METHOD OF CALCULATING THE COST OF WATER AND ELECTRICAL POWER FOR NUCLEAR DESALINATION SYSTEM

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A method of determining the economic factors of double-purpose systems is set out; this provides separate and fairly strict determinations of the expenses involved in the production of electrical power and fresh water, and hence enables their net cost to be ascertained. The effect of the main parameters of the system on the net cost of fresh water is examined. The economic indices of double-purpose systems with reactors of various types are calculated for several values of their thermal power.

Preliminary technical-economical studies [1-4] have shown that the use of nuclear reactors for desalinating salt water and producing electrical power is one of the most promising fields for the use of these systems.

From the technical point of view the possibility of using nuclear reactors as sources of heat for the simultaneous production of fresh water and electrical power raises no doubts. The economic aspects of using nuclear reactors for this purpose are considerably more complex, since the scale of their use will depend substantially on the economic competitiveness of such systems in relation to ordinary heat sources. Hence it is of particular present interest to study the economics of double-purpose nuclear reactors.

The degree of competitiveness of nuclear-power desalination systems is affected by the specific siting of the plant, the demands for fresh water and power, and also the question of optimizing the level of economy.

Clearly the most promising system for these purposes is a nuclear reactor characterized by a low value of the fuel component of the cost of power, and specific capital expenses which fall more sharply as the specific thermal power increases. Naturally for such reactors an increase in the power-utilization factor is especially important, since the fuel component is independent of this, while the capital component is inversely proportional to it. The possibility of storing the fresh water produced means that, in principle, there is a good possibility of exploiting a nuclear desalination plant with an extremely high power-utilization factor; this creates favorable conditions for the competitiveness of nuclear systems in relation to ordinary sources of heat.

Among the types of reactor most developed and adopted in the Soviet Union we must primarily mention the I. V. Kurchatov Beloyarsk Atomic-Power Station [5, 6], the Novo-Voronezh Atomic-Power Station [7], and to a smaller extent also the Shevchenkov Atomic-Power Station [8].

The only common factor for all desalination plants with such reactors is the principle of the combined development of electrical power and heat at a potential suitable for the heating steam used in desalinizing the water. This potential is determined by the operating conditions of the distillation plant.

An important index for power desalination systems is the quantitative relation between the two products, electrical power and fresh water. For a certain temperature level of the heating steam used in freshening the water, this ratio depends on the initial parameters of the cycle; the higher these are, the greater will be the relative yield of electrical power. Hence systems with reactors of the Beloyarsk or Shevchenkov types will be characterized by a considerably higher proportion of usable electrical power than those with Novo-Voronezh-type reactors. This fact must be borne in mind when selecting the plant for a specific region, since the requirements for electrical power and fresh water may differ considerably for different regions as well as their cost.
An important question is also that of the specific power of the reactor. The problem of increasing this is most simply solved for reactors of the channel type.

**Methodical Requirements for Determining the Cost of Fresh Water and Electrical Power**

The existence of two forms of production in the double-purpose system creates a series of difficulties and arbitrary aspects in the calculation of its economic indices. In various countries, several methods of calculating the cost of electrical power and fresh water are used. For example, the most widely used is the method of naming (fixing) a value for the electrical power, considered as a side product of the desalination nuclear plant [2]. If the double-purpose plant is included in a power-supply system, the price for the electrical power produced is fixed by starting from the lowest price of electrical power from other sources in the supply system. This gives the lowest value of the arbitrary cost of the electrical power. If, however, the double-purpose nuclear plant is set up in a region where there is no electrical system or no power stations at all, then the price for the electrical power produced is fixed by considerations of economic conditions. This gives the highest arbitrary price of electrical power.

With this method of calculation, the cost of fresh water is determined by the yearly expenses of operating the double-purpose plant, less the sale of electrical power at the arbitrarily-fixed price.

For conditions in the USSR, from the popular-economy point of view, both forms of production from the double-purpose nuclear station are equally important, and another method of calculating the economic indices is required; this must enable the costs of electrical power and fresh water to be estimated individually and prices fixed in accordance with this. We have developed such a method and shall now indicate its principles.

In general, the annual cost of production for the nuclear double-purpose station is made up of the cost of production of fresh water (\(S_{f,w}\)) and electrical power (\(S_{el}\)):

\[
S = S_{f,w} + S_{el} \text{ roubles/year.} \tag{1}
\]

The cost of production of fresh water may be determined as the sum of the costs of the essentially evaporating part of the system (\(S_{e,p}\)) and those of the heat used in the heating steam (\(S_{h,s}\)):

\[
S_{f,w} = S_{h,s} + S_{e,p}. \tag{2}
\]

The value of \(S_{e,p}\) is determined by amortized deductions from the investment in the equipment of the evaporating part, expenses in repairs, wages, etc.

The problem is to determine the cost of production of the heating system.

For a fixed thermal power of the nuclear reactor (and its parameters) used in the double-purpose plant, the electrical power will always be lower than when this reactor operates in a condensation atomic-power station (APS). This is because the production of fresh water requires heating steam at a potential which could have been used in the condensation turbine. In other words the yield of heating steam is associated with a diminished yield of electrical power. Hence part of the costs of production of electrical power in a condensation APS (the part associated with the underproduction of the double-purpose station) must be treated as a cost of production for the heating steam.

Hence the annual costs of production for the heat in the heating steam may be determined as the difference between the costs of production of electrical power for the purely-condensation APS and those of the electrical power (at the same net cost) developed by the double-purpose station, i.e.,

\[
S_{h,s} = C_e(W_c - W_d). \tag{3}
\]

Here \(C_e\) is the net cost of electrical power when using the given reactor in a condensation APS in kopecks/(kWh), \(W_c\) is the electrical-power yield in a condensation APS in kWh/year, \(W_d\) is the electrical-power yield using the same reactor in the double-purpose plant, also in kWh/year.

In determining the costs of production of fresh water, we must calculate the annual production costs (and hence net cost) of fresh water without counting the cost of the heat, and also the production costs of the heat in the heating steam associated with the underproduction of electrical power, regarding its net cost as the same both for the condensation APS and for the double-purpose station. Strictly speaking, the latter is only valid if the transformation from the condensation APS to the double-purpose plant is not accompanied by the elimination of some equipment peculiar