Complex Automated Electrolysis Unit for Wastewaters Treatment and Drinking Water Purification

E. Arakcheev [1], V. Brunman [2], M. Brunman [3], A. Konyashin [3], A. Petkova [2]

[1] GC "Spetsmash", Dzerzhinsk, Russia
E-mail: info@specmach.ru
[2] Laboratory "Mechatronics", Peter the Great Saint-Petersburg Polytechnic University, St. Petersburg, Russia
[3] Department "Automats", Peter the Great Saint-Petersburg Polytechnic University, St. Petersburg, Russia
E-mail: automats@inbox.ru

Received: 21.10.2015

Abstract. Article describes construction principles and design of comprehensive electrolysis unit that produces simultaneously chlorinated anolyte and sodium ferrate. Anolyte will permit to carry on water treatment at the municipal water supplies or enterprise territory and the ferrates – the treatment of industrial wastewaters, so the unit will ensure that treated wastewaters discharged into the environment without any harm. Integrated electrolysis unit for the production of reagents for drinking water purification and wastewaters treatment does not have any domestic analogues, and can ensure the competitiveness of the domestic water treatment processing systems compared to foreign made analogues by price, productiveness and energy efficiency.

Keywords: Water, industrial wastewaters, disinfection, anolyte, ferrates, electrolysis unit, energy efficiency

INTRODUCTION

A new approach to water treatment is a creation of an ecologically safe and economically effective integrated electrolysis unit (IEU), generating anolyte (mainly Cl_2) from the solution of salt in water and liquid ferrates (NaOH) from the waste of anolyte electrolytic production [1]. At this, the anolyte and the ferrates are used directly at the place of production: anolyte for disinfection of drinking and industrial water for own needs of the enterprise, and the ferrates for processing of industrial wastewaters.

A membrane electrolysis was chosen as a promising method for obtaining chlorine-containing anolyte for disinfection of drinking and industrial water, and for production of sodium ferrate for wastewater treatment [2]. Proposed by authors an environmentally sound and economically efficient integrated electrolysis unit (IEU) allows to combine two electrolysis processes (obtaining of anolyte and production of ferrates) in one unit with an adaptive performance management system.

Such an approach, which includes intelligent control of the electrolysis process for both products at the same time, gives a possibility to avoid violations of regulations and legislative acts in the field of water treatment, improve the quality and increase the energy efficiency of the overall process.

DESIGN OF AN INTEGRATED ELECTROLYSIS UNIT

The IEU combines modules for production of anolyte and ferrates with the systems of gas outlet and recirculation of anolyte and catholyte and automated unit control system (Fig. 1).

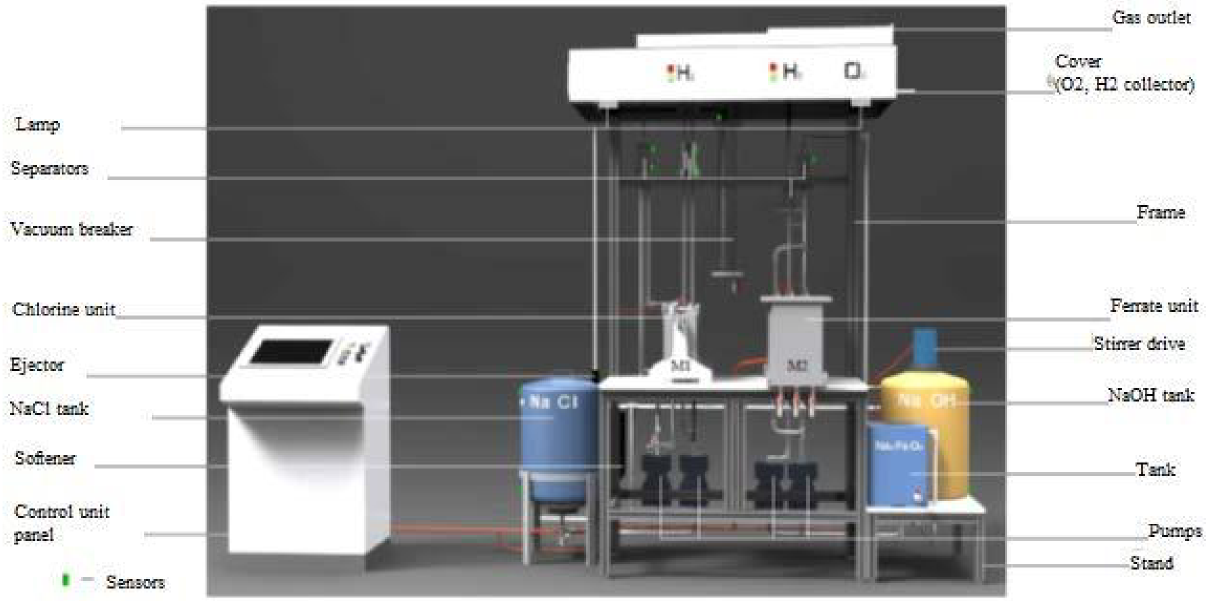

Figure 1. General view of experimental integrated electrolysis unit

Module M1 for producing anolyte (Fig. 2) consists of a DC power supply 1, a tank for preparing the salt solution 2, cell E1, which is divided for anode and cathode compartments by ion-exchanging membrane 4, with two electrodes – cathode 5 and anode 6, pumps for dispensing the salt solution in the anode chamber and water in the cathode chamber, an ejector for dispensing anolyte in water, tanks to store water 8 and alkali 9, separators of hydrogen 10 and chlorine 11 from cathode and anode chambers, sensors controlling the amount of chlorine in water and gas, and alarm annunciators of contamination of premises with chlorine/hydrogen.

Module M2 for production of ferrates (Fig. 2) contains a DC power supply source 12, the cell E2, with the at least one consumable iron-containing anode 14 and the cathode 15, pumps for dispensing alkali in the anode and the cathode chambers, a tank 17 for the accumulation of the ferrates, the hydrogen (18) and oxygen (19) separators from cathode and anode chambers, and the device for ferrates dosing.

All the styles used in this template are described in Table 1. Most of styles should be applied on a whole paragraph. Please try to avoid creating new styles because it can lead to difficulties in proceedings book assembly.

The unit also contains diaphragm pumps for feeding and dosing of reagents in the cells and a control unit with sensors for monitoring production parameters of anolyte and ferrates. The controlling unit operates in the specified mode and control the performance of the unit.

The case of the membrane cell E1 for the production of anolyte is divided into two chambers by a semi-permeable cation-exchange membrane. The cathode chamber is made of chlorine-resistant titanium, the anode chamber – of alkali with concentration of 30–35 % – resistant stainless steel. As cation exchange membranes operating at alkali concentrations of 30–35 %, membranes of Flemion 811 or Nafeon-2030 types can be used.

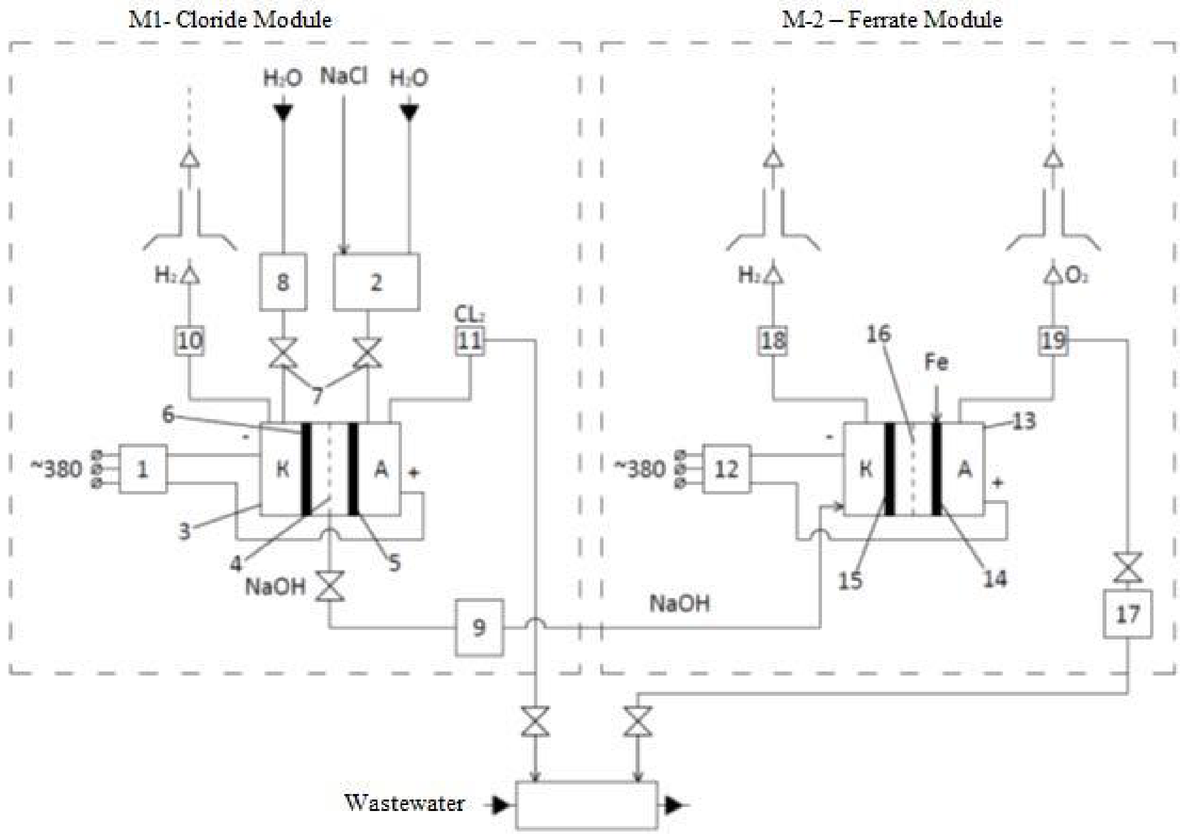

Figure 2. A schematic diagram of apparatus for integrated producing of chlorine-containing reagent and sodium ferrate: 1, 12 – electrolytic cells power supplies units; 2 – tank for brine preparation; 3,13 – cell E1 for the production of anolyte and E2 for the production of sodium ferrate; 4, 16 – cation-exchange membrane; 5, 15 – cathode; 6 – anode; 7 –valves controlling the feed of salt solution and water; 8 – can for water; 9 – intermediate tank with a solution of sodium hydroxide; 10, 18 – cathode separators; 11, 19 – anode separators; 14 – consumable anode; 17 – tank with sodium ferrate

The case of the membrane cell E2 for the production of ferrate is made of alkali-resistant polypropylene, and is divided into three chambers, separated by a semi-permeable cation exchange membrane. As cation exchange membranes operating at alkali concentrations of 30–35 %, membranes of Flemion 811 or Nafeon-2030 types can be used also.

The feedstock for the operation of the unit is tap water and salt for the brine. Salt is fed into the brine tank manually. Water and brine contains in the tanks, which filling is controlled by a floating mechanism. Then they are served into the first module by pumps. The recirculation loop of the first module contains separators to separate products of liquid and gaseous phase. The alkali produced of the first module reserves in a separate tank, from which it supplied to the second module by pumps.

Controlled rectifier with two independent outputs delivers a direct electric current on each of the modules. The by-produced hydrogen from both modules is displayed in a separate ventilation system, which has the pressure sensor for monitoring the pressure of hydrogen in the exhaust.

The integrated electrolysis unit automated control system (ACS) optimizes production process of anolyte and ferrates while minimizing energy consumption. The unit ACS controls the following parameters: the minimum level of liquid in tanks with water and brine; minimum and maximum liquid level in the alkali tank, both separators and in the second module; the chlorine concentration in the treated water; reduced pressure in the branch vacuum breaker; overpressure in the hydrogen exhaust system; temperature of the output liquids of each module; hydrogen and chloride permissible concentration exceeding alerts from the air sensor (Fig. 1). ACS manages the following actuators: unit tap water supply valve; modules DC power supply; pumps for feedstocks supply to the modules; emergency extractor; automatic feeder system.

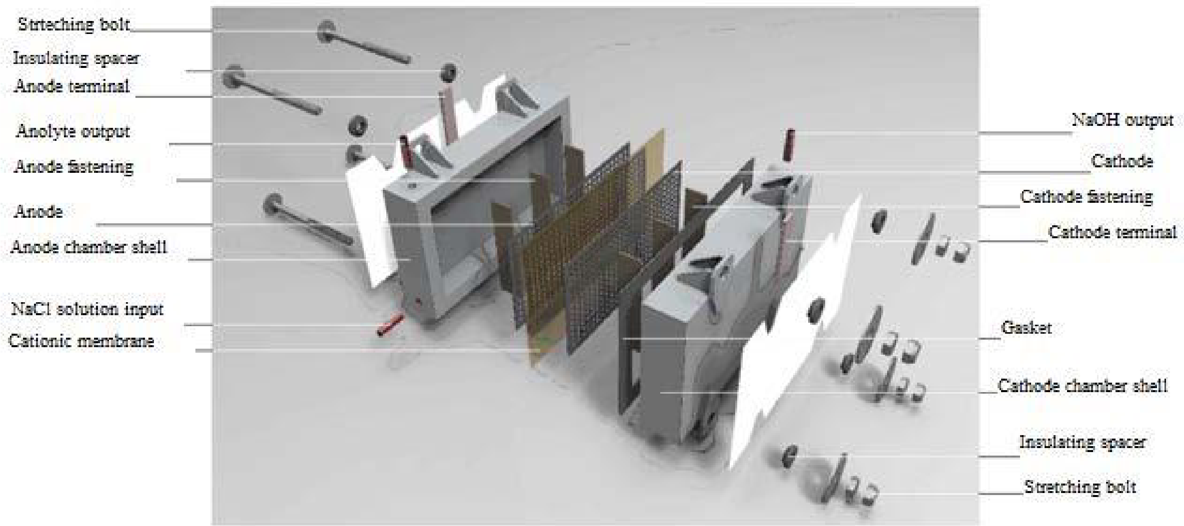

Figure 3. Device for producing chloride (anolyte) (as a part of IEU) layout scheme

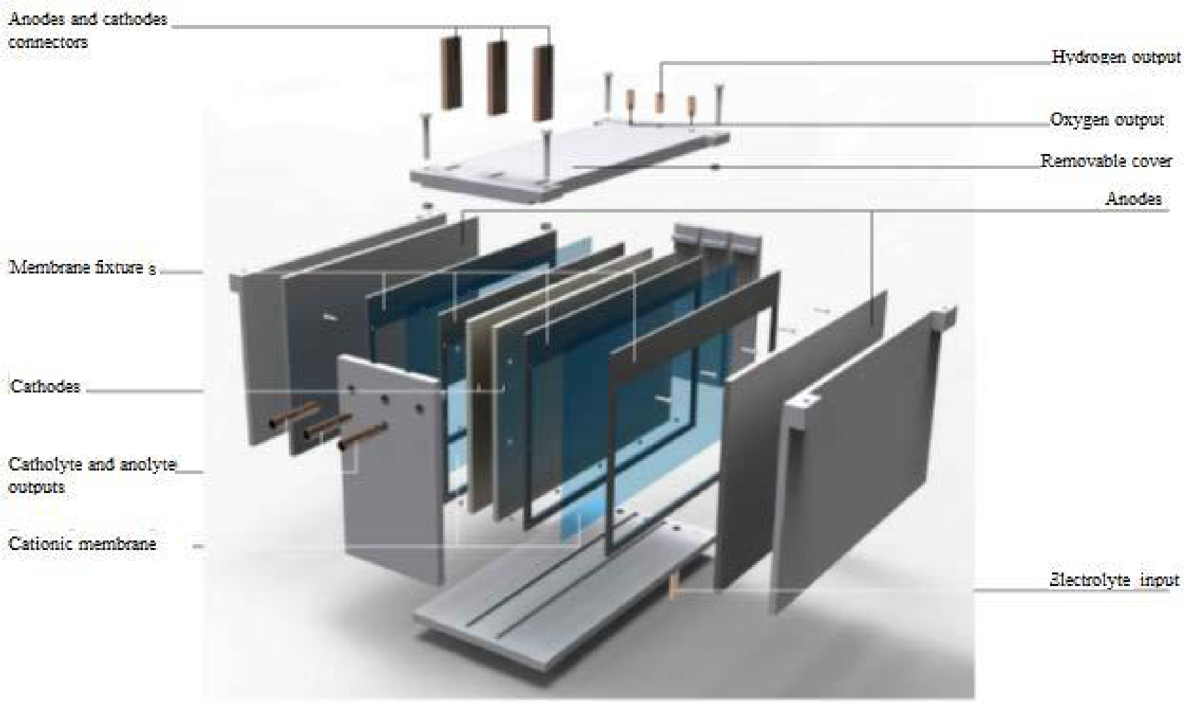

Figure 4. Device for producing ferrate (as a part of IEU) layout scheme

ACS supports following modes: unit launch, operation with automatic control, operation with manual control, regular stop and emergency stop. Automatic control of anolyte production carried out on a sensor readings of residual chlorine in the treated water feedback providing a residual chlorine content in the range 1.8–2.3 mg/l [3]. Ferrate production carried out by a given amount of wastewater, which is determined statistically. In case of exceeding the critical level in any of the monitored parameters of process safety ACS starts emergency ventilation, gives an audible alarm and starts emergency stop process by turning off modules power supply and terminating object water supply.

TECHNOLOGICAL PARAMETERS OF PROCESS

Experimental integrated electrolysis unit produces 65 g of chlorine and 25 g of sodium ferrate per hour. Cell E1 of the module M1, which produces chlorine-containing anolyte, is supplied by DC current of up to 60 amps, at a voltage of 3 to 4 V. The maximum specific power consumption of the module is 3.5 kWh / kg. Depending on the area of the electrodes (solid or perforated) maximum current density can vary respectively from 1400 to 1600 A/m^2. Thus, Flemion 811 or Nafeon-424 can be used as cation-exchange membrane.

Purified softened water is fed into the cathode chamber of the electrolytic cell E1. The saturated salt solution is fed to the anode chamber of E1. The electrolysis process takes place in cell E1 at the optimum temperature of 60-80 Co. Anolyte from the anode chamber through the chlorine separator is sucked by an ejector into the processed wastewaters transportation system.

Solution of sodium hydroxide with a concentration of 25 % to 35 % goes from the cathodic chamber through a hydrogen separator to the intermediate storage tank of alkali, and gaseous hydrogen is deflected. Then, the solution of sodium hydroxide is fed into the chamber of the cell E2, which is part of the module M2, for the production of sodium ferrate.

The cell E2 is fed by the DC power supply of 45A at a voltage of 3–3.5 V. The maximum specific power consumption of the module is 6 kWh / kg. The anode in the electrolytic cell E2 may be solid, perforated, or of expanded metal. At this, the current density does not exceed 250 A/m^2, which also allows the use Flemion 811 or Nafeon-424 type's membrane. Electrolysis in cell E2 runs at temperature less than 60 °C. Solution of sodium ferrate from the anode chamber through the oxygen separator is fed into the tank for accumulation of the product, and gaseous oxygen is deflected. Gaseous hydrogen is removed from the cathode chamber through the separator.

The separators of both modules are used for visual control of the boundary between liquid and gaseous media with separate removal of gaseous hydrogen and oxygen, and for control of chlorine inflow system for the absence of leakage in the unit.

SUMMARY

Proposed unit as feedstock uses tap water, salt and electricity, so it can easily be implemented into the production cycle. Such installation will permit to carry on water treatment at the municipal water supplies or enterprise territory and ensure that treated wastewaters be discharged into the environment without any harm.

The integrated electrolysis unit automatic control system allows real-time monitoring and managing of reagents production in automatic or manual mode, chose the necessary dosage ratio of the reagents, keep records of the unit operation and solve emergency problems.

The developed integrated electrolysis unit for producing reagents for purification of drinking water and wastewaters processing has no domestic analogues and can ensure the competitiveness of home wastewater processing systems compared to foreign made analogues by price, productiveness and energy efficiency.

Technology of anolyte (chlorine) production by membrane electrolysis is less energy-intensive as compared to the production of hypochlorite on consumption site method, which is used in foreign analogues [4]. The main advantage of using a membrane electrolysis for ferrate manufacturing is providing its larger output by used current, and, consequently, greater energy efficiency, than in diaphragmless electrolytic cells described in analogue projects. This is because in the absence of the separator, ferrate ions reach the cathode and are partially exposed to electrochemical recovery, including molecular hydrogen formed in the cathode area.

In addition, the presence of the membrane prevents the mixing of gaseous hydrogen and oxygen, generated by electrolysis in different cells. This increases the explosion safety of the entire installation and eliminates the need for purging the cell with inert gas, used by analogue projects, which, in turn, also reduces energy costs.

Work is performed with financial support from the RF Ministry of Education and Science, project unique identifier – RFMEFI57514X0080.

REFERENCES

1. V.E. Brunman, A.P. Petkova and M.V. Brunman, "Construction principles and design of autonomous mobile systems for water treatment and disinfection at the place of use of reagents," International Research Institute «EDUCATO», No. 6, pp 18-22, 2014.
2. E. N. Arakcheev, V. E. Brunman, M.V. Brunman, A.H. Volkov, V.A. Dyachenko, A.V. Kochetkov and A.P. Petkova, "Modern Advanced Technology for Disinfection of Water and Wastewater," Hygiene and Sanitation, vol. 94, No. 4, pp. 25-32, 2015.
3. GOST 51232-98 (1998). Drinking water. General requirements for the organization and methods of quality control.
4. Ballast water treatment. Unit and method of ferrate usage. Russian Federation Patent. KR101202765, MPK C02F1/461 (19 November 2012).