REGULATION OF THE THERMAL LOADING BY PAKS NUCLEAR POWER STATION

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Abstract

This paper is a survey of the thermal loading caused by the heated cooling water of Paks Nuclear Power Station. It deals with the interrelations of the Danube and the nuclear power plant, and examines the ruling situations from the point of view of hydrology, water temperature and operation. It presents a suggestion for the operation of the cooling system of the power plant that can be applied to reduce the thermal loading during the critical summer period and to observe the water quality regulations of thermal pollution.

Keywords: protection of water quality, thermal pollution of rivers, fresh-water cooled power stations.

Introduction

The thermal loading of water plants using fresh-water cooling system can cause pernicious change of water quality in rivers and lakes. In order to protect water quality and to avoid harmful thermal pollution, thermal loading became limited by regulations (ROCHLICH, 1972; KHALANSKI, 1973).

The regulation of thermal loading varies from country to country, according to climate, water quality, and hydrological conditions, but usually the following parameters are limited:

- highest temperature, t_{max};
- maximum temperature difference, Δt_{max};
- the rate of heating, concerning the water reach below the mixing zone.

Recent research proved that from the parameters mentioned above, t_{max} could be considered as a limit that may influence the operation of the power plant of Paks during the summer period (ÖLLŐS- SZOLNOKY, 1979; OSZTHEIMER-SZABOLCS, 1978; GULYÁS, 1984). We mention that revelation of the process of thermal load distribution is very important, because the transport and distribution of an accidental pollution coming from the nuclear power plant are determined by the transport and mixing processes of the warm water.

The Cooling System of Paks Nuclear Power Station and the Characteristics of Thermal Loading

The fresh-water cooled Paks Nuclear Power Station (*Fig.1*) is the greatest industrial water consumer of Hungary. In its water consumption the demand of cooling water is the most significant which is 80 to 100 m^3/s at the present 1760 MW capacity, and it will rise to a max. discharge of 210 m^3/s at 4000 MW total capacity. This discharge is used for cooling the condensers, and is taken to the Danube at an increased temperature of 7 – 9°C. During the winter operation thermal wastes are inducted to the Danube by a reduced discharge of 60 m^3/s, while the temperature difference exceeds 10°C.

The cooling water system of condensers is connected to the Danube with open channels *(Fig.2)*. After passing the trash racks, cooling water is pumped to the drum or rotary filters from the navigable low-level cold-water canal of the Danube, situated in the section of 1527 km. Passing the filters, cooling water flows to the condensers where it warms up to 7-9 °C. The heated water flows through regulating weirs to the high-level warm-water canal and then back to the Danube.

Our investigations indicated that the warm water taken to the Danube flowed in the form of 'warm-water sheaf' along the right side of the river, and mixed with the cool water gradually (SZOLNOKY, 1980-1,2). At the beginning the initial temperature difference of 7–9 °C decreases rapidly. Afterwards the process of mixing and cooling becomes ever slower. During the low-discharge period the warm-water sheaf gets closer to the left bank in the distance of 60–80 km, so the permanent temperature of water increases slightly in this zone. The over-temperature of the section decreases faster in lower reaches, so that its measured value is less than 1 °C at the border of the country. Water licence declares a limit of 30 °C highest temperature at the checking point in a distance of 500 meters from the warm-water input.

Thermal changes mentioned above affect organisms (SZOLNOKY, 1981,1987)*(Fig.3)*. In the internal system of the power plant, running from the condensers to the Danube, the change of temperature affects those planktonic organisms which move together with the water; they are the most important elements of self-purification. In the eternal system the dwelling period is practically constant, in normal summer operation max. 20 minutes.

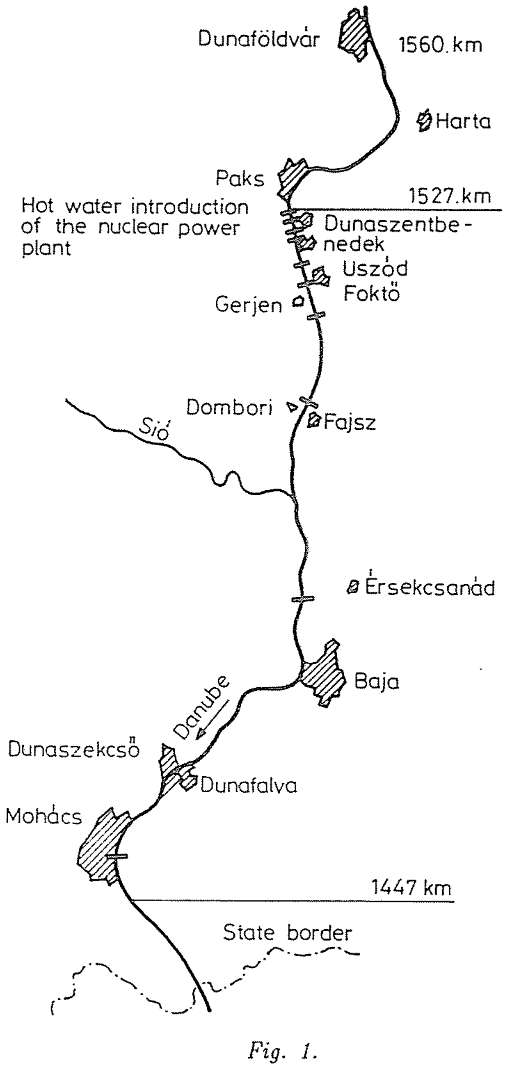

Fig. 1.

At the beginning of the mixing process in the Danube, the over-temperature decreases rapidly; approximately after 10 minutes and 500 meters from the input, in the checking point, it has decreased from the nominal value of 9 °C to 6–8 °C. In the next 20–40 km (5–10 hours dwelling period) the over-temperature decreases to 2–3 °C then it fades into the natural thermal changes taking place in other reaches of the Danube.

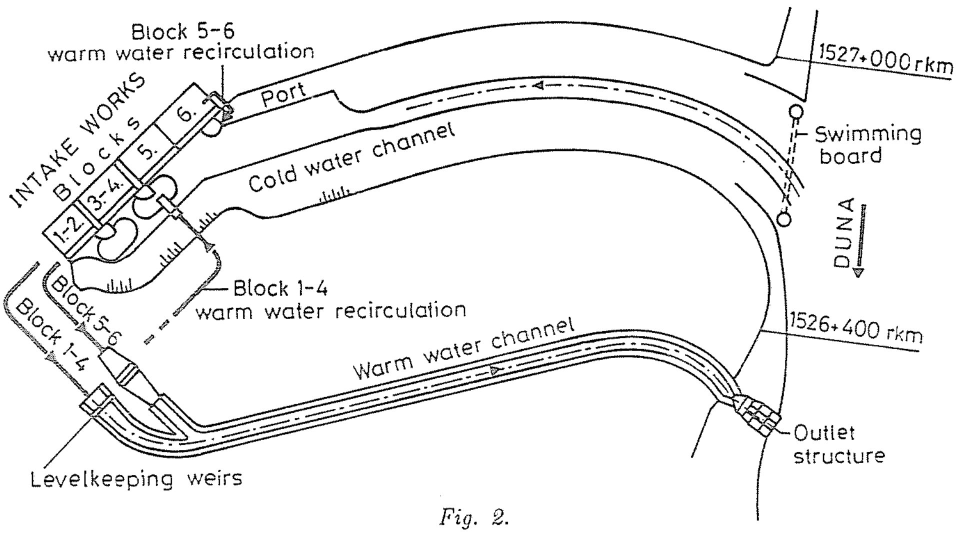

Fig. 2.

Considering thermal loading we have to emphasize that thermal (and other, for example, mechanical) impact on cooling water are relatively significant, and not negligible compared to other processes investigated on the Danube. Therefore the investigation and supervision of the thermal pollution cannot be separated from the characteristic of the power plant, the parameters of the hydraulic machinery and equipment, and from the definite features of operation. Operational possibilities should be utilized systematically.

Standard Hydrological Conditions of the Thermal Loading on the Danube

To get proper information on the thermal loading and its consequences, it is indispensable to determine the hydrological background of the Danube, the natural thermal conditions, the joint occurrence of the standard temperatures and discharges, and the probability of the occurrence. Therefore we have studied the temperature and discharge data of the Danube at Paks, registered from 1946 to 1987. After statistical processing we made simulation analysis by inserting the operation of the power plant into the hydrological process of the last 42 years. Regarding our hydrological research we emphasize the following conclusions *(Fig.4)*:

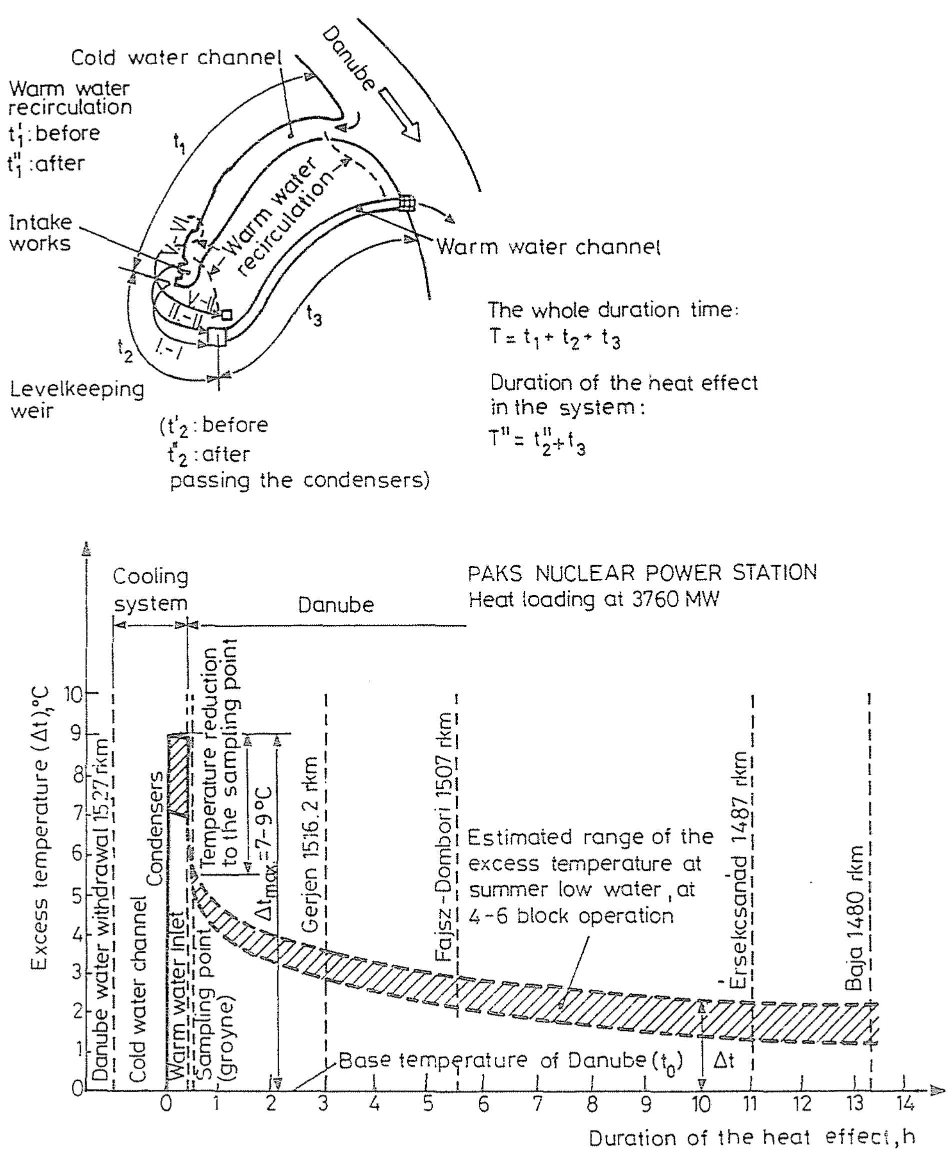

Fig. 3.

- The highest summer temperature, which is the most significant for thermal pollution, caused by the returned cooling water is generally 21–24 °C but on rare occasions it exceeds 25 °C. The maximum of the water temperature data is well defined, it is in July or August.

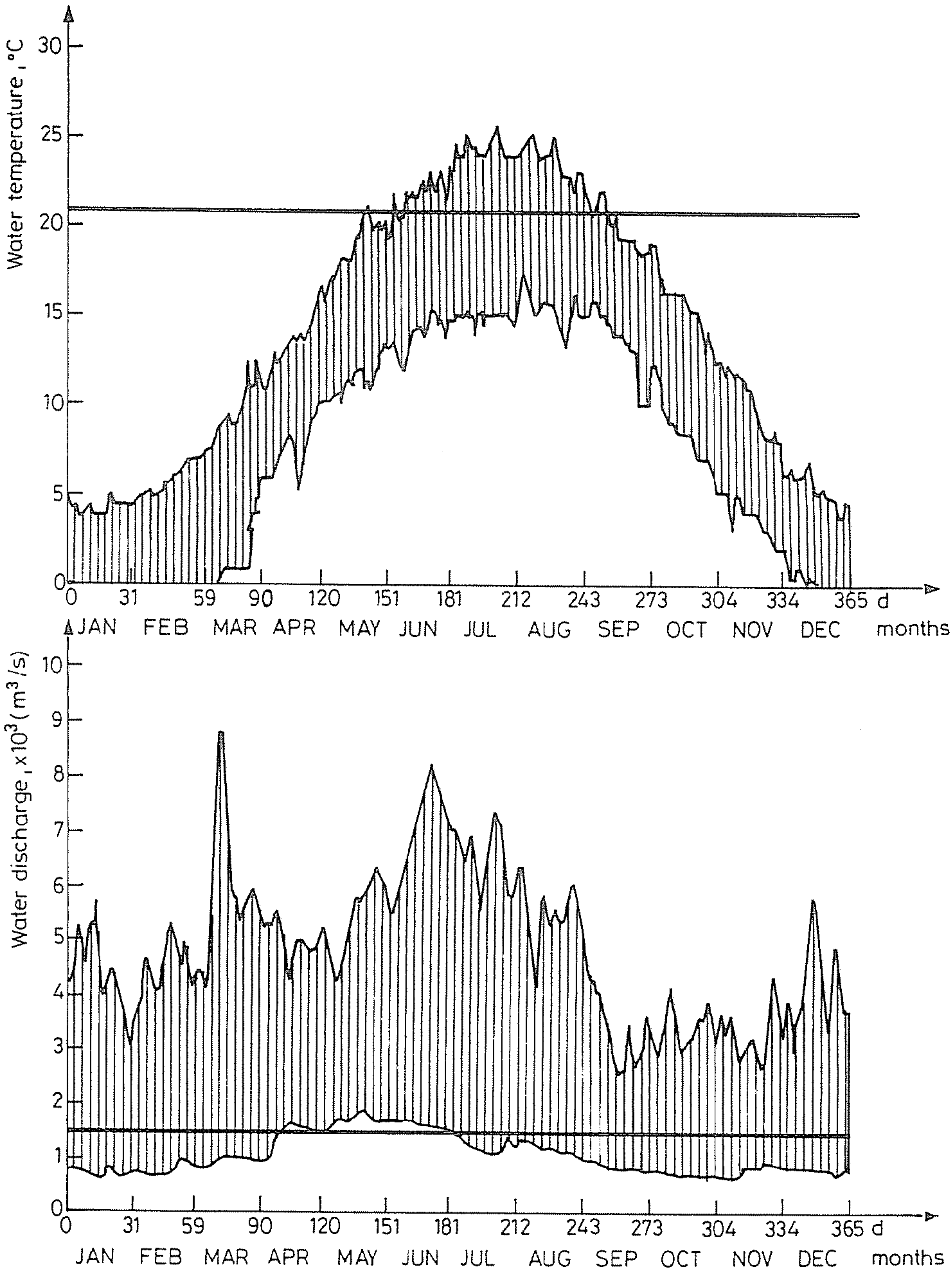
Water temperature, °C
30
25
20
15
10
5
0
0 31 59 90 120 151 181 212 243 273 304 334 365 d
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC months
Water discharge, x10^3 (m^3/s)
10
9
8
7
6
5
4
3
2
1
0
0 31 59 90 120 151 181 212 243 273 304 334 365 d
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC months

Fig. 4.

- The change of the discharge data is not regular, so low discharge values, which are significant for the maximum relative thermal loading of the Danube, can occur at any time during the year.
- The typical characteristic of the Danube that reduces the risk of thermal pollution is that high water temperatures occur only in July and August, while low discharge values (around 1000 m^3/s) occur from September.

The establishments mentioned above prove that the standard situation, according to the operation of the power plant, is the summer maximum water temperature period. Namely a small possible rise of the high temperature increases rapidly the number of critical operation states, whereas a higher rise of temperature of the small discharge in autumn or winter time is not so significant.

Operational Conditions Affecting Thermal Loading

From our point of view the most important characteristics of the operation are the following:

The rate of heating of the cooling water, the value of the temperature difference (Δt) is a result of energetic optimization. The temperature difference of 9 °C in the condensers of the Paks Nuclear Power Station is a nominal value which is required by energy production, but it can possibly be changed at economical sacrifices.

The nominal value of the temperature difference is modified because the delivery head of the pumps changes according to the water level of the Danube, therefore the efficiency and the discharge capacity of the pumps also change according to the characteristic curves. Accordingly, during the investigations of the critical cases of thermal loading we have to consider the temperature difference not as a strictly declared value but as an optimum of a certain range, which must be determined according to aspects of the economic and ecological system.

On the one hand, it means that during the high–water period of the Danube (at decreased delivery head) the capacity of the pumps is greater than the discharge required for the optimum of the whole energy production system. On the other hand, during the low-water period, giving up the pumping optimum, adjusting the inlet conditions of the pumps the delivery of cooling water should be increased *(Fig.5)*. It means the utilization of the actual operational reserve. This solution is also prosperous to give a smaller thermal shock to the organisms transported through the system.

The checking, changing and maintenance of the heating elements of the nuclear power station is carried out yearly, according to a plan.

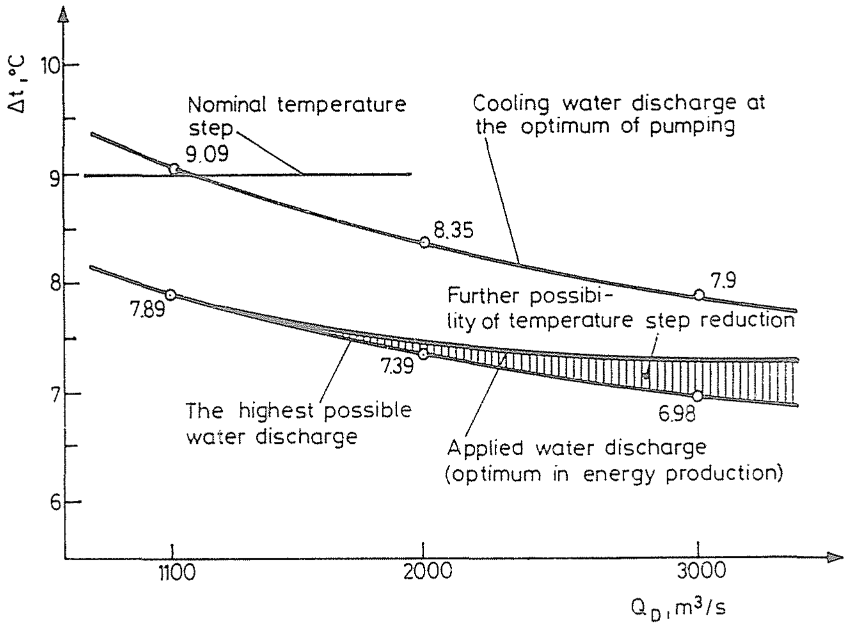

Fig. 5.

The 30–60–day long stops of the blocks are scheduled from April to November considering the energy demand of the country. Thus, with agreement of the energy industry it can be declared in the water licence that during the critical summer period one block of the power plant should be stopped. This can assure a lower cooling water demand of 70–75 m^3/s instead of the maximum 90–100 m^3/s at present. Later, after the completion of the power plant this will be 155–185 m^3/s instead of the nominal 210 m^3/s cooling water discharge.

The economic aspects of decreasing the temperature difference can be examined with the evaluation of the efficiency of the whole energy production process. It can be proved that the decrease of the temperature difference results in higher efficiency. It means that only a part of the excess energy consumption results in excess costs, therefore they are negligible.

It can also mean that the power plant applies this operation mode – without any water quality regulations and controlling – not only in the critical high–temperature days but during the whole summer period in order to increase its own efficiency. Thus the operation decreases the negative effects of thermal loading already now, so the water temperature in the checking point does not exceed the limit of 30 °C.

Summary

Thermal loading is a result of the described characteristic of the nuclear power station. To reduce the risk of thermal pollution, the following statements can be made:

– Considering the capacity of the Danube, the thermal loading by the Paks Nuclear Power Station should be solved both at the present and at the planned capacity.

– Considering the ratio between the discharge of the Danube and the thermal loading of the power station, we have to protect primarily the cooling water flowing through the power plant and we have to ensure its earliest possible mixing with the cooling water of the Danube. From this point of view the cooling tower built in the system of warm water return is not the only and best solution. As long as the Danube is not loaded by several power stations, the main problem is not the warming of the whole water body of the river but the protection of the stream flowing through the cooling system. Thus, all solutions that rapidly decrease the excess temperature of the cooling water leaving the condensers (e.g. cold water mixing, series of weirs, etc.) are competitive with the cooling tower, which has extremely high costs of investment and operation and also causes mechanical impacts. Therefore the research for right solutions and the utilization of local potentialities are significant tasks of further investigations.

– Considering the limit of 30 °C (possibly valid in the future as well), the highest 21–25 °C temperature of the Danube and the 9 °C nominal temperature difference of the power plant, it is evident that solutions must be worked out for the temporary decrease of the temperature difference in order to observe the regulation limit in the future. It means such operational solutions when the economically optimal temperature difference of 8–9 °C can be temporarily reduced in case of risk of thermal pollution. This solution is inseparable from the increase of costs of pumping ensuring the water supply of the power plant.

– Thermal loading may be environmentally dangerous, not by itself but together with other pollution in the Danube. Therefore the evaluation of the thermal loading can only be made with full knowledge of the water quality changes of the Danube. Since the quality is influenced by several factors, it will be increasingly required to join demands of energy production and water quality management through a flexible, efficient co-operation.

– It is to state that further research is required first of all in investigation and revision of the standard hydrological-operational stages and to find right solutions to the rapid decrease of the excess temperature of the heated cooling water.

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