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# TEST OF EXPERIMENTAL ULTRAFILTRATION INSTALLATION

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***Abstract:*** *The paper presents the test results of an ultrafiltration unit. During the test, one of the main parameters of the ultrafiltration process, membrane permeability and a rational process parameter, a linear velocity in the range of 4-7* $\frac{m}{s}$*. According to the results, it can be determined that the process is considered effective if the membrane permeability remains maximum for a long time at a given selectivity and with minimal energy consumption. It was found that for ultrafiltration separation of concentrated solutions of iron hydroxide, the optimal values of the linear velocity are in the range of 5.0-10.0* $\frac{m}{s}$ *at an overpressure of 0.6-1.2 MPa.*

***Key words:*** *ultrafiltration unit, suspension, wastewater, membrane, iron hydroxides, concentration, solution, crimping of the installation*

Based on the technology of wastewater from heavy metal ions, we proposed a redox sorption process with preliminary sorbent production by the electrolysis-membrane method and subsequent membrane-sorption treatment [1÷4]. The efficiency of this technology depends on the efficiency of the ultrafiltration unit. Tests of the laboratory ultrafiltration unit were carried out on a suspension consisting of iron (II) and (III) hydroxides with a concentration of *3,2* $\frac{gr}{lit}$. The use of high linear velocities (up to 17,0 $\frac{m}{s}$) and a decrease in the volume of the test solution was achieved through the use of a coaxially located in a tubular ultrafilter, which made stainless steel inserts [5].

The ultrafiltration unit for separating the suspension (Fig. 1) included a tubular type ultrafilter (1) with an insert, an ND pump - 0.4 (2) plunger type pumps with a hydraulic accumulator (3) and a “water jacket” (4), built directly into the plunger (5), a sorbent recirculation vessel (6) with a float system (7) providing a constant liquid level in the storage vessel, and a stainless steel coil (8) for thermostating the test solution, a water shutter (9), which excluded oxygen oxidation air iron (II) pressure gauges (10, 20) controlling the inlet and outlet pressure of the ultrafilter, a rotameter (11) located at the inlet of the ultrafilter, and providing control of the volumetric flow rate through the ultrafilter, valves (12÷17, 21), rotameter (18), controlling the volumetric speed of tap water entering the cooling coil of the thermostat. The coil (8) of the storage vessel (6) was connected in series with the “water jacket” (4) of the pump plunger (5) and connected to the thermostat pump (19).

The necessary linear speed in the filtering element (1) was set along the rotameter (11) with a valve (12) located on the bypass line (bypass).

The experimental work was carried out in the following sequence. First, the reliability of the seals (pressure testing of the installation) and the strength of the power frame under high pressure were checked. Then, the time to establish a stationary mode at a given linear speed was determined. After that, the main parameters of the ultrafiltration process were taken.

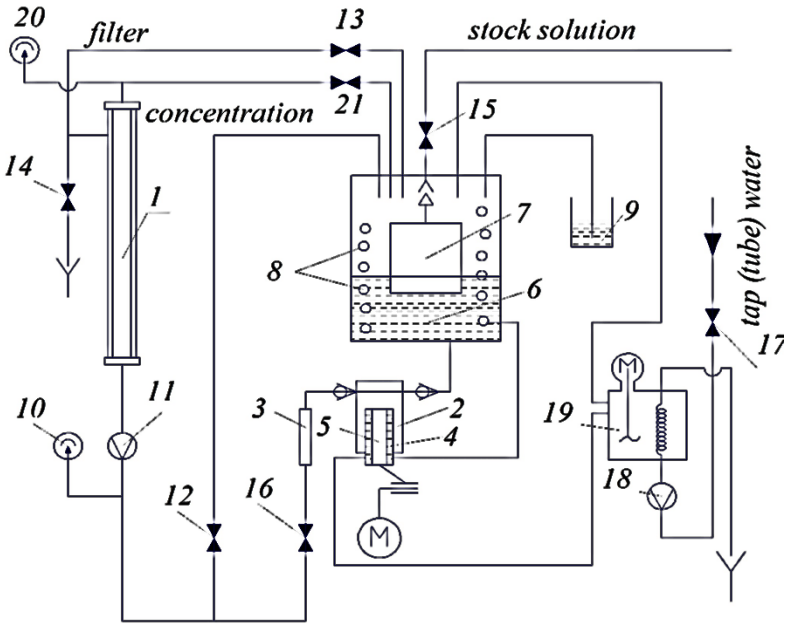



**Fig. 1.** Schematic diagram of the ultrafiltration unit 1 – ultrafilter with insert, 2 – pressure pump ND-0.4, 3 – accumulator, 4 – water jacket, 5 – plunger, 6 – recirculation vessel – storage, 7 – float system, 8 – coil, 9 – water lock, 10 and 20 – pressure gauges, 11 and 18 – rotameters, 12 ÷ 17, 21 – valves, 19 – thermostat.

One of the main parameters of the ultrafiltration process is the permeability of the membranes. The process is considered effective if the permeability of the membrane for a long time remains maximum at a given selectivity and with minimal energy consumption. With this in mind, we measured the dependence of the specific membrane permeability on the linear flow velocity, which varied from 0.5 to 17.0 $\frac{m}{s}$ (Fig. 2). The permeability value for a particular linear velocity was measured every 5 minutes. In this case, the linear velocity increased by 1.0 $\frac{m}{s}$ in the case of operation in the mode of its increase, or decreased in the case of a decrease of 1 $\frac{m}{s}$.

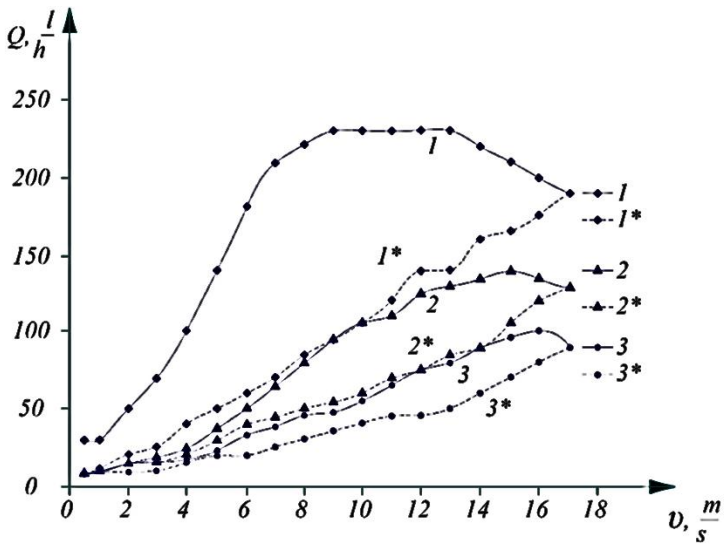



**Fig. 2**. The dependence of the specific permeability (*Q*) of the F-1 membrane on the linear velocity (*υ*) of electrolyte 1, 2, 3 — increase in overpressure from 0.05 to 2.6 *MPa* 1*, 2*, 3* — decrease in overpressure from 2.6 to 0.05 *MPa*

Fig. 2 (curve 1) show that the membrane permeability increases with increasing linear velocity from 0.5 to 9.0 $\frac{m}{s}$. In the speed range of 9.0-13.0 $\frac{m}{s}$ the permeability values did not change and reached a maximum value of 0.23 $\frac{m}{h}$. Starting at a speed of 14.0 and up to 17.0 $\frac{m}{s}$, a decrease in permeability values to 0.19 $\frac{m}{h}$ was observed.

It was possible to explain this dependence while passing the speed range in the opposite direction from 17.0 to 0.5 $\frac{m}{s}$ (Fig. 2, curve 1*). Curve 1 * lies significantly lower than curve 1, and together they form a hysteresis loop. It is known [5] that the formation of hysteresis loops when taking ultrafiltration parameters indicates plastic deformation of the selective membrane layers (plastic shrinkage of the membrane). Without shrinkage of the membrane, an increase in pressure tends to increase the permeability of the membrane. This is observed in the speed range from 0.5 to 9.0 $\frac{m}{s}$ (Fig. 2, curve 1). The output of the permeability values to a plateau at a linear velocity of 10.0–13.0 $\frac{m}{s}$ indicated that the contribution of the growing driving force from 1.20 to 1.72 *MPa* is compensated by shrinkage of the membrane. The curve section from 14.0 to 17.0 $\frac{m}{s}$ is characterized by a decrease in permeability from 0.23 to 0.19 $\frac{m}{h}$ due to deformation of the selective membrane layer, despite the increase in pressure from 1.92 to 2.40 *MPa*. Thus, the increase in permeability at a linear velocity from 14.0 to 17.0 $\frac{m}{s}$ due to an increase in pressure is much less than its decrease due to shrinkage of the membrane structure.

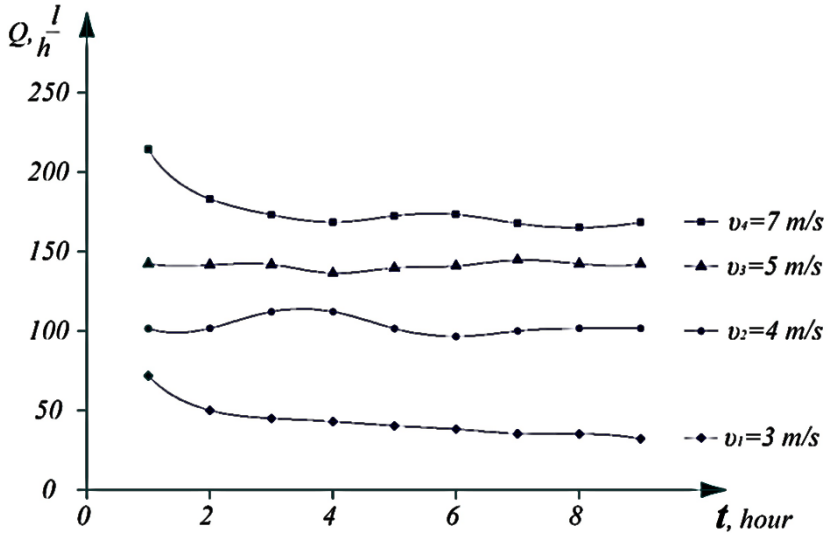
Repeated removal of permeability values from linear velocity in the forward (curve 2) and reverse (curve 2*) directions led to the formation of a second hysteresis loop. The area of this loop is much smaller than the area of the first, but it is larger than the area of the third loop, obtained in the same way as the previous two. Considering that the area of the hysteresis loop characterizes the rigidity of the membrane [1], we can conclude that there are significant differences in the physicochemical properties of the same membrane in all three series of the experiment.

A decrease in the area of the hysteresis loop is associated with an increase in the rigidity of the membrane due to shrinkage of its porous structure (pore contraction), which led to a loss of permeability (Fig. 2). From the data obtained, it can be concluded that a linear velocity of more than 14.0 $\frac{m}{s}$ negatively affects the physicochemical state of the membrane, since it leads to irreversible deformation due to pressure.

Three times the pressure on the membrane in the range from 0.25 to 2.6 *MPa*, which is necessary to ensure linear velocities from 0.5 to 17.0 $\frac{m}{s}$, leads to a decrease in the efficiency of the membrane by more than 10 times. This indicates that the optimal speed range for ultrafiltration separation is between 5.0-10.0 $\frac{m}{s}$, which is provided by an excess pressure of 0.6-1.2 *MP*a.

For a more accurate determination of the lower and upper limit of optimal velocities, the dependence of the specific membrane permeability on time was taken at various linear velocities

(from 0.5 to 17.0 $\frac{m}{s}$) (Fig. 3*a*). The obtained dependences of specific permeability on time are divided by the nature of the curves into two groups: Fig. 3*a* (1, 2, 3, 4) and fig. 3*b* (6, 7), and curve 5 (Fig. 3*b*) occupies an intermediate position. The first group of dependences indicates a fairly stable operation of the membrane, and the second indicates unstable (Fig. 3*b*) with a sharp drop in permeability. Curve 5 for 8 hours has features characteristic of the second group, and the next hour does not undergo changes, which is characteristic of the first group of dependencies (Fig. 3*a*).




Thus, the stable operation of the membrane is observed in the speed range of 3-7 m / s. However, the linear velocity of 3.0 $\frac{m}{s}$ can't be taken into account due to the relatively low specific permeability (0.05 $\frac{m}{h}$). Therefore, the rational parameter of the process is the linear velocity in the range of 4-7 $\frac{m}{s}$. Another main parameter of the ultrafiltration process is the selectivity of the membranes.

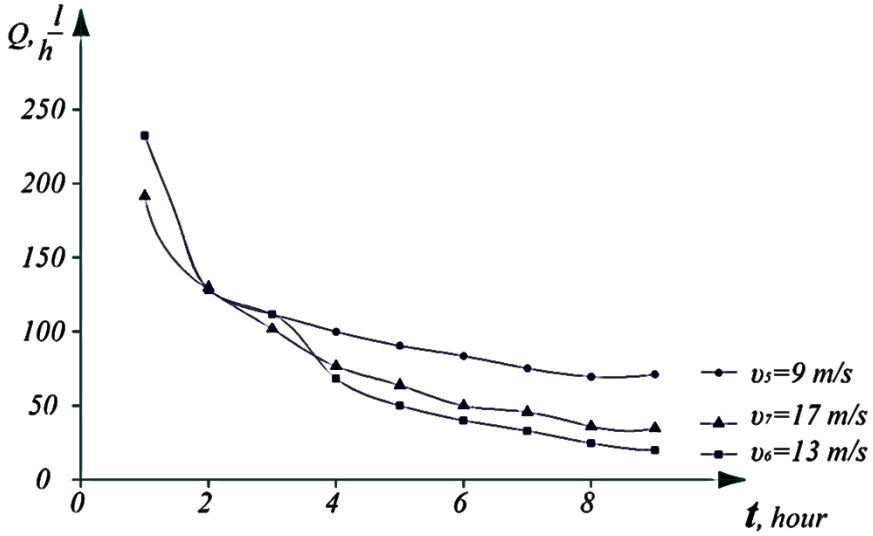



**Fig. 3.** The dependence of the specific permeability (*Q*) of the *F-1* membrane on time (*t*) at various linear velocities ($V_l$): *a*) 1-3.0; 2-4.0; 3-5.0; 4-7.0; *b*) 5-9.0; 6-13.0; 7-17.0

Thus, the presence of a calibrated turbulent insert in the tubular ultrafilter, a flow accumulator at the pump outlet, and a bypass line at the installation made it possible to carry out ultrafiltration separation of concentrated and diluted solutions of iron hydroxide suspension in a

wide range of linear velocities. It was found that for ultrafiltration separation of concentrated solutions of iron hydroxide, the optimal values of the linear velocity are in the range of 5.0-10.0 $\frac{m}{s}$ at an overpressure of 0.6-1.2 *MPa,* and an overpressure above 1.6 *MPa* deforms irreversibly selective layer of ultrafiltration membrane F-1.

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