CHAPTER 6.
FRAGMENTS OF SCIENTIFIC RESEARCH OF ELECTROCHEMICAL SYSTEMS WITH A NEW GENERATION OF 2016 MB ELEMENTS, SELECTED PUBLICATIONS

This chapter is a logic continuation of the fifth chapter and is dedicated to new technical and engineering solutions in the field of electrochemical systems for various purposes.

Like the entire content of this book, it is not free from the impressions of the authors who have been observing the history of their inventions for many years.

6.1. AQUATRON: NEW ELECTROCHEMICAL SYSTEMS WITH MB ELEMENTS

Bakhir V.M.

The possibility of great savings or complete elimination of the use of chemicals in different technological processes by using metastable compounds synthesized in electrochemical systems discovered in the seventies of the last century [1–11], was first implemented on an industrial scale for reagent-free control of the properties of formation water and drilling muds used in drilling deep oil and gas wells. The world's first publications on an abnormal chemical activity of water after unipolar electrochemical exposure and on abnormal values of the redox potential of electrochemically activated water and solutions were made in 1974 [12–24]. The only source of these publications was the Central Asian Research Institute of Natural Gas, where these studies were initiated in 1972 and are still developing nowadays [25–27].


ТЕХНОЛОГИИ

АКВАТРОН: НОВЫЕ ЭЛЕКТРОХИМИЧЕСКИЕ СИСТЕМЫ С ЭЛЕМЕНТАМИ МБ

Water supply and sewerage journal. *— № 5–6. — 2016. — p. 28–44.*

The electrochemical systems created in the period 1972–1984 are based on original diaphragm flow-through electrolyzers with graphite or ferrosilite anodes, chlorine or asbestos-cement diaphragms operating at a current of 100 to 1000 amperes, at a voltage of 12 to 24 volts and providing treatment of formation salty water or drilling mud with a productivity from five to six to several tens of cubic meters per hour. After acceptance of the systems by the interdepartmental commission of the USSR Ministry of Gas Industry, USSR Ministry of Oil Industry, USSR Ministry of Oil Industry and USSR Ministry of Gas Industry in 1979, their production was organized at the enterprises of PO Uzbekneft, VPO Soyuzuzbekgazprom and the *Bolshevik* Kokand Plant of Gas Fittings and Non-Standard Equipment of the USSR Ministry of Gas Industry. In to-

tal, in 1975–1988, about 5,000 UEV and UOBR systems were produced for electrochemical unipolar treatment of formation water and drilling mud. The imperfection and fragility of the first industrial electrochemical systems were compensated by their high economic efficiency and short payback period which did not exceed 1 month.

At the end of the seventies, the results of the practical industrial application of a fundamentally new electrochemical technique and systems in the oil and gas industry became widely known in the country and attracted the attention of specialists in various industries. For about 10 years, starting from 1978, the main task of specialists who got acquainted with the phenomenon of anomalous physicochemical activity of water and aqueous solutions after unipolar (cathode or anode) electrochemical treatment was to study the possibility of practical use of new knowledge to improve their own production processes and solving scientific problems of creating new technologies. Quite suitable for these purposes were the simplest laboratory, prototype and serial samples of industrial devices and apparatus manufactured under the authors' supervision at the production facilities of the Central Asian Research Institute of Natural Gas (SREDAZNIIGAZ), production structures of the Uzbekgazprom VPO, Uzbekneft PO and Turkmengazprom VPO. In the period 1985–1987, enterprises of the USSR Ministry of Defense Industry NPO VOSTOK, Central Research Institute of Automation and Hydraulics (CNIIAG), LNPO AVANGARD produced prototype and serial samples of industrial and laboratory electrochemical devices, also under the author's supervision.

Positive results obtained in laboratory or industrial test sites required further development, which demanded other electrochemical systems adapted to specific tasks. The apparent simplicity of obtaining electrochemically activated alkaline (catholyte) and acidic (anolyte) water, described in popular scientific publications [28–34], has generated and continues to generate a large number of «inventors» and companies manufacturing devices for producing electrochemically activated water, which is called a variety of names. However, this area of science and technology is very difficult for research, since all the most important processes of electrochemical transformation of liquids occur in the interelectrode and intradiaphragm space filled with an extremely chemically aggressive gas-liquid mixture of the products of electrochemical reactions. These superoxidized and super-reduced products, separated by a membrane permeable to ion migration, move due to several factors: electromigration in an electric field; transfer by convective vortex flows of liquids formed at the boundaries of microlocal regions with different temperature gradients; due to disturbances caused by gases released on the electrode surfaces, as well as due to the pressure flow of liquids in the electrode chambers, which occurs in an electric field with variable intensity gradients at a current density of several thousand amperes per square meter.

The properties of electrochemically activated catholyte and anolyte of fresh water are influenced by the synthesis conditions, which include not only mineralization, chemical composition of starting water, materials of electrodes and diaphragm, current and voltage, but also the ratio of volumes of liquid electrochemically activated in the electrode chamber and directly in areas of the electrode double electric layer (DEL). Also important are the magnitude and rate of change in the temperature of the liquid in the DEL and in the electrode chamber during electrochemical action, the rate of reactions of neutralization of highly active products of electrochemical reactions in the electrode chamber due to electromigration and tunnel transfers, neutralizing agents through the septum (diaphragm or membrane), and other factors. The authors carried out the design of new electrochemical devices specifically for each of the numerous technologies at the request of specialists in various industries. [35–50].

The core thing of the author's team research and development has always been the design of electrolyzer. The search for optimal design for unipolar (only the anode or only the cathode) treatment of various liquids (mineralized, fresh or distilled water, milk, whey, vegetable and mineral oils, oil, drilling mud and grout, domestic and industrial wastewater), with different temperature and deliverability through electrode chambers with different pressure at the diaphragm, different voltage at electrodes and current density, all in all, created many different types of electrolyzers [51], which were produced in single units or small batches by various enterprises according to the drawings of the authors and under their supervision. As a result of these works, in 1989, a design of a flow-through electrochemical cell with a ceramic oxide-zirconium microfiltration diaphragm was created, which possesses the properties of a universal electrochemical instrument [52]. This cell provided not only an effective change in the pH and redox properties of various liquids flowing through the electrode chambers in a forward or countercurrent flow with an adjustable pressure drop across the diaphragm, but also a sufficiently deep (60–90%) electrochemical transformation of electrolytes in fresh and low-mineralized solutions. The authors named this device a flow-through electrochemical modular element, known as FEM-1 element. [52, 53].

Until 1990, the technical literature referred to devices for producing electrochemically activated solutions as either devices for electrical treatment of water, or electroactivators, or (rarely) diaphragm electrolyzers. With

the advent of the FEM-1 element, which could be used both in the singular and in an assembly of several elements of the same type, the term «electrochemical reactor» was introduced, with its distinctive features formulated for the first time [54–56].

An electrochemical reactor, unlike its closest analogue, a diaphragm electrolyzer, has much more engineering and technical degrees of freedom and is designed for the electrochemical transformation of a wide variety of liquids, i. e., not only water or aqueous solutions of electrolytes in a wide range of concentrations — from zero to saturated solutions, but also a wide range of organic and inorganic liquids on water and non-aqueous basis. In a flow-through electrochemical modular reactor, the physicochemical, electrical and mechanical properties of various structural and auxiliary materials with geometric dimensions are combined in an optimal way, i. e., taking into account the whole variety of processes of movement and simultaneous electrochemical transformation of liquids and gases of different nature and chemical composition. and the configuration of the electrodes, electrode chambers, the entire interelectrode and intra-electrode space, as well as the parameters and properties of the filtering volume of the diaphragm. Since the intensity and rate of energy and mass transfer in the reactor vary significantly along the main direction of movement of the interelectrode medium in proportion to the current density, flow rate and strongly depend on the chemical composition and concentration of the initial substances, as well as products of electrochemical reactions in each microvolume of the interelectrode space, including the diaphragm, the optimal combination of all those parameters and factors is largely determined by the reactor operation parameters, that is, in fact, by the flow-chart of the electrochemical synthesis process.

The first FEM-1 modular elements were manufactured for three years (1989–1991) at the experimental plant of the All-Union Scientific Research and Testing Institute of Medical Equipment (VNIIIMT) and at the Laboratory of Electrotechnology (LET LLC), founded by the authors of the first patents [52, 53] V. M. Bakhir and Yu. G. Zadorozhny.

With the improvement of flow-through electrochemical modular elements, the number of electrochemical devices for various purposes with their use increased. Thus, while the number of commercially used FEM-1 elements was less than 1000, the number of FEM-2 elements manufactured and sold as part of electrochemical devices [57] exceeded 100,000, and that of FEM-3 elements was more than a million. FEM-2 elements were manufactured until 1996 under a license from the authors of patents by the EMERALD Joint Soviet-British Enterprise (JE EMERALD) and a number of enterprises, including LET LLC, on orders from JE EMERALD. After the license was withdrawn, the enterprise produced FEM-2 elements for some time in violation of copyright, but was forced to stop production by a court decision, and also due to the appearance on the market of electrochemical devices with more sophisticated FEM-3 elements [58].

In 1997 V. M. Bakhir and Yu. G. Zadorozhny received RF patent No. 2088693 entitled «Device for obtaining products of anode oxidation of a solution of chlorides of alkali or alkaline earth metals». This invention opened a new area in electrochemical technology — ion-selective electrolysis with a diaphragm. The first industrial implementation of this technology was in electrochemical systems using FEM-3 elements. The development of the technology of ion-selective electrolysis with a diaphragm, the expansion of the range of tasks and the range of technological processes, where electrochemical technologies provided significant economic and technical advantages in comparison with existing technologies and technical means of water disinfection and purification, led to the appearance of flow-through electrochemical modular elements FEM-7 (RF patent No. 2176989, 2000) and FEM-9 (RF patent No. 3370885, 2004). These elements have significantly improved the electrolysis process of concentrated (150–300 g/l) sodium chloride solution — ion-selective electrolysis with a diaphragm. For the first time in the world, this process was implemented in AQUACHLOR devices used for disinfection of drinking water, wastewater at large, medium and small municipal water treatment plants, as well as water in swimming pools.

In 2009, based on the generalization and analysis of the experience in the production and operation of the FEM-3, FEM-7 and FEM-9 elements, the MB-11 and MB-26 reactors (RF patent No. 2350692, 2009) were created, referred to as «Bakhir Module». MB reactors had improved technical, economic and electrochemical parameters, in comparison with previously created FEM elements, due to design optimization, as well as due to the use of standardized methods for selecting diaphragms for modular electrochemical elements in terms of physicochemical, filtration and adsorption-chemical and electrokinetic properties and parameters depending on the specific conditions of their intended operation and technological operation parameters. Reactors MB-11 and MB-26 were serially produced by LET LLC with permission and under the guidance of the authors until 2010.

Serial production of original FEM and MB elements of all types was organized at LET LLC and operated under the designer's supervision and with their direct par-

Fig. 6.1.1. Modular electrochemical element MB-26D model 28600M7P19–03 in a dielectric case (2011–2014). The MB element designation is in accordance with TU 3614–015–77350578–2016.

ticipation in the period from 1990 to 2010. In 2011, LET LLC was subjected to a raider seizure and the full name of the enterprise was changed. The short designation of the enterprise (LET LLC) was retained by the raiders for obvious reasons. The authors, together with the main group of specialists (technologists and designers), continued to work on improving electrochemical systems within the framework of economic and licensing agreements between the Vitold Bakhir Electrochemical Systems and Technologies Institute and the Delfin Aqua LLC. By this time, scientists and specialists of the Vitold Bakhir Electrochemical Systems and Technologies Institute completed the next stage of work to study the effect of physicochemical, filtration properties and design parameters of ceramic oxide-zirconium diaphragms on the operational performance of reactors under various conditions. The results of the work served as the basis for the creation of new designs of MB elements with oxide-zirconium diaphragms.

The technical solutions used in the design of the new electrochemical reactors were outlined in Russian patents № 2042639, 2063932, 2078737, 2096529, 2141454, 2145940, 2153474, 2176989, 3370885, 2350692, UK patent GB.2253860 and certificates for utility model RF 20513, 20514 for FEM, MB and RPE reactors. The main technical ideas of the new MB elements (Fig. 6.1.1) were the following: to reduce the degree of inhomogeneity in the functional parameters of the diaphragms by reducing their number, to increase the guarantee of the structural strength of the diaphragms by choosing the direction of the filtration flow inward through the cylindrical wall of the diaphragm, to reduce the anode current density by increasing the number of anodes in the element and thereby increasing the anode coating lifetime.

The production of experimental models of technical electrochemical systems in the form of MB elements with dielectric bodies was organized at the Delfin Aqua enterprise (Moscow) in 2011. Over the entire period of pilot testing and operation (from 2011 to 2014), more than 300 reactors of this type were produced, which were tested mainly as part of AQUACHLOR-M devices of various capacities (Fig. 6.1.2). The main purpose of the industrial pilot tests (in addition to the commercial benefits from the sale) was studying options for optimizing the process of ion-selective electrolysis with a diaphragm while simultaneously operating several separate elements with different filtration and physicochemical properties of zirconium oxide diaphragms, as well as studying the durability and reliability of design solutions with filtration flow through the diaphragm directed from the external (anode) space to the inside of the tubular diaphragm, into the cathode chamber space.

In the design of MB elements with a dielectric body, the problem of self-cleaning of the diaphragm and the cathode chamber during operation is solved. The use of cooled anodes has also made it possible to increase the productivity of the reactor, and a rather large volume of free anode space of the elements allows for reducing the moisture content of electrolysis gases. Due to these and other design innovations, the operating time without maintenance of MB elements with a dielectric body and zirconium oxide diaphragms has increased on average by 5–8 times reaching 30.000–40.000 hours of continuous operation. The technology of direct production of hypochlorous acid in the concentration range from 15 to 20 % has been developed for the first time on MB elements with a dielectric body.

Fig. 6.1.2. *AQUACHLOR-1500M devices with a chlorine capacity of 1.5 kg per hour with MB-26D modular electrochemical elements in a dielectric body. The AQUACHLOR-1500M device contains 8 MB-26 elements of model 28600M1P4–05. Electric power consumption is 7.0 kW, weight 600 kg.*

Before proceeding to the presentation of the essence of constructive and technological changes in the new generation of flow-through electrochemical modular MB cells, manufactured in accordance with TU 3614–015–77350578–2016 and being the main part of AQUATRON devices, it seems necessary to clarify the essence of the ion-selective electrolysis technology with a diaphragm. It is this technology that is the main one for almost all types of devices of the AQUATRON family, which has incorporated all currently known electrochemical systems developed by the creative team of the Vitold Bakhir Electrochemical Systems and Technologies Institute. The following figures explain this effect, called Ion Selective Diaphragm Electrolysis [59].

Fig. 6.1.3 is a flow-chart of the process of industrial chlorine electrolysis with a cation-active membrane. Modern industrial electrolyzers are a stack of flat electrochemical cells (elements) consisting of electrodes and an ion-selective polymer membrane separating them developed by DuPont Company.

The Nafion membrane is made in the form of a thin (no more than 200 microns) film of tetrafluoroethylene and perfluorinated vinyl ether with sulfo groups. The working surface area of the membrane in an individual element is up to 3 square meters. The membranes are sensitive to contamination of the initial salt solution with ions of multivalent metals and organic substances. The membranes cannot operate at alternating pressure drops, at a constant pressure drop of more than 0.1 bar. In this regard, both chlorine and hydrogen in membrane electrolyzers are produced and transported at a pressure close to atmospheric. Once wetted, membranes lose their ion-selectivity when they are re-wetted after drying. All industrial electrolyzers operate at a chemical composition and concentration of the initial solution constant in time, require strictly specified and unchanged operating conditions over time. Nevertheless, the membranes need to be periodically replaced, at least once every 3 years or

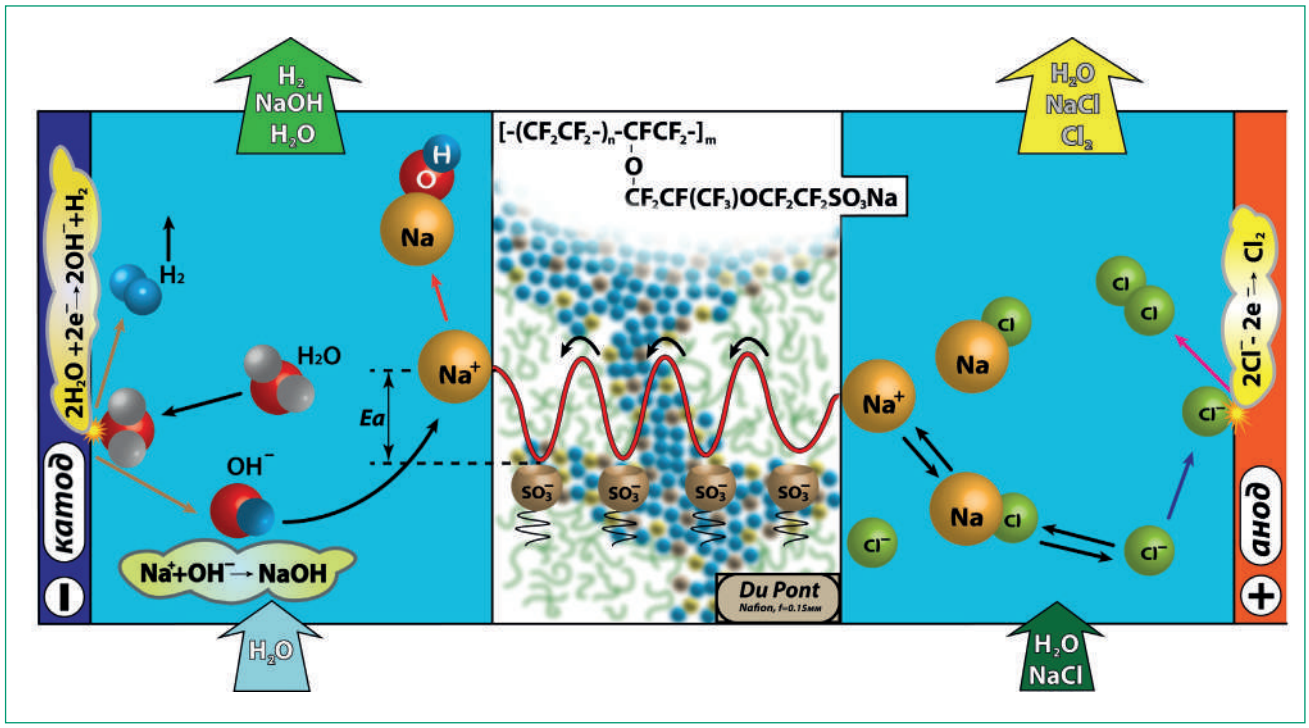


Fig. 6.1.3. *Parameters of the process of charge transfer through the membrane is determined by speed of electromigration of cations in the polymer electrolyte. There is no pressure drop across the membrane. The process does not provide complete decomposition of the sodium chloride solution entering the anode chamber; it requires the introduction of distilled water into the cathode chamber.*

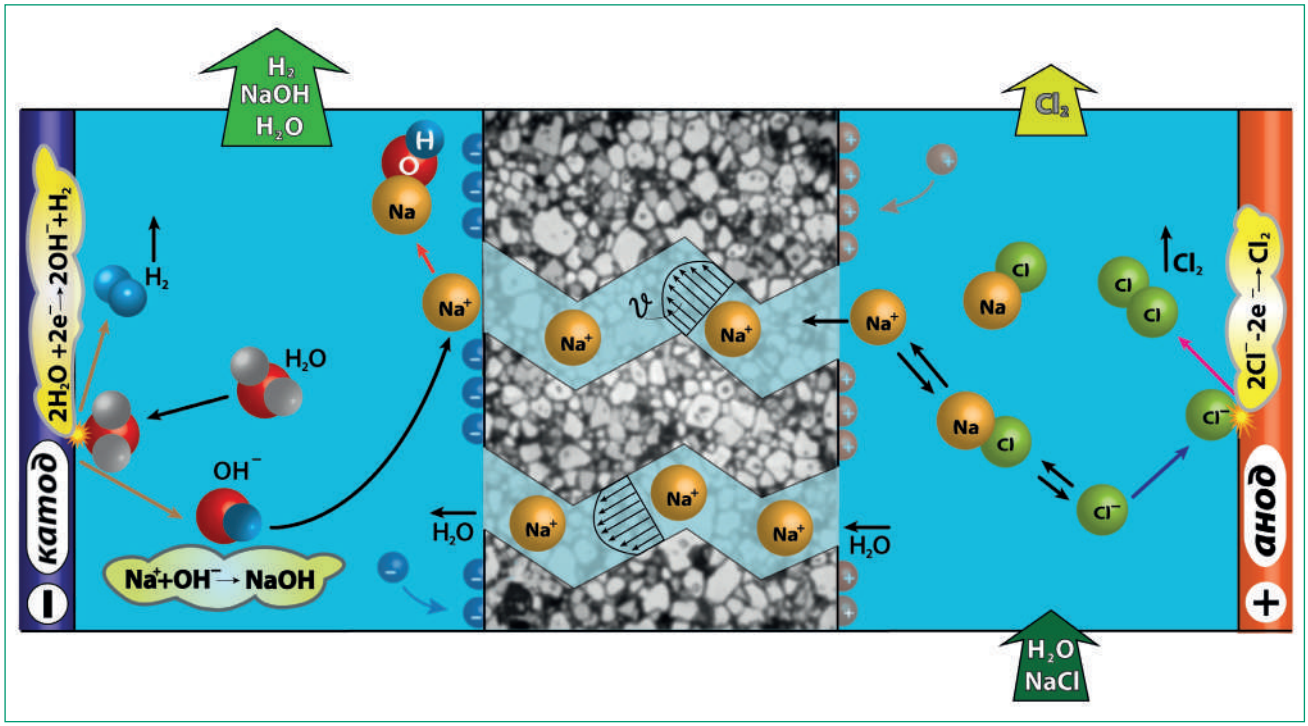


Fig. 6.1.4. A ceramic inactive diaphragm with pore sizes from 0.01 to 0.1 μm turns into a cation-active MEMBRANE under the action of a superposition of the pressure field (from the anode to the cathode) and the electric field. The parameters of the charge transfer process through the diaphragm are determined by the rate of the filtration flow of the electrolyte solution in a porous medium represented by inert metal oxides. The process provides continuous and complete electrolytic decomposition of sodium chloride solution into chlorine, caustic soda solution and hydrogen.

more often, even with small deviations from optimal operating conditions. To replace the diaphragms, complex equipment is required, the mandatory presence of special lifting devices (crane beams), replacement work is carried out only by the specialists of the manufacturer. Before replacing even one defective membrane, a lengthy electrolyzer shutdown procedure is required. Anolyte and catholyte, after leaving the electrode chambers of the membrane electrolyzer and removing chlorine from the anolyte, are conditioned in the external hardware system of the electrolysis process in order to normalize the chemical composition, after which they are returned to the electrolyzer.

Fig. 6.1.4 shows the same chlorine electrolysis process implemented in a FEM (MB) element with a ceramic ultrafiltration diaphragm. In the MB elements, the process of complete separation of the initial saline solution into gaseous chlorine, sodium hydroxide solution and hydrogen takes place. At the same time, additional operations typical for membrane electrolysis processes are not required: removal and dechlorination of the anolyte, its enrichment with sodium chloride, the introduction of distilled water into the cathode chambers of the reactor.

Chlorine formed in the anode chambers of the MB elements is at a pressure of 1.5 to 3.0 bar (the pressure gradient is directed from the anode to the cathode) and occupies a volume of several milliliters. Chlorine and hydrogen are transported to places of use or discharge via high pressure fluoroplastic tubes. A diaphragm made of a material that is chemically resistant and insensitive to contamination of any nature (alumina in alpha form), operates in the MB element at a pressure drop of 1.5 to 3.0 bar and, due to an electric field in a porous medium with a strength of 1 to 3 V/cm, ensures the mass transfer of sodium cations together with the solvent (water) into the cathode chamber. In this case, the electric field blocks the filtration transfer of chlorine anions, and the filtration flow through the diaphragm with a pressure gradient of 6–10 bar/cm, in turn, blocks the penetration of hydroxyl anions from the cathode chamber into the anode chamber. Thus, the ceramic diaphragm turns into a cation-active diaphragm and provides complete decomposition into components (chlorine, caustic soda solution, hydrogen) of the sodium chloride solution entering the reactor without the cost of additional conditioning and return to the reactor. At the same time, electrolysis gas sampling systems are not required, since both hydrogen and chlorine are transported through pressure lines.

Fig. 6.1.5 shows the process of obtaining a concentrated (up to 30%) solution of hypochlorous acid in an MB element with a ceramic diaphragm. In this case, in the same MB element, the ceramic ultrafiltration diaphragm turns into anion-active one when the direction of the pressure field gradient is reversed: from the cathode to the anode. It should

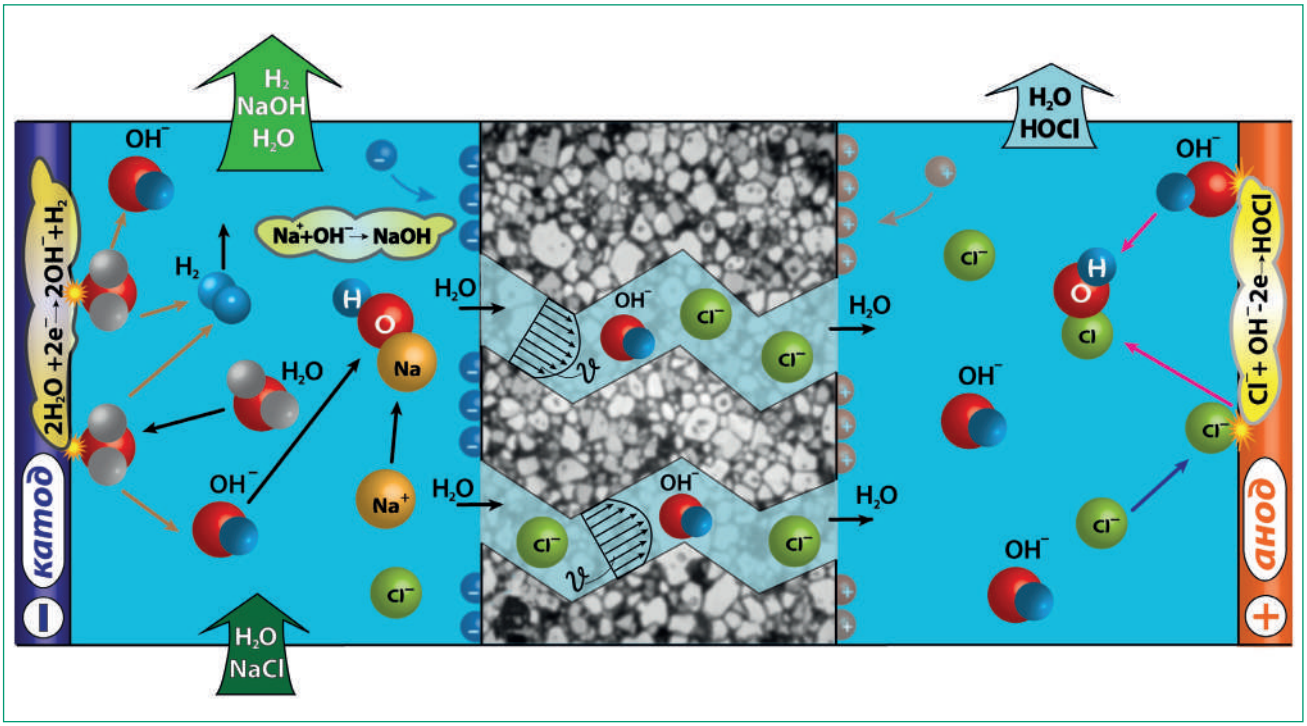


Fig. 6.1.5. *A ceramic inactive diaphragm with pore sizes from 0.01 to 0.1 μm turns into an anion-active MEMBRANE under the action of a superposition of the pressure field (from the cathode to the anode) and the electric field. The process ensures the production of a solution of caustic soda, hydrogen and hypochlorous acid from a sodium chloride solution with a concentration of up to 30%.*

be noted that the rate of mass transfer (electromigration plus filtration) is thousands of times higher than that of diffusion movement of ions in the polymer membrane. The high selectivity of the diaphragm in the ion-selective electrolysis mode does not decrease in the presence of impurities in the electrolyte and is provided by the balance between the current strength (the amount of electricity flowing per unit of time) and the rate of introduction of the initial substances in the solution into the electrochemical reactor.

The practical use of this process will fundamentally solve the problem of disinfecting drinking water, wastewater, swimming pool water by replacing chlorine (reacts with water to form hydrochloric and hypochlorous acid) and sodium hypochlorite solution (it reacts with water to form inactive hypochlorite ion, contains ballast substances — salt and sodium hydroxide) to an aqueous solution of only hypochlorous acid. In practice, the process of synthesizing pure hypochlorous acid by the above method is used by colleagues from Blue Safety (Germany). The introduction of a solution of hypochlorous acid into the supply line of tap water to the premises of a medical institution in an amount regulated by the sanitary and hygienic standards for residual chlorine ensures that there are no biofilms on the inner surfaces of the water supply lines after reverse osmosis filters, which is unattainable with a standard water supply system.

MB electrochemical elements use ceramic diaphragms, which are not afraid of organic impurities, or polyvalent metal ions in the starting solution, or pressure drops, or changes in the chemical composition and concentration of the initial solutions, or repeated drying and moistening. It is these features that distinguish them from membrane electrolyzers and that is why they are called electrochemical reactors, i. e. devices that, by analogy with most types of chemical reactors, have the ability to operate in a wide range of concentrations, fluid flow rates, pressures and temperatures.

A comparative study of MB elements with a dielectric body and an electrode body made it clear that a prerequisite for the effectiveness of ion-selective electrolysis with a diaphragm for each type of technological process (synthesis of chlorine and caustic soda, production of hypochlorous acid, synthesis of persulfuric acid) is pressure and electric field gradients in the porous space of the diaphragm. An obstacle for the optimal choice of technological parameters in a number of technological processes is the constructive complexity of solving the problem. For example, the non-compression production of chlorine under high pressure, as well as the implementation of some technological processes, requires MB elements that can operate at a pressure in the anode chamber of up to 6 bar with a pressure drop across the diaphragm of up to 2.0–2.5 bar. Manufacturing MB elements with a dielectric body capable of operating under such conditions is a very difficult task. An increase in the dielectric body strength leads to an increase in its dimensions, which does not allow achieving the optimal rate

of product removal per unit area occupied by the electrochemical system. The solution is found within the framework of previously made inventions or, more precisely, within the framework of the secrets of technology surrounding the previous inventions.

Research work in the field of development and improvement of the technology of ion-selective electrolysis with a diaphragm the authors of this technology had been doing for many years, made it possible to develop at the end of 2015 electrochemical modular elements of a new generation with the volumetric current density much higher than similar parameters for elements of previous generations (1000–3000 amperes per liter in MB elements of the new generation (2016) versus 200–500 amperes per liter in MB elements of all previous generations). The use of modular electrochemical elements of the new (2016) generation in the existing devices STEL, EMERALD, AQUACHLOR, ECOCHLOR and others made it possible to increase their productivity several times while maintaining the same dimensions and weight, and also opened the way to the creation of a number of fundamentally new electrochemical systems of most diverse aplications.

The period from 2009 to 2015 was dedicated to the analysis of the information accumulated during the fifteen-year period (1995–2010) of wide industrial application of STEL and AQUACHLOR devices with the electrochemical elements assembled using zirconium oxide diaphragms. Long-term observations and special studies of ceramic samples produced from various raw materials by companies in Vietnam, China, the United States and Germany in comparison with samples of oxide-zirconium ceramics prepared according to various recipes and various technological methods at a Russian company have shown the need for a significant reduction in the average pore size in comparison with the zirconium oxide ceramics used. Primary general technical requirements for ceramic diaphragms for FEM-3 elements were as follows: acid resistance (according to GOST 473.1–81) not less than 99.9%; alkali resistance (according to GOST 473.2–81) not less than 99.9%; taper is allowed within the outer diameter tolerance; the diaphragm must withstand the internal pressure of water with a temperature of + 10….. + 800 °C, equal to 3 kgf/cm^2; water flow at 25°C within 0.2–0.5 ml/h·m^2·Pa; pore size — within 0.1 ÷ 1.0 μm.

For the FEM-7 and FEM-9 elements using diaphragms with an outer diameter of 26–29 mm and a wall thickness of 2–3 mm, an additional condition was introduced: the end of the diaphragm was to be machined so that the deviation of the perpendicularity of the end relative to the axis of the diaphragm did not exceed — 0.05 mm. The chemical composition of the feedstock for all diaphragms was the same: Al_2O_3 — no more than 80%; stabilized zirconium dioxide — not less than 20%; yttrium oxide — no more than 7% (depending on the chemical composition of the starting materials). The diaphragms were manufactured by manual slip casting into plaster molds. The proportions of the initial components, the slurry preparation technology, the drying and firing technology were varied. Thus, during the period from 1991 to 2014, about three million diaphragms of various standard sizes were manufactured.

In 2010, specialists and experts of the Vitold Bakhir Electrochemical Systems and Technologies Institute began work to find an alternative to oxide-zirconium diaphragms in order to ensure the production of MB elements with the same physicochemical properties, reliably operating in aggressive media for a long time and having specified values of porosity and permeability of ceramic diaphragms. The initial stage in achieving this goal was a system of scientifically substantiated quality criteria for ceramic diaphragms, fragmentarily outlined below using the example of a diaphragm for MB-26 and MB-11 elements.

1. *Tubular porous ceramic element with an outer diameter in the range of 28–31 mm and a wall thickness of 2.5–3.0 mm (Fig. 6.1.6).*

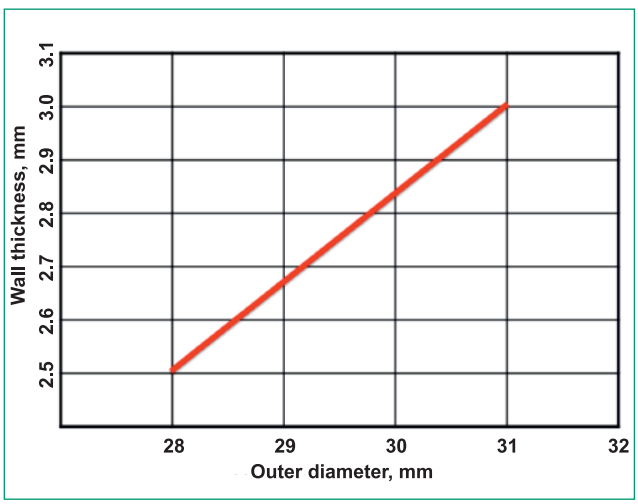


Fig. 6.1.6. *Size ratio of ceramic diaphragms for MB-26 elements.*

The following size ratios, mm, are acceptable:

29 x 2.5; 30 x 2.75; 31 x 3.0. The first number is the outer diameter, the second is the wall thickness. When delivered in batches, deviation in thickness is 0.2 mm and in diameter 0.3 mm.

Smaller wall thickness corresponds to smaller diameter, larger wall thickness corresponds to larger diameter. Length — 700 mm. Acid resistance (according to GOST 473.1–81), not less than 99%. Alkali resistance (according to GOST 473.2–81), not less than 99%. Water flow at 25 °C from 0.01 to 1.5 ml/h·m^2·Pa. The specific value of the flow rate is set and agreed upon for a batch of at least 10,000 pieces.

It is allowed to apply a filtering coating on the external or internal surfaces (by prior agreement). Filtration characteristics correspond to the ultrafiltration range.

2. Tubular porous ceramic element with an outer diameter in the range of 10–12 mm and a wall thickness of 1.5–1.7 mm (Fig. 6.1.7).

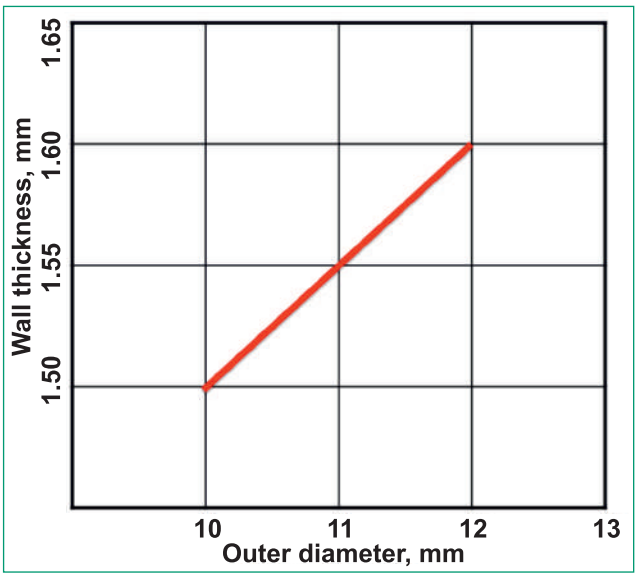


Fig. 6.1.7. *Size ratio of ceramic diaphragms for MB-11 elements.*

The following size ratios, mm, are acceptable:

10 x 1.5; 11 x 1.6; 12 x 1.7. The first figure is the outer diameter, the second is the wall thickness. When delivered in batches, deviation in thickness is 0.1 mm and diameter 0.2 mm.

Smaller wall thickness corresponds to smaller diameter, larger wall thickness corresponds to larger diameter. Length — 300 mm. Acid resistance (according to GOST 473.1–81), not less than 99%.

Alkali resistance (according to GOST 473.2–81), not less than 99%.

Water flow at 25° C from 0.01 to 1.0 ml/h·m^2·Pa. The specific value of the flow rate is set and agreed upon for a batch of at least 10,000 pieces.

It is allowed to apply a filtering coating to the external or internal surfaces (as agreed). Filtration characteristics correspond to the ultrafiltration range.

Variations in the combination of certain physicochemical parameters and geometric dimensions of diaphragms are used in the manufacture of specialized models of MB elements intended for application in various technological processes as a tool for changing the properties and reactivity of liquid media used in these processes. At the same time, in each of the areas of use, an analysis of technical and economic indicators and technological parameters of the operation of MB elements is carried out. The following Table 6.1.1 shows some comparative characteristics of FEM and MB elements of different designs and different production periods. Data for MB elements are given for models used in experimental studies of various technological processes

Table 6.1.1

Sizes and ratios of parameters of the main structural elements of flow-through electrochemical modular reactors (FEM and MB elements)

Parameter name	Formula or ratio	FEM-3 (1992)	FEM-7 (1997)	FEM-9 (2003)	MB-26T (2016)	MB-11T (2016)
1	2	3	4	5	6	7
Anode inner diameter (D1), mm	–	6	14	14	15	6
Anode outer diameter (D2), mm	–	8	16	16	18	8
Diaphragm inner diameter (D3), mm	–	9.5	23	21	23.6	9.5
Diaphragm outer diameter (D4), mm	–	11.5	28	26	29.3	12.5
Cathode inner diameter (D5), mm	–	14	36	34	36	15
Cathode outer diameter (D6), mm	–	16	40	38	38	18
Electrode chamber length (L_{ec}), mm	–	185	290	290	640	400
Interelectrode distance (IED), mm	IED=($D_5 - D_2$):2	3.0	10.5	9.0	9.0	3.5
Geometric anode area (S_{ag}), mm^2	$S_{ag} = \pi D_2 L_{ec}$	4640	14500	14500	36173	10048
Geometric cathode area (S_{cg}), mm^2	$S_{cg} = \pi D_5 L_{ec}$	8130	34800	30960	72346	18840
Geometric area of the diaphragm outer surface (S_{dcg}), mm^2	$S_{dcg} = \pi D_4 L_{ec}$	6680	25497	23675	58881	15700
Geometric area of the diaphragm inner surface (S_{dag}), mm^2	$S_{dag} = \pi D_3 L_{ec}$	5518	20943	19122	47427	11932
Cross-sectional cathode chamber area (S_c), mm^2	$S_c = 0.785 (D_5^2 - D_4^2)$	50	402	377	343	54

1	2	3	4	5	6	7
Cross-sectional anode chamber area (S_a), mm^2	$S_a = 0.785 (D_3^2 — D_2^2)$	20.6	214	145	183	20.6
Cross-sectional diaphragm area (S_d), mm^2	$S_d = 0.785 (D_4^2 — D_3^2)$	33	200	184	237	52
Cathode chamber volume (V_c), mm^3	$V_c = S_c L_{ec}$	9259	116580	109330	219529	21600
Anode chamber volume (V_a), mm^3	$V_a = S_a L_{ec}$	3811	62060	42050	117120	8240
Physical anode area (S_{af}), mm^2	$S_{af} = \lambda_1 \pi D_2 L_{ec}$	8500	35220	35030	65080	18100
Physical cathode area (S_{cf}), mm^2	$S_{cf} = \lambda_2 \pi D_5 L_{ec}$	8500	35120	31140	73450	19240
Physical diaphragm outer surface area (S_{dcf}), mm^2	$S_{dcf} = \lambda_3 \pi D_4 L_{ec}$	6700	26000	23700	75240	21320
Physical diaphragm inner surface area (S_{daf}), mm^2	$S_{daf} = \lambda_4 \pi D_3 L_{ec}$	5600	21000	19500	60200	17300
The ratio of the physical area of the cathode (Scf) to the volume of the cathode chamber (Vc), mm-1	S_{cf}: V_c	0.9	0.3	0.3	0.3	0.9
Physical anode area (S_{af}) to anode chamber volume (V_a) ratio, mm^{-1}	S_{af}: V_a	2.2	0.6	0.8	0.5	2.1
Physical electrodes area ($S_{cf} + S_{af}$) to electrode chambers volume ($V_c + V_a$) ratio, mm^{-1}	$(S_{af} + S_{cf})$: $(V_a + V_c)$	1.31	0.39	0.43	0.41	1.25
The ratio of the volume of the cathode chamber (Vc) to the volume of the anode chamber (Va)	V_c: V_a	2.4	1.9	2.6	1.9	2.6
Cathode chamber volume (V_c) to the sum of volumes of anode chamber (V_a) and diaphragm (V_d) ratio	V_c: $(V_a + V_d)$	0.93	0.97	0.97	0.97	0.93
Physical anode (S_{af}) and cathode (S_{cf}) surface areas ratio	S_{af}: $S_{cf} \geq 0.8$	1.0	1.0	1.1	0.89	0.94
Physical cathode surface (S_{cf}) and diaphragm outer surface (S_{dcf}) areas ratio	S_{cf}: $S_{dcf} \geq 0.9$	1.3	1.3	1.3	0.98	0.90
Physical anode surface (S_{af}) and diaphragm inner surface (S_{daf}) areas ratio	S_{af}: $S_{daf} \geq 1$	1.5	1.7	1.8	1.1	1.0
Cross-sectional electrode chambers (S_c, S_a) and diaphragm (S_d) areas ratio	$0.8 \leq S_c$: $(S_a + S_d) \leq 3.1$	0.9	0.9	1.1	2.2	1.4
Interelectrode distance (IED), anode (S_{af}), cathode (S_{cf}) physical surface areas and anode (V_a) and cathode (V_c) electrode chambers volumes ratios	$3.0 \leq IED [(S_{af} + S_{cf})$: $:(V_a + V_c)] \leq 4.5$	3.9	4.1	3.9	3.7	4.4
Current (I), A	–	0.5–5.0	0.5–30	0.5–35	0.5–250	0.1–50
Voltage (U), V	–	10–30	3–5	3–5	4–9	3–50
Concentration of electrolyte solutions (C_s) in working chambers of FEM and MB elements, mol/L	–	less than 0.1	more than 0.5	more than 0.5	more than 0.1	more than 0.001

in order to further determine the optimal physicochemical parameters of the diaphragm and technological modes of operation of the elements.

As for the most important characteristic of membranes — ion-selective conductivity, due to the discovered phenomenon — ion-selective electrolysis with a diaphragm [59], a ceramic ultrafiltration diaphragm acquires the properties of an effective ion-selective partition when operating in an electric field in superposition with a filtration field specified by a pressure drop. Data on ion-selective properties and optimal conditions for their existence for each modification of diaphragms are determined individually for each batch and are important for almost all types of devices with new generation MB elements.

Due to the optimal selection of these characteristics for MB elements used in the AQUACHLOR and ECOCHLOR

devices, their specific productivity (the amount of chlorine produced per day per unit of production area, taking into account the passes) reached 360 kg of chlorine per day from one square meter, which exceeds the same indicator for large chlorine-caustic plants.

The generalized operating parameters of AQUACHLOR and ECOCHLOR devices are as follows: salt consumption for the production of 1 kg of chlorine — 1.8 kg; electricity consumption for the production of 1 kg of chlorine — 2.5–3.5 kW; concentration of sodium hydroxide in catholyte — 250 g/l.

Fig. 6.1.8 shows previous generations models of AQUACHLOR and ECOCHLOR devices of various years of production, as well as modern devices based on new generation MB elements.

Compact modular high-performance devices for obtaining electrolysis products of sodium chloride solution, used at each local place of chlorine application, will allow replacing chlorine-caustic plants, completely eliminating the transportation and storage of liquefied chlorine at consumer enterprises, and will also make it possible to solve the problems of chlorine use in an absolutely safe way in the technological process, not only for large consumers (5 or more tons of chlorine per hour), but also for facilities where chlorine consumption ranges from tens and hundreds of grams per hour to several tens of kilograms per hour.

The emergence of electrochemical modular MB elements of a new type (TU 3614–015–77350578–2016, certificate of conformity GOST R No. 1964392) has made it possible to radically expand the technical and engineering capabilities of industrial electrochemical equipment and household electrochemical systems. Devices for electrochemical conversion of water and aqueous solutions of electrolytes, as well as electrochemical systems for industrial production of various chemical substances at the places of use, equipped with new electrochemical modular MB elements, since January 2016 have a common name AQUATRON DEVICES (TU 3614–017–77350578–2016, certificate of conformity GOST R No. 1964393) and, depending on the model and modification (performance), corresponding to the well-known names of the devices previously created by the same authors [51], allow solving various problems of providing consumers with the necessary products and services in the entire spectrum of electrochemical activation applications. The development and serial production of new types of goods for an expanded range of applications necessitates the creation of a classification system for AQUATRON electrochemical devices.

Since all electrochemical systems (electrochemical devices) with the electrochemical reactor represented by MB elements are designed to transform the physicochemical properties of water and various technological aqueous solutions, as well as to obtain products of electrochemical synthesis — hydrogen, oxygen, chlorine, alkalis, acids and peracids, these devices are collectively named AQUATRON. The epistemological roots of this name stem from the functional and stylistic characteristics of the scope of application of the products, that is, AQUATRON is a device that controls any properties of water or any aqueous medium — solution, emulsion, suspension in a non-reagent way. Taking into account the multiplicity of technical and engineering solutions used in the created electrochemical

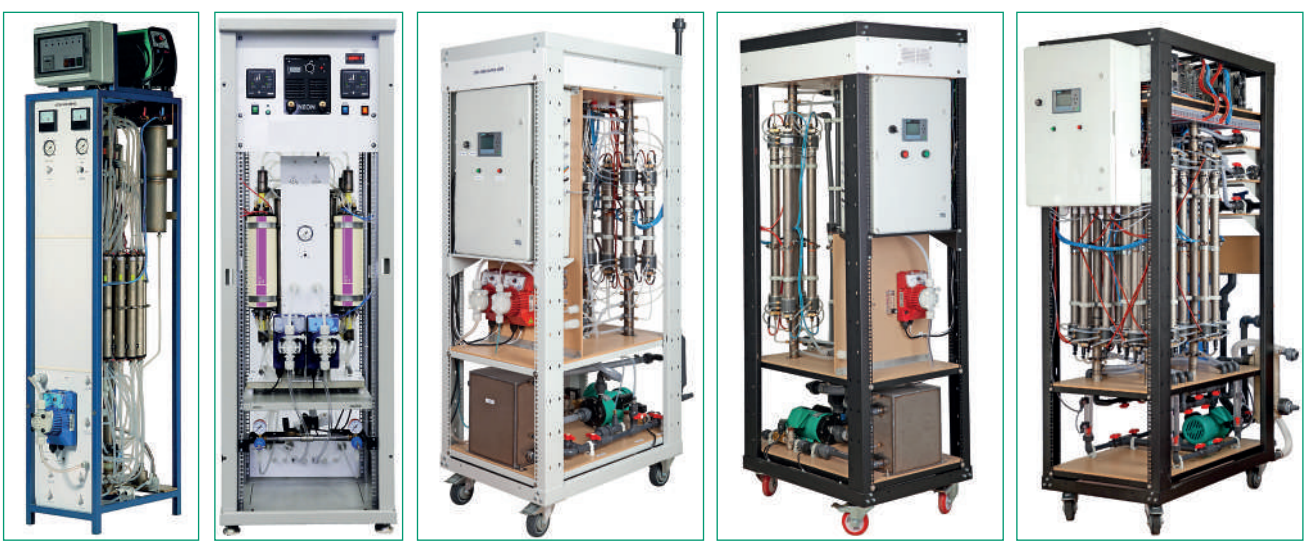


Fig. 6.1.8. *AQUACHLOR devices from left to right: AQUACHLOR-500 (A-500) device with a capacity of 500 grams of chlorine per hour, needs frequent cleaning of the electrochemical reactor with hydrochloric acid, 2005; A-500M device, 500 grams of chlorine per hour, equipped with a self-cleaning body-case reactor, manual control, 2012; A-600, A-1500, A-4000 devices with a capacity of 600, 1500 and 4000 grams of chlorine per hour, self-cleaning reactors made of new generation MB elements (2016), remote monitoring and control, 2018.*

systems and those under development for various purposes for various fields of application, they were divided into classes of AQUATRON devices. Classes of AQUATRON devices are characterized by a two-digit number after the main name.

EMERALD (AQUATRON-01) is a class of devices for purification of fresh drinking water, with the technological scheme of water purification based on direct electrochemical action on the purified water in diaphragm modular electrochemical MB elements. A distinctive feature of EMERALD devices from other known devices for water purification is that after treatment in EMERALD devices, the purified water acquires a redox potential (ORP), which characterizes the activity of electrons in water close to the ORP of the internal environment of the human body (from minus 150 to minus 300 mV). EMERALD devices are manufactured in accordance with the technical solutions set forth in RF patents Nos. 2038322, 2038323, 2056364, 2090517, 2091320, 2096337, 2040477, 2149835, 2207982, 2322395, 2322394, 2350692, UK patents Nos. 2253860, 2257 certificates for utility models of the Russian Federation No. 3599, 3600, 3601. The use of electrochemical MB elements of a new type manufactured in accordance with TU 3614–015–77350578–2016, allows increasing the efficiency of water purification by 30–50% and ensuring the creation of EMERALD (AQUATRON -01) devices with an extended capacity range — from 10 to 500 liters per hour versus 40–60 liters per hour in previously known models. Also, EMERALD devices (AQUATRON-01), equipped with MB electrochemical elements with a high volumetric current density, provide a deeper degree of water purification from antibiotics, antidepressants, hormones, pesticides and other organic compounds that cannot be destroyed and removed in the existing municipal drinking water treatment systems.

In the class of AQUATRON-01 devices, the most representative is the family of household EMERALD devices of various models, differing in technological water purification schemes, productivity, and the presence of various auxiliary systems (modifications). For the first time, EMERALD devices appeared on the Russian market in 1991, their production was organized at the EMERALD Joint Soviet-British Enterprise. EMERALD devices are usually installed in city apartments near pressurized drinking water supply lines, mainly in the kitchen, above or below the sink. The drain line of these devices is connected to a common sewer pipe or diverted to the sink.

Another group of devices of this class is represented by coolers under the general name EMERALD-REDOX. These devices provide protection of water in the tanks of coolers from microbiological contamination, and also impart antioxidant properties to water (lower the redox potential) directly in the process of filling glasses with cold or hot water. Used in homes and offices with a relatively small need for pure drinking water.

The third group of devices — EMERALD-REDOX-M — is represented by dispensers that are connected to the drinking pressure water supply line and are designed to provide kindergartens, schools, hospitals, hotels and other facilities with a sufficiently high consumption of drinking water with pure antioxidant drinking water.

AQUATRON-02 is a new class of devices for purification of fresh water from wells or surface water sources from iron, manganese, organic impurities, including microorganisms and microbial toxins, by introducing a freshly obtained solution of oxidants — products of anodic oxidation of water or a water-salt solution — into purified water followed by filtration water through a quartz charge for efficient heterophase catalytic purification. Devices of this type are used for water purification in cottages and small villages with hourly water consumption from 500 to 50,000 liters per hour.

Groups of devices of this class similar in flow chart differ in the method of obtaining and the method of introducing solutions of oxidants, as well as in the actual flow chart of water purification — two-stage (with a storage tank and constant operating parameters of the oxidant dosing system) and one-stage (without a storage tank and injecting a solution of oxidants at a rate proportional to water flow).

STEL (AQUATRON-05) DEVICES make a class of devices for electrochemical synthesis of anolyte ANK. Anolyte ANK is a universal environmentally friendly antimicrobial solution of a wide spectrum of action and application produced from an aqueous solution of sodium chloride by introducing chlorine-oxygen and hydroperoxide oxidants into water saturated with free hydroxyl groups and dissolved hydrogen, previously purified from ions of heavy metals, iron, manganese, magnesium, calcium. The optimum content of a mixture of chlorine-oxygen and hydroperoxide oxidants in anolyte ANK is 500 mg/l. STEL devices are manufactured in accordance with the technical solutions set forth in the patents of the Russian Federation Nos. 033807, 2038322, 2076847, 2088539, 2155719, 2207983, 2208589, 2322397, 2321681, 2350692.

This class includes STEL-10N-120–01, STEL-60–03-ANK devices, which are designed to produce anolyte ANK with a total mineralization of up to 5 g/l at a concentration of oxidants of 500 mg/l. The preservation time of the functional activity of anolyte ANK produced by these devices does not exceed 5 days.

Another family of devices is represented by modifications of the STEL-ANK-PRO system. Devices of this type make it possible to obtain anolyte ANK with a mineralization of 1.0–1.2 grams per 1 liter at a concentration of oxidants of 500 mg/l. The retention time of the functional properties of such anolyte ANK is 30 days with a significantly lower corrosiveness in comparison with anolyte ANK from the devices of the previous group.

The third group of STEL devices is called STEL-ANK-SUPER and allows for the synthesis of anolyte ANK SUPER with the total mineralization not exceeding 0.9 grams per 1 liter at a concentration of oxidants of 500 mg/l. This makes it possible to increase the preservation period of the functional properties of the anolyte ANK SUPER up to 6 months, as well as to further reduce the corrosive activity of the anolyte.

In 2016, the development of a new group of devices began, allowing to reduce the total mineralization of ANK SUPER anolyte to 0.5 grams per 1 liter at a concentration of oxidants also equal to 0.5 grams per 1 liter. This will make it possible to achieve an even longer time for maintaining the functional properties of the anolyte with a more significant decrease in its corrosivity.

The use of electrochemical modular elements with increased volumetric current density in STEL (AQUATRON-05) devices (serial production since 2016) makes it possible to increase the productivity of anolyte ANK, anolyte ANK SUPER by five times while maintaining the same dimensions and power consumption of the devices. Also, unlike previous systems of a similar purpose, STEL (AQUATRON-05) devices, which have been produced since 2016, can operate not only from pressure water sources, but also convert any fresh water into a solution (into anolyte ANK or anolyte ANK SUPER) (from distilled to ordinary drinking) in containers of any volume (from 10 to 10,000 liters or more) with a cruising (indicated in the passport) capacity for oxidants, which makes it possible to raise the concentration of oxidants in the container to 5000 mg/l (5 g/l) instead of the limiting maximum value for all STEL-type devices today is 500 mg/l (0.5 g/l). The new technology for the production of anolytes ANK and anolytes ANK SUPER makes it possible to realize a number of new possibilities for the use of solutions, including for the needs of the army and navy.

STEL PEROX (AQUATRON-10) is a class of devices for electrochemical synthesis of anolyte PEROX. Anolyte PEROX is a unique antimicrobial solution, with percarbonic acids and sodium or potassium peroxocarbonates as the active ingredients. Anolyte PEROX is produced from an aqueous solution of sodium or potassium carbonate or bicarbonate. Anolyte PEROX is an environmentally friendly product possessing no corrosive activity and having pronounced antimicrobial properties. The total mineralization of anolyte PEROX does not exceed 0.6 g/l. STEL-PEROX (AQUATRON-10) devices are manufactured in accordance with the technical solutions set forth in RF patents Nos.2329335, 2329197.

The class of AQUATRON-10 devices is represented by a group of STEL-PEROX devices, which, in addition to anolyte PEROX, produce electrochemically activated catholyte with a total mineralization not exceeding 1 g/l. This catholyte has pronounced detergent properties that exceed those for detergent solutions. A catholyte of this type has the symbol K-001, where the three-digit number corresponds to the approximate concentration of alkali metal hydroxide in grams per liter (g/l).

In 2016, the development of a new model of AQUATRON-10 devices began, based on electrochemical elements with an increased volumetric current density which will make it possible to obtain solutions of percarbonic acids that are stable over time with increased concentrations of active substances. This will make it possible to widely use the unique and most environmentally friendly antimicrobial solution in various fields: in medicine, in air, rail and water transport, in the food industry and military affairs.

STEL-UNIVERSAL (AQUATRON-15) is a class of devices for electrochemical synthesis of electrochemically activated anolyte and catholyte from fresh water and solutions of various electrolytes. The total content of dissolved substances in synthesized electrochemically activated solutions (anolyte and catholyte), as a rule, does not exceed 1.0 g/l. AQUATRON-15 devices are manufactured in accordance with the technical solutions set forth in RF patents Nos. 2204530, 2148027, 2157793.

The class of AQUATRON-15 devices is represented by a model range of STEL-UNIVERSAL devices, which differ in performance and some features of the basic hydraulic circuit. The devices allow for synthesizing anolytes ANFOS, ALOX-M, A, with the active substances being respectively electrochemically activated perphosphoric, peracetic acids or a mixture of oxidants obtained from fresh water or water-salt solution.

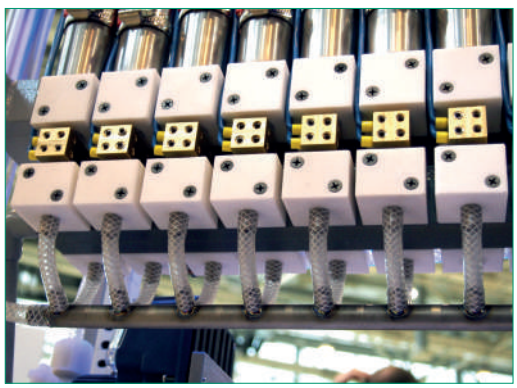
Another group of devices for the same purpose is represented by devices with reactors made of electrochemical elements with an increased volumetric current density, which will expand the range of products by including such substances as carboxylic acids, quaternary ammonium compounds as starting materials, and also solve the problem of refining petroleum products and crude oil from sulfur by direct electrochemical action in the flow-through.

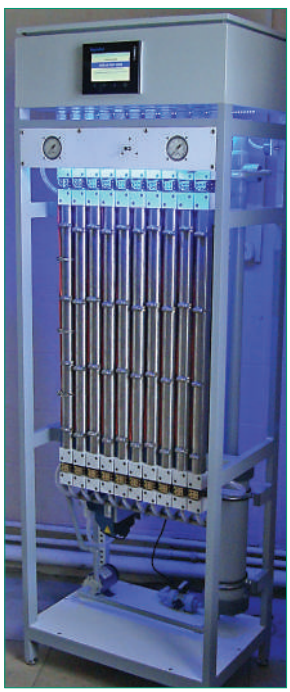
AQUACHLOR (AQUATRON-20) is a class of devices for converting a sodium chloride solution into a solution of oxidants used in the processes of disinfection and water purification, and a concentrated electrochemically activated solution of caustic soda (catholyte K-190, i. e. with a sodium hydroxide concentration of 190 g/l), with a degree of salt conversion solution above 99.5%. AQUATRON-20 devices are manufactured in accordance with the technical solutions set forth in patents of the Russian Federation No. 2088693, 2270885, 2176989, 2350692, USA — 7,897,023.

This class of technical electrochemical systems is represented by AQUACHLOR and AQUACHLOR-M devices. The upper limit of the performance range of a single device is limited to 500 grams per hour.

The use of electrochemical elements with a high volumetric current density in the new models of AQUATRON-20 devices makes it possible to increase the productivity of final products by 3–4 times while maintaining the same energy consumption and dimensions of the devices (Fig. 6.1.9; 6.1.10).

Fig. 6.1.9. *AQUACHLOR-3000 device.*





Chlorine capacity: 3 kg/h;
Caustic soda productivity: 3.4 kg/h;
Output of catholyte (18% aqueous NaOH solution): 19 l/h;
Power consumption: 10 kW;
Current strength — 2400 A; Voltage 4.4V;
Overall dimensions (HxWxD): 1750x600x400 mm;
Weight: 95 kg. Salt (sodium chloride) consumption: 5.4 kg/h;
Salt consumption in solution (270–300 g/l): 18–20 l/h.
Provides disinfection of up to 72.000 m³ of water per day.

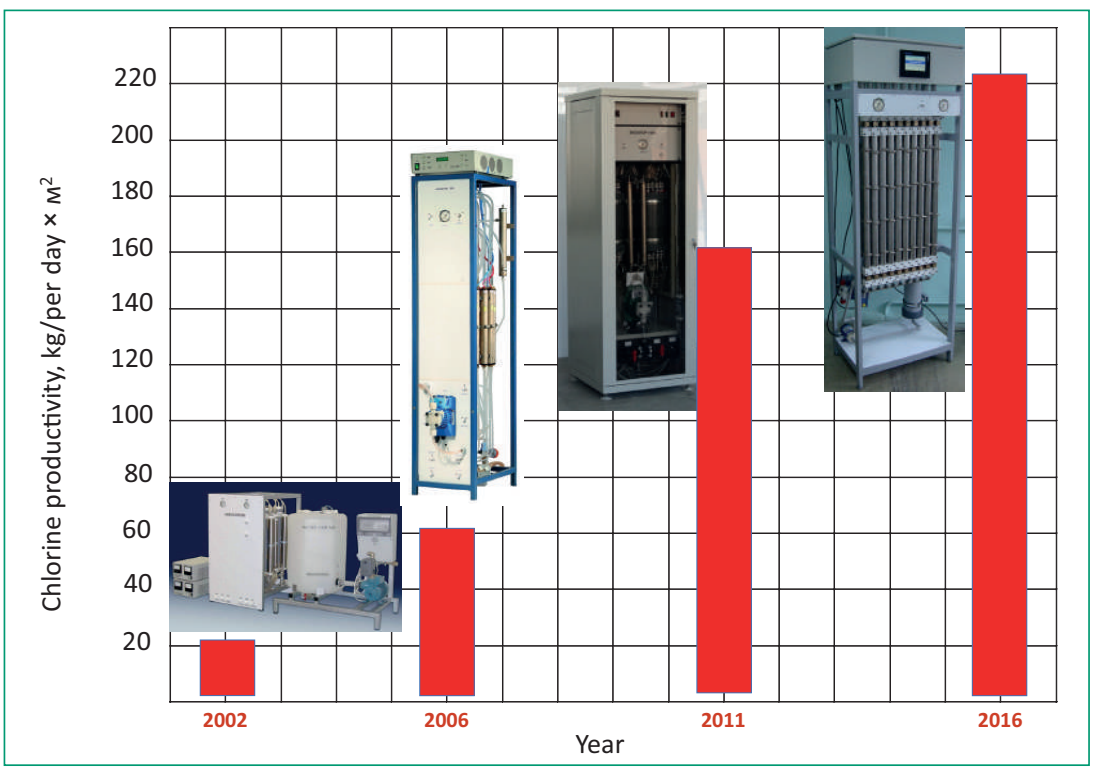


Fig. 6.1.10. *Productivity of AQUACHLOR devices referred to the floor area they occupy.*

ECOCHLOR (AQUATRON-25) is a class of devices for the electrochemical synthesis of gaseous chlorine and concentrated caustic soda solution. AQUATRON-25 devices are compact, safe modular chlorine-caustic systems that have no analogues in the world. The capacity of a single module varies from 1 to 10 kg/h for chlorine gas.

Flow charts of electrochemical synthesis processes in AQUATRON-20 and AQUATRON-25 devices differ in systems at the outlet of chlorine from the anode circuit, where the pressure can be in the range from 1 to 6 atm. In the AQUATRON-25 devices, in contrast to the AQUATRON-20 class devices, devices for heating chlorine in front of the pressure stabilizer and moisture extraction systems are required before being supplied to consumers. AQUATRON-25 devices are manufactured in accordance with the technical solutions set forth in RF patents Nos. 2270885, 2350692.

Until 2016, the class of electrochemical systems AQUATRON-25 was represented by a model range of ECOCHLOR devices with a maximum chlorine capacity of 500 grams per hour. The use of electrochemical elements with a high volumetric current density in ECOCHLOR devices will increase the productivity of these devices for chlorine and caustic soda by three times while maintaining the same energy consumption (by reducing the voltage on electrochemical modular elements) and with unchanged overall dimensions of the device, as well as creating modular ECOCHLOR devices with chlorine capacity up to 10 kg per hour.

AQUATRON-30 is a class of devices for the synthesis of highly purified sodium hypochlorite solution, compact modular devices that generate an electrochemically activated concentrated sodium hypochlorite solution with a minimum content of ballast substances, i. e. sodium chloride and hydroxide; and sodium chlorate. The degree of sodium chloride utilization in the process of converting the starting solution reaches 95%. AQUATRON-30 devices are manufactured in accordance with the technical solutions set forth in RF patents Nos.2157793, 2148027, 2145940.

OXITRON-M (AQUATRON-35) is a class of devices for the synthesis of electrochemically activated hydrochloric acid used in the leaching of non-ferrous, precious and rare metals from the dumps of ore-dressing plants, blast furnace slags, ore, scrap of non-ferrous and rare metals. AQUATRON-35 devices are manufactured in accordance with the technical solutions set forth in RF patents Nos. 2079575, 2270885, 2350692. This class is represented by OXITRON-M devices, with the maximum capacity not exceeding 100 liters of activated hydrochloric acid per hour. The use of new technological solutions for synthesis, associated with the use of modular electrochemical elements of a new generation, will make it possible to achieve the productivity of a single modular system OXITRON-K up to 1000 liters of activated hydrochloric acid per hour.

OXITRON-K (AQUATRON-40) is a class of devices for the synthesis of hydrochloric acid from chlorine and hydrogen — unique devices that have no analogues in the world. The process of synthesis of hydrochloric acid does not require preliminary deep purification of the starting solution of sodium chloride, as well as the removal of moisture from hydrogen and chlorine before feeding into the reaction chamber. The process safety is guaranteed by the new principle of gas supply to the reaction chamber. AQUATRON-40 devices are manufactured in accordance with the technical solutions set forth in RF patents Nos.2176989, 2079575, 2270885, 2350692.

This class is represented by OXITRON-K devices, the maximum productivity of which does not exceed 50 grams of hydrogen chloride per hour. The use of new technological solutions for synthesis, associated with the use of modular electrochemical elements of a new generation, will make it possible to achieve the productivity of a single modular OXITRON-K device up to 10 kilograms of hydrogen chloride per hour.

ROSTOK (AQUATRON-45) is a class of devices for producing a solution of electrochemically activated nitrogen and phosphorus fertilizers in irrigation water without changing its mineralization. In AQUATRON-45 devices, ordinary irrigation water is converted into an analogue of water after a spring thunderstorm, which has a beneficial effect on the growth and development of plants. Chlorides, sulfates and carbonates of ions of alkali and alkaline earth metals, which make up the natural mineralization of this water, are converted into nitrates and phosphates of these metals. The technological process of the synthesis of nitrates and phosphates in irrigation water makes it possible to create conditions for feeding plants with selectively specified fertilizers, choosing their optimal concentrations corresponding to the phases of plant development. AQUATRON-45 devices are manufactured in accordance with the technical solutions set forth in RF patents Nos.2063932, 2079575, 2207982.

This class is represented by ROSTOK devices with a capacity of 30 to 500 liters per hour for irrigation water with dissolved mineral fertilizers in the form of phosphates and nitrates of alkali and alkaline earth metals in a concentration of 0.01 to 1.3 mg/l. The use of new generation MB elements in the technological scheme of ROSTOK devices will increase the productivity of a single modular ROSTOK device up to 5000 liters per hour.

AQUATRON-50 is a class of devices for producing four types of products — depending on the need: acidic solution of oxidants produced by AQUATRON-20 (AQUACHLOR) devices, anolyte ANK SUPER produced by AQUATRON-05 (STEL-ANK-SUPER) devices, sodium hypochlorite solution produced by AQUATRON-30 devices, moist chlorine gas produced by AQUATRON-25 (ECOCHLOR) devices, sodium hydroxide solution with a concentration of up to 20%.

The class of AQUATRON-50 devices is represented by OXITRON-UNIVERSAL devices intended for the army and the Ministry of Emergency Situations.

AQUATRON-55 is a class of devices for the production of a solution of hypochlorous acid with a concentration of 5 to 30% from a solution of sodium chloride. Experimental models.

AQUATRON-60 is a class of devices for the synthesis of persulfuric acid from concentrated sulfuric acid solution. Experimental models.

BAZEKS (AQUATRON-65) is a class of devices for regulating the redox potential of solutions for hemodialysis in order to ensure the achievement of biocompatibility of the dialysis solution in redox equilibrium.

This class is represented by two models of the BAZEKS devices with a capacity of 5 and 25 liters per hour for purified water for hemodialysis with a redox potential in the range from — 300 to — 500 mV. Experimental models.

ENDOSTERIL (AQUATRON-70) is a class of devices for sterilization of endoscopic medical equipment with electrochemically activated solutions.

This class is represented by the ENDOSTERIL device, where disinfection, pre-sterilization cleaning and sterilization of the endoscope is carried out in an automatic mode using electrochemically activated low-concentration anolyte and catholyte obtained from a highly diluted aqueous salt solution.

Under development now is an experimental device AQUATRON-70-PEROX, where Anolyte PEROX is used as a washing and sterilizing solution.

CRYSTAL-C (AQUATRON-75) is a class of devices for purification of concentrated sodium chloride solutions from hardness salts.

This class is represented by an experimental model of the CRYSTAL-S device, which is being prepared for production in 2016.

REFERENCES

1. *Bakhir V.M. Method for controlling physicochemical properties of drilling mud. The USSR author's certificate № 1035047, 1979. Бахир В.М. Способ регулирования физико-химических свойств бурового раствора. Авторское свидетельство СССР, № 1035047, 1979.*
2. *Bakhir V.M. Device of electric treatment for drilling mud — UOBR: Inf. sheat № 27. M VNIIEGAZPROM, 1979 Бахир В.М. Установка для электрообработки бурового раствора — УОБР: Инф. листок № 27. М, ВНИИЭГАЗПРОМ, 1979.*
3. *Bakhir V.M. Device for electric treatment of saline water — UEV: Inf. leaf № 28. M VNIIEGAZPROM, 1979. Бахир В.М. Установка для электрообработки минерализованной воды — УЭВ: Инф. листок № 28. М, ВНИИЭГАЗПРОМ, 1979.*
4. *Bakhir V.M., Mamadzhanov U.D. Surface phenomena in disperse systems in a unipolar electrical stimulation//Report at the VII All-Union Conf. on colloid chemistry and physicochemical mechanics. — Minsk: Science and Technology 1977. Бахир В.М., Мамаджанов У.Д. Поверхностные явления в дисперсных системах в условиях униполярного электрического воздействия//Докл. на VII Всесоюзной конф. по коллоидной химии и физико-химической механике. — Минск: Наука и техника, 1977.*
5. *Bakhir V.M., Atadzhanov A.R., Mamadzhanov U.D., Alekhin S.A., Mariampolsky N.A., Nadzhimitdinov A.Kh. Activated materials. Some questions of the theory and practice//Proceedings of the Academy of Sciences of UzSSR. Ser.tehn.sciences, 1981, № 5. Бахир В.М., Атаджанов А.Р., Мамаджанов У.Д., Алехин С.А., Мариампольский Н.А., Наджимитдинов А.Х., Активированные вещества. Некоторые вопросы теории и практики//Изв. АН УзССР. Сер. техн. наук, 1981, № 5.*
6. *Bakhir V.M., Kirpichnikov P.A., Liakumovich A.G., Spector L.E., Mamadzhanov U.D. The mechanism of changes the reactivity of activated substances//Proceedings of the Academy of Sciences of UzSSR.*

Ser.tehn.sciences. 1982, № 4. — P.70–74. Бахир В.М., Кирпичников П.А., Лиакумович А.Г., Спектор Л.Е., Мамаджанов У.Д. Механизм изменения реакционной способности активированных веществ//Изв. АН УзССР. Сер. техн. наук. 1982, № 4. — С.70–74.

7. *Bakhir V.M., Spector L.E., Mamadzhanov U.D. The physical nature of the phenomena of substances activation//Proceedings of the Academy of Sciences of UzSSR. Ser.tehn.sciences. 1983. №1. Бахир В.М., Спектор Л.Е., Мамаджанов У.Д. Физическая природа явлений активации веществ//Изв. АН УзССР. Сер. техн. наук. 1983. №1.*
8. *Bakhir V.M., Kirpichnikov P.A., Liakumovich A.G. and others. On the nature of electrochemical activation of fluids.//Proceedings of the Academy of Sciences of the USSR. — 1986. v.286, № 3. — p. 663–666. Бахир В.М., Кирпичников П.А., Лиакумович А.Г. и др. О природе электрохимической активации сред.//Докл. АН СССР. — 1986. т. 286, № 3. — с. 663–666.*
9. *Bakhir V.M., Tsikoridze N.G., Spector L.E., Dadiany R.G., Zadorozhny Yu. G., Mechekhiya M.V., Liakumovich A.G., Kirpichnikov A.P., Agadzhanian S.I., Latyshev Yu. V.Electrochemical activation of water solutions and its technological application in the food industry//Tbilisi GruzNIINTI: Series: Food industry. 1988. Vol. 3. 81 p. Бахир В.М., Цикоридзе Н.Г., Спектор Л.Е., Дадиани Р.Г., Задорожний Ю.Г., Мечехия М.В., Лиакумович А.Г., Кирпичников А.П., Агаджанян С.И., Латышев Ю.В. Электрохимическая активация водных растворов и ее технологическое применение в пищевой промышленности//Тбилиси: ГрузНИИНТИ: Серия: Пищевая промышленность. 1988. Вып. 3. 81 с.*
10. *The essence and prospects of electrochemical activation. NIITEI. 25.04.89, № 410 — chem. industry 89. Bakhir V.M. Сущность и перспективы электрохимической активации. НИИТЭИ. 25.04.89, № 410 -хп 89. Бахир В.М.*
11. *Bakhir V.M. Electrochemical activation. — M.: VNIIIMT. 1992. — 2 p. — 657 p; — Ill. Бахир В.М. Электрохимическая активация. — М.: ВНИИИ мед. техники,1992. — 2 ч. — 657 с; — ил.*
12. *Mamadzhanov U.D., Bakhir V.M., Shamsutdinova V.N., Bakhir T.M. Method of processing of drilling mud. The USSR author's certificate № 929682, 22.04.1974. Мамаджанов У.Д., Бахир В.М., Шамсутдинова В.Н., Бахир Т.М. Способ обработки бурового раствора. Авторское свидетельство СССР № 929682, 22.04.1974.*
13. *Bakhir V.M., Aleksandrov A.A., Zadorozhny Yu. G., Sokolov Yu. N., Sorokin L.A. Device for regulating of drilling mud parameters. The USSR author's certificate № 746082, 11.02.1976. Мамаджанов У.Д., Бахир В.М., Александров А.А., Задорожний Ю.Г., Соколов Ю.Н., Сорокин Л.А. Устройство для регулирования параметров бурового раствора. Авторское свидетельство СССР № 746082, 11.02.1976. Mamajanov U.D.,*
14. *Mamadzhanov U.D., Sorokin L.A., Bakhir V.M., Sokolov Yu. N., Zadorozhny Yu. G.Device for controlling parameters of drilling mud. The USSR author's certificate № 895152, 09.01.1976. Мамаджанов У.Д., Сорокин Л.А., Бахир В.М., Соколов Ю.Н., Задорожний Ю.Г. Устройство для регулирования параметров бурового раствора. Авторское свидетельство СССР № 895152, 01.09.1976.*
15. *Mamadzhanov U.D., Gavrilov E.G., Alimdzhanov Kh.A., Bakhir V.M., Aleksandrov A.A., Sorokin L.A., Sokolov Yu.N., Zadorozhny Yu.G. Method for preparing of drilling mud. The USSR author's certificate № 619500, 19.01.1977. Мамаджанов У.Д., Гаврилов Е.Г., Алимджанов Х.А., Бахир В.М., Александров А.А., Сорокин Л.А., Соколов Ю.Н., Задорожний Ю.Г. Способ приготовления бурового раствора. Авторское свидетельство СССР № 619500, 19.01.1977.*
16. *Sokolov Yu. N., Bakhir V.M., Mamajanov U.D., Aleksandrov A.A., Hashimov M.A., Aleksandrov V.A., Zadorozhny Yu. G., Gaziyev D.Sh., Kopach A.A. Device for electric treatment of water. The USSR author's certificate № 691419, 11.07.1977. Соколов Ю.Н., Бахир В.М., Мамаджанов У.Д., Александров А.А., Хашимов М.А., Александров В.А., Задорожний Ю.Г., Газиев Д.Ш., Копач А.А. Устройство для электрообработки воды. Авторское свидетельство СССР № 691419, 11.07.1977.*
17. *Mamadzhanov U.D., Bakhir V.M., Aleksandrov A.A., Sokolov Yu.N., Zadorozhny Yu.G., Rizaev G.S., Bakhir T.M., Aleksandrov V.A. Method of drilling mud processing. The USSR author's certificate № 716321,*

11.07.1977. Мамаджанов У.Д., Бахир В.М., Александров А.А., Соколов Ю.Н., Задорожний Ю.Г., Ризаев Г.С., Бахир Т.М., Александров В.А. Способ обработки бурового раствора. Авторское свидетельство СССР № 716321, 11.07.1977.

18. *Mamadzhanov U.D., Sorokin L.A., Bakhir V.M., Sokolov Yu. N., Aleksandrov A.A. Device for foam destruction. The USSR author's certificate № 835169, 06.10. 1977. Мамаджанов У.Д., Сорокин Л.А., Бахир В.М., Соколов Ю.Н., Александров А.А. Устройство для разрушения пены. Авторское свидетельство СССР № 835169, 06.10.1977.*
19. *Nadzhimitdinov A. Kh., Bakhir V. M., Aleksandrov A. A., Sokolov Yu. N., Zadorozhny Yu. G., Aleksandrov V. A. Device for water desalination. The USSR author's certificate № 713140, 21.11.1977. Наджимитдинов А.Х., Бахир В.М., Александров А.А., Соколов Ю.Н., Задорожний Ю.Г., Александров В.А. Устройство для опреснения воды. Авторское свидетельство СССР № 713140, 21.11.1977.*
20. *Sokolov Yu. N., Bakhir V. M., Aleksandrov A. A., Zadorozhny Yu. G., Bakhir T. M., Aleksandrov V. A., Moshnyager Ya. I. Apparatus for drilling mud treatment. The USSR author's certificate № 662688, 22.02.1978. Соколов Ю.Н., Бахир В.М., Александров А.А., Задорожний Ю.Г., Бахир Т.М., Александров В.А., Мошнягер Я.И. Устройство для очистки бурового раствора. Авторское свидетельство СССР № 662688, 22.02.1978.*
21. *Mamadzhanov U.D., Bakhir V.M., Alekhin S.A., Zadorozhny Yu.G., Bakhir T.M. Method of drilling mud processing and device for its implementation. The USSR author's certificate № 904364, 22.03.1979. Мамаджанов У.Д., Бахир В.М., Алехин С.А., Задорожний Ю.Г., Бахир Т.М. Способ обработки бурового раствора и устройство для его осуществления. Авторское свидетельство СССР № 904364, 22.03.1979.*
22. *Mamajanov U.D., Bakhir V.M. Dergach G.I. Magnetoelectric properties of drilling muds and their use to improve drilling efficiency. — M.: VNIIEGAZPROM, 1975. — 39 p. Мамаджанов У.Д., Бахир В.М., Дергач Г.И. Магнитоэлектрические свойства буровых растворов и их использование для повышения эффективности бурения. — М.: ВНИИЭГАЗПРОМ, 1975. — 39 с.*
23. *Bakhir V.M., Zadorozhny Yu. G., Aleksandrov V.A., Rizaev G.S. Some questions of drilling mud electrotreatment. — Tashkent, Fan, 1977. Abstracts of the II republics. Conf. of young scientists and specialists on production technology of gas transport. Бахир В.М., Задорожний Ю.Г., Александров В.А., Ризаев Г.С. Некоторые вопросы электрообработки буровых растворов. — Ташкент, Фан, 1977. Тезисы докладов на II Республ. конф. молодых ученых и специалистов по технологии добычи и транспорта газа.*
24. *Alekhin S.A., Bakhir V.M., Dzhanmamedov Sh. Kh., Mariampolsky N.A., Ruban A.A. Experience in the use of methods of electrochemical activation of drilling mud. — M., VNIIEGAZPROM. Drilling of gas and offshore oil wells. Ref. art. 1981, vol. 3. Алехин С.А., Бахир В.М., Джанмамедов Ш.Х., Мариампольский Н.А., Рубан А.А. Опыт использования методов электрохимической активации бурового раствора. — М., ВНИИЭГАЗПРОМ. Бурение газовых и морских нефтяных скважин. Реф. сб. 1981, вып. 3.*
25. *Mamadzhanov U.D. The past years, the thorny paths. — Tashkent, Kvinta Print, 2012. — 88 p. Мамаджанов У.Д. Минувшие годы, тернистые пути. — Ташкент, Kvinta Print, 2012. — 88 с.*
26. *Mamadzhanov U.D., Saidov U.Kh. Activativation of substances. — Tashkent, Tafakkur Bo'stoni, 2015., — 232 p. Мамаджанов У.Д., Сайидов У.Х. Активация веществ. — Ташкент, Tafakkur Bo'stoni, 2015., — 232 с.*
27. *AO «O'ZLITINEFTGAZ» Uzbek R&D Institute of Oil and Gas Industry — Tashkent, Kvinta Print, 2015. — 208 p.; — ill. Узбекский научно-исследовательский и проектный институт нефтяной и газовой промышленности. — Ташкент, Kvinta Print, 2015. — 208 с; — ил.*
28. *Latyshev V.M. The Uncanny Water. Inventor and rationalizer, № 9, 1981. Латышев В.М. Неожиданная вода. Изобретатель и рационализатор, № 9, 1981 г.*
29. *Yegorov Yu. N. Academician Vakhidov: Activated water is promissing. Inventor and rationalizer, № 9, 1981. Егоров Ю.Н. Академик Вахидов: активированная вода перспективна. Изобретатель и рационализатор, № 9, 1981 г.*

30. *Yevseev E. These activated liquids. Technique and science. № 11, 12, 1981, № 1, 1982, № 12, 1984. Евсеев Е. Эти активированные жидкости. Техника и наука. № 11, 12, 1981 г., № 1, 1982 г., № 12, 1984 г.*
31. *Novogrudsky E. E. «Living and dead water» — what's behind the boom? Literature newspaper № 37 (5051) of 11.09.1985, p.12. Новогрудский Е. Е. «Живая вода и мёртвая» — что за сенсацией? Литературная газета № 37 (5051), 11.09.1985 г., с.12.*
32. *Latyshev V. M. Where are you flowing to, «Uncanny Water»? Inventor and rationalizer, № 2, 5, 1985. Латышев В. М. Куда течёшь, «неожиданная вода»? Изобретатель и рационализатор, № 2, 5, 1985 г.*
33. *Onatskaya A. A., Muzalevskaya N. I. Activated water.//Chemistry — traditional and paradoxical. L., LSU, 1985, p. 88–114. Онацкая А. А., Музалевская Н. И. Активированная вода. В кн. Химия — традиционная и парадоксальная. Л., ЛГУ, 1985 г., с. 88–114.*
34. *Gladkov V., Morozov N., Reut V. Water extravaganza. Pravda, № 189 (24446), of 08.07.1985. Гладков В., Морозов Н., Реут В. Водная феерия. Правда, № 189 (24446), 8.07.1985 г.*
35. *Mamadzhanov U. D., Alekhin S. A., Gurevich L. E., Yumashev A. P., Goncharov P. V., Kuznetsov E. B., Bakhir V. M. Apparatus for electric treatment of drilling mud. The USSR author's certificate № 1021210, 11.12.1980. Мамаджанов У. Д., Алехин С. А., Гуревич Л. Е., Юмашев А. П., Гончаров П. В., Кузнецов Э. Б., Бахир В. М. Устройство для электрообработки бурового раствора. Авторское свидетельство СССР № 1021210, 11.12.1980.*
36. *Mamadzhanov U. D., Kuznetsov E. B., Bakhir V. M., Burov A. A., Spector L. E., Klimenko V. I. Apparatus for processing of drilling mud. The USSR author's certificate № 1134697, 22.03.1982. Мамаджанов У. Д., Кузнецов Э. Б., Бахир В. М., Буров А. А., Спектор Л. Е., Клименко В. И. Устройство для обработки бурового раствора. Авторское свидетельство СССР № 1134697, 22.03.1982.*
37. *Spector L. E., Kirpichnikov P. A., Bakhir V. M., Liakumovich A. G., Kuznetsov E. B., Fridman B. S., Mamadzhanov U. D. Device for electrical processing of liquid. The USSR author's certificate № 1100770, 05.31.1982. Спектор Л. Е., Кирпичников П. А., Бахир В. М., Лиакумович А. Г., Кузнецов Э. Б., Фридман Б. С., Мамаджанов У. Д. Устройство для электрической обработки жидкости. Авторское свидетельство СССР № 1100770, 31.05.1982.*
38. *Spector L. E., Liakumovich A. G., Bakhir V. M., Kuznetsov E. B., Mamadzhanov U. D., Gamer P. U., Zadorozhny Yu. G. Device for drilling mud treatment. The USSR author's certificate № 1090049, 06.10.1982. Спектор Л. Е., Лиакумович А. Г., Бахир В. М., Кузнецов Э. Б., Мамаджанов У. Д., Гамер П. У., Задорожний Ю. Г. Устройство для обработки бурового раствора. Авторское свидетельство СССР № 1090049, 06.10.1982.*
39. *Bakhir V. M., Spector L. E., Latyshev Yu. V., Zadorozhny Yu. G., Mamadzhanov U. D., Mirzakarimova G. R., Kirpichnikov P. A., Liakumovich A. G., Bakhir T. M. Portable device for electric treatment of liquid. The USSR author's certificate № 1215306, 08.12.1982. Бахир В. М., Спектор Л. Е., Латышев Ю. В., Задорожний Ю. Г., Мамаджанов У. Д., Мирзакаримова Г. Р., Кирпичников П. А., Лиакумович А. Г., Бахир Т. М. Переносное устройство для электрообработки жидкости. Авторское свидетельство СССР № 1215306, 08.12.1982.*
40. *Bakhir V. M., Spector L. E., Zadorozhny Yu. G., Lysenko N. M., Rudinsky Ya. A. Device for electrochemical treatment of liquid. The USSR author's certificate № 1719316, 17.10.1986. Бахир В. М., Спектор Л. Е., Задорожний Ю. Г., Лысенко Н. М., Рудинский Я. А. Устройство для электрохимической обработки жидкости. Авторское свидетельство СССР № 1719316, 17.10.1986.*
41. *Zadorozhny Yu. G., Bakhir V. M., Spector L. E., Belikov V. S., Lysenko N. M., Podkolzin A. A., Dmitriev N. N., Shtefan V. N., Grachev Yu. A. Device for electrochemical treatment of liquid. The USSR author's certificate № 1634643, 02.12.1986. Задорожний Ю. Г., Бахир В. М., Спектор Л. Е., Беликов В. С., Лысенко Н. М., Подколзин А. А., Дмитриев Н. Н., Штефан В. Н., Грачев Ю. А. Устройство для электрохимической обработки жидкости. Авторское свидетельство СССР № 1634643, 02.12.1986.*
42. *Spector L. E., Bakhir V. M., Zadorozhny Yu. G. Device for unipolar electric treatment of liquid. The USSR author's certificate № 1476806, 05.03.1987. Спектор Л. Е., Бахир В. М., Задорожний Ю. Г.*

Устройство для униполярной электрообработки жидкости. Авторское свидетельство СССР № 1476806, 05.03.1987.

43. *Spector L. E., Bakhir V. M., Zadorozhny Yu. G., Shtefan V. N. Device for unipolar treatment of liquid. The USSR author's certificate № 1476807, 05.03.1987. Спектор Л. Е., Бахир В. М., Задорожний Ю. Г., Штефан В. Н. Устройство для униполярной обработки жидкости. Авторское свидетельство СССР № 1476807, 05.03.1987.*
44. *Mashkov O. A., Baldin V. P., Krylov K. P., Zdvizhkov Yu. V., Prilutsky V. I., Zadorozhny Yu. G., Shtern K. M., Bakhir V. M. Device for the sorption of toxic substances from biological fluids. The USSR author's certificate № 1680209, 29.03.1988. Машков О. А., Балдин В. П., Крылов К. П., Здвижков Ю. В., Прилуцкий В. И., Задорожный Ю. Г., Штерн К. М., Бахир В. М. Устройство для сорбции токсических веществ из биологических жидкостей. Авторское свидетельство СССР № 1680209, 29.03.1988.*
45. *Bakhir V. M., Zadorozhny Yu. G., Leonov B. I., Mashkov O. A., Perlovsky R. Sh., Prilutsky V. I., Pulavsky A. M., Ryzhnev V. Yu., Shtern K. L. Method for cleaning of dialysis membranes. The USSR author's certificate № 1707823, 09.13.1988. Бахир В. М., Задорожний Ю. Г., Леонов Б. И., Машков О. А., Перловский Р. Ш., Прилуцкий В. И., Пулавский А. М., Рыжнев В. Ю., Штерн К. Л. Способ очистки диализных мембран. Авторское свидетельство СССР № 1707823, 13.09.1988.*
46. *Pulavsky A. M., Bakhir V. M., Ryzhnev V. Yu., Byalko M. V., Zadorozhny Yu. G., Shtern K. L. Device for electrochemical treatment of liquids. The USSR author's certificate № 1679746, 12.26.1988. Пулавский А. М., Бахир В. М., Рыжнев В. Ю., Бялко М. В., Задорожний Ю. Г., Штерн К. Л. Устройство для электрохимической обработки жидкостей. Авторское свидетельство СССР № 1679746, 26.12.1988.*
47. *Pulavsky A. M., Bakhir V. M., Ryzhnev V. Yu., Byalko M. V., Zadorozhny Yu. G., Shtern K. L. Method of laundry washing and a device for its implementation. The USSR author's certificate № 1687684, 12.26.1988. Пулавский А. М., Бахир В. М., Рыжнев В. Ю., Бялко М. В., Задорожний Ю. Г., Штерн К. Л. Способ стирки белья и устройство для его осуществления. Авторское свидетельство СССР № 1687684, 26.12.1988.*
48. *Akimov Yu. P., Belikov V. S., Davydov A. A., Bakhir V. M. Domestic electroactivator. Certificate for industrial design № 26926, 05.04.1988. Акимов Ю. П., Беликов В. С., Давыдов А. А., Бахир В. М. Электроактиватор бытовой. Свидетельство на промышленный образец № 26926, 05.04.1988.*
49. *Bakhir V. M., Vedenkov V. G., Lir I. L., Leonov B. I., Pulavsky A. M., Ryzhnev V. Yu. Method for producing washing and sterilizing solutions for cleaning and preparation of biofilters for re-use. The USSR author's certificate № 2033807, 19.04.1990. Бахир В. М., Веденков В. Г., Лир И. Л., Леонов Б. И., Пулавский А. М., Рыжнев В. Ю. Способ получения моющего и стерилизующего растворов для очистки и подготовки биофильтров к повторному использованию. Авторское свидетельство СССР № 2033807, 19.04.1990.*
50. *Leonov B. I., Mashkov O. A., Vedenkov V. G., Prilutsky V. I., Overchenko A. V., Zadorozhny Yu. G., Lir I. L., Naida N. N., Bakhir V. M. Apparatus for hemodialysis. The USSR author's certificate № 2032426, 06.07.1990. Леонов Б. И., Машков О. А., Веденков В. Г., Прилуцкий В. И., Оверченко А. В., Задорожний Ю. Г., Лир И. Л., Найда Н. Н., Бахир В. М. Устройство для гемодиализа. Авторское свидетельство СССР № 2032426, 06.07.1990.*
51. *Bakhir V. M. Electrochemical activation: inventions, systems, technology. — M., Viva Star, 2014. — 514 p. with ill. Бахир В. М. Электрохимическая активация: изобретения, техника, технология. — М., Вива-Стар, 2014., — 514 с., ил.*
52. *Bakhir V. M., Zadorozhny Yu. G. The electrochemical treatment of water and a device for electrochemically treating water. UK Patent 2253860 B, 12.03.1991.*
53. *Bakhir V. M., Zadorozhny Yu. G. An electrolytic method of drinking water purification. UK Patent 2257982 B, 24.07.1991.*
54. *The electrochemical reactor 23.3.0061.00.00. (STP 21.5-19-31). A complete set of technical documents. M., VNIIIMT, 1989. Реактор электрохимический 23.3.0061.00.00. (СТП 21.5-19-31). Полный комплект технических документов. М., ВНИИИМТ, 1989 г.*

55. *Bakhir V.M. Laboratory electrochemical diaphragm flow-through reactor RPE-1. Manual. M., FMPK GVTs State Statistics Committee of the USSR, 1990. — 35 p. Бахир В.М. Лабораторный электрохимический диафрагменный проточный реактор РПЭ-1. Руководство по эксплуатации. М., ФМПК ГВЦ Госкомстата СССР, 1990. — 35 с.*
56. *Bakhir V.M., Zadorozhny Yu. G. Electrochemical reactors RPE. — M.: Giperoks, 1991. — 35 p; ill. Бахир В.М., Задорожний Ю.Г. Электрохимические реакторы РПЭ. — М.: Гиперокс, 1991. — 35 с; — ил.*
57. *Bakhir V.M., Zadorozhny Yu.G. Device for electrochemical treatment of water. Patent № 2042639, 03.04.1992. Бахир В.М., Задорожний Ю.Г. Устройство для электрохимической обработки воды. Патент № 2042639, 03.04.1992.*
58. *Bakhir V.M., Zadorozhny Yu. G. Apparatus for electrochemical treatment of water. RF Patent № 2078737, 26.05.1994. Бахир В.М., Задорожний Ю.Г. Устройство для электрохимической обработки воды. Патент РФ № 2078737, 26.05.1994.*
59. *Bakhir V.M., Zadorozhny Yu.G., Leonov B.I., Panicheva S.A., Prilutsky V.I. Electrochemical activation: a universal tool for green chemistry. — M.: Marketing Support Services, 2005. — 176 p.; — ill. Бахир В.М., Задорожний Ю.Г., Леонов Б.И., Паничева С.А., Прилуцкий В.И. Электрохимическая активация: универсальный инструмент зеленой химии. — М.: Маркетинг Саппорт Сервисиз, 2005. — 176 с.; — ил.*

УДК 544.6+625.35
ББК 24.57
Э45

Bakhir V. M., Panicheva S. A., Prilutsky V. I., Panichev V. G.

Э45 ELECTROCHEMICAL ACTIVATION: INVENTIONS, SYSTEMS, TECHNOLOGY

The book considers theoretical concepts and hypotheses about the nature of the phenomenon of electrochemical activation of substances discovered by Vitold M. Bakhir in the seventies of the last century. It provides information on the most significant inventions in the field of electrochemical activation and the results of the practical implementation of inventions in various fields of science, engineering and technology. It describes various electrochemical systems for producing liquids with an abnormally high activity in oxidation-reduction, catalytic and biocatalytic processes.

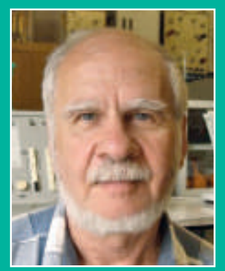
Based on the experience of engineering and practical use of electrochemical systems for production environmentally friendly, safe for humans and animals electrochemically activated detergents, disinfectants and for production of the environmentally friendly sterilizing solutions, the authors predict further development of electrochemical activation technology. Various examples show that the role of electrochemical activation in the near future will steadily increase not only in the field of drinking water disinfection and purification, wastewater and swimming pool water treatment, food industry and agriculture, but also in chemical, petrochemical and mining industries to save raw materials, time and energy, while improving environmental safety and efficiency of the processes.

The book is intended for a wide range of specialists and students interested in the application of electrochemical technologies in various fields of human activity.

ISBN 978-5-6047707-0-2

VITOLD BAKHIR — the creator of new scientific and technical field — electrochemical activation (ECA). Doctor of Technical Sciences, Professor, Scientific Director at Electrochemical Systems and Technologies Institute. The author of more than 400 inventions with copyright certificates of the USSR and patents of the Russian Federation, USA, Canada, Great Britain, Germany, Switzerland, Italy, Japan, China, South Korea. The above-mentioned inventions are implemented in several hundred thousand various electrochemical devices in many countries. The author of 7 monographs and more than 300 scientific articles.

SVETLANA PANICHEVA — Ph. D., expert in medical electrochemical solutions, experienced in electrochemical medical devices, investigational new drug applications and food safety products development, creation of cGMP manufacturing for stabilized electrochemically activated hypochlorous acid formulations, preparing FDA submissions for topical drug products, validation, and manufacturing. The author of more than 50 international patents and more than 100 publications.



VLADIMIR PRILUTSKY — Ph. D., Scientific Consultant at Electrochemical Systems and Technologies Institute, expert in medical sciences, the author of 20 inventions, 5 monographs and more than 200 scientific articles in the field of electrochemical activation. The author of a number of new concepts on the interaction of electrochemically activated water and solutions with objects of animate and inanimate nature. His ideas have served as a basis for creating fundamentally new technological processes and technical electrochemical systems widely recognized and used in practical medicine.

VADIM PANICHEV — expert in Electrochemical Technology Applications for Regulated Industries (Pharma, Medical Devices, Biotech, etc.), working over the past 25 years in Electrochemical Equipment Design and Development, Product Development and process validation for DOD, Agricultural, Medical Devices and Pharma Industries. The author of international patents for methods of manufacturing and application of electrochemically activated solutions and stabilized hypochlorous acid formulations.

ISBN 978-5-6047707-0-2

BAKHIR V. M.
PANICHEVA S. A.
PRILUTSKY V. I.
PANICHEV V. G.

ELECTROCHEMICAL ACTIVATION

INVENTIONS SYSTEMS TECHNOLOGY

ELECTROCHEMICAL ACTIVATION

Vitold Bakhir Institute