

THERMAL IMPACT STUDIES

FOR FRENCH COASTAL NUCLEAR SITES

by

Y. COEFFE (1), P.M. CLIQUE (2), and B. MANOHA (2).

ABSTRACT :

The paper presents the different stages of the environmental studies performed at the Laboratoire National d'Hydraulique concerning some of the French coastal nuclear power plants using a once - through cooling system, and the different means used, in function of the proper characteristics of the site, to come to an optimum inlet-outlet configuration leading to a minimum thermal impact and to a minimum recirculation of the heated waters at the intake. The paper particularly describes the original studies performed for the Flamanville power plant where a special computer controlled tank has been used.

1. INTRODUCTION

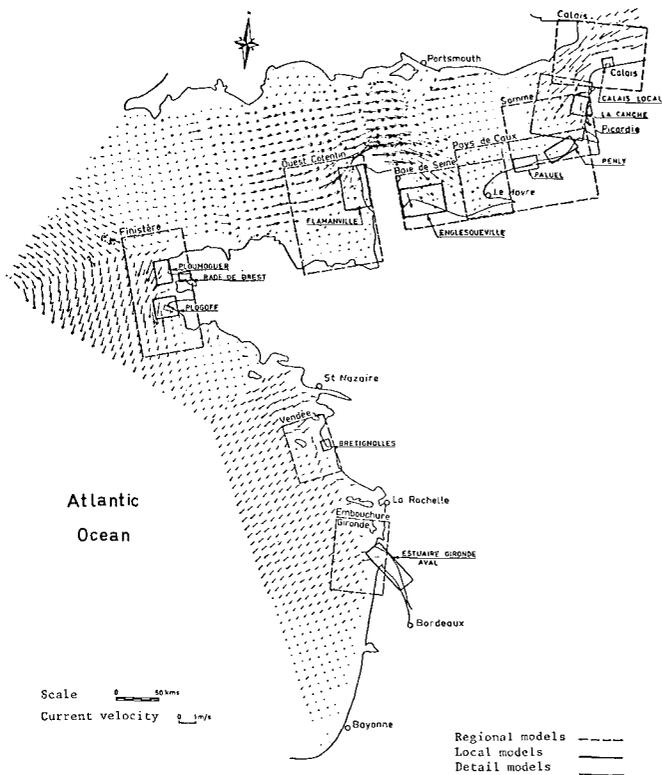
The setting up of a coastal nuclear power plant using a once - through cooling system requires many environmental studies because of the importance of the coastal works leading to an important impact on the marine environment. For example the last generation of french coastal nuclear power plants (Paluel, Flamanville, Penly) are made of four units of 1300 MWe each, needing an intake and discharge flow of 180 m³/s (corresponding to the average annual flow of the river Seine in Paris), with a discharge temperature elevation of 15°C.

So the thermal studies are particularly important as to :

- minimize the effect on the marine environment
- minimize the recirculation of the heated waters at the intake as to optimize the efficiency of the plant.

(1). Head of the maritime hydraulics division, Laboratoire National d'Hydraulique, E.D.F., Chatou, France.

(2). Research engineers, Laboratoire National d'Hydraulique, E.D.F., Chatou, France.



2 HOURS AFTER HIGH TIDE AT BREST

TIDAL CURRENTS COMPUTED ON THE FRENCH COAST

Fig. 1

These two problems are of course closely connected and can be solved by way of numerical and physical models calibrated on many field measurements which are essential for a good knowledge of the medium where the calories will be diluted.

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2. DIFFERENT MEANS USED

2.1. Field measurements

The studies of the impact on the marine environment of the warm waters discharged by a nuclear power plant as Flamanville (4 x 1 300 MW needs 180 m³/s of water with a discharge temperature elevation of 15°C) require a very good knowledge of the hydrometeorological characteristics of the site, and in particular of the tidal currents which are the main factor of dilution of the calories for the different french sites chosen up to now (cf. Flamanville). Therefore many drogue trackings and punctual current measurements by currentmeters are performed around the site as to evaluate the characteristics of the marine currents, and in particular the drift and the excursion of the waters.

Many other field measurements are performed, as the meteorological conditions (wind, air and water surface temperature) which are essential to estimate the exchange coefficient with the atmosphere which is the final sink of the calories, the waves (for the protection of the discharge and intake works), the salinity, the vertical profiles of water temperature (eventual possibility of thermocline), the bathymetry of the site, etc.

All these measurements enable then to evaluate the relative effects of the different parameters as to choose the most appropriate means to be used (different types of numerical or physical models), and to calibrate them as accurately as possible.

2.2. Numerical models

Many different numerical models can be used for the evaluation of the thermal impact ; they are mostly used for the intermediate and the far field, the near field being preferably studied by way of physical models.

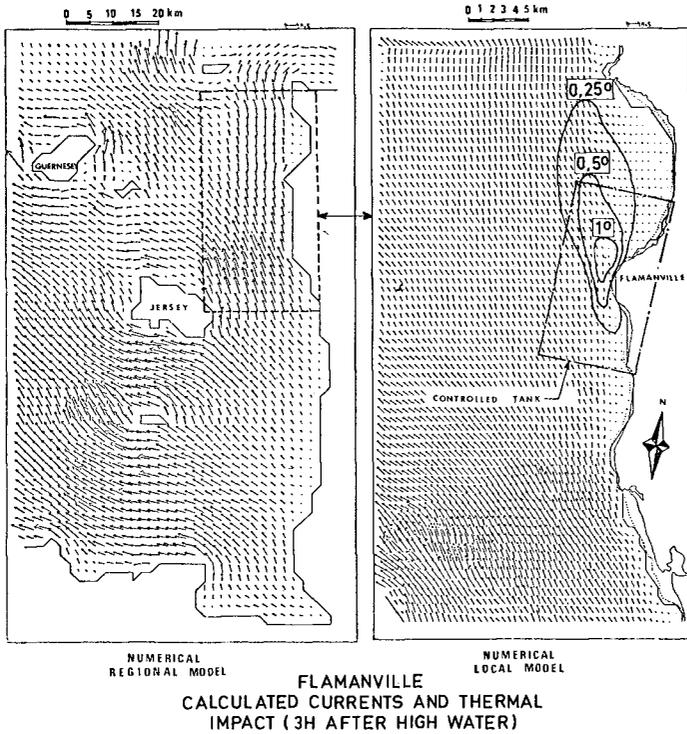


Fig. 2

2.2.1. Current models

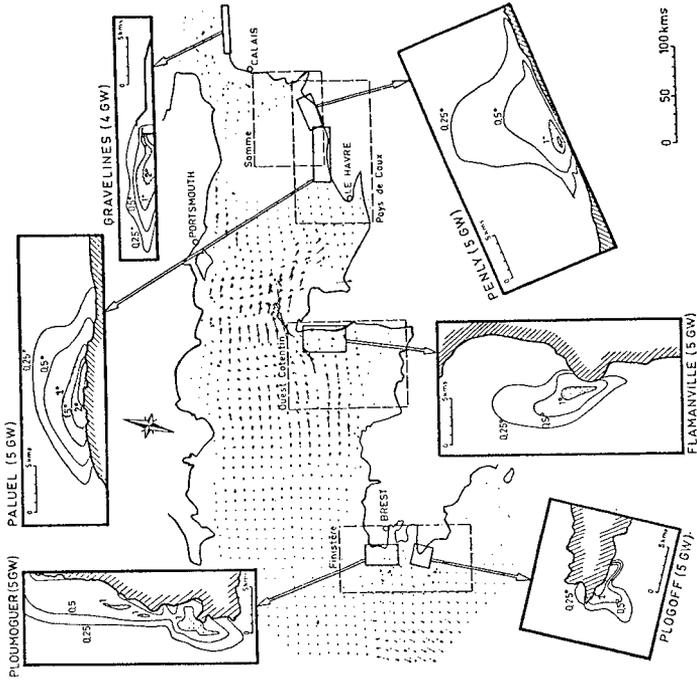
The dilution of the calories is made by advection, diffusion and finally by exchange with the atmosphere ; different types of models can be used for the description of the current fields in which the calories will be diluted. For the nuclear power plants erected along the English Channel (ex : Flamanville), the currents are due to the tide and are nearly homogeneous along the vertical. Then bidimensional models of tidal currents, calibrated on field measurements, are used. A complete description of this type of numerical model, called CYTHERE ES, which can now take into account tidal flat flooding and drying, is presented in the ASCE paper : "New Method for Tidal Current Computation" (ASCE vol. 108, N° WW3, August 1982) ; let us just say that it is based on a fractional step method in which momentum advection is calculated using the method of characteristics, horizontal momentum diffusion is calculated using an implicit finite difference scheme, and wave propagation is calculated using an iterative alternating direction implicit algorithm. Many different zones, covering various areas, have then been studied (see figure 1) :

- "large models" (10 km gridmesh) cover the English Channel, the Bretagne, and the Atlantic coast ;
- "regional models" (2 to 2,5 km gridmesh) are then used for the far field ; their boundary conditions of flows and levels are given by the "large models" (additional calibrations and adjustments being performed if necessary) : Baie de Saint-Malo, baie de Seine, Finistère, etc.
- "local models" (about 500 m gridmesh) cover then the intermediate field (boundary conditions given by the regional models) : Paluel, Flamanville, Penly, etc.(figure 1) ;
- "detail models", with small and irregular gridmeshes can also be used for a finer description of particular zones in the near field (boundary conditions given by the local models).

The figure 2 presents the example of Flamanville where regional and local models of currents were built, each model using the results of its corresponding bigger sized model as boundary conditions.

2.2.2. Thermal models

The thermal impacts and their evolution during the tide, especially in the intermediate and far field, are then computed through bidimensional numerical models using the results of the above mentioned current models, where the equations of advection diffusion and exchanges with the atmosphere have been solved ; the order of magnitude of the dispersion coefficients used in these models are generally between 0,5 m²/s (transversal) and 5 m²/s (longitudinal), the exchange coefficients ranging between 30 and 100 W/m²/°C ; the intake and discharge zones are described by a refined gridmesh enabling a more precise evaluation of the near field impact.



THERMAL IMPACTS CALCULATED FOR DIFFERENT COASTAL POWER PLANTS

Fig. 3

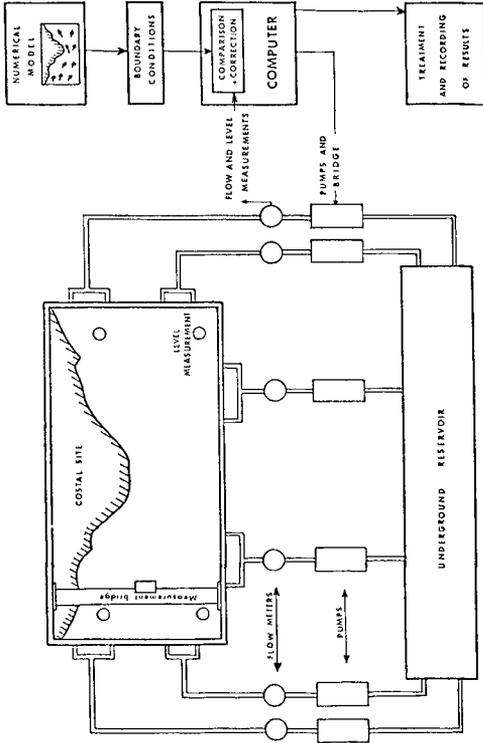
Some examples of results are shown on figure 3 where the thermal impacts calculated for different coastal nuclear power plants are presented :

- Gravelines : it was the first coastal nuclear plant, with an intake and an outfall made through free surface channels (intake inside the Dunkerque harbour, outfall outside the harbour).
- Paluel : as for Flamanville and Penly, the intake is erected along the shore (free surface channel), and the discharge is made through offshore submerged outfalls with high discharge velocities enabling a good initial dilution.
- Flamanville : this plant is erected on a cape with high current velocities contributing to a good dilution of the calories.
- Penly : on this site is a marine drift to the North East enabling a good renewal of the waters and thus a relatively small thermal impact.
- Ploumoguier : this project was situated inside a bay enjoining to make the discharge far away from the coast as to dilute the calories in the strong currents off the bay and to avoid a too important heating of the bay ; the difficulties of this project made it abandoned.
- Plogoff : this site, finally abandoned for political and ecological reasons, was very favourable from a thermal point of view because of the existence of an important dissymmetry between the ebb and the flood, leading to a big tidal drift to the West considerably reducing the thermal impact.

2.3. Physical models

In fact other numerical models can be used for the study of the near field, especially three-dimensional models, but usually most of the near field problems are studied by way of physical models taking into account more accurately and continuously the tridimensional aspects of the dilution : topography, density effects, turbulent mixing, vertical profiles of velocities and temperatures, etc...

As the boundary conditions on classical physical models are usually very long and hard to work up, we have recently built for the environmental studies a special test stand (first used for the Flamanville power plant) which is a hybrid model reducing those difficulties by using both numerical and physical techniques, i.e. a physical model whose boundary conditions are given by the numerical current models and automatically controlled by a computer.



WORKING DIAGRAM OF THE TANK
CONTROLLED BY COMPUTER

fig. 4

3. THE COMPUTER CONTROLLED TANK

3.1. Purpose of the model

The computer controlled tank developed by the L.N.H. allows to reproduce, without long manual adjustments, any configuration of non steady flow, for example tidal currents.

The large dimensions of the tank and of its whole equipment make the installation work as a testing stand allowing the study of successive sites one after the other, the only parameters to introduce being the topography and the boundary currents derived from field measurements or from a numerical model of larger area. If the boundary conditions are well known, they will be immediately reproduced whereas their reproduction with classical model equipments needs to proceed cautiously and tentatively during three months to one year, according to the complexity of the current field. If the boundary conditions are badly known, their determination by progressive adjustments in terms of the velocities obtained in the model will be possible within an iteration time of a few weeks, whereas the classical technology makes this research quite impossible because of the long iteration time. This automatic control by computer therefore induces an important gain of time.

3.2. Dimensions of the model.

The dimensions of the model are :

- Overall length : 54,50 m
- Useful length : 47,50 m
- Overall width : 31,40 m
- Useful width : 28,40 m
- Overall depth : 1,50 m
- Useful depth : 1,20 m

The underground associated storage capacity is about 1 200 m³.

3.3 Simulation of the levels and currents

The working diagram of the tank is presented on figure 4.

The model is equipped at its three open boundaries with six water supply systems (2 for each boundary), each one being completely independent from the others and automatically controlled by a computer.

Three of them consist in reversible axial pumps dispatching the water from the underground reservoir to the model or from the model to the underground reservoir with a flow ranging between - 500 l/s (drainage of the model) and + 500 l/s (supply of the model). These pumps are equipped with direct current motors and thyristor speed variators.