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INVESTIGATION OF THE MOISTURE EXCHANGE IN A STATIONARY ADSORBENT LAYER THROUGH WHICH AIR IS PASSED

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The nonstationary moisture exchange between a stationary adsorbent layer and the air passed through it has been experimentally investigated. It is shown that the air humidity can be effectively regulated at both the stage of water adsorption (air dehumidification) and the stage of water desorption (air humidification) with the use of commercially produced desiccants. The degree of dehumidification and humidification of the air passed through an adsorbent can be varied from 0 to 1 by varying the nature of the adsorbent, the size of its granules, and the time for which it is in contact with the air flow.

Introduction. Adsorbents are widely used in practice for removal of water from gas flows [1–3]. A wet gas is dried by passing through a dry adsorbent layer absorbing water. In this case, the adsorbent itself saturates with water and contains it in its bulk. The inverse process of water-vapor desorption occurs in a moist adsorbent regenerated by a dry gas passed through it, just as in the case of short-cycle adsorption conducted without heating [4]. In this case, a wet gas emerges from an adsorbent layer and carries away the water absorbed. Combination of the indicated two processes makes it possible to realize moisture exchange between the input and output air flows, e.g., in a system for ventilation of buildings; in this case, an adsorbent serves as a water buffer. Unlike the short-cycle adsorption realized without heating, which makes it possible to obtain a gas with a dew point of -40^{o}C and lower, the air dried in a ventilation system must have a higher dew point at which ice is not formed at the output of a device. This dew point can range from -25 to -5^{o}C depending on the climate of a concrete region. The dynamics of such systems depends on the mechanism of formation of the adsorption (desorption) front in the process of passage of wet (dry) air through an adsorbent layer; this mechanism was described in [1]. Even though the dynamic behavior of a stationary adsorbent layer depends on the adsorption equilibrium, the adsorption kinetics, and the hydrodynamics of the gas flow, the qualitative pattern of the process is mainly determined by the adsorption isotherm [1, 5]. In an equilibrium isothermal model, the form and velocity of the adsorption front formed in an adsorbent depend on the adsorption isotherm used, which can be linear, concave, or convex. In the first case, a stationary front propagates with a constant velocity in an adsorbent. In the second case, the front propagating through an adsorbent layer broadens. In the third case, the front formed contracts. Calculations performed with account for the mass transfer in the adsorbent granules and the axial diffusion give an additionally broadened adsorption front. A stationary front is obtained in the case where a convex isotherm is used in the calculations, and calculations performed with the use of a concave isotherm give a slowing-down and broadening front.

In [3, 6], the water-adsorption front formed in a stationary adsorbent layer was investigated by the NMR-micrography method providing a means for visualization of the profile of the water adsorbed in an adsorbent layer and in individual adsorbent granules [7]. Investigations were carried out in a stationary layer of the modified adsorbent "calcium chloride in silica gel mesopores" whose ability to adsorb water is higher as compared to the nonmodified adsorbents [8, 9]. Since the adsorption isotherm is convex for this material in the adsorption range studied, the calculations have shown that in the process of adsorption there arises a stable water-adsorption front that moves along the

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layer with a constant velocity [3, 6]. In [10], alumina oxide modified with calcium chloride was investigated. This adsorbent is the object of the present investigations.

The process of adsorption (desorption) is accompanied by heat release (absorption); therefore, along with the adsorption front, in an adsorbent layer there arises a heat front that moves along the layer with a higher velocity as compared to the velocity of travel of the adsorption front [11, 12]. It is very important to take into account the inhomogeneous temperature distribution along an adsorbent layer in the process of investigation of both the short-cycle process of adsorption [1, 4] and the moisture exchange considered in the present work. Nonisothermal processes of heat-and-mass transfer cannot be described within the limits of the above-mentioned simple model; their analysis calls for detailed mathematical simulation or direct experimental investigations.

In the present work, we experimentally investigated the moisture exchange between a stationary adsorbent layer and the air passed through it, which can be considered as a model of the moisture exchange in a ventilation system. The moisture-exchange was realized in a periodic regime, just as in the case of short-cycle adsorption: in the first (and any odd) half-cycle, a wet air passed through the adsorbent was completely or partially dried and, in the second (and each even) half-cycle, a relatively dry air supplied to the other end of the adsorbent layer was humidified, passing through it. In the process of investigations, we measured the relative and absolute humidity of the air and its temperature at the input and output of the adsorbent layer in the stationary regime and calculated the degree of moisture exchange at the stages of dehumidification and humidification depending on the nature of the adsorbent, the size of its granules, the volume rate of the air flow supplied, and the duration of the process.

Experiment. As the adsorbents, we used commercially produced dehumidifiers — alumina oxide (Al_2O_3), KSM silica gel, and an IK-011-1 adsorbent (TY-2163-024-03533913-99) representing alumina oxide modified with calcium chloride (10–12 mass %). Calcium chloride was introduced into the initial alumina oxide granules by impregnation of them with its aqueous solution; then the granules were dried at 150^{o}C for 2 h. Alumina oxide and IK-011-1 granules 1.8 and 4.5 mm in diameter and 6–8 mm in length, respectively, and spherical silica-gel granules 2–6 mm in diameter were used in the experiments.

Experiments were carried out in the following way: an adsorbent was placed into a cylindrical adsorber 210 mm is diameter (the length of the adsorber layer was 160 mm) whose weight was usually 3 kg. Before the adsorbent was placed into the adsorber, it was held in air for 48 h at a temperature of 20^{o}C and a humidity of 30–35%.

At the stage of adsorption, an air at room temperature, saturated with water vapor to a relative humidity $\varphi = 29.5 \pm 1.5\%$ (Table 1), was supplied to the input of the adsorber. The temperature and humidity of the air at the input and output of the adsorbent layer were measured. After a certain time (10 min as a rule), a reverse flow of air at room temperature with a relative humidity of $2.3 \pm 1.2\%$ was supplied to the other end of the layer (desorption stage) (Table 2). The humidity of the input and output air was measured by an Iva-6B thermohydrometer with an accuracy of $\pm 1.0\%$, and the air temperature was measured by chromel-copel thermocouples with an accuracy of $\pm 0.1^o$C. The volume rate of the air flow was changed from 5.0 to 31.3 m^3/h and measured by a flowmeter.

The portion of water absorbed by the sorbent at the end of the adsorption stage in relation to the total amount of water entering the layer was calculated as an integral over the adsorption half-cycle:

$$\alpha = \frac{\int (d_{\text{in}} - d_{\text{out}})\, dt}{\int d_{\text{in}} dt} ,$$

and the portion of water released from the sorbent at the end of the desorption stage was calculated in relation to the total amount of water released from the layer as

$$\beta = \frac{\int (d_{\text{out}} - d_{\text{in}})\, dt}{\int d_{\text{out}} dt} .$$

Experimental Results and Discussion. Figure 1 presents typical distributions of the relative and absolute humidity and the temperature of the air at the input and output of an adsorbent layer in the stationary regime at the adsorption and desorption stages. The time of change to the stationary regime depends on the initial state of the

TABLE 1. Relative φ and Absolute *d* Humidity, Dew Point T_d, and Temperature *T* of the Air at the Input and Output of an Adsorber at the Adsorption Stage

Air flow rate, m^3/h	Input				Output				α
	φ, %	*T*, °C	*d*, g/m^3	T_d, °C	φ, %	*T*, °C	*d*, g/m^3	T_d, °C	
Adsorbent Al$_2$O$_3$ (4.5/8 mm)									
5.0	30.1	20.7	5.6	2.6	11.5–15.9	17.4–18.4	1.7–2.5	–11.7 – –7.3	0.65
10.7	29.3	21.1	5.6	2.6	11.5–15.5	18.7–22.0	1.9–3.1	–10.4 – –4.8	0.64
14.6	29.5	21.7	5.8	3.2	9.5–13.5	20.1–24.8	1.7–3.2	–11.7 – –4.5	0.64
18.6	28.5	21.3	5.5	2.4	11.4–15.6	21.7–22.2	2.2–3.1	–8.7 – –4.8	0.61
24.9	27.9	21.6	5.5	2.4	10.8–14.5	21.5–24.9	2.1–3.5	–9.3 – –3.4	0.53
31.3	28.6	21.3	5.5	2.4	12.6–16.2	23.6–24.4	2.8–3.7	–6.0 – –2.7	0.49
Adsorbent IK-011-1 (4.5/8 mm)									
5.0	30.0	23.0	6.4	4.5	7.3–8.9	19.2–20.5	1.2–1.6	–15.6 – –12.4	0.80
10.7	29.5	21.6	5.8	3.2	7.7–9.8	18.8–21.8	1.3–1.9	–14.7 – –10.4	0.77
14.6	30.4	22.8	6.4	4.5	8.2–11.0	20.5–25.7	1.5–2.7	–13.0 – –6.4	0.72
18.6	30.3	22.8	6.3	4.3	8.0–10.9	20.8–27.2	1.5–3.0	–13.0 – –5.2	0.70
24.9	28.4	22.4	5.9	3.4	8.4–11.3	20.1–26.7	1.5–3.0	–13.0 – –5.2	0.66
31.3	29.6	22.5	6.1	3.8	10.9–12.0	23.2–27.1	2.3–3.3	–8.7 – –4.1	0.65
Adsorbent Al$_2$O$_3$ (1.8/6 mm)									
5.0	29.6	20.3	5.4	2.1	7.9–11.7	17.2–18.2	1.2–1.8	–15.6 – –11.1	0.75
10.7	28.9	21.4	5.6	2.6	7.0–11.7	18.5–23.7	1.1–2.6	–16.5 – –6.9	0.72
14.6	28.4	21.1	5.4	2.1	7.2–11.2	19.2–24.9	1.2–2.7	–15.6 – –6.4	0.71
18.6	28.8	21.4	5.6	2.6	7.0–11.4	20.2–25.7	1.3–2.8	–14.7 – –6.0	0.69
24.9	28.5	21.2	5.4	2.1	7.7–11.4	24.4–26.2	1.8–2.9	–11.1 – –5.6	0.66
31.3	28.3	21.4	5.5	2.4	6.8–12.1	23.0–26.1	1.4–3.1	–13.8 – –4.8	0.62
Adsorbent IK-011-1 (1.8/6 mm)									
5.0	31.0	20.1	5.5	2.4	1.4–1.7	17.8–18.5	0.2–0.3	–33.7 – –29.7	0.98
10.7	30.0	20.5	5.5	2.4	1.4–1.6	18.5–25.0	0.2–0.4	–33.7 – –26.9	0.95
14.6	28.0	21.9	5.6	2.6	1.9–2.8	20.1–28.7	0.3–0.8	–29.7 – –19.9	0.93
18.6	28.3	22.3	5.8	3.2	2.8–4.7	20.8–29.5	0.5–1.5	–24.7 – –13.0	0.88
24.9	27.3	21.8	5.4	2.1	4.3–6.6	24.5–27.7	1.0–1.8	–17.5 – –11.1	0.80
31.3	27.2	22.7	5.7	2.9	4.2–8.0	22.0–28.2	0.9–2.3	–18.6 – –8.3	0.74
Adsorbent KSM									
5.0	30.7	19.3	5.2	1.6	5.0–6.2	14.8–15.0	0.6–0.8	–22.8 – 19.9	0.87
10.7	30.1	19.8	5.3	1.9	4.0–6.0	16.0–18.5	0.6–1.0	–22.8 – –17.5	0.87
14.6	29.9	19.9	5.3	1.9	4.9–7.0	16.8–21.7	0.7–1.4	–21.2 – –13.8	0.84
18.6	30.3	19.9	5.4	2.1	5.2–8.0	17.8–24.5	0.8–1.9	–19.9 – –10.4	0.81
24.9	29.4	19.7	5.1	1.3	6.2–9.2	18.2–24.6	1.0–2.1	–17.5 – –9.3	0.74
31.3	30.1	19.7	5.3	1.9	7.2–9.8	20.0–25.1	1.3–2.4	–14.7 – –7.8	0.71

TABLE 2. Relative φ and Absolute *d* Humidity, Dew Point T_d, and Temperature *T* of the Air at the Input and Output of an Adsorber at the Desorption Stage

Air flow rate, m^3/h	Input				Output			β
	φ, %	*T*, °C	*d*, g/m^3	T_d, °C	φ, %	*T*, °C	*d*, g/m^3	
Adsorbent Al_2O_3 (4.5/8 mm)								
5.0	3.2	18.3	0.5	–24.4	30.1–29.3	20.1–18.8	5.3–4.8	0.87
10.7	2.7	18.6	0.4	–25.9	27.6–25.1	20.5–17.1	5.1–3.7	0.86
14.6	2.3	19.3	0.4	–27.0	23.8–22.4	20.2–16.0	4.3–3.1	0.87
18.6	2.6	18.8	0.4	–26.1	23.5–21.5	19.8–14.7	4.1–2.7	0.84
24.9	3.5	19.5	0.6	–22.7	21.4–19.9	18.0–15.0	3.4–2.6	0.78
31.3	3.0	19.0	0.5	–24.6	21.0–18.7	16.2–14.7	2.9–2.3	0.79
Adsorbent IK-011-1 (4.5/8 mm)								
5.0	2.5	19.5	0.4	–26.1	25.4–22.7	23.4–22.9	5.5–4.8	0.90
10.7	3.0	18.9	0.5	–24.7	24.3–21.6	21.8–20.1	4.8–3.8	0.87
14.6	2.8	20.7	0.5	–24.2	25.1–23.1	22.8–20.3	5.3–4.2	0.87
18.6	2.6	20.6	0.5	–25.1	24.6–23.8	22.1–17.5	4.9–3.6	0.84
24.9	3.0	20.0	0.5	–24.0	23.6–22.7	21.1–15.6	4.5–3.0	0.84
31.3	2.5	20.0	0.5	–25.7	23.9–23.3	19.1–14.8	4.0–3.0	0.85
Adsorbent Al_2O_3 (1.8/6 mm)								
5.0	2.1	17.8	0.3	–28.9	20.1–19.0	28.4–26.4	5.8–4.9	0.91
10.7	1.9	19.1	0.3	–29.1	28.0–24.7	20.9–17.2	5.2–3.7	0.90
14.6	1.5	18.9	0.3	–31.4	25.0–24.0	19.3–17.7	4.2–3.7	0.90
18.6	1.6	19.1	0.3	–30.7	25.5–24.2	19.4–14.7	4.3–3.1	0.89
24.9	1.7	19.1	0.3	–30.1	24.8–21.6	17.0–13.6	3.6–2.6	0.87
31.3	1.9	19.5	0.3	–28.8	25.4–24.1	17.4–13.8	3.8–2.9	0.87
Adsorbent IK-011-1 (1.8/6 mm)								
5.0	1.2	17.7	0.2	–34.2	34.1–31.1	17.5–16.6	5.3–4.7	0.98
10.7	1.2	18.3	0.2	–33.7	33.8–31.0	18.3–16.6	5.4–4.4	0.96
14.6	1.0	19.8	0.2	–34.7	30.0–28.3	19.5–15.6	5.1–3.8	0.96
18.6	1.0	20.2	0.2	–34.4	28.6–27.0	20.5–14.3	5.2–3.3	0.95
24.9	1.2	19.6	0.2	–33.1	24.7–27.6	18.5–13.0	4.0–3.1	0.93
31.3	1.4	20.5	0.3	–31.1	25.0–27.2	20.9–13.9	4.7–3.3	0.91
Adsorbent KSM								
5.0	2.2	15.3	0.3	–29.9	21.2–17.3	19.8–17.5	3.8–2.6	0.90
10.7	2.1	16.3	0.3	–29.7	22.4–18.3	20.2–16.9	4.0–2.7	0.90
14.6	2.5	16.8	0.4	–27.8	21.9–19.8	19.7–14.9	3.8–2.5	0.86
18.6	2.1	17.2	0.3	–29.3	22.6–20.4	19.2–16.6	3.8–2.9	0.89
24.9	2.7	17.3	0.4	–26.7	22.6–21.3	18.1–13.2	3.5–2.4	0.86
31.3	3.0	17.4	0.5	–25.5	23.7–22.5	16.7–12.7	3.4–2.5	0.84

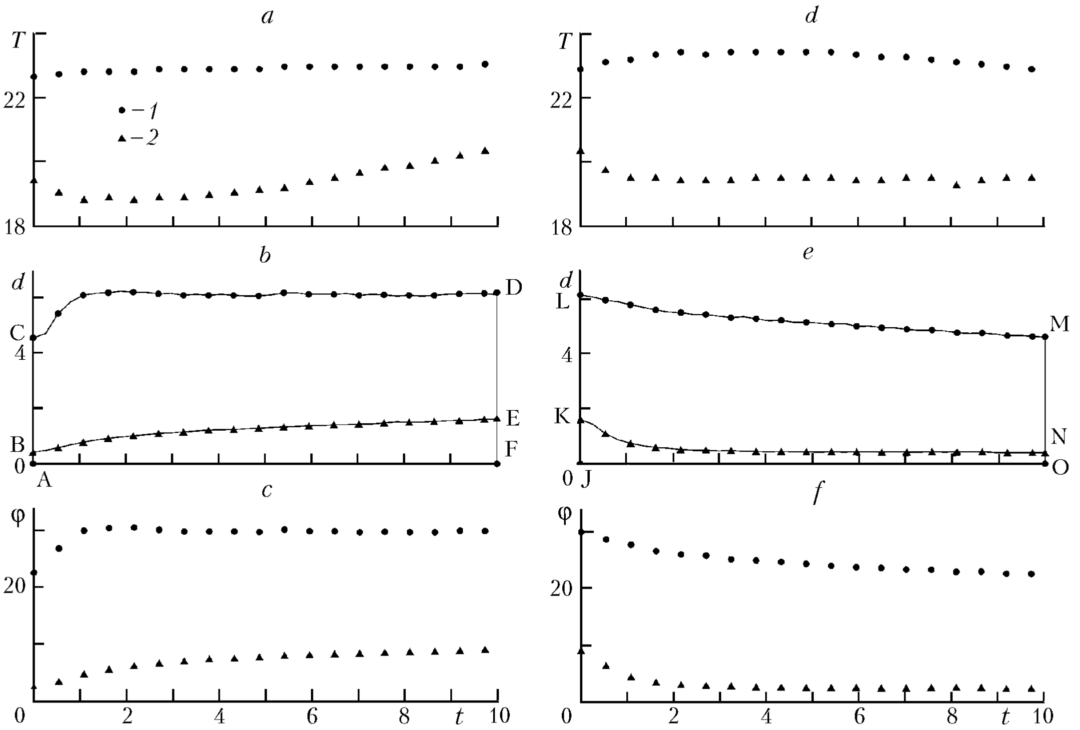

Fig. 1. Evolution of the temperature (a, d) and the absolute (b, e) and relative (c, f) humidities of the air at the wet (1) and dry (2) ends of the IK-011-1 (4.5/8 mm) adsorbent layer of length 160 mm during a half-cycle of adsorption (a, b, c) and desorption (d, e, f) in the stationary regime at an air flow rate of 5.0 m^3/h. T, ^oC; d, g/m^3; φ, %; t, min.

adsorbent and the volume rate of the air flow. Under the conditions of our experiments, this time was approximately 30 min. In the stationary regime, the amount of water absorbed by the sorbent at the adsorption stage (determined by the area BCDE in Fig. 1b) differs from the amount of water released from the sorbent at the desorption stage (determined by the area KLMN in Fig. 1e) by ±2–4%.

At the adsorption stage, the relative humidity at the input (at the "wet end of the adsorber") was maintained constant (Table 1). The air passed through the adsorbent layer was dried; because of this, the humidity of the air at the output (at the "dry end of the adsorber") was dependent on the time (Fig. 1b and c), the volume rate of the wet-air flow supplied, the adsorbent nature, and the size of its granules. The air humidity increased monotonically with time and was φ_e = 1.6–16.2% or d_e = 0.3–3.7 g/m^3, which corresponds to a dew point ranging from –29.7 to –2.7^{o}C. All these quantities increased with increase in the volume rate of the air flow supplied, i.e., with decrease in the time for which the air was in contact with the adsorbent, while the portion of water adsorbed from the air passed in the forward direction α decreased correspondingly. The quantity α was determined from the ratio between the areas $(S_{ACDF} - S_{ABEF})/S_{ACDF}$ on the curve of the dependence of the absolute humidity on the adsorption time (Fig. 1b). The values of T, d, and φ depend mainly on the nature of the adsorbent used. The absorptivity of the adsorbents studied increases in the series IK-011-1 > KSM > Al_2O_3, which correlates with their statistic moisture capacity. Comparison of pure and modified alumina oxides shows that the introduction of the salt into the pores significantly increases the degree of drying. For example, the degree of drying of air with the use of the IK-011-1 (1.8/6 mm) adsorbent exceeds 0.95 at large times τ of contact, i.e., practically all moisture that was introduced into the layer is absorbed by the adsorbent. Even at an air flow rate of 31.3 m^3/h ($\tau \approx 0.5$ sec), the layer absorbs more than 70% of the moisture (α = 0.74). For a pure Al_2O_3 matrix (1.8/6 mm), these values are 0.75 and 0.62, respectively.

The degree of moisture exchange decreases substantially with increase in the size of the adsorbent granules, which is evidence of a decrease in the rate of the process because of the mass transfer on the surface or in the bulk of the granules. For example α = 0.80 and 0.65 for the IK-011-1 (4.5/8 mm) adsorbent at air flow rates of 5.0 and

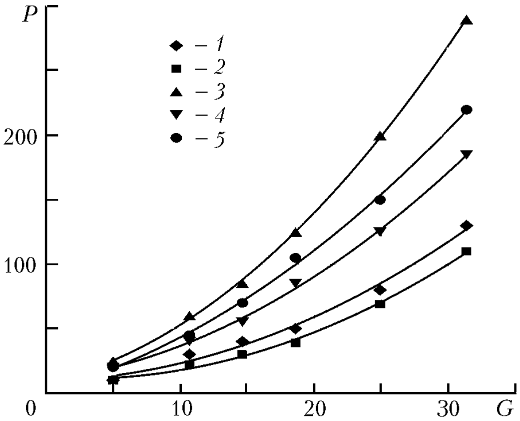

Fig. 2. Dependence of the hydrodynamic resistance of an adsorbent layer of length 160 mm on the air flow rate: 1) IK-011-1 (4.5/8 mm); 2) Al_2O_3 (4.5/8 mm); 3) IK-011-1 (1.8/6 mm); 4) Al_2O_3 (1.8/6 mm); 5) KSM. P, Pa; G, m^3/h.

31.3 m^3/h, while for the IK-011-1 (1.8/6 mm) adsorbent this quantity is much smaller (see Tables 1 and 2). The minimum dew point was −12.4 for the IK-011-1 (4.5/8 mm) adsorbent and −29.7°C for the IK-011-1 (1.8/6 mm) adsorbent. This is explained by the fact that the sorption front narrows substantially with decrease in the size of the granules. For the IK-011-1 (1.8/6 mm) adsorbent, at air flow rates of 10–12 m^3/h the front does not reach the adsorber edge for the adsorption half-cycle and the dew point of the output air ranges from −27 to −30°C. At higher air flow rates the front reaches the adsorber edge and T_d increases substantially. Note that, as the granule size decreases, the mass transfer intensifies and, as a result, the hydrodynamical resistance of the adsorbent layer increases (Fig. 2); therefore, the granule size should be selected such that a compromise between these two tendencies be provided.

The air temperature also changes at the adsorption stage; in this case, $\Delta T = T_{out} - T_{in}$ changes from +7.5 to −3.5°C (see Tables 1 and 2). Since heat is released in the process of water-vapor adsorption, it may be suggested that the air is heated at this stage. The maximum temperature to which the air is heated can be calculated on the assumption that all adsorption heat is expended in heating the air, i.e., that there takes place adiabatic heating. If all moisture is absorbed in the layer, the adiabatic heating ΔT_{ad} is independent of the air flow rate; it is determined by the absolute humidity of the input air and, at the humidity of 6.0 ± 0.5 g/m^3 typical for our experiments, is equal to 12.0 ± 1.0°C. If a part of the water is not adsorbed in the layer, the degree of heating decreases proportionally to the decrease in the amount of the adsorbed water. The actual heating will be smaller than the calculated one because a part of the heat is expended in heating the adsorbent. This heat can be disregarded, beginning with the instant of time the heat front reaches the adsorbent edge, i.e., the instant the whole adsorbent is heated.

The heat measured in the experiments was always lower than the heat calculated in the adiabatic approximation. Moreover, at low rates of the air flow, the air is cooled and not heated. This is explained in our opinion by the fact that the wet air with a temperature T_{in} enters the nonisothermal adsorbent layer, whose average temperature, after the desorption stage, is lower than T_{in}. The air gives up heat to the relatively cold adsorbent layer and is cooled. The cooling effect enhances with decrease in the air flow rate and, at low air flow rates (lower than 5–7 m^3/h), can be dominant and responsible for $\Delta T < 0$, which was observed in the experiments. In this case, the heat front propagates inside the layer in both cases where air is passed in the forward and backward directions; therefore, the temperature of the output air changes insignificantly during a half-cycle. When the air flow rate increases, the heat front reaches the adsorbent edge, with the result that the temperature at the output increases significantly due to the adsorption heat and reaches 28.2°C for the IK-011-1 (1.8/6 mm) adsorbent at an air flow rate of 31.3 m^3/h.

A relatively dry air was supplied to the back ("dry") end of the layer. The air passed through the adsorbent layer was humidified; in this case, its humidity decreased monotonically with time and, before the change of its direction to the reverse, was φ_e = 31.1–18.3% or d_e = 4.9–2.4 g/m^3 depending on the experimental conditions (see Fig. 1e and f and Tables 1 and 2). The absolute humidity of the air at the output of the layer as well as the amount of water β released from the air passed in the backward direction decreased with increase in the volume rate of the air flow supplied, i.e., with decrease in the time for which the air is in contact with the adsorbent. The quantity β was determined from the ratio between the areas $(S_{JLMO} - S_{JKNO})/S_{JLMO}$ on the curve of the dependence of the absolute humidity on the desorption time (Fig. 1e). This quantity is mainly dependent on the adsorbent nature; it increases in the series IK-011-1 > KSM > Al_2O_3, i.e., in the same consecutive order in which α increases (see Tables 1 and 2). Thus, the larger the amount of water absorbed by the air passed in the forward direction, the larger the amount of water released from the air passed in the backward direction.

The relative humidity of the output air depends insignificantly on the air flow rate since, at high air flow rates, the decrease in the absolute humidity is compensated on average by the decrease in the temperature due to the water desorption. At low air flow rates, the temperature of the air at the output of the adsorbent can increase by 1.5–4.5°C as a result of two processes — the heating of the air due to the specific heat of the adsorbent layer heated after the adsorption stage and the cooling of the air due to the desorption of water vapor. Thus, the mechanisms of moisture exchange and heat exchange are qualitatively close at the adsorption and desorption stages.

Note that modified alumina oxide absorbs and contains a much larger amount of water than pure alumina oxide free of salt. It is likely that, varying the amount of the salt at the synthesis stage, one can change the adsorption ability of this adsorber and, in doing so, select the most optimum of its values in accordance with the humidity of the input air at the adsorption and desorption stages [13]. For example, the amount of salt in the vapor should be increased when the air humidity at the adsorption stage is decreased.

Conclusions. Commercially produced desiccants can be effectively used as moisture buffers regulating the moisture in the output air flow at both the stage of water adsorption (water drying) and the desorption stage (water humidification). The use of the modified IK-011-1 adsorbent allows one to increase the amount of moisture accumulated in the air passed in the forward direction by 1.3–1.8 times and, accordingly, to increase the amount of water released from the air passed in the backward direction. The degree of drying and humidification of the air passed through an adsorbent can be changed from 0 to 1 by changing the nature of the adsorbent, the size of its granules, and the time of contact with the air flow. For example, for IK-011-1 (alumina oxide modified with calcium chloride) with granules of diameter 1.8 mm, at contact times exceeding 1.5 sec, practically all moisture was returned back to the air passed in the backward direction, which points to the fact that this adsorbent can be effectively used for both drying and humidification of air. Air can be humidified or dried to the required degree with the use of a minimum amount of this desiccant. The efficiency of moisture exchange increases with decrease in the sizes of the adsorbent granules, which points to the fact that the mass transfer slows down in this case. The moisture exchange between the sorbent and the air passed through it can be controlled by changing the degree of modification of the sorbent, the size of its granules, and the air flow rate (contact time).

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NOTATION

d, absolute humidity, g/m^3; d_{in}, d_{out}, and d_e, absolute humidity of the air at the input and output of the sorbent and at the end of the process, g/m^3; G, air flow rate, m^3/h; P, resistance, Pa; T, temperature, °C; T_{in}, temperature of the air at the input of the sorbent, °C; T_d, dew point of the air, °C; ΔT, change in the temperature of the air, °C; ΔT_{ad}, change in the temperature of the air as a result of its adiabatic heating, °C; t, times of the process, min; α, portion of water absorbed by the sorbent at the end of the adsorption stage; β, portion of water released from the sorbent at the end of the desorption stage; τ, contact time, sec; φ, relative humidity, %; φ_e, relative humidity at the end of the process, %. Subscripts: ad, adiabatic; in, input; out, output; e, end of the process, d, dew point.

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