A phenomenological approach to optimize work of water desalting devices and technology of their creation. II

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There are many papers that research in depth the work of water desalting devices at some limitations on possible character of processes in them (for example / 1, 2 /). Nevertheless, at creation of a concrete desalting device there is always the necessity to have a rather simple and flexible phenomenological approach which is not connected with strict limitations on character of processes that go in the device and simultaneously allows us to optimize technical characteristics of the device and technology of its creation.

To solve some optimization tasks for water desalting devices we can use the phenomenological approach in which relevant quantities, that we need to optimize, can be presented in the form of functions of parameters of an equivalent electric circuit of the device and some parameters of device operation / 3 /.

Selecting different equivalent electrical circuits in the framework of the phenomenological approach we can take into account influence of different factors on the optimal value of the quantities of interest. However, staying only in the framework of equivalent electrical circuits we can't get, for example, the real extent of water purification by the device and change of purification during the purification cycle. Nevertheless, the approach allows us to consider many practical tasks of water desalting device operation and the results presented in / 4 / show undoubted fruitfulness of this approach. If we add in consideration a simple equation for the concentration of the ions to be removed in the purified water, we will get a relatively simple and convenient way for complete optimization of the main relevant quantities of water desalting device operation / 5 /.

Here, we present some other results obtained by now in the framework of the same approach. The operation of a water desalting device was researched for a general case of the nonlinear inner medium of the device when its inner resistance depends on the time during the working cycle and the current flowing through the device. The calculations was performed for the simplest equivalent electrical circuit with capacitance C and resistance R(I, t) and for the periodic rectangular-form-with-change-of-the-polarity voltage applied to the device. The quantities of interest were the productivity of the device, the amount of moles of the ions that was removing from the purified water per unit time; the spent electrical power; the ratio of these two quantities and the times of turning of the capacitance charge into zero during the cycle. The amount of the produced purified water per unit time that the device could have provided in the case of 100% purification is then equal to the productivity of the device divided by the initial concentration of the ions to be removed from the water that is being purified.

The device productivity was presented in the form of CV/(Fz)/T times a function of dimensionless parameters of the problem. Here, C stands for the electrical capacitance of the circuit, V stands for the amplitude of the applied voltage of device operation, T is the time of the cycle of device operation, F and z are correspondingly the Faraday's number and absolute value of the charge number for ions to be removed that is assumed to be the same for all of them for simplicity. The spent electric power was presented in the form $CV^2/ 2T$ times some function of the dimensionless parameters mentioned above. And the productivity of the device per unit of the spent power was presented in the form of 2/(FzV) times ratio of two dimensionless functions mentioned above.

The obtained expressions for the dimensionless functions of the quantities of interest (the productivity, the spent electrical power, the productivity per unit of the spent power and the times of turning of the capacitance charge into zero during the cycle) were found to be functions of two dimensionless parameters, p1 and p2.

$$p1 = \int_0^T \frac{dt}{R(I(t),t)C}$$

$$p2 = \int_T^{2T} \frac{dt}{R(I(t),t)C}$$

Here, 2T is the period of the applied voltage. The time from 0 to T is the time during a half cycle during which there is an interval of purification. For the symmetric-on-operation cases of two half cycles and in the case of using of “dry” ideal ion selective membranes, the discussed dimensionless functions depends only on one of the parameters, p1.

On the basis of the obtained results, for the researched type of the applied voltage, we can select optimal values of the p1 and p2 for any given requirements of device operation. The values of these parameters for a current pilot sample of the device can be obtained from an experiment. Difference of the optimal and current values can prompt direction of change of the current technology. Repeated experiments for device pilot samples created on new changed technologies can allow us to verify our choice for optimization and give us some estimation of suitability of the selected equivalent circuit.

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References

1. A. M. Johnson and John Newman, J. Electrochem. Soc. 1971, 118, 510.
2. Kun-Lin Yang, Tung-Yu Ying, Sotira Yiacoumi, Costas Tsouris, and E. Steven Vittoratos, Langmuir 2001, 17, 1961.
3. A.Z. Shekhtman, The paper of this 203rd Meeting of The Electrochemical Society, Paris 2003.
4. The report on the work done for Material Methods LLC (Newport Beach, CA) in August-September, 2002.
5. The report on the work done for Material Methods LLC (Newport Beach, CA) in September-October, 2002.

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