STUDY OF THE SPECIFIC PRODUCTIVITY OF MEMBRANES DURING THE CONDUCT OF THE PERVAPARATION PROCESS FOR THE SEPARATION OF LIQUID CARBOHYDRATE MIXTURES

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Abstract

The report presents the prospects for the use of membranes in pervaporation processes for the separation of liquid carbohydrates and their properties in increasing the efficiency and reducing the energy consumption of such processes. The work is aimed at studying the effectiveness of using membranes in pervaporation processes, which is a key stage in the separation of complex mixtures of liquid carbohydrates.

Keywords: *membrane, pervaporation, membrane apparats.*

Introduction. Membrane technology has long been of interest to scientists and industrial researchers for its prospects in reducing energy consumption and increasing the productivity of separation processes. Literary sources [1-3] investigate different types of membranes and their effectiveness in pervaporation processes. This includes membrane distillation, which can be more targeted to certain components and allows to lower the temperature of the process, making it more economical and energy efficient.

When calculating membrane devices, an important value on which the area of the working surface of the membranes depends is their specific productivity or permeability. When determining the permeability by calculation, a number of problems arise related to the hydrodynamic and mass exchange features of the membrane separation process. Therefore, it is considered the most promising and expedient to determine the permeability experimentally.

Materials and methods. Research on determining the permeability of pervaporation membranes was carried out on an experimental setup, the scheme of which is presented in Fig. 1.

The membrane installation consists of a membrane device 4, which contains tubular pervaporation membranes (membrane elements) fixed in tubular grids, a shell-and-tube heat exchanger 3 and a refrigerator - a condenser 6, a heater 8, tanks 1 and, pump 2 and a compressor 5.

The membrane installation works as follows. From tank 1, the mixture of hydrocarbons with the help of pump 2 through heat exchanger 3, in which it is heated to the required temperature, is fed to the distribution device of the membrane apparatus and evenly irrigating the membrane elements, flows down their outer surface. At the same time, certain classes of hydrocarbons (permeate) pass through the walls of the tubular membrane elements under the influence of molecular diffusion and, evaporating from the inner surface of the latter, mix with the moving flow of the vapor-gas mixture, which is pumped by compressor 5. The vapor-gas mixture then enters the refrigerator-condenser 6, in which the vapor of hydrocarbons (permeate) is condensed and poured into the container 7, and the steam-gas mixture is sucked by the compressor 5, pumped through the calorifier 8, where it is heated to the required temperature, again fed into the membrane apparatus 4. The partially separated mixture of hydrocarbons is poured from the membrane apparatus 4 into container 1. To maintain a constant concentration of hydrocarbons, fresh initial mixture is constantly added to container 1. Thus, the membrane installation works in continuous mode.

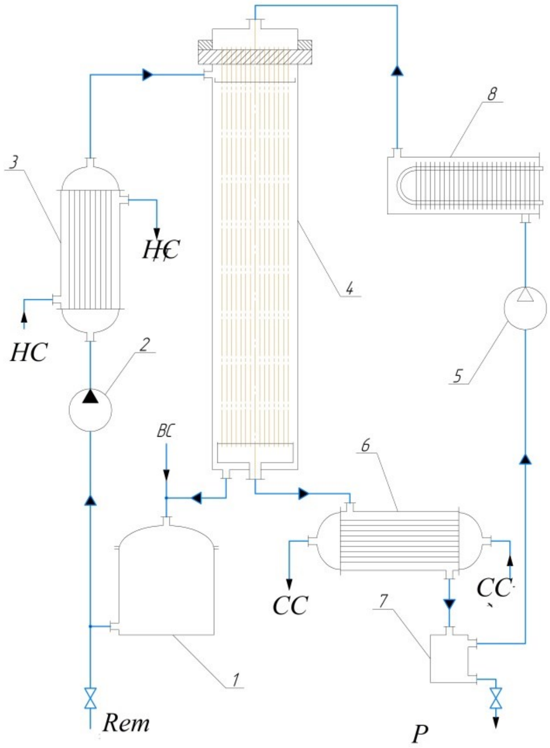

Fig. 1 Scheme of the experimental setup

Research was conducted with mixtures of representatives of the following classes of hydrocarbons:

1. Saturated hydrocarbons (hexane, octane);
2. Halogen derivatives of saturated hydrocarbons (methylene chloride, chloroform, dichloroethane);
3. Monoatomic alcohols (methanol, ethanol, isopropanol, butanol);
4. Simple ethers (diethyl ether);
5. Mercaptans and sulfides (ethyl mercaptan, dimethyl sulfoxide);
6. Aldehydes and ketones (acetaldehyde, acetone);
7. Carboxylic acids (acetic acid);
8. Amines (triethylamine);
9. Cycloparaffins (cyclohexane);
10. Aromatic hydrocarbons (benzene, toluene, divinylbenzene, styrene);
11. Halogen derivatives of aromatic hydrocarbons (chlorobenzene);
12. Aromatic nitro compounds (nitrobenzene).

All substances with which the research was conducted are solvents and according to chemical classification are divided into two groups - protolytic and aprotic solvents.

Solvents from groups 3, 5, 6, 7 are protolytic, and aprotic - from groups 1, 2, 4, 8, 9-12.

Research results. During a series of experiments on the separation of mixtures of aprotic and protolytic solvents at the experimental setup (Fig. 1), a permeate containing 0.3÷0.5 % protolytic solvents was obtained

The results of the research are given in Tables 1 and 2.

Table 1. Membrane permeability to aprotic solvents depending on wall thickness δ_M

№ п/п	The name of the solvent	Permeability G, кг/м^2·год			
		t °C	δ_M=1,5 мм	δ_M=1,3 мм	δ_M=1,3 мм
1	Methylene chloride	35	7,1	6	4,5
2	Chloroform	28	5,32	4,5	3,36
3	Dichloroethane	40	3,7	3,1	2,32
4	Hexane	50	6,5	5,5	4,12
5	Diethyl ether	20	7,7	6,5	4,87
6	Triethylamine	40	5,91	5	3,75
7	Cyclohexane	40	3,78	3,2	2,4
8	Benzene	40	3,9	3,3	2,48
9	Toluene	40	1,54	1,3	0,98
10	Ethylbenzene	40	3,3	2,8	2,1
11	Styrene	40	3,5	3	2,25
12	Chlorobenzene	50	4,7	4	3

Table 2. Membrane permeability to proteolytic solvents depending on wall thickness δ_M

№ п/п	The name of the solvent	Permeability G, кг/м^2·год			
		t °C	δ_M=1,2 мм	δ_M=1,3 мм	δ_M=1,5 мм
1	Methanol	50	0,47	0,4	0,3
2	Ethanol	60	0,41	0,35	0,26
3	Isopropanol	60	0,23	0,2	0,15
4	Butanol	60	0,17	0,15	0,11
5	Acetone	40	0,59	0,5	0,38
6	Dimethylsulfoxid	80	0,23	0,2	0,15
7	Acetic acid	45	0,06	0,05	0,038

Conclusion. The following features of the pervaporation process were revealed during research with individual components:

1. Aprotic solvents have 10÷100 times higher specific productivity than protolytic ones. This is due to the presence of oxygen atoms in the molecules of protolytic solvents. Therefore, they have a higher specific heat of vaporization than aprotic ones, which in turn affects the driving force of the pervaporation process and the permeability of membranes. Therefore, mixtures of aprotic and protolytic hydrocarbons are subject to membrane separation.
2. Hydrocarbons, which include chlorine and amino groups, have a particularly high specific productivity.
3. As research has shown, the specific productivity of pervaporation membranes depends on temperature: it increases with increasing temperature. This dependence is described by the Arrhnius law [4].
4. Also, with a decrease in the thickness of the membrane, the specific productivity of the latter increases in a quadratic relationship. There is a decrease in thickness by 1.5 times, which makes it possible to increase the specific productivity by 2.25 times.

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