Problems of reliability and economy work of thermal power plants water treatment based on baromembrane technologies

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Abstract. The introduction of baromembrane water treatment technologies for water desalination at Russian thermal power plants was beganed more than 25 years ago. These technologies have demonstrated their definite advantage over the traditional technologies of additional water treatment for steam boilers. However, there are problems associated with the reliability and economy of their work. The first problem is a large volume of waste water (up to 60% of the initial water). The second problem is expensive and unique chemical reagents complex (biocides, antiscalants, washing compositions) is required for units stable and trouble-free operation. Each manufacturer develops his own chemical composition for a certain membrane type. This leads to a significant increase in reagents cost, as well as creates dependence of the technology consumer on the certain supplier. The third problem is that the reliability of the baromembrane units depends directly on the water preliminary treatment. The popular pre-cleaning technology with coagulation of aluminum oxychloride proves to be unacceptable during seasonal changes in the quality of the source water at a number of stations. As a result, pollution, poisoning and lesion of the membrane structure or deterioration of their mechanical properties are observed. The report presents ways to solve these problems.

Introduction
Baromembrane technologies such as new water treatment technologies have found their wide application in industry and energy, and are now very popular. This is due to their high automation level, which makes it possible to reduce labor costs and improve the production culture, as well as improve the region ecological state.

However, in the course of these installations operation, problems related to the reliability and economy were identified.

1. The first problem is a sewage large volume
Reverse osmosis gives a large volume due to a low utilization rate of the source water. In some cases, up to 60% of the source water is discharged into the sewage system. This makes baromembrane technology inefficient in terms of water consumption [1]. To solve this problem in part, the following methods are used [2]:
   • thermal distillation of reverse osmosis sewage;
   • wastewater treatment in the electro-ionization unit;
   • use of "booster" unit (waste water is directed to an additional reverse osmosis unit);
   • creation of flow recirculation circuits.
All these decisions imply substantial capital costs for their implementation.
Department of Thermal power stations of Kazan state power engineering university developed and patented [2-5] drainless water desalination schemes for thermal power plants. One such scheme is shown in figure 1.

![Diagram of water treatment for a thermal power plant](image)

**Figure 1.** Water treatment of thermal power plant.
I – pretreatment unit; II – softened water unit; III – reverse osmosis unit; IV – ion exchange unit.
1 – feed water stream; 2 – clarifier; 3 – coagulated water tank; 4 – mechanical filter; 5 – Na-cationite filter; 6 – softened water tank; 7 – reverse osmosis; 8 – H-cationite filter; 9 – OH-anionite filter; 10 – deaerator; 11 – high-pressure steam boiler; 12 – tapping softened water stream from the softened water tank; 13 – reject stream from the reverse osmosis unit; 14 – permeate stream from the reverse osmosis unit; 15 – desalted water stream supply from the OH-filter; 16 – deaerated water stream; 17 – line of regeneration water stream from the H-filter; 18 – line of regeneration water stream from the OH-filter; 19 – neutralizer tank; 20 – installation for the chemically purified water preparation; 21 – line of the rinsing water stream from the mechanical filter; 22 – line of removing the regeneration solution stream from the Na-cation filter; 23 – washing solutions tank; 24 – line of washing solutions stream to the clarifier; 25 – line for the discharge of sludge from the clarifier; 26 – line for pH correction of softened water.

This scheme drainless is achieved by using wastewater as feed water for the heating system after pre-mixing with softened water.

Similarly, the waste volume can be reduced by revealing the hidden internal reserves of the water treatment scheme, without using significant capital and additional operating costs. It is possible to identify such reserves by developing of a mathematical model of the water treatment scheme [2, 7] and optimizing of water flows within the circuit (figure 2).

2. **The second problem is expensive and unavailable chemical reagents**

In spite of the fact that baromembrane technology is considered to be a non-reagent desalting method, a complex of expensive and unique chemical reagents (biocides, antiscalants, washing compositions) is required for its stable and accident-free operation. These reagents uniqueness lies in the fact that each manufacturer develops its own chemical composition, for a certain type of membrane. This leads to their significant rise in price, as well as creates the consumer dependence on a certain supplier.

The solution to this problem is the development of cheap, affordable and unified chemical reagents, the production of which is based on experimental studies of the various washing effectiveness compositions.
3. The third problem is the preliminary water purification

Operational experience has shown that a prerequisite for normal operation of reverse osmosis plants is deep water preliminary treatment from hardness salts, fine dispersion, colloids, iron and organic compounds.

At the pre-cleaning stage power plants coagulation with aluminum oxychloride is traditionally applied [8]. However, this method is effective only with a low value of the feed water [9], a organic compounds small content with the optimal pH-value strict maintenance. According to the experiment [10], in the organic complexing substances absence, the range of formation of a stable aluminum hydroxide precipitate with a minimum content of soluble aluminum forms (3+) is pH-value 6.0 - 6.8 (figure 3).

In the presence of complex-forming organic substrates such as fulvic and humic acids, the distribution character varies considerably (figure 4). In the period of high water, when the content of humic substances in the river water increases significantly (by two or more times) due to peat flushing into rivers, the aluminum solubility due to complexation reactions increases and it is possible to break through the filters practically at any pH-value.

This effect has a significant effect on the membrane modules reliability - their productivity is reduced, the number of chemical washes is increased, the normative service life is reduced due to sedimentation in the pores and on their surface.
Figure 3. Distribution of equilibrium aluminum (3+) soluble and insoluble forms in an aqueous solution corresponding to the Volga water in the winter time in the absence of organic impurities. The initial aluminum salt content is $5 \cdot 10^{-6}$ M.

Contamination, poisoning and membrane structure disturbance or their mechanical properties deterioration occurs.

Figure 4. Distribution of equilibrium aluminum (3+) soluble and insoluble forms in an aqueous solution corresponding to the Volga water during the flood period. The initial aluminum salt content is $5 \cdot 10^{-6}$ M.

It is interesting to note that iron (II) sulphate in its coagulation area ($\mathrm{pH} = 10 - 10.2$) does not have such a disadvantage as increased solubility under the action humic substances.
Thus, it is possible to solve the problem of baromembrane modules reliability by using coagulation with iron salts in the pre-treatment stage [3-6]. The quality of softened water from such pre-cleaning allows, after admixing the reverse osmosis concentrate and spent regeneration water from H- and OH-filters (figure 1), to use it as initial water for the chemically to treated water installation. It significantly increases the economic characteristics of the water treatment scheme.

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