FRESHWATER SUPPLY FOR SHIPS DESALINATED BY METHOD OF ELECTRODIALYSIS

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Abstract: *For the purpose of freshwater supply for ships, we have explored the desalination process of sea water by electrodialysis. From the analysis of the obtained results, the desalination process of the Black Sea water by electrodialysis has been explored. The average salt content of the Black Sea water is 15-16 g/l, and the global ocean water - 35 g/l, while the salt content in water from the Baltic Sea is 5.77 g/l. The Black Sea water was diluted with fresh water up to a concentration of 5.77 g/l.*

Electrodalysis is the most effective method for desalination of natural waters with low salinity. So, we have taken water equivalent to salt water content of the Baltic Sea water. Desalination of this water is effective and requires little energy. To reduce salt content of sea water, the separation was carried out on reverse osmosis membranes with a selectivity of 70%, and then the penetrant was separated by electrodialysis. Every 5 minutes, the solution loses 55.8% of salt. During the treatment (45 min), water is desalinated up to a concentration of 51.2 mg/l, and it can be used for industrial (technical) or household purposes. Calculation have shown that the selectivity of membranes during desalination was 99.11%.

As a result, on the basis of theoretical and experimental studies of seawater desalination by electrodialysis, there have been developed the principal circuits of the system of environmental safety of ballast water and water treatment facilities in the port, for environmental safety of ballast water and for obtaining industrial water.

KEYWORDS: *DESALINATION, ELECTRODIALYSIS, CONCENTRATION POLARIZATION.*

1.Introduction

The problem of fresh water supply for ships have been existed over the course of a history of the maritime fleet. The water on ships has always been limited. This was due to a deterioration of water quality during a long-term storage, as well as due to the limitation of fresh water tank volumes on ships. Provision of water through its obtaining from the shore cannot be considered to be economically justified, and this is carried out in exceptional cases, since its cost at the coastal provision stations increases sharply (coastal water is 5-15 times more expensive than desalinated water), and when refueling in foreign ports requires large currency spending (the cost of 1 ton of fresh water now amounts on average 10-15 USD). Therefore, the feasibility of desalination of sea water on ships is obvious and is beyond questions. It has been established that the freshwater supplies on ships depend on their type and the cruising radius and make up 2-8% of deadweight.

In recent years, both in domestic and in foreign practices, a significant number of freshwater generators have appeared, the principle of operation and methods of obtaining water in which differ significantly from the earlier design solutions. The ship power plants are more and more equipping with the reverse osmosis freshwater generators, characterized by high ecological quality. The electrodialysis type installations, especially intended for small vessels of the fishing fleet also attract attention.

We have studied the process of sea water desalination by electrodialysis and the problem of freshwater supply for ships.

Just like in any other liquid phase process, in this case, concentration polarization plays an important role as well. In presence of concentration polarization, there occurs an increase in gradient of the concentration potential on the ion-exchange membrane. At this time, diffusive ion leakage is growing in membrane. Thus, purely ionic transfer for a given electric potential is several times decreased. During such concentration polarization there is considerably increasing in the diluted solution the difference of the ohmic potential as well, since as a rule, the ohmic resistance of the electrolyte solution is inversely to its ionic concentration. Since the dissolved electrolytes flow, which is intended for separation, is approximately proportional to current density, the electric power consumed for separation of the solute's volume unit goes up proportionally to current density. On the other hand, the fixed cost of the electro-membrane module for the given quantity of solution intended for separation is often reducing with the increase in current density. In consequence of above stated, there is always existed the optimal current density, when the total cost of power inputs and capital expenditures is minimal. At the same time, this optimal value often exceeds the highest possible value, which in practice is obtaining for diluted solution during motion at high-velocity in narrow channel. **[1,4].** Thus, and so, in the first place the working current density is limited by concentration polarization, but not due to process efficiency. Proceeding from this, it is reasonable to intensify the process through the reduction of adverse effect of concentration polarization that is possible to achieve by action of pulsed pressure in the channel between membranes [2].

2. Preconditions and means for resolving the problem

The assigned task requires conduction of theoretical and experimental investigations for calculation and designing the high-performance electro-membrane devices that is of high topicality and represents scientific novelty.

A mathematical model of non-steady and non-isothermal electro-membrane process we've developed, with account for simultaneous action of gravitational and forced convections, when meeting the electrical neutrality condition, under the influence of pulsed pressure, allows for implementing electrodialysis processes on the rationally designed electro-membrane devices, with optimal regime parameters [3].

An experimental study of electrodialysis was carried out on a laboratory installation (Pic. 1) for the purpose of studying the processes of desalination, concentrating solutions, synthesis of new substances, pH correction, obtaining highly demineralized water, amino acid separation, acid and alkali extraction from solutions of the corresponding salts, removal of inorganic compounds from organic solutions.

The installation is manufactured in the form of a wall-mounted bench (1) on which there are mounted: the unit of mechanical filtration of solutions (2), electromembrane device (3), pump unit (4) with the electrical power supply sources (5), hydraulic panel with rotameters (6), manometers (7), control valves (8), sampling equipment valves (9) and an electrical power supply source for the device (10). The working tanks are (11) are with the outlet valves. In the upper part of the working tanks, it is necessary to provide the inlet holes for filling working solutions with a funnel. The device is installed on a worktable by analogy with the example of placement shown in Figure 1.

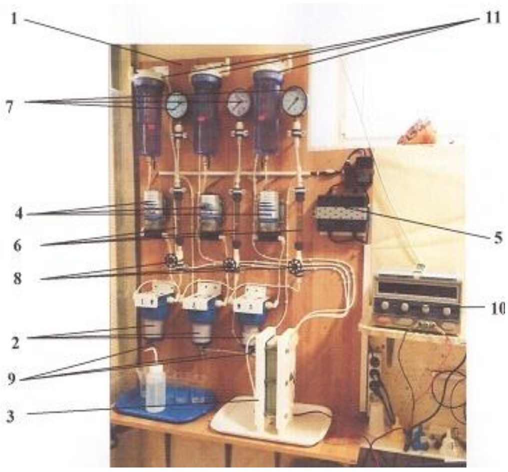

Fig.1. *A laboratory installation of electrodialysis .*

For the purpose of seawater desalination by membrane technology, the paper dwells on studying the electrodialysis processes of 20,10 and 1% sodium chlorine solutions. As the model solutions, we used NaCl solutions of different concentrations; the direct current source is a rectifier HY3005C, which allowed for obtaining the current density of 15 mA/cm^2.

The analysis of the test results shows that when the initial concentration of NaCl salt is 20.85 g/l. The NaCl solution loses 20% of NaCl during the first 15 minutes, within 20 minutes, the solution begins to clear faster, losing 70% of NaCl. In the last 5 minutes, desalination slows down again. The solution loses only 5% of salt. Current almost constantly, but suddenly starts to reduce. This is because the low-concentration electrolyte is poorer than the high-concentration electrolyte. Finally, the salt content of the concentrate is 31.0 g/l, which is close to the limit of NaCl salt dissolution. This means that the process occurs without dilution of the concentrate, and crystalline may appear in the salt solution, and it is possible to obtain two products: NaCl salt and water.

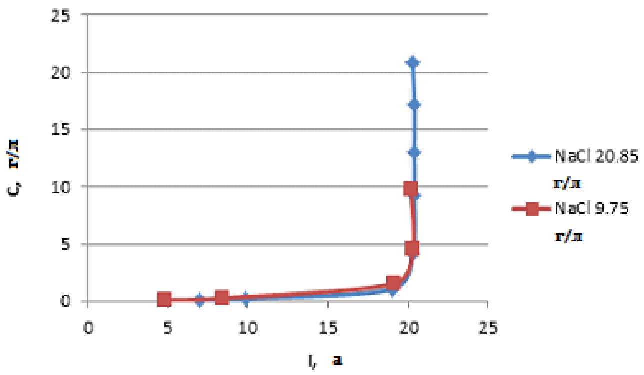

Fig.2. *NaCl concentration depending upon a current intensity*

When the concentration of NNaCl was 9.75 g/l, for the first and last 5 minutes, the concentration was reduced to 50%, for the test from 10 to 15 minutes, the concentration was decreased by 80%. Entirely in the process of electrodialysis, the concentration of the solution was decreased from 9.75 g/l to 0.091 g/l. In addition, it can be noted that a high degree of purification is observed when the concentration is 1 g/l.

Figure 2 illustrates the dependence of the NaCl concentration on the a current intesity, from which it can be seen that the curves are practically identical. This can be explained by the fact that the chemical compositions of liquids that need to be analyzed are the same, that is. they conduct electric current in the same way.

At significantly lower concentration of the solution, the salt content in the solution is 1.09 g/l and decreases by 50% on average every 5 minutes. Based on the results, we can say that if a salt solution with NaCl concentration is 1 g/l, in order to speed up this process, it is necessary to use less selective membranes, increase the voltage or take another new technological solution.

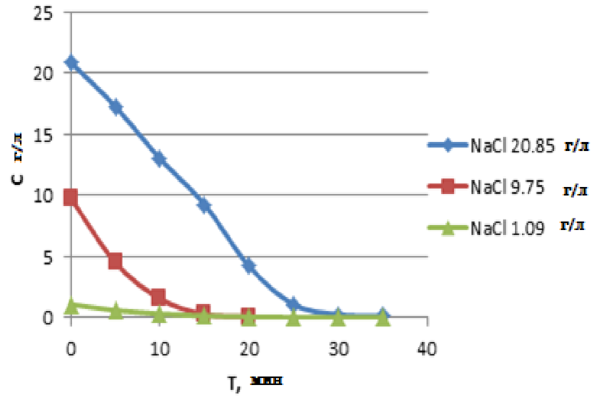

Fig.3. *The rate of electrodialysis of NaCl*

Figure 3 illustrates the rate of electrodialysis of a NaCl solution of various concentrations. We can see that when the initial concentration is 9.75 g/l, the solution is cleared. At this time, the first test (initial concentration - 20 g /l) of NaCl concentration in the solution reaches 10 g/l. Thus, it can be concluded that membrane is more effective, when the NaCl concentration varies from 10 g/l to 1 g/l.

Comparison of the curves presented in Figure 3 demonstrates that the experimental results are not only in a qualitative, but also in a very good quantitative coincidence with the data of theoretical calculations. This means that the mathematical models we are using, adequately describe the nonstationary isothermal processes occurring in the chambers of electromembrane systems.

3. Conclusion

Based on the analysis of the results obtained, we have studied desalination of the Black Sea water by electrodialysis. The average salt content of the Black Sea water is 15-16 g/l, in the global ocean -35 g/l, while waters of the Baltic Sea – 5,77 g/l. Water of the Black Sea was diluted with freshwater to a concentration of 5,77 g/l. The results of the desalination process of the Black Sea water by electrodialysis are presented in Table 1.

Electrodialysis is most effective in desalination of natural waters with low salinity. Thus, we took water with salt water content equivalent to the Baltic Sea water, and desalination of this water is effective and does not require much energy. To reduce salt content of sea water, the separation was carried out on reverse-osmosis membranes with selectivity of 70%, and then the penetrant was separated by electrodialysis. Every 5 minutes, the solution loses 55,8% of salt. During the treatment (45 min), water is desalinated to 51.2 mg/l concentration and can be used for the industrial (technical) purposes or domestic consumption. Calculations have shown that during desalination, selectivity of membranes was 99,11%.

The water testing results (diluted to 5,7 g/l).

On the basis of theoretical and experimental studies of seawater desalination with electrodialysis, we have developed the flow diagrams of a system environmental safety of ballast waters and water treatment facilities in the port, for obtaining industrial water and freshwater supply for ships.

4. References

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