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Methodical Approach for Selection of Design Parameters of Electrodialisys Diaphragmless Apparatus for Regeneration of Electrolyte-Containing Solution

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Abstract

In the study the initial conditions of use of electrodialyzer with insulating screens instead of the membranes are specified. The methodical approach of determination of the design parameters of this unit is suggested.

***Key words**: electrodialysis, electrochemical regeneration, electrolytes, membranes, insulating screens, constructive parameters*

Timeliness

One of the most important environmental problems of metallurgical industry is the handling of environmentally hazardous waste solutions containing electrolytes. In the studies [1, 2] an improved method of electrochemical regeneration of these solutions and the device for its implementation is suggested, which represents by itself an electrodialyzer with insulating screens instead of the membranes (Figure). The suggested method and equipment allow to avoid the disadvantages of the classical electrodialysis: high cost of electricity, concentration polarization, the use of expensive membranes. The productivity increase and cost reduction of the regeneration process is achieved by simplifying the design of the apparatus and eliminating the use of porous partition walls (membranes), which ensures the exclusion of their clogging and therefore eliminates the need for periodic cleaning and replacement of partitions. Reduction of energy costs is achieved due to the absence of membranes, due to which it is not necessary to overcome their resistance. The need for advance preparation (cleaning) of the recovered electrolyte from the suspended particles that cause clogging of the membrane pores is eliminated. A change in the method of selection of electrodialysis products eliminates the need for chemical-resistant equipment for pumping of regeneration products.

Statement of the problem: the practical implementation of the suggested method and the equipment caused the need to determine the optimal constructive dimensions of the elements of the main unit (electrodialyzer).

The aim is to offer the method of calculating constructive dimensions of an electrodialyzer with insulating screens instead of the membranes.

The Main Part

1. The Initial Conditions

1.1. The electrochemical regeneration is performed in the effluent or waste electrolytes of <u>the same</u> technological process (without mixing of waste solutions containing waste from different production).

1.2. The technological process is usually performed based on the <u>scheduled technologies</u> (e.g., metal etching technique using acidic electrolytes, followed by washing of the parts with the amount of water scheduled by the manual) <u>with known maximum possible percentages</u> of the pollutants in the washing liquid.

1.3. As the basic designs for the installation of the units of electrodialysis separation technology the existing technological capacities are used (for example, the existing workshop septic tanks) with known structural dimensions. In the design of new production the design dimensions of basic technological capacities are carried out by well-known design methods (for example, by the method of determining the required capacity of workshop septic tanks [3]), taking into account of projected production.

1.4. Electrical and technical parameters of the structural elements are determined by the current regulations on electrical safety: the requirement of SAE (Electrical Code, Art.1.1.32 [4]) for the safe voltage of direct current electric equipment is up to 110 V. However, given the increased risk of projected technology and in order to reduce current load depending on electrical conductivity (concentration) of the electrolyte, we can recommend the use of stabilized DC power supplies with a maximum output voltage of 60V according to the recommendations of State Construction Code V.2.5-27-2006 "Protective measures of electrical safety in electrical units of buildings and structures", Art. 2.3.1.1 [5].

1.5. The theoretical amount of electricity Q_{theor} consumed for the transfer of 1 g-eq of substance according to Faraday's rule is equal to 26.8 A·h or 96491 Cl, and the amount of electricity (A·h) required for demineralization of ^{3} of water from the concentration C_1 to a concentration C_2 (g-eq/m^3) will be determined by the formula

$$Qtheor = (I \cdot t)theor \cdot (C1 - C2), \quad (1)$$

where I is the power of current, flowing through the solution, and t is the time, hr.

In practice, at the implementation of electrodialysis there was observed a loss of voltage to overcome the ohmic resistance in the cells and at the electrodes, so the actual amount of consumed electricity is more than theoretical. The degree of sophistication of electrodialysis is characterized by *ratio of current output* h_e. The theoretical value of h_e ranges from 0.3 (for the inactive membranes) to 1.0 (in an ideal process). The losses of voltage on the electrodes are substantially greater than the losses for the ohmic resistance in the solution. To reduce these losses to 3-5% multichamber electrodialyzers are applied, consisting of a large number of chambers (up to 300 pcs). It is also necessary to ensure an acceptable time of electrodialysis at given values of low voltage of power supply, at which the speed of movement of ions is not more than 0.004 cm/s (it is necessary to provide the shortest possible distance between the individual cells of an electrodialysis – the screen with the electrode).

2. Calculation Method

2.1. The structural dimensions of separating screens are determined by the design sizes of basic technological capacities (calculated volumes and depth of craft tanks) and the estimated percent concentration of pollutants in the regenerated solution. Thus:

2.1.1. The height of the screens is determined by the depth of technological capacity: the size of their immersed part should be less than the depth of the capacity:

- by the value of the planned (defined constructively taking into account the planned frequency of cleaning) acceptable level of the insoluble residue settled on the bottom;

- as well as by the value providing clearance hole with the area not less (or equal) than the calculated area of screen cross section (see 2.1.2 below).

The height of the screen above the highest possible level of neutralized solution should provide an exception of overflow into the interior capacity both of the solution and the floating pollutants on its surface (it is defined constructively).

2.1.2. The total internal volume of separating screens from the bottom to the level of neutralized (recovered) solution (overflow holes level) (V_{int}) is determined by multiplying the basic technological capacity volume (V_{bath}) by the percentage concentration of pollutants:

$$V_{int.} = V_{bath} \cdot \omega , \quad (2)$$

where ω is a percentage concentration of pollutants, expressed as a decimal fraction.

2.1.3. The volume of individual display is obtained by dividing the total internal volume of the screens by their number (see section 1.5 above), which is defined structurally: by the surface area of the main technological capacity and the minimum sizes of such elements of the electrodialyzer as electrodes (their smallest possible outer diameter). At that time the even distribution of screens with the electrodes is planned by the area of the main technological capacity. The inner diameter of the separation screen can be obtained by the known geometric formulas for calculation of the cylinder volume taking into account the deductible volume of the electrode.

2.1.4. The calculation of the required value of power supply voltage U and current I, flowing through the electrodes (for approving the acceptability of the selected cross-sections of the electrodes) is performed by the required time cycle, determined by the rate of flow of waste effluent from basing on the formula (1)

$$I = \frac{Q_{\text{theor}}.}{t_{\text{theor}} \cdot (C_1 - C_2)}, \quad (3)$$

$$U = I \cdot R, \quad (4)$$

where R is the resistance of current circuit (it is determined taking into account the specific resistivity of the solution).

Conclusions

1. An electrodialysis device with insulating screens instead membranes can be applied for regeneration of waste water and process solutions formed in various industries and having various qualitative and quantitative composition of the contaminants. Thus, the geometric dimensions of the electrodialysis device can not be unified.

2. The design parameters of the elements of electrodialysis unit with insulating screens instead of the membranes are determined by calculation for each case, depending on the size of the base technological capacities and the concentration of pollutants in the regenerated solution.

3. The height of the insulating shield depends on the depth of the technological capacity to defend the level of sediment and the size of the cross section of the screen. The number of screens is determined structurally and depends on the surface area of the main storage vessel, the number and the size of the electrodes.

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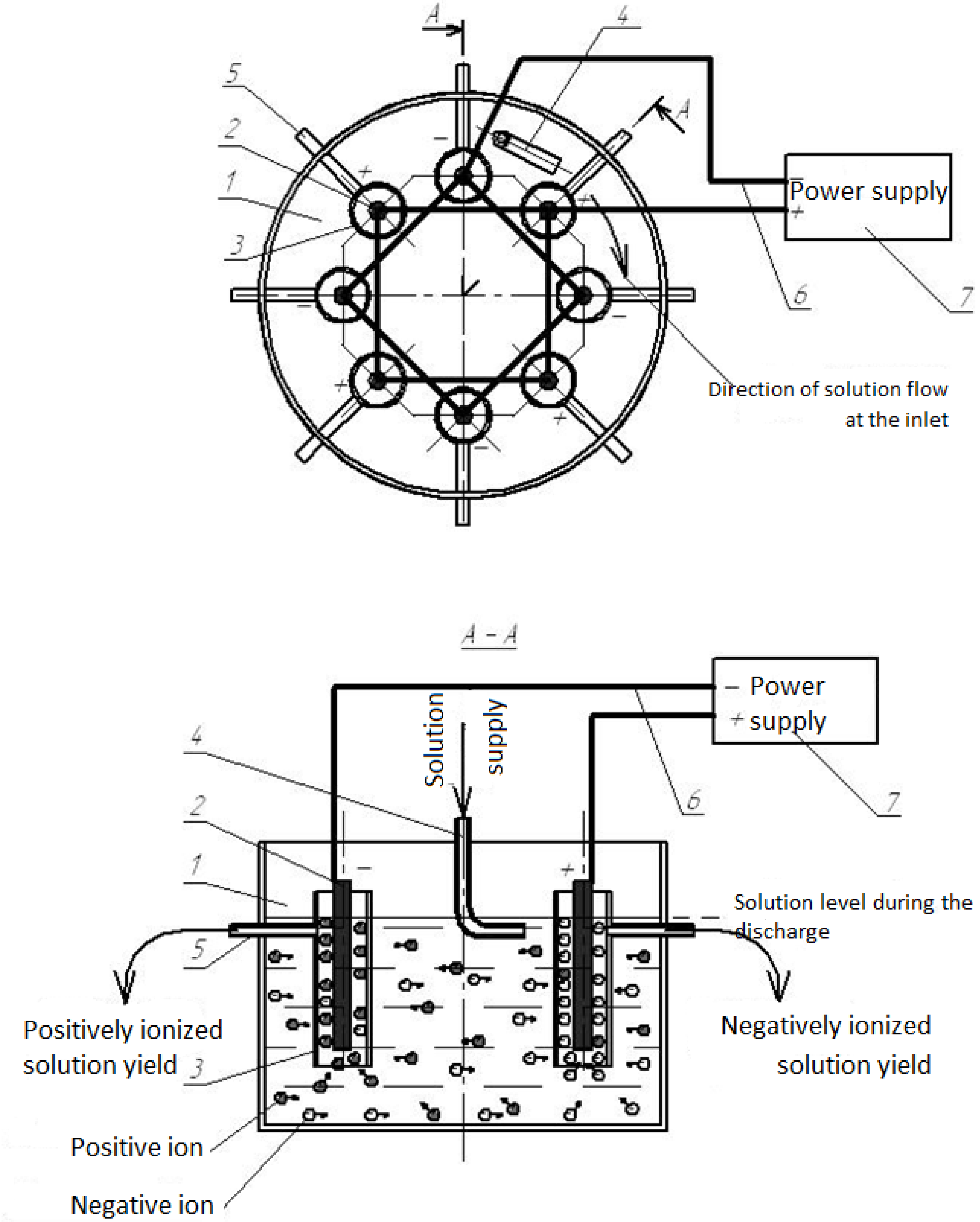

Figure 1 Equipment scheme: 1 – a capacity with regenerated solution; 2 – graphite electrodes; 3 – screens from chemically resistant electric insulation material (glass, plastics, etc.); 4 – regenerated solution supply piping; 5 – overflow pipe; 6 – connecting electric wires; 7 – electric power supply.