1. Maryna MIKHALIEVA[1], 2. Vasyl PARAKUDA[2], 3. Yuryi SHABATURA[1], 4. Lubomyra ODOSII[1], 5. Krzysztof PRZYSTUPA[3]

Hetman Petro Sahaidachnyi National Army Academy: Lviv (1), «Scientific-research Institute for Metrology of Measurement and Control Systems», Lviv, (2), Lublin University of Technology (3)

ORCID. 1. 0000-0001-5612-3737, 2. 0000-0001-7044-5740, 3. 0000-0002-9961-1244, 4. 0000-0003-2438-7759, 5. 0000-0002-9961-1244

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Electrical method for a water control after an osmosis process for the standard unit of ultrasound power in the aquatic environment

Abstract: *The article discusses the issue of water quality improved by the metrological characteristics of the standard unit of ultrasound power in the aquatic environment by an automated control of the purification process. The received experimental results demonstrate that this new electric method of control is highly efficient.*

Streszczenie. W *artykule omówiono problem jakości wody. Poprawę jakości uzyskano przez zastosowanie metody wykorzystującej ultradźwięki. Proces oczyszczania sterowano automatycznie. Na podstawie otrzymanych wyników eksperymentalnych wykazano wysoką skuteczność zastosowanego sterowania w tej metodzie.* (***Elektryczna metoda kontroli wody po procesie osmozy w środowisku wodnym)***

Keywords: electrophysical characteristics of liquids, conductivity sensors, operational control
Słowa kluczowe: właściwości elektrofizyczne cieczy, przetworniki przewodności, sterowanie operacyjne

Introduction

Active ultrasound storing in modern technologies requires a continuously adjusted accuracy of changing parameters of ultrasound. Reliability and the reliability of energy parameters in ultrasound are especially important for efficiency and safety of ultrasound. For the whole, the Scientific-Research Institute for Metrology of Measurement and Control Systems carries out metrological research and monitors the standards to maintain stable functions and reduce metrological characteristics, especially to expand dynamical and frequency ranges from the hour to the removal of one unit.

The company complies with the international standard IEC 61161: 2013 "Ultrasonics - Power measurement - Radiation force balances and performance requirements". The National State Standard of the Single Thrust for Ultrasound in the Water Environment AUV-01-2018 is the one in the straining of ultrasound based on the method of the gravimetric time-dependent radioactive force.

The current national standard of single pressure for ultrasound allows ultrasound pressure in the frequency range from 0.5 MHz to 15.0 MHz, in the range of pressure from 0.005 to 10 W. It has the following metrological indicators: measurement uncertainty by type A - uA = 0.7%; measurement uncertainty by type B - uB = 5.3%; total standard uncertainty - uC = 5.4 %; extended uncertainty (к=2) - U = 10.7 %.

The company also complies with the international standard IEC 61127-2: 2007 "Ultrasonics - Hydrophones - Part 2: Calibration for ultrasonic fields up to 40 MHz". The national state standard of the unit of ultrasonic pressure in the aquatic environment of NDETU AUV-02-2018 reproduces the unit of ultrasonic pressure in line with the method of reciprocity with two transducers.

Today, the national standard unit of ultrasonic pressure in the aquatic environment reproduces the unit of ultrasonic pressure in the range from 5.0 to 100 kPa and the frequency range from 0.5 to 10 MHz. It has the following metrological indicators: uncertainty of measurement by type A - uA = 5.8%; uncertainty of measurement by type B - uB = 6.6%; total standard uncertainty - uC = 8.8%; extended uncertainty (k = 2) - U = 18.0%.

In the systematic analysis of the whole set of the considered national standards, our attention was drawn to water which is an indispensable component of the standards. The current technology of handling this component requires the stability of its parameters, which in turn affects the metrological characteristics of the standards as a whole.

Water purification by reverse osmosis is based on the process of saline flow from the solution towards fresh water through separating semipermeable membranes, accompanied by the creation of additional excess pressure exceeding osmotic pressure.

The application of the standard method of reverse osmosis in a modern design of special devices is limited by a formation of a salt-saturated film on a membrane surface, which significantly deteriorates performance of such devices. The composition of the water at the outlet of treatment equipment depends on the composition of the water at the inlet. We propose to automate a control of water composition using the electric method. This approach will improve the management process of water purification and preserve efficiency of equipment.

Given the importance of the efficiency factor, we refer to a group of methods used in the most modern devices, i.e. automatic analyzers. They are based on physicochemical methods of analysis like spectrophotometric, potentiometric, conductometric, polarographic as well as a number of other methods and their various combinations.

The main disadvantage of the conductometric method, the only non-destructive method mentioned above, is its low selectivity. The conductometric method is based on the measurement of electrical conductivity and is used to determine generalized indicators.

The authors applied a modern modification of the conductometric method which is now better known as imitation spectroscopy. Imitation spectroscopy is not currently used to study the composition of multicomponent liquids, although some studies are ongoing.[1]

The purpose of these studies is to develop a theoretical justification and experimental testing of a water control system as a specialized environment for the national standards of power and ultrasonic pressure in the aquaatic environment, after standard purification by osmosis.

New scientific results, namely finding certain facts like extrema, negative conductivity, etc. have been obtained during the study of multicomponent aqueous solutions in a multifrequency electromagnetic field.

As is known from metrology, a measuring method can be implemented by direct and indirect methods. It is important to develop and improve the principles of construction of measuring instruments with direct transformation and to create on this basis methods and devices for monitoring composition of liquids.

We offer a new direct method of controlling water composition by measuring electrical parameters. Indicators that characterize non-electrical properties of water are measured by converting its physicochemical properties into an electrical signal using sensors. The liquid which is placed in an electric circuit is considered as a complex passive quantity - immittance.

Such sensors are capacitive, inductive or resistive. An immittance sensor in our research was a converter of non-electric quantity, and an informativr parameter is an admixture, or the complex conductivity of the object.

The advantage of the alternating current methods of studying liquids is that the noise due to polarization resistance is eliminated.

Since this method involves the use of the field of the high part, the value of alternating current always consists of the active value, or real and reactive components:

(1)
$$Z = R + jX$$
$$G = G_W + jG_B$$

where: R - active resistance, X - reactive resistance; G_W - active conductivity; G_B - reactive conductivity; j - imaginary unit.

If at constant voltage, for example, the active component of the electrical conductivity of the capacitive cell is measured, then we will receive:

(2)
$$G_W = \frac{\omega^2 R_L C^2}{1 + \omega^2 R_L{}^2 (C + C_L)}$$

For the reactive component:

(3)
$$G_B = \frac{\omega^2 R_L C C_L (C + C_L)}{1 + \omega^2 R_L{}^2 (C + C_L)}$$

The optimal sensitivity of the measurements is obtained at the maximum change of the measured value depending on the specific conductivity. For both types of curves, such a phenomenon occurs in the areas with the steepest slope, in the area of the bending point. [1-8]

Research conditions

Two-electrode immersions with a flat shape of electrodes were used in the research. The admittance method is based on measuring conductivity components, which inform about composition. The object, i.e. water is considered as a capacitor whose capacity is determined by the dielectric constant of interelectrode space. The dielectric constant depends on composition, frequency of the electromagnetic field, temperature, geometric dimensions and a material of electrodes, and a distance between them. Temperature compensation is not technically difficult to be specified, and geometric dimensions of electrodes are fixed.

We applied capacitive sensors which are modern devices for generating electromagnetic fields of different frequencies to improve the physico-chemical method of controlling composition of aqueous solutions.

The multi-channel meter used in the research is a measuring unit that consists of a set of primary transducers - air condensers and a temperature sensor and is connected to a computer via a serial port. The computer was designed to process and visualize the results. To reduce interference, the converter is placed in a shielded housing where is also the temperature sensor. These devices are controlled by a digital signaling device which exchanges data with the board of the data displau unit.

The composition of the water to be entered into a standard osmotic treatment plant and after the treatment process was investigated by standard laboratory methods. Their immittance spectra were studied in parallel. The analysis and comparison of its spectra indicate the sensitivity of the method. [9-16]

Discussion of research results

Let us consider the results of water studies before the purification process (Voda 1) and after it (Voda 2) with equilibrium measurements (three attempts).

After purification by osmosis, a much smaller value of the reactive component of the complex conductivity in the range up to 5.75 KHz was obtained (Figure 1).

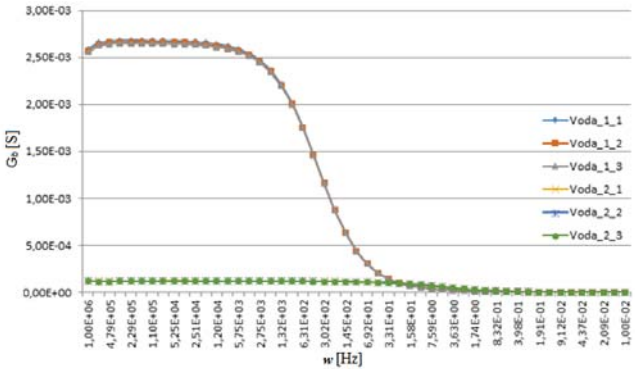

Fig. 1. Measurement of the reactive component of the conductivity Gb (S)

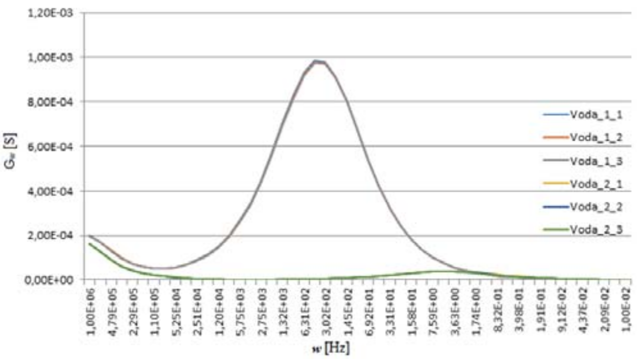

Fig. 2 Measurement of the active component of conductivity Gw (S)

The extremum of the active component of conductivity at 0.302 KHz for water before osmosis was obtained (Figure 2).

Water samples - Voda 1 and Voda 2 were investigated by the standard laboratory method. The content of Calcium (Ca) ions before purification was 1.7 g / l - Voda 1; after cleaning - 0.25 g / l.

The content of Ca ions is used to evaluate one of the important indicators - water hardness which is eliminated by the process of osmotic purification. We can assume that the extremum of the graphical dependence of Figure 2 is due to the relatively high concentration of calcium ions.

Therefore, the admitttance method allows us to estimate the content of the controlled substances (in this case, hardness salts) in a short time by the measured electrical parameters.

The practical application (algorithm of the method) of the proposed method is as follows:

- specify experimentally the dependence of the active and reactive components of the conductivity of the solution of the reference sample of the test fluid on the frequency of the electromagnetic field in a range of 50Hz ÷ 100Hz,
- determine the volume of this solution in the carbon converter which changes the polarity of the reactive component of conductivity,
- determine the selective value for the controlled substance in the reference value of the field frequency at which the reactive component is zero at the normalized maximum concentration of this substance [17]

Conclusions

The new electric method and possibility of an automated control of water entered into an installation to satisfy the standard is formulated from the test results and specified dependences of the composition of multicomponent liquid (water) on electric indicatora. The autohors also obtained the expermental research results witch can be further investigated and implemented directly in NDETU AUV-01-2018 and NDETU AU-02-2018 installations that satisfy the improved standards of an automated control of the aquatic environment.

This means that certain predictions about the possible change of water as en environment for the standards during their operation can be formulated from electrical research.

***Authors**: Maryna Mikhalieva, PhD, Hetman Petro Sahaidachnyi National Army Academy: Lviv, UA, E-mail: galmih@ukr.net, ORCID:0000-0001-5612-3737;*
Vasyl Parakuda, Ph.D, «Scientific-research Institute for Metrology of Measurement and Control Systems», Lviv , UA, E-mail: v.v.parakuda@gmail.com
Lubomyra Odosii, Ph.D, Hetman Petro Sahaidachnyi National Army Academy: Lviv, UA, E-mail: odosiu@ukr.net, ORCID:0000-0003-2438-7759;
Yuryi Shabatura, Dr.Sc, Hetman Petro Sahaidachnyi National Army Academy: Lviv, UA, E-mail: shabaturayuriy@gmail.com, ORCID:0000-0002-9961-1244;
Krzysztof Przystupa, PhD, Eng. Lublin University of Technology, k.przystupa@pollub.pl, ORCID: ORCID:0000-0002-9961-1244.

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