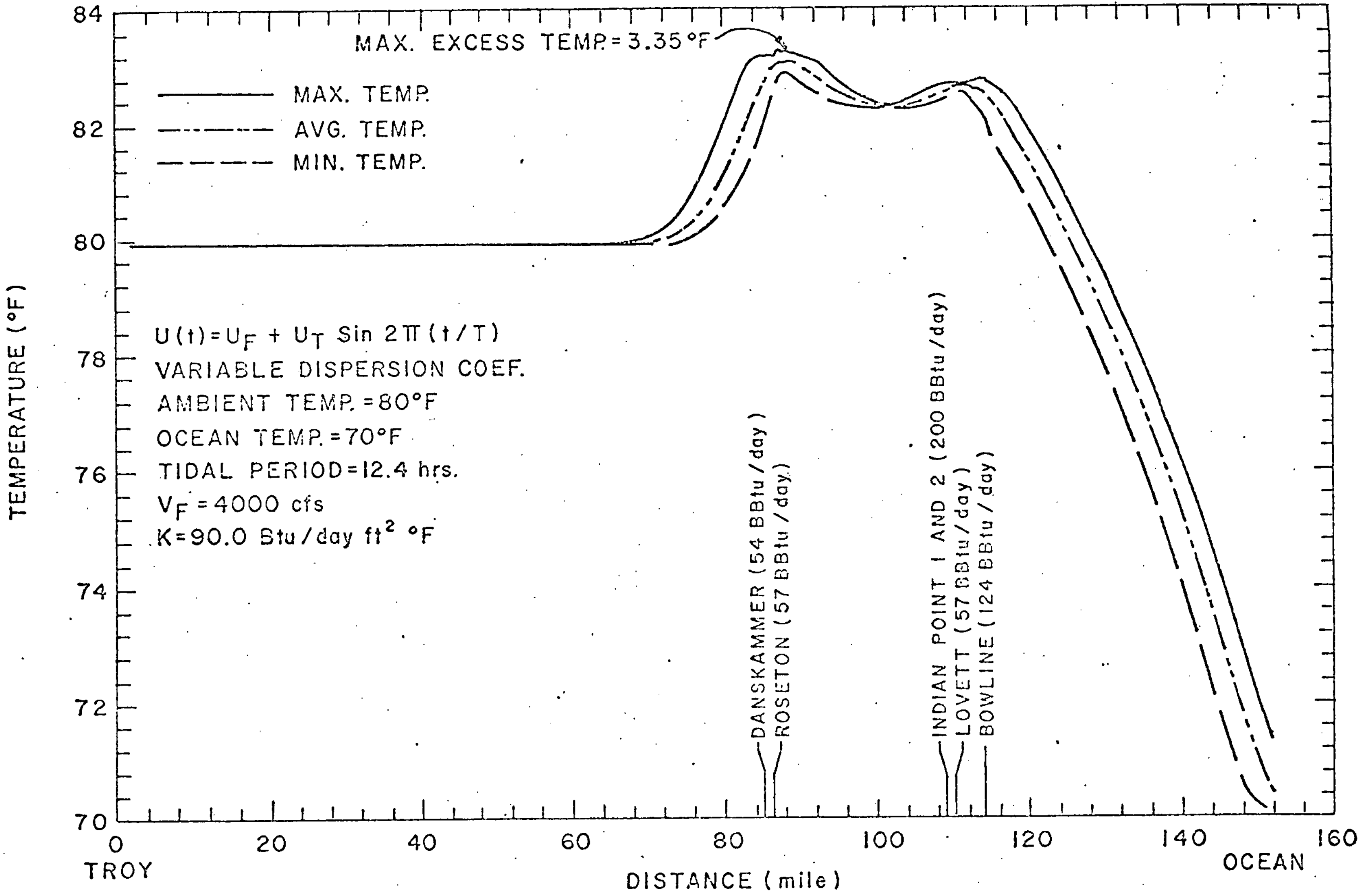


Fig. 8, TIDAL MAXIMUM, AVERAGE AND MINIMUM TEMPERATURE AS A FUNCTION OF DISTANCE FROM TROY, N.Y. WHEN DANSKAMMER, ROSETON, LOVETT AND BOWLINE POWER PLANTS ARE IN FULL OPERATION.

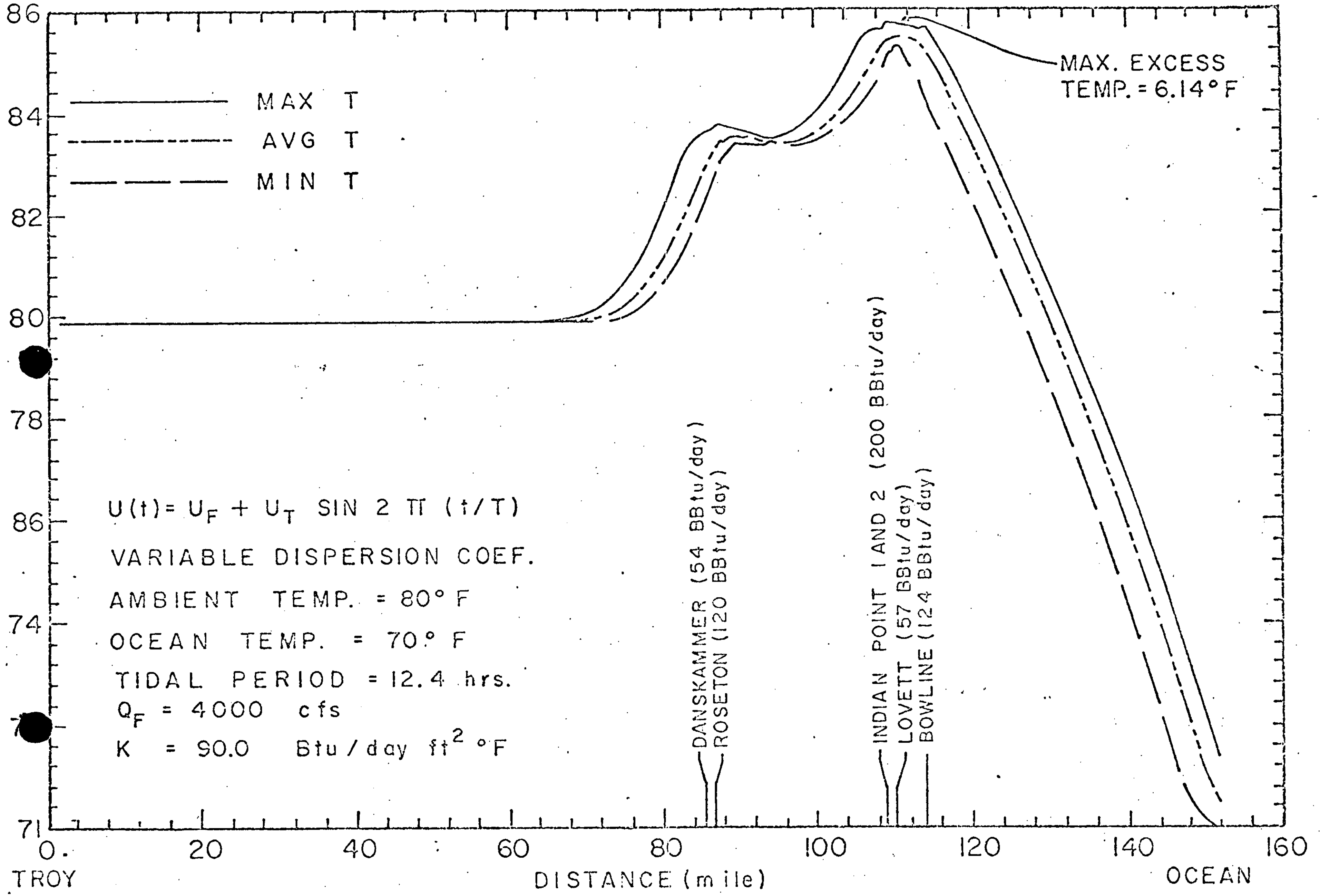


Fig. 9 TIDAL MAXIMUM, AVERAGE AND MINIMUM TEMPERATURE AS A FUNCTION OF DISTANCE FROM TROY, N.Y. WHEN ALL FIVE POWER PLANTS ARE IN FULL OPERATION.

Enclosure No. 2

II. Probable Reduction in Survival of Young of the Year Striped Bass in the Hudson River as a Consequence of the Operation of Danskammer, Roseton, Indian Point Units 1 and 2, Lovett, and Bowline Steam Electrical Generating Stations.

C. P. Goodyear

February 8, 1973

INTRODUCTION

On December 15, 1972, the Atomic Safety and Licensing Board requested the staff to prepare data to reflect calculations of the combined effects of power plants on the Hudson River. The staff believes that the most serious consequence of plant operations will be caused by the mortality of young fishes withdrawn with the water used for cooling the condensers of the various plants. The staff has performed a preliminary study of one phase of that problem, i.e., the effect on striped bass young of the year.

Because the distribution of young striped bass in the estuary is related to the fresh water flows, the staff examined the potential effects of multiple plant operations for various flow situations. This was accomplished by utilizing flow data collected during different past years as an input to the model. Thus, the estimated reduction of striped bass young of the year presented in Table 1 illustrates comparatively the importance of the various facilities and combinations of facilities over a range of flow conditions. Data from 1964 represent a low flow situation, 1968 data represent a high flow situation, and 1969-70 data are similar to the mean flows over the period from 1949-1966.

Although the results presented here are preliminary, the staff, however, feels that they are generally correct, particularly when used to infer the relative importance of the different power plants. Additional evaluation is needed to insure accuracy and to increase precision in the estimates.

The Model

The model employed in this study is basically similar to the one presented by the staff in Appendix V-3 of the Final Environmental Statement for Indian Point Unit No. 2. However, the present model is more sophisticated in many respects and has been found to closely predict the distribution of striped bass in the Hudson. A detailed description of the model is currently being prepared but will be omitted here in the interest of a timely presentation of the initial results. However, the general features are outlined below.

The spawning distribution was considered to be the same as that estimated by the HRFI investigation but was dependent on temperature. Fish were considered to be entrainable for approximately 64 days. Mortality upon condenser passage was considered to be 100%. Natural mortality was a function of age but not a function of density. The concentration of entrainable individuals in the intake water of each power plant was considered to be the same as the mean concentration of the adjacent cross section. Migratory responses were considered to be a function of convective water flows and the vertical movements of the fish as modified by the product of the S/A ratio* with a coefficient for habitat preference.

The model utilized 18 river compartments as described in Table 2. Freshwater flow as estimated by the USGS for Poughkeepsie for various years was used to determine the position of the salt front in the estuary and to establish the advective transport between compartments. The operating characteristics and locations of the power plants that were considered in this study are presented in Table 3.

$$\text{*S/A ratio} = \frac{\text{shoal area of compartment}}{\text{total surface area of compartment}}$$

TABLE 1. ESTIMATED REDUCTION IN STRIPED BASS YOUNG OF THE YEAR*

	Percentage Reduction According to Flow Year Simulated						
	1949	1955	1964	1967	1968	1969	1970
CONDITION							
No plants (base)	0	0	0	0	0	0	0
Roseton, Danskammer IP 1&2, Lovett, Bowline	55.4	64.0	54.4	48.7	38.2	63.8	61.4
Roseton, Danskammer, Lovett, Bowline	37.1	40.9	40.4	33.3	29.2	41.5	40.5
IP 1&2	32.9	42.8	25.6	26.8	14.4	41.7	39.9
Roseton, Danskammer	15.1	12.2	23.7	16.9	5.3	9.4	12.8
Danskammer	5.9	4.5	10.5	6.7	1.8	3.4	4.8
Lovett	12.4	16.0	9.5	9.7	4.5	15.6	15.1
Bowline	13.9	18.4	10.6	9.7	21.9	22.6	18.5

*Assuming flow conditions similar to the year specified

Table 2. SEGMENT PARAMETERS OF THE STAFF'S HUDSON RIVER STRIPED BASS TRANSPORT MODEL

Segment	Upper* Bound	Lower* Bound	Midpoint*	Length (mi)	Width (ft x 10^{3})	Cross Section (ft^{2} x 10^{4})	Shoal Area (ft^{2} x 10^{6})	S/A**	Volume (ft^{3} x 10^{9})	RIVFAC (10^{3} ft^{3}/sec)
1	135.0	125.0	130.0	10.0	2.0	29.6	4.75	0.44	1.56	0.[illegible]
2	125.0	115.0	120.0	10.0	3.5	38.6	3.86	0.75	2.04	0.0
3	115.0	105.0	110.0	10.0	4.0	68.6	2.54	0.59	3.62	0.0
4	105.0	95.0	100.0	10.0	4.0	82.3	9.32	0.44	4.34	0.0
5	95.0	85.0	90.0	10.0	4.5	116.0	7.86	0.33	6.12	0.0
6	85.0	77.5	81.25	7.5	3.0	119.0	1.64	0.14	4.71	0.0
7	77.5	70.0	73.5	7.5	2.5	124.0	1.12	0.11	4.91	0.0
8	70.0	62.5	66.25	7.5	3.5	154.0	4.72	0.34	6.10	0.0
9	62.5	55.0	58.75	7.5	6.2	160.0	3.97	0.16	6.34	3.0
10	55.0	50.0	52.5	5.0	2.0	185.0	0.18	0.03	4.88	4.5
11	50.0	45.0	47.5	5.0	2.0	131.0	0.25	0.04	3.46	8.0
12	45.0	40.0	42.5	5.0	4.0	160.0	4.89	0.46	4.22	14.[illegible]
13	40.0	35.0	37.5	5.0	11.0	202.0	5.89	0.89	5.33	20.0
14	35.0	30.0	32.5	5.0	9.0	187.0	3.84	0.58	4.94	26.0
15	30.0	25.0	27.5	5.0	9.0	216.0	3.84	0.58	5.70	30.0
16	25.0	20.0	22.5	5.0	6.0	193.0	3.84	0.87	5.10	36.0
17	20.0	15.0	17.5	5.0	4.5	143.0	2.67	0.22	3.78	43.0
18	15.0	10.0	12.5	5.0	4.5	140.0	2.54	0.21	3.70	50.0

*Locations are miles upstream from battery

**S/A = Ratio of shoal area to total surface area

TABLE 3. POWER PLANTS ON THE HUDSON RIVER

STATION	LOCATION (mile point)	FLOW (cfs x 10^{-3})	TEMPERATURE RISE (F°)
Danskammer	66	686	14.5
Roseton	65	1,448	15.4
Indian Point	43	2,650	15.0
Lovett	42	720	14.8
Bowline	38	1,711	13.5