

**ADSORPTION HEAT TRANSFORMATION UNDER CLIMATIC CONDITIONS
OF THE RUSSIAN FEDERATION**

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**АДСОРБЦИОННОЕ ПРЕОБРАЗОВАНИЕ ТЕПЛА В КЛИМАТИЧЕСКИХ УСЛОВИЯХ
РОССИЙСКОЙ ФЕДЕРАЦИИ**

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***Аннотация.** Эффективная энергетика необходима для гармоничного развития экономики государства. Для России одной из важнейших проблем является снижение энергоёмкости в производственном и бытовом секторах. Ключевым моментом для решения данной проблемы является разработка следующих научно-технических задач: 1) снижение доли тепловых отходов промышленности, транспорта и т.д., бесполезно рассеивающихся в окружающую среду 2) использование альтернативных источников энергии. Одной из технологий, позволяющих эффективно решать поставленные задачи, является адсорбционное преобразование тепла. В основе этой технологии лежит обратимый процесс сорбции-десорбции. Данная технология не только позволяет эффективно использовать энергию тепловых отходов или солнца непосредственно в момент генерации, но и запасать её. Основным недостатком альтернативных источников энергии является несогласованность по времени между производством энергии и её потреблением. Тепловую энергию такого типа необходимо аккумулировать, чтобы сделать доступной для потребителей. Адсорбционные преобразователи тепла (АПТ) могут быть использованы для: 1) обогрева помещений, 2) охлаждения (кондиционирование), 3) запасаения тепла. Эффективная эксплуатация АПТ может быть реализована только в случае грамотного подбора рабочей пары «адсорбент-адсорбтив» в соответствии с требованиями конкретного рабочего цикла. Одним из важнейших факторов, влияющих на выбор рабочей пары, являются климатические условия, в которых будет функционировать АПТ. В данной работе анализируется возможность реализации адсорбционных приложений в различных регионах России. Работа состоит из четырех частей: 1) анализ климатических условий различных регионов России и выбор рабочих циклов, оптимальных для каждого региона; 2) анализ граничных условий работы выбранных циклов АПТ; 3) обобщение данных о сорбционном равновесии различных сорбентов с парами воды и метанола и их аппроксимация функциями; 4) выбор подходящих рабочих пар для рассматриваемых циклов АПТ.*

Introduction. Despite the significant progress achieved in the adsorption heat transformation (AHT) over the past decades, further improvement in the performance is necessary [1]. It has been recently shown that materials characterized by step-wise (S-shaped) sorption curves (isotherms, isobars) are profitable for the AHT [2]. However, each particular AHT cycle presents specific requirements to the adsorbent properties depending on

the type of application (cooling, heating, etc.), the climatic zone where the AHT will be used, and the energy source available for the sorbent regeneration. In other words, a sorbent showing a good performance in one AHT cycle may be completely ineffective in others. To date a tremendous number of novel adsorbents (nanostructured materials, MOFs, AlPOs, SAPOs, composites salt/matrix, etc.) have been developed that makes a routine search for the adsorbent for a specific cycle a labor-intensive and time-consuming task.

Materials and methods. Recently, a generalization of adsorption data for various adsorbents and working fluids has been suggested to form a database, which will be a helpful instrument for the selection of the working pair for a specific AHT cycle [3]. Following this way, here we present the summarized adsorption data for different pairs for AHT.

Results and discussion. It is known that for many working pairs the sorption curves (isotherms, isobars) presented as function of the Polanyi potential $\Delta F = RT \ln(P_0(T)/P)$ converge to a universal sorption curve (see, e.g. Fig. 1). P_0 is saturated pressure of sorbate at temperature T .

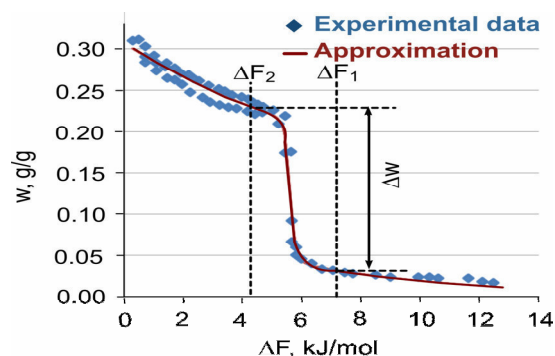


Fig. 1. Experimental data and approximation for pair AlPO18-water

In this paper the adsorption equilibrium of water and methanol with a large number of adsorbents is analyzed. The universal adsorption curves are plotted in the coordinates “sorption w – the Polanyi potential ΔF ”. The plotted curves are approximated by parametric equations and the parameters are tabulated. They represent a database of adsorption data for a large number of working pairs for AHT. The functional dependence $w=f(\Delta F)$ allows the amount Δw of sorptive exchanged in the AHT cycle to be assessed as $\Delta w = w(\Delta F_2) - w(\Delta F_1)$ (Fig. 1), where ΔF_1 and ΔF_2 are the Polanyi potential, corresponding to regeneration and adsorption stages, respectively. We considered several typical AHT cycles, namely cooling and heating, for several climatic zones (cold, warm and hot). Their operating conditions of the AHT are determined by the temperatures of condensation T_{con} , evaporation T_{ev} , and the temperature T_{reg} of the heat available for the adsorbent regeneration. Using the temperatures T_{ev} , T_{con} , and T_{reg} the values of boundary potentials ΔF_1 and ΔF_2 can be calculated as

$$\Delta F_1 = -RT_{reg} \ln (P(T_{con})/P(T_{reg})) \quad (1)$$

$$\Delta F_2 = -RT_{con} \ln (P(T_{ev})/P(T_{con})) \quad (2)$$

Considering the amount Δw of the working fluid exchanged in the AHT cycles considered, the most promising working pairs are selected for these cycles. Thus, Fig. 2a illustrates that under conditions of the cooling cycle ($T_{con} = 30^\circ\text{C}$, $T_{reg} = 75^\circ\text{C}$, $T_{ev} = 3^\circ\text{C}$) the adsorbent AlPO-18 exchanges the largest amount of water Δw among the adsorbents analyzed.

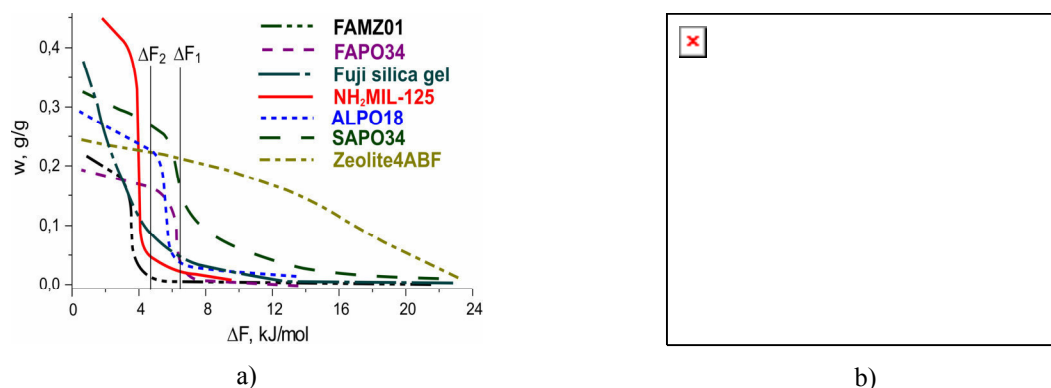


Fig. 2. a) Universal curves of water adsorption on different materials. b) Diagram for pair ALPO18-water:
 $\Delta w = f(\Delta F_1, \Delta F_2)$

Using the functional dependence $w=f(\Delta F)$, a more detailed analysis of the working pair applicability for the AHT cycles with different operating conditions can be carried out. For example, the adsorption equilibrium of the pair “ALPO-18 – water” is fitted by the function (Fig. 1):

$$w = (A \cdot \Delta F + B) / (1 + \exp(-k_1 \cdot (\Delta F - C_1))) + L / (1 + \exp(-k_2 \cdot (\Delta F - C_2))) \quad (3)$$

where A, B, C1, C2, L, k1, k2 are numerical coefficients. Let's consider the refrigeration cycle for drugs keeping with $T_{ev}=3^\circ\text{C}$. Plotting the amount of water cycled on ALPO-18 (Fig. 2b) at different temperature T_{con} and T_{reg} one can estimate which T_{reg} is required for different T_{con} (means, in different climatic zones). Thus, from the diagram $\Delta w(T_{con}, T_{reg})$ (Fig. 2b), it is evident that at $T_{con}=36^\circ\text{C}$, $T_{reg} \geq 80^\circ\text{C}$ is needed for $\Delta w \geq 0.15$ g/g to be exchanged by ALPO-18. If the ambient temperature drops down to 20°C , then $T_{reg}=60^\circ\text{C}$ is sufficient for reaching $\Delta w = 0.20$ g/g. Thus, using the functional dependences $w=f(\Delta F)$, the diagrams $w(T_{con}, T_{reg})$ can be plotted to evaluate the potential of the working pair for the specific AHT cycle under different climatic conditions.

Conclusion. The universal sorption curves for a wide range of conventional and innovative sorbents (activated carbons, silica gels, alumina, aluminophosphates, MOFs, "Salt in porous matrix" composites, etc) using methanol and water as sorptives were calculated. For each universal curve, an analytical functional relationship was selected. Recommendations on the optimal climatic conditions for the use of the considered working pairs were given.

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