CHAPTER 198

Studies on Thermal Diffusion and Verification of the Third Nuclear Power Plant in Taiwan

By

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Abstract

In general, hydraulic model tests and numerical simulations can be used for securing enough informations in order to assess the environmental impact by thermal discharge after the power plant operation. However, the numerical simulations should be verified by the consequence of hydraulic model tests or the field data. Then, the numerical model can be used as a prediction model to foresee the nature of thermal diffusion when the additional generators will be operated.

The third nuclear power plant in Taiwan has been constructed in 1984. In order to protect the abundant corals which distributed on the rocky bottom around this power plant, a complete studies on thermal diffusion have been performed, accordingly, a verification with field measurements were also made in this paper.

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1. Introduction

The third nuclear power plant is located at the southest coast of Taiwan and beside Nan-Wan-Bay, 1984, two units (951MW) have been constructed and attended the commercial operation, afterwards, the other two units also performed at 1985. The intake and outlet are installed on the northern and western coastline of this bay as shown in Fig-1.

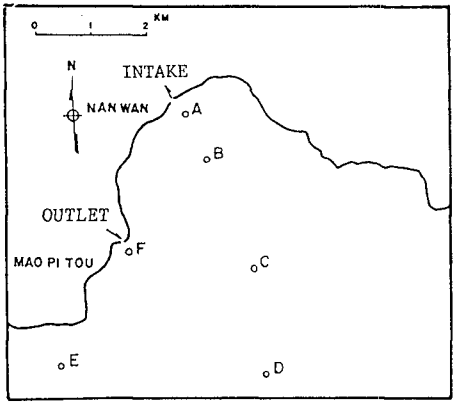


Fig-1

According to the marine ecology studies in the vicinity of Nan-Wan-Bay from August 1976 to December 1977, it showed that the abundant corals distributed on the rocky bottom about from 6m to 30m water depth. From the research of relationships between the growth of corals and water temperature, it points out that the corals will grow well in water below 29^0C,and they can not with stand long periods of exposure at 31^0C, then as water temperature increases more than 32^0C that the corals will die rapidly. Accordingly, in order to prevent the impact on corals resulting from the discharge of heated water, the complete studies on thermal diffusion and verification were made. And the results would be presented in this paper.

2. Field Surveys and Data Analysis

The complete analysis of field survey data had to be done before the hydraulic model tests and numerical simulations were progressed. They are:

(1). Topography, water depth and coastline surveys:

The field surveys should be done at least twice in a year for the necessity to discretize the continuous domain in numerical simulations or to construct the hydraulic model.

(2). Analysis of wind speeds and wind directions:

According to the results obtained from Nan-Wan station, it is obviously to see from Fig-2, that the wind contributes in NE direction for 48.9% of occurence is the main wind at Nan-Wan area. And the average wind velocity is about 10m/sec in this direction.

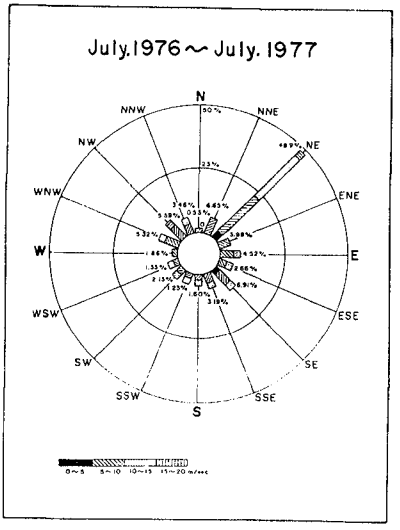


Fig.—2 Monthly maximum wind velocity and wind direction at Nan—Wan Station

(3). Analysis of water temperature:

The temperature data were collected by Taipower Exploration Team from July, 1976 to July, 1977 at Nan-Wan area. Table-1 indicates the monthly average water temperature, monthly maximum and minimum water temperature throughout the interval.

Table—1 Water Temperature

Month	Manthly Average Water Temperature°C	Monthly Maximum Water Temperature°C	Manthly Minimum Water Temperature°C
1976 June	28.1	30	24.9
July	29.3	31	27.4
Aug.	29.3	31	28.0
Sep.	28.0	30.1	25.2
Oct.	27.0	29.1	25.1
Nov.	24.4	27.2	21.0
Dec.	23.6	26.0	22.0
1977 Jan.	23.4	25.7	21.4
Feb.	23.2	25.7	20.5
Mar.	24.8	27.5	20.2
Apr.	26.4	28.9	22.5
May	28.2	29.7	26.2
June	27.7	29.5	26.1
July	27.4	30.6	24.5

(4). Analysis of tidal records: Fourteen months of tidal records at Nan-Wan area have been analyzed by least square method in harmonic analysis with twenty-one tidal constituents. Table-2 shows the amplitudes and phase angles for respective tidal constituents. The comparsion between prediction of tidal motion equation created by these tidal constituents and tide records was shown in Fig-3.

Table-2 Analysis results of tidal constituents

consti. name	angular frequency	amplitude (cm)	phase angle (deg.)
M_2	28.9841042	26.842	39.00
K_1	15.0410686	18.772	240.36
O_1	13.9430356	16.042	91.68
MKS_2	29.0662415	0.836	296.81
φ_1	15.0821353	1.770	264.61
OP_2	28.9019669	0.525	294.38
S_1	15.0000000	0.606	268.42
S_2	30.0000000	11.061	191.86
S_0	0.0410686	7.294	54.92
S_{00}	0.0821373	8.074	147.78
R_2	30.0410667	0.102	219.94
T_2	29.9589333	0.701	353.66
P_1	14.9589314	6.801	263.00
ϕ_1	15.1232059	0.339	297.58
π_1	14.9178647	0.357	330.34
N_2	28.4397295	5.343	280.98
MP_1	14.0251729	1.571	334.90
Q_1	13.3986609	2.829	320.75
K_2	30.0821373	2.900	332.14
$M_{4/1}$	1.0158958	1.994	19.04
ν_2	28.5125831	0.940	353.54
Total		115.7	

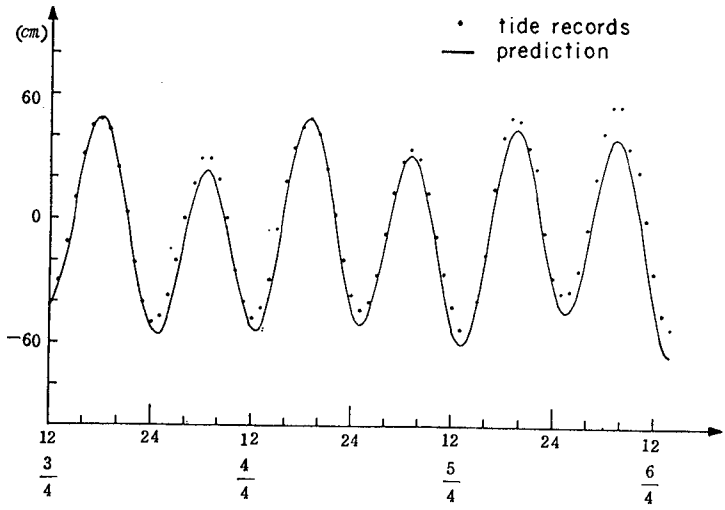


Fig.— 3 Comparison between tide records and prediction

(5). Analysis of measuring currents:

Owing to the ocean current data at Nan-Wan site, four major current constituents at this area are M_2, S_2, K_1 and O_1. And the Analysis results are displayed in Table-3 and Table-4.

Table – 3 Analysis results of current measurement at D station

Name	X – direction amplitude (cm/sec)	phase angle (degree)	Y – direction amplitude (cm/sec)	phase angle (degree)
M_2 = 12.42 hr	27.07	23.90	5.39	123.90
S_2 = 12.00 hr	10.35	7.50	2.81	97.50
K_1 = 23.93 hr	13.07	167.86	2.29	257.86
O_1 = 25.82 hr	16.56	18.24	4.56	108.24

Table – 4 Analysis results of current measurement at E station

Name	X – direction amplitude (cm/sec)	phase angle (degree)	Y – direction amplitude (cm/sec)	phase angle (degree)
M_2 = 12.42 hr	27.99	340.70	8.29	186.78
S_2 = 12.00 hr	26.86	42.33	3.79	237.55
K_1 = 23.93 hr	17.99	43.49	7.54	221.03
O_1 = 25.82 hr	8.40	226.38	5.22	91.41

3. Hydraulic Model Tests

The hydraulic model tests have been completed by Tainan Hydraulics Laboratory according to the previous analysis. A distorted model (horizontal scale is 1/1152, vertical scale is 1/144) was determined by comparing the heat on sea surface which calculated from field data with those examined from laboratory. The results of far-field model tests were shown in Fig-4∿Fig-7.

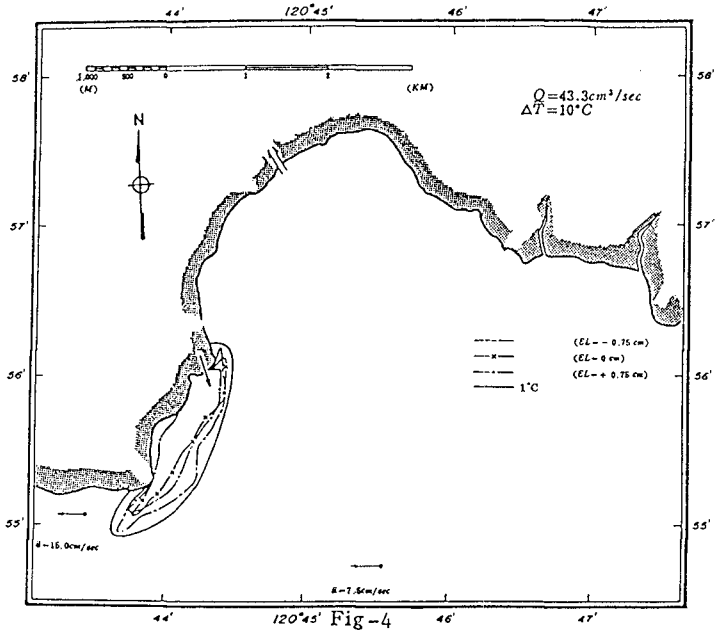
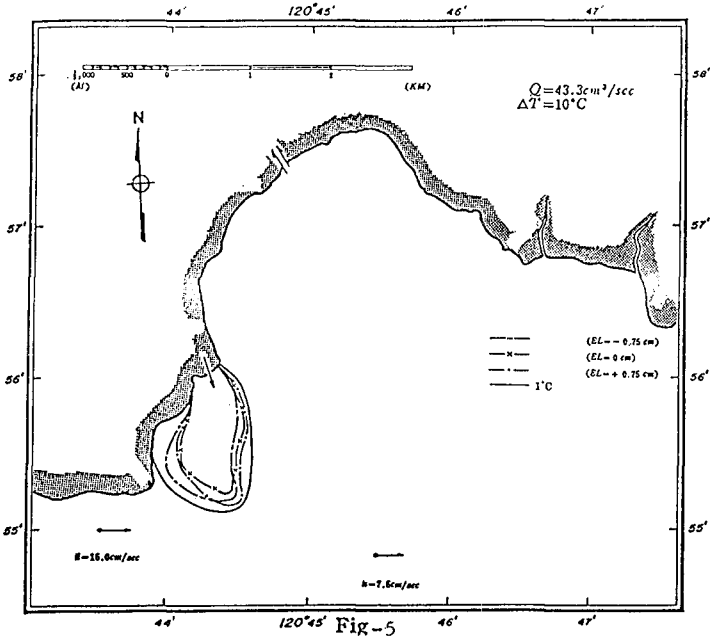

44'
120°45'
46'
47'
58'
57'
56'
55'
1,000
500
0
1
2
(M)
(KM)
N
Q=43.3cm³/sec
ΔT=10°C
(EL=-0.75 cm)
(EL=0 cm)
(EL=+0.75 cm)
1°C
u=16.0cm/sec
u=7.5cm/sec

Fig-4


44'
120°45'
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57'
56'
55'
1,000
500
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1
2
(M)
(KM)
N
Q=43.3cm³/sec
ΔT=10°C
(EL=-0.75 cm)
(EL=0 cm)
(EL=+0.75 cm)
1°C
u=16.0cm/sec
u=7.5cm/sec

Fig-5

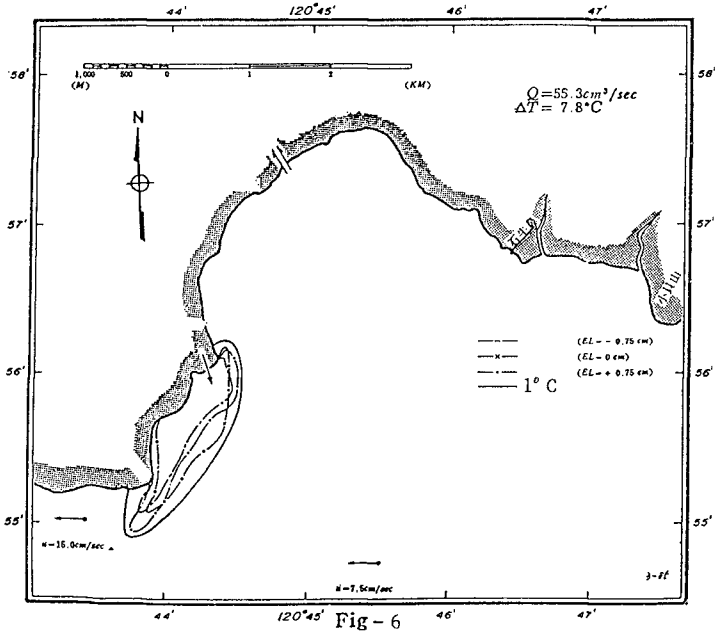
120°45'
44'
46'
47'
58'
57'
56'
55'
1,000 500 0 1 2
(M)
(KM)
Q=55.3cm³/sec
ΔT= 7.8°C
N
(EL = - 0.75 cm)
(EL = 0 cm)
(EL = + 0.75 cm)
1° C
u=16.0cm/sec
u=7.5cm/sec

Fig – 6

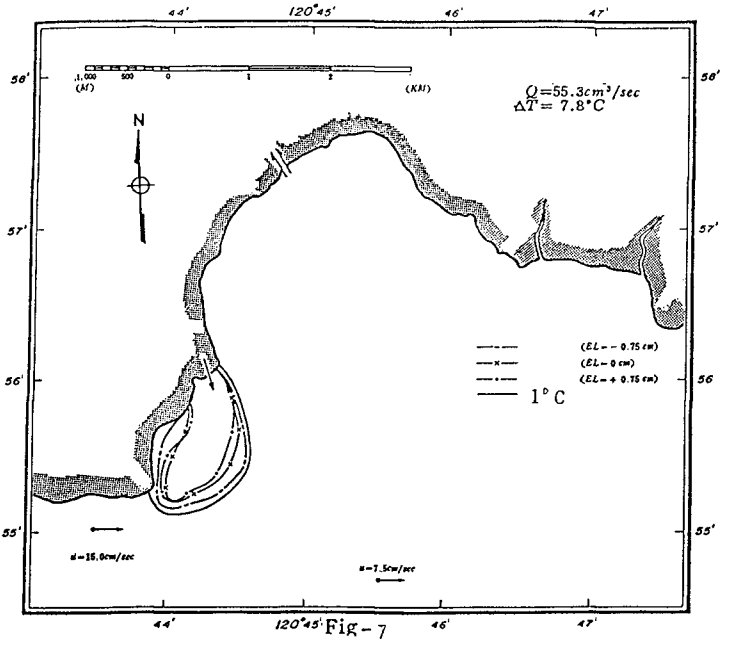
120°45'
44'
46'
47'
58'
57'
56
55'
1,000 500 0 1 2
(M)
(KM)
Q=55.3cm³/sec
ΔT= 7.8°C
N
(EL = - 0.75 cm)
(EL = 0 cm)
(EL = + 0.75 cm)
1° C
u=16.0cm/sec
u=7.5cm/sec

Fig – 7

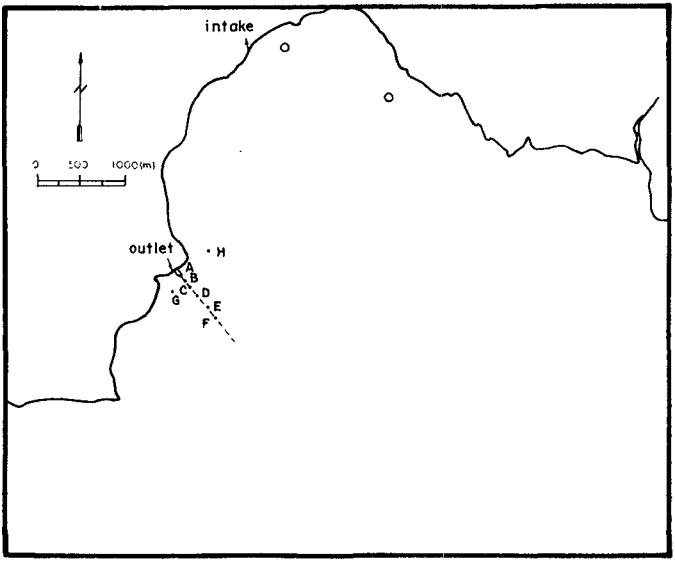

Fig. — 8 Schematic diagram of measuring Points for vertical temperature distribution

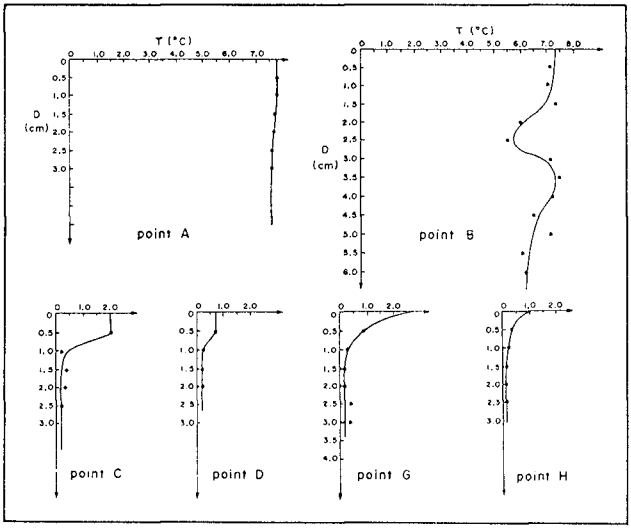

Fig-9

Fig-4 shows the envelope of 1 degree centigrade temperature increasing in conditions of two units operation, the cooling water discharge is 43.3 C.M.S., cooling water temperature rised is 10 degree centigrade and under strong flooding tide action. The result of Fig-5 is in the same conditions as Fig-4 excepts the ocean current is strong ebbing tides. Since the ambient water temperature in Nan-Wan Bay is so high that a great amount of cold water will be pumped from deep sea to mix with the hot water discharged from condensers. The results of this nature are shown in Fig-6 and Fig-7.

Besides, for the request to assure that the coral could grow well, an adjustment was made by installing a 120-meter-long flow-guided breakwater from the outlet to somewhere the water depth is 8 meters that it would keep the heated water floating on the surface layer. And the measuring points for vertical temperature distribution and the corresponding results in an undistorted model were described in Fig-8 and Fig-9 respectively.

4. Numerical Simulations

A two-dimensional model was used to simulate the flow patterns and temperature distributions under tides and currents action. The horizontal diffusion coefficient and thickness of warm water floating on surface layer in the numerical simulations could be determined from the hydraulic model tests. The currents boundary conditions were set at both sides in x-direction of the finite-difference grid domain, but the boundary condition in the south was controlled by tides. The numerical model covered an area of 8.5Km×10.0Km. That meant it had 34 grids in x-direction and 40grids in y-direction with a grid size of 250m. The numerical simulations were accomplished throughout 4500 time steps with a value of time step by 30 seconds. Fig-10∿Fig-13 show the simulated flow patterns at Nan-Wan area by a two-dimensional numerical model when the time level was the 3000th, 3300th, 3600th and 3900th respectively. And the corresponding temperature distributions were shown in Fig-14∿ Fig-17.

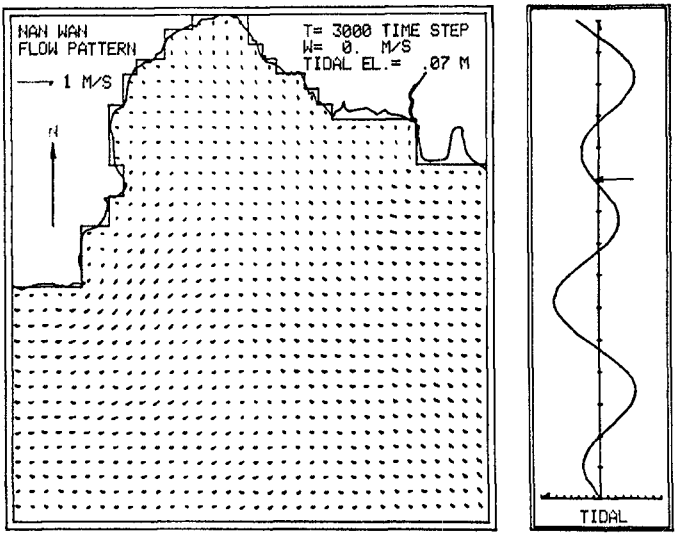
NAN WAN
FLOW PATTERN
1 M/S
N
T= 3000 TIME STEP
W= 0. M/S
TIDAL EL.= .07 M
TIDAL

Fig-10

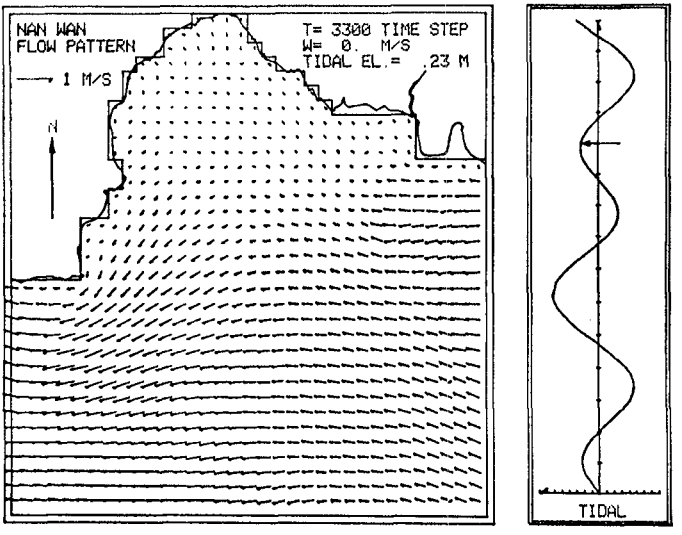
NAN WAN
FLOW PATTERN
1 M/S
N
T= 3300 TIME STEP
W= 0. M/S
TIDAL EL.= .23 M
TIDAL

Fig-11

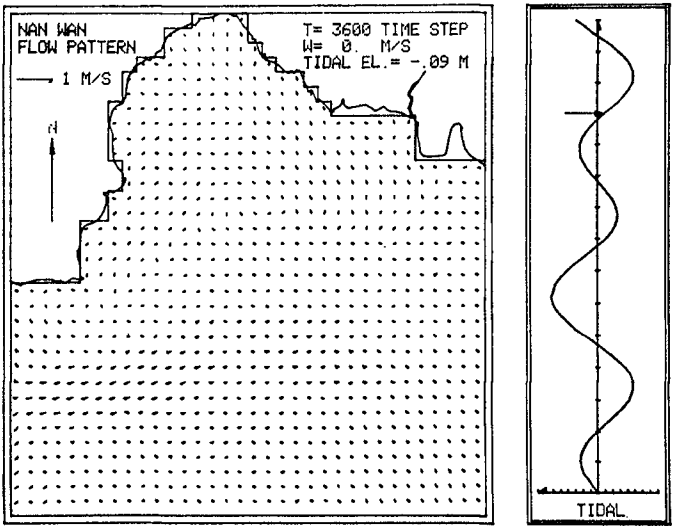
NAN WAN
FLOW PATTERN
1 M/S
N
T= 3600 TIME STEP
W= 0. M/S
TIDAL EL.= -.09 M
TIDAL

Fig-12

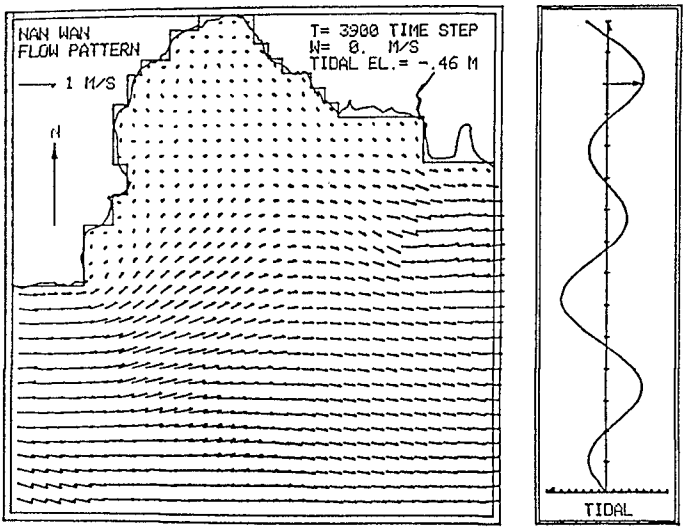
NAN WAN
FLOW PATTERN
1 M/S
N
T= 3900 TIME STEP
W= 0. M/S
TIDAL EL.= -.46 M
TIDAL

Fig-13

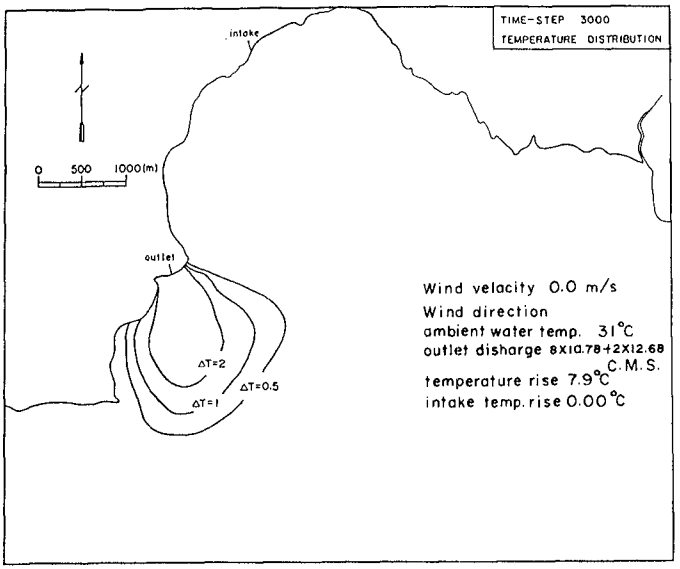
TIME-STEP 3000
TEMPERATURE DISTRIBUTION
intake
0 500 1000(m)
outlet
ΔT=2
ΔT=0.5
ΔT=1
Wind velocity 0.0 m/s
Wind direction
ambient water temp. 31°C
outlet disharge 8X10.78+2X12.68 C.M.S.
temperature rise 7.9°C
intake temp. rise 0.00°C

Fig-14

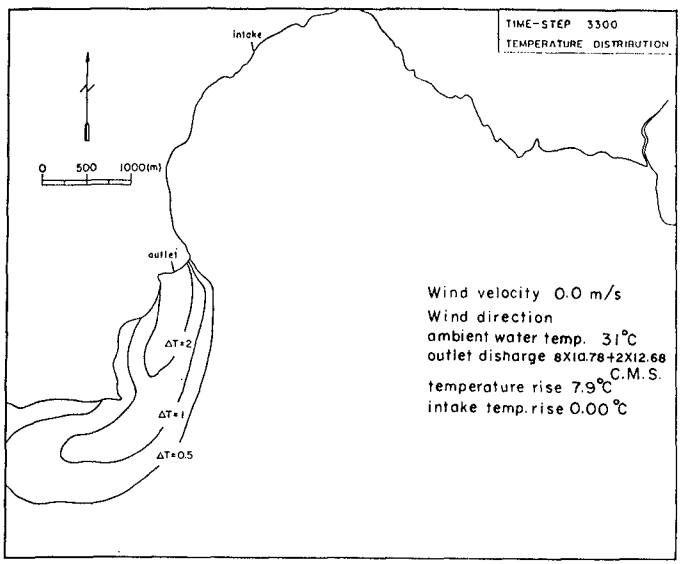
TIME-STEP 3300
TEMPERATURE DISTRIBUTION
intake
0 500 1000(m)
outlet
ΔT=2
ΔT=1
ΔT=0.5
Wind velocity 0.0 m/s
Wind direction
ambient water temp. 31°C
outlet disharge 8X10.78+2X12.68 C.M.S.
temperature rise 7.9°C
intake temp. rise 0.00°C

Fig-15

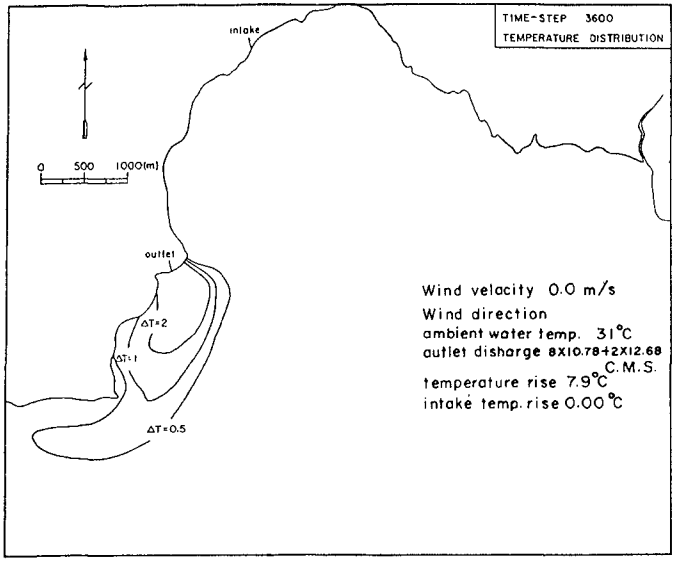
TIME-STEP 3600
TEMPERATURE DISTRIBUTION
intake
0 500 1000(m)
outlet
ΔT=2
ΔT=1
ΔT=0.5
Wind velocity 0.0 m/s
Wind direction
ambient water temp. 31°C
outlet disharge 8X10.78+2X12.68 C.M.S.
temperature rise 7.9°C
intake temp. rise 0.00°C

Fig-16

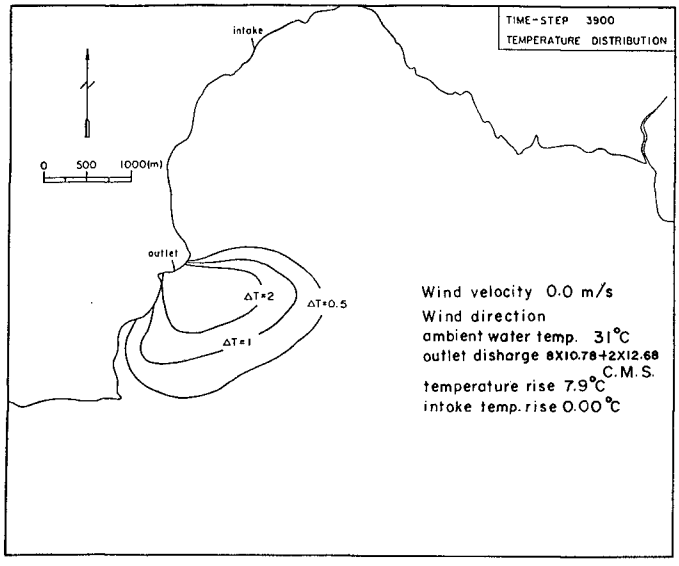
TIME-STEP 3900
TEMPERATURE DISTRIBUTION
intake
0 500 1000(m)
outlet
ΔT=2
ΔT=0.5
ΔT=1
Wind velocity 0.0 m/s
Wind direction
ambient water temp. 31°C
outlet disharge 8X10.78+2X12.68 C.M.S.
temperature rise 7.9°C
intoke temp. rise 0.00°C

Fig-17

5. Verification and Conclusion

After the third nuclear power plant operation from 1984, monitoring program has been proceeded to thermal diffusion in Nan-Wan-Bay. Four fixed monitoring stations were installed around the outlet, and the thermisters (General Ocean 6070-type) were set below the water surface from 0.5m to 5.0m separately.In addition,a large scale survey was also performed by motor-boats for every season. Based on the above results, the numerical calculations of temperature distributions could be verified by field measurements from a large scale surveys. Fig-18 is the temperature distribution obtained from numerical calculation and Fig-19 is the results plotted from field data at the same tide condition . And the comparison of vertical temperature distributions between the hydraulic model tests and field data are also presented in Fig-20.

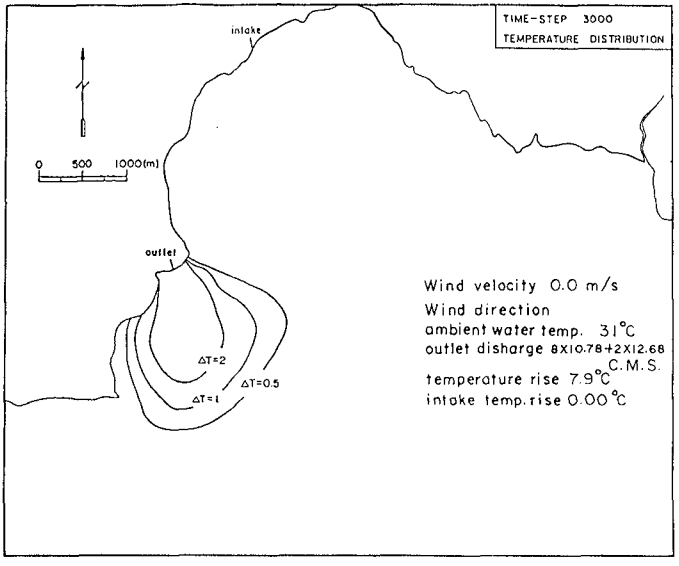

Fig-18

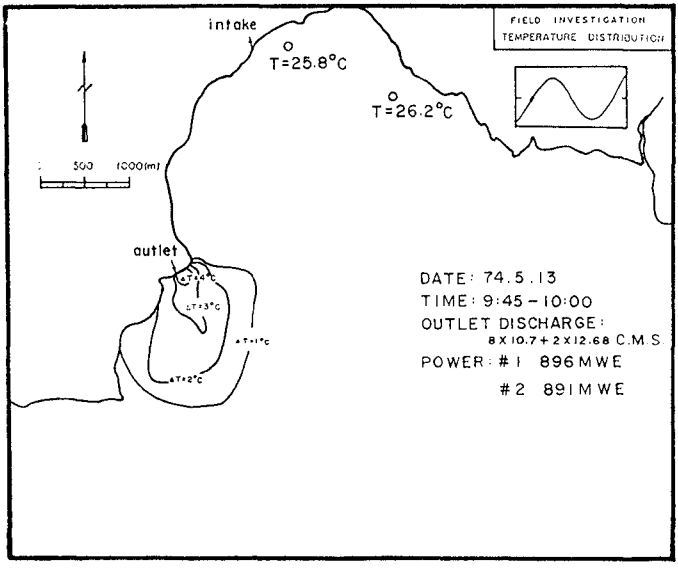
FIELD INVESTIGATION
TEMPERATURE DISTRIBUTION
intake
T=25.8°C
T=26.2°C
500 1000(m)
outlet
ΔT=4°C
ΔT=3°C
ΔT=1°C
ΔT=2°C
DATE: 74.5.13
TIME: 9:45 – 10:00
OUTLET DISCHARGE:
8X10.7+2X12.68 C.M.S
POWER: #1 896MWE
#2 891MWE

Fig-19

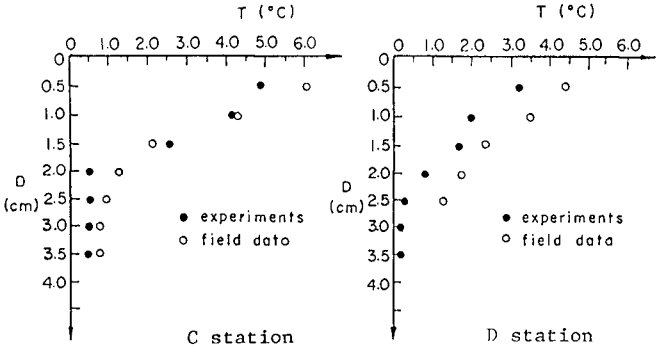
T (°C)
0 1.0 2.0 3.0 4.0 5.0 6.0
D (cm)
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
● experiments
○ field data
C station
T (°C)
0 1.0 2.0 3.0 4.0 5.0 6.0
D (cm)
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
● experiments
○ field data
D station

Fig-20

According to a number of elaborated hydraulic model tests and numerical simulations on thermal diffusion of the third nuclear power plant in Taiwan, the discharged warm water floating on the surface layer has been proved from field investigations that showed the abundant corals have not affected by warm water and they have grown well until now.

6. References

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