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Materials Science

Cryosorption Pump CSD-0.25D

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ABSTRACT. Experimental data of the testing of the main technical characteristics of the cryosorption pump CSD-0.25D designed and manufactured by us are presented in the paper. *© 2010 Bull. Georg. Natl. Acad. Sci.*

Key words: *cryosorption pump, adsorbent, final vacuum.*

The aim of the paper is to present the main characteristics of the cryosorption pump CSD-0.25D, designed and manufactured by us: action speed, final vacuum, liquid nitrogen discharge and long-term reliability. Testing was conducted on special vacuum testing stand. General view of the above-mentioned pump CSD-0.25D with flexible connecting tube is given in [1].

Tracing 10^6 molecules in an open flow area Ø-160 of the pump, which is a cylindrical canal with the ratio of the length to the radius equalling L/R=0.5, the value of the conduction coefficient of molecular flow 0.79 was obtained, which corresponds with great accuracy to the calculation results received by the Clausing formula and some other methods [2].

Using the known values of the coefficient of condensation β by the Monte-Carlo method [3] we can count the quantity of adsorption particles N_{ads} and count the coefficient of capture $\Gamma_{capt.}$ for the pump. With the help of $\Gamma_{capt.}$ we can calculate the speed of action, one of the main characteristics of the vacuum pump.

Calculation of the action speed of the cryosorption pump at evacuation of vapours. The dependence of action speed S on the pressure of vapours P in the chamber of high vacuum area, i.e. while the molecular regime of flowing is preserved, can be expressed by the correlation:

$$S = \Gamma_{capt.}\, 1/4 \sqrt{8RT/\pi\mu}\cdot F_0\,(1 - P_s/P), \qquad (1)$$

where R is universal gas constant equalling $8.314\cdot10^3$ J/kg·mol·grad.; T – absolute temperature, K; μ - molar mass of evacuated gas, kg/mol; F_0 surface area, m^2; P_s – pressure of saturated vapours, Pa; P – absolute pressure, Pa.

Calculation of the speed of action of cryosorption pump at evacuation of gases. Pressure P_{in} in the inlet cross-section of the pump at constant inleakage can be calculated according to the formula [4]:

$$P_{in} = P_0 + \Delta P_{dyn} + \Delta P_{entr} + \Delta P_{ads}, \qquad (2)$$

The first summand P_0 is the pressure in the pump, reached before the creation of inleakage ($P_0 = P_{lim}$). The value ΔP_{dyn} presents an increase of gas pressure on the surface of the adsorbent's grain as compared to the averaging value on cross-section of the grain. The value ΔP_{dyn} is defined by adsorption-diffusion characteristics of adsorbent and can be calculated by the formula:

$$\Delta P_{dyn} = KR^2Q / D_{eff}\,\Gamma_{dyn} M_{ads}, \qquad (3)$$

where K is the coefficient, depending on the grain's form; Q – gas flow, Pa·m^3/s; D_{eff} – effective coefficient of diffusion; Γ_{dyn} – dynamic adsorption of gas; M_{ads} – mass of adsorbent, kg.

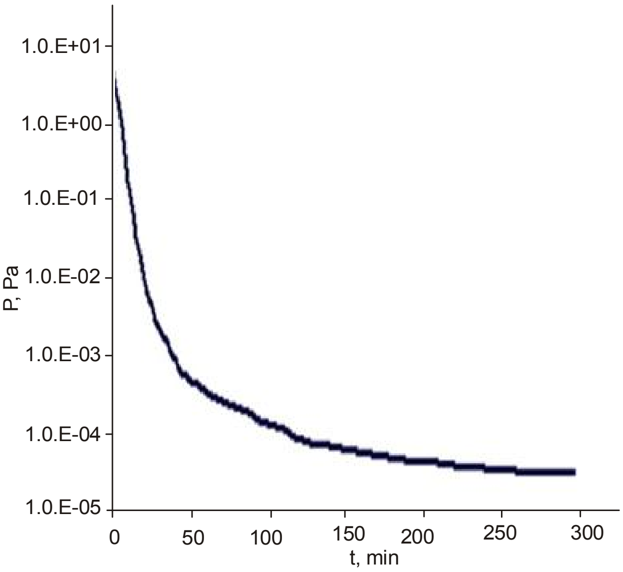

Fig. 1. Dynamics of pressure change in the pump after the first filling of fluid nitrogen.

As the experience shows, D_{eff} and Γ_{dyn} in a complex way depend on pressure and temperature. Also significant changes in dynamic isoterms and values P_{dyn} and Γ_{dyn} for the layers of an adsorbent of different thickness are revealed. This points to the noticed gradient of the concentration of adsorption gas on thickness of the adsorbent's layer in the conditions of noncontinuous adsorption at constant inleakage.

The third summand ΔP_{entr} is defined by the transmitting capability of the elements of the pump and can be calculated according to the known formula

$$\Delta P_{entr} = Q/G_{trans}, \quad (4)$$

where G_{trans} is the transmitting capability of the pump's elements and determined by the Monte-Carlo method.

For Δt time the quantity of the gas $Q\Delta t$ will be pumped, the adsorbent's absorption of which will cause an increase of the pressure on the value:

$$\Delta P_{ads} = Q\Delta t/M_{ads}\Gamma_{dyn}. \quad (5)$$

Correlations (2)-(5) allow to calculate the dependence of the pump's action speed on the pressure in the inlet tube. Therefore we have to introduce a series of values Q and find a corresponding value of P_{trans}. Then for each pair of values Q and P_{trans} it is possible to calculate the pump's action speed by the formula

$$S=Q/P_{trans}. \quad (6)$$

The time of attainment of final vacuum. According to the equation (2) the duration of time interval t, during which high vacuum is created by the pump, can be calculated by the formula:

$$t= [(P_{trans} - P_0 - \Delta P_{dyn} - \Delta P_{entr.})/Q]\Gamma_{dyn} M_{ads.} \quad (7)$$

The calculations showed that the increase of the number of the molecule's traced trajectories practically was not reflected on the results. In the calculations of the value of the adhesion coefficient to the cryosurfaces for carbon dioxide and water are assumed to be equal to 0.9 and 1.0, respectively, and to the sorbent surfaces for gases equal to 0.2.

The data on the main cryovacuum characteristics of the pump obtained as a result of the experimental testing are presented below: limiting pressure, evacuation speed in the working pressure range, liquid nitrogen discharge and long-term service.

Limiting pressure. After the pump's start, the measurements of the pressure were conducted for 5 hours. The results of the measuremnts are presented in Fig. 1. According to the experiment, limiting pressure reached by the pump without gas loading totalled $3{\cdot}10^{-5}$ Pa.

Speed of evacuation. After the basic pressure $P_0=3{\cdot}10^{-5}$ Pa was reached the calibrated flow Q of the gas N_2 under investigation was established. At this inleakage testing pressure P was measured and then calculation of the evacuation speed was made by the formula $S= Q/(P-P_0)$.

Liquid nitrogen discharge. Liquid nitrogen discharge is a significant exploitation economic characteristic of the cryopump. Measurements conducted with the help of special flowmeter showed that discharge of liquid nitrogen totalled 8 litres per day.

Long-term service before regeneration. The long-term service of the cryopump in high vacuum is determined by the formula (7). It must be noted that the long-term service before regeneration significantly depends

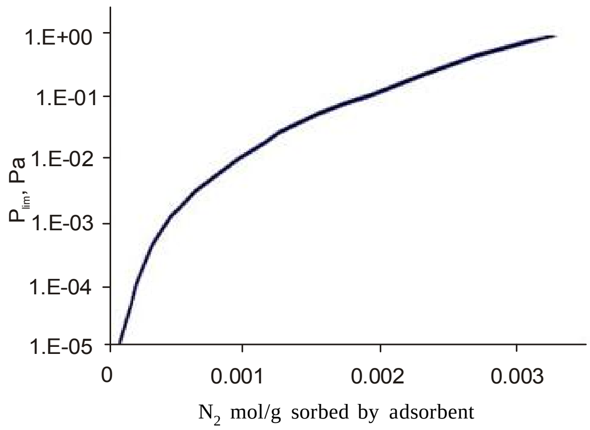

Fig. 2. Dependence of pressure change on the quantity of the adsorbed nitrogen in vacuum chamber.