The separation process of methane-butane fraction from natural gas before transport

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Abstract. A series of experiments of adsorption of vapor-air mixtures of some individual hydrocarbons on fibrous sorbents out of polyethylene and polypropylene is made. The calculated changes of concentrations of hydrocarbons in the vapor-air mixture base on experimental data. It is shown that concentration of hydrocarbons decreases after column by 1.4 times and that sorption capacity of fibers reaches 1 g of hydrocarbons on 1 g of a fibrous sorbent. This result was assumed as a basis of calculation of model of the separator for separation of hydrocarbons C_{1-4} from water and fractions C_{5-n}, the degree of separation of the first stage gas of the Verkhne – Tarskoe's field was 98 %.

1. Introduction

The damage by harmful aerosols in countries with the developed industry forces them to take the measures for reduction of volumes of emissions and for providing a normal sanitary state of the atmosphere.

The choice of the method of air purification depends on the specific conditions and it is determined by technical and economic calculations. One of the main methods of purification of air from pollutants is a filtration through the filter nozzles of different types and multicomponent composition of air pollutants causes the application of materials for filtering nozzles with polyfunctional action.

An attempt was made to use polymer fibers the resulting by a technology from waste of domestic and industrial thermoplastic [1, 2] for vapor recovery of hydrocarbons from the air.

2. Experimental

Experiments were made on laboratory installation for research of absorption of vapors of a heptane, a hexane, benzene and toluene on fibers of polyethylene and polypropylene at 20, 40 and 60 ^{0}C. Average diameter of the fibers used in this work made 40 microns, density of packing of the filter is 150 kg/m^3, fiber layer height in a column is 100 mm.

Experiments were made as follows. Into the flask placed in the thermostat we poured 100 cm^3 of hydrocarbons, turned on the thermostat and kept a flask and a column with fiber connected to a neck flask up to achievement of the set temperature. After this we turned on compressor with a constant consumption of air 1.8 of dm^3/min. Through certain periods of time a column with fiber was weighed and an additional weight was defined.

Installation is supplied with the refrigerator on exit from a column for measurement of losses of the hydrocarbons with air (V_4), which passed through fibrous material.

3. Results and considerations

The experiment results of sorption capacity for polypropylene and polyethylene fibers are shown figures 1 and 2.
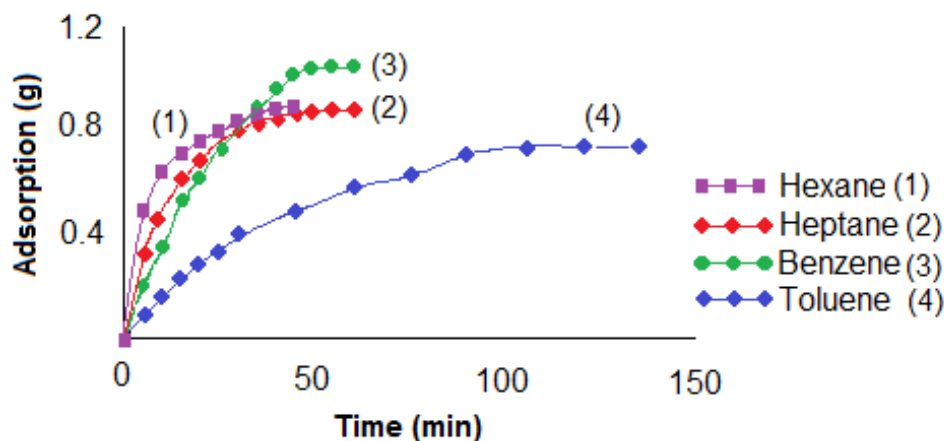

Figure 1. The adsorption of hydrocarbons on the polypropylene fiber (g/g of fiber).

Process of adsorption of these hydrocarbons can be described by:

$$A = A_\infty \cdot kt/(1 + kt) \tag{1}$$

where A is an amount of adsorbed substance, A_∞ is a maximum quantity of adsorbed substance at fiber saturation, k – constant of adsorption process, t – time of adsorption.
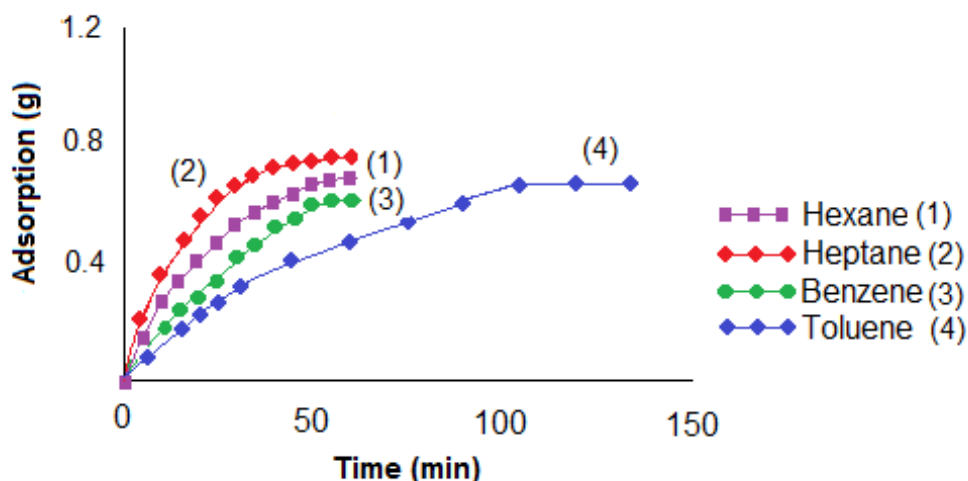

Figure 2. The adsorption of hydrocarbons on the polyethylene fiber (g/g of fiber).

In table 1 results of mathematical processing of the schedules represented in figures 1 and 2 on the equation (1) are given. In table 2 results material balance of experiments of adsorption of hydrocarbons on the column with a mass of 1 gram of fiber are given. Balance is calculated based on the volume of hydrocarbon filled into flask (V_1), residue in flask volume (V_2), on fiber weight hydrocarbon calculated for volume (V_3), and losses of hydrocarbons with air (V_4).

Table 1. The calculation constants of hydrocarbons by equation (1).

Hydrocarbon	Temperature (^{0}C)	Polyethylene		Polypropylene	
		A_∞	K	A_∞	K
Hexane	40	1.122	0.029	1.032	0.172
	60	1.175	0.210	1.281	0.223
Heptane	40	1.063	0.049	1.088	0.085
	60	0.799	0.332	0.907	0.839
Benzene	40	1.103	0.019	2.010	0.022
	60	3.472	0.047	1.917	0.097

According to table 2 changes of concentration of hydrocarbons after a column are calculated with a constancy of concentration before and after a column. For example, concentration for hexane and polypropylene fibers varies from 0.22 cm^3/dm^3 to 0.155 cm^3/dm^3 and for octane and polypropylene fibers varies from 0,018 cm^3/dm^3 to 0,013 cm^3/dm^3, i.e. concentration of hydrocarbons is reduced by 1.4 times. These results were assumed as a basis at design and production of the model of the separator which is shown in figure 3.

Table 2. The material balance for adsorption of hydrocarbons on polypropylene (A) and polyethylene (B) fibers at a temperature of 60 ^{0}C and at an air flow rate of 1.8 dm^3 / min.

Saturation time (min) / Hydrocarbon	(V_1)		(V_2)		(V_3)		(V_4)	
	A	B	A	B	A	B	A	B
10 / Hexane	10	10	5.9	5.6	1.3	1.31	2.8	3.09
10 / Heptane	10	10	7.6	7.8	1.097	0.88	1.303	1.32
120 / Octane	10	10	6.1	6.2	1.12	1.38	2.78	2.42
12 / Benzene	10	10	6.35	7.4	1.46	1.13	2.19	1.47
50 / Toluene	10	10	7.8	7.8	1.09	0.70	1.11	1.5

At preparation of gas for transport it is necessary to extract water and hydrocarbons C_{5-n} from it, because water vapors and hydrocarbons C_{5-n} at temperature decrease are condensed, forming liquid, ice and hydrate corks in pipelines.

For implementation of objectives the following operations are carried out: cleaning, dehydration, gas compressing and extraction from sour gas of petrol fractions [3-4]. These are multistage power-intensive processes. Various devices for separation and purification of gases are known: system from several adsorbents [4], removal of impurity C_{5-n} by their absorption [5-7], gas-liquid separators [8-11], filter nozzles on columns [12, 13]. Disadvantage of all these devices, in our opinion, is lack of possibilities for simultaneous separation of water and hydrocarbons C_{5-n} from faction C_{1-4}.

The most promising, in our opinion, is a device for gas purification from impurities in the form of a vertical cylindrical housing with a tangential inlet pipe, a gas outlet nozzle, a nozzle of liquid discharge, a horizontal wall and a rotor in the form of a perforated cup [12]. In perforated glass two shells are installed coaxially and with a gap, one of them is adjacent to the perforated glass and this shell is executed by the continuous, but other is perforated. Thus a both shells don't reach to bottom of perforated glass and adjoin respectively to external and internal diameters of ring tray established under them. End of drain tube is removed into cavity of vertical cylindrical case. Disadvantage of device is a low degree of gas purification C_{1-4} from other hydrocarbons because shells are not working as an adsorbent but for dehydration the diethylene glycol is recommended.

We made the separator model which is schematically given on figure 3.

The separator consists of the case cooled by tap water in which the rotating cartridge. It consists from internal and external perforated shells which connected by the upper distributor of cooling water and the lower tank of cooling water. The space between shells is filled by adsorbent from polyolefin fibers which is cooled by water flowing in pipes from the distributor to tank. The lower part of the shell is executed in the form of continuous pipe and the bearing with consolidation is pressed on it. The same bearings are pressed on a pipe of tank and branch pipe of input into cartridge of the cooling water connected with an engine shaft by coupling. Thus, rotation of the cartridge with adsorbent is provided and cameras of input of initial mixture of hydrocarbons and water from the camera of separation of liquid and gaseous hydrocarbons are hermetically separated. On an internal surface of case are established the regiments at an angle $50 - 70^0$ in relation to an internal axis of installation, which reduce a spraying of the liquid leaving the cartridge under the influence of centrifugal forces and the direction of this liquid into branch pipe of outlet of condensate.
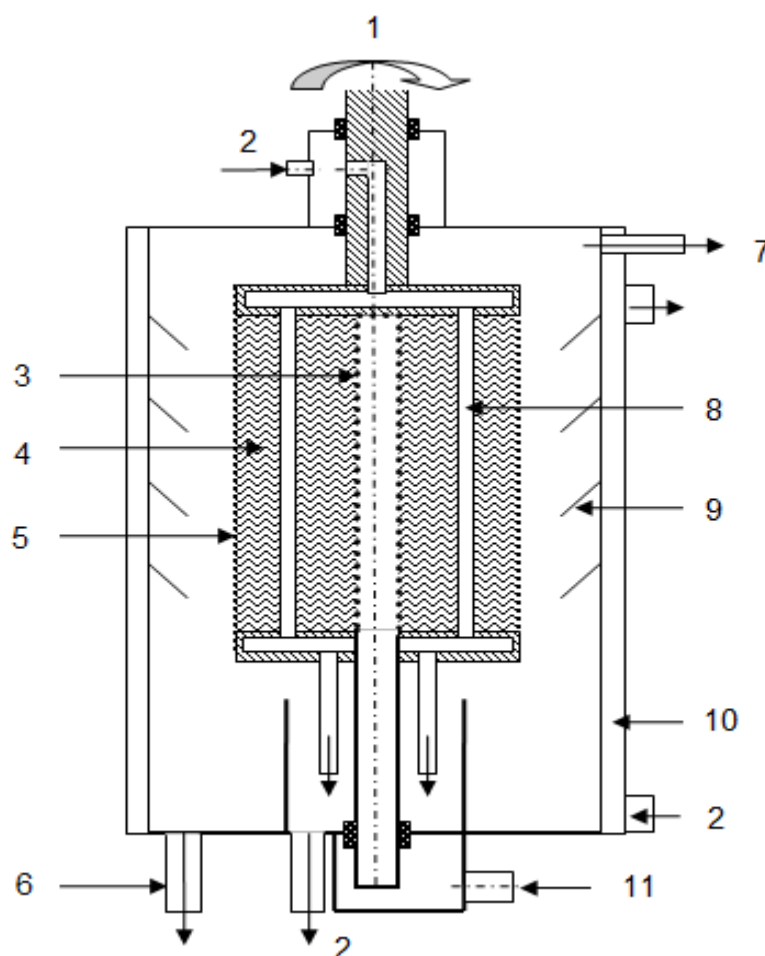

Figure 3. Scheme of model of separator for separation of hydrocarbons C_{1-4} from water and fractions C_{5-n} : 1 − rotation drive; 2 –coolant; 3 – punched shaft; 4 – fibrous adsorbent; 5 – punched rotor shirt; 6 – pipe output of hydrocarbons C_{5-n}; 7 – gases C_{1-4}; 8 – tubes for coolant; 9 – reflectors drops; 10 – cooling shirt; 11 – initial mixture of gases on separation.

Tests of separator showed that extent of division at the first stage of sour gas of the Verkhne – Tarskoe's field makes 98%. Results of experiment are presented in table 3.

Table 3. Material balance of preparation of initial raw gas of the Verkhne – Tarskoe's field to transport according to technological scheme (fig. 3).

Feed gas composition		Contents of components after separator (mass %)		Contents of components after column (mass %)	
Component	Mass (%)	Gas	Condensate	Gas	Condensate
Carbon dioxide	0.859	0.859	-	0.859	-
Nitrogen	1.402	1.402	-	1.402	-
Methane	32.684	32.684	-	32.684	-
Ethane	6.506	6.506	-	6.506	-
Propane	22.451	22.451	-	22.451	-
Isobutane	11.044	11.044	-	11.044	-
N-butane	13.679	13.679	-	13.679	-
Pentanes	8.548	1.2604	7.2876	-	1.2604
Hexanes	2.338	0.2361	2.1019	-	0.2361
Heptanes	0.439	0.0135	0.4285	-	0.0135
Octanes	0.045	0.0004	0.0446	-	0.0004

4. Summary

- It is shown that fibers from junk and waste of thermolayers can be used for extraction of hydrocarbons from steam-air mixes in the adsorptive columns with a nozzle from fibers of thermolayers, for example, in processes of catching of hydrocarbons from gas fractions deleted from oil at its preparation for transport.

- The separator model for division of natural gases and gas condensate into methane-butane fraction and fraction of other heavier hydrocarbons into one stage on the rotating fibrous nozzle with regulation of its temperature is developed; degree of separation at the first stage of sour gas of the Verkhne – Tarskoe's field makes 98%.

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