

At this time it is felt necessary to produce a high oil-free vacuum in facilities for a number of science and engineering areas. Such conditions can be assured by performing the prevacuum evacuation by an oil-free method also. The prevacuum evacuation of nitrogen, air, and other gases by nitrogen, neon, and hydrogen pumps was investigated in a number of papers ([1-10], for instance). The processes being realized during cryo-evacuation by helium prevacuum pumps have been studied considerably less [3, 11].

A description of the installation, the method of performing experiments, and the results of cryo-evacuation of nitrogen in a $4 \cdot 10^{-2}$ -5 Pa pressure range are presented in this paper (the Knudsen numbers computed with respect to the diameter of the condensing surface are from ~ 2 -0.03). A copper surface cooled by liquid helium was the condenser.

Description of the Experimental Module

The experimental installation on which the investigations studying the cryo-evacuation of nitrogen were performed consists of four subsystems: A) the system for pouring liquid helium and removing helium vapors in the gas holder; B) the system assuring continuous flooding with nitrogen during the experiment. The necessary stream of gas being studied is set up by using a number of RM-GS rotameters of different productivity and pressure regulators; C) the experimental module based on the serial helium cryostat KG-60/300, and D) the system of preliminary evacuation of the vacuum chamber that consists of a prevacuum mechanical pump, a nitrogen trap, and a diffusion high-vacuum pump.

The experimental module (Fig. 1) is connected to all the subsystems and consists of 7, the serial helium cryostat KG-60/300, the vacuum chamber 6, and the helium vessel 3. The pressure in the system is measured by using PMT-4 thermocouples 1, ionization LM-3-2 and PMI-10-2 vacuumeters 2. The gas delivery is realized by means of the distributive network 5 in the hemispherical shape. The vacuum chamber is submerged in a liquid nitrogen bath. All the elements of the experimental module are fabricated from stainless steel (except the copper cover 4 of the helium vessel).

Method of Performing the Investigation

Chilling of the vacuum chamber by liquid nitrogen is performed after its evacuation for 10 h by a diffusion high-vacuum pump and its attainment of a $4 \cdot 10^{-2}$ Pa pressure. The pressure is reduced to $3 \cdot 10^{-4}$ Pa during filling with N_2 . Then liquid helium is poured and the pressure in the vacuum chamber is lowered to $7 \cdot 10^{-5}$ Pa. The gaseous nitrogen is admitted after the liquid helium had covered the condensing surface completely (a conclusion about this is made by the reading of the helium level gauge fabricated from a niobium-titanium superconducting alloy and mounted within the helium vessel). During the whole delivery of the nitrogen the pressure p is measured by vacuumeters and is determined by the sensors 1 and 2. The characteristic dependences are represented in Fig. 2, where τ is the nitrogen filling time in sec. The area of the condensing surface equals $4.4 \cdot 10^{-3}$ m², the area of the annular gap between the helium vessel and the vacuum chamber is $6.3 \cdot 10^{-4}$ m²; consequently, it was assumed that the condensation occurs only on the surface of the cryopanel 4. If repetition of the experiment became necessary the helium was evaporated, the vacuum chamber was evacuated by a preliminary rarefaction system, and the helium was poured again.

Discussion of the Main Results

The characteristic dependences $p(\tau)$ are represented in Fig. 2 for different values of j , where the line 1 corresponds to the stream of delivered nitrogen $j = 0.38 \cdot 10^{-3}$ kg/(sec·m²), 2 to $j = 6.45 \cdot 10^{-3}$ kg/(sec·m²). At the beginning of the nitrogen delivery (for all the

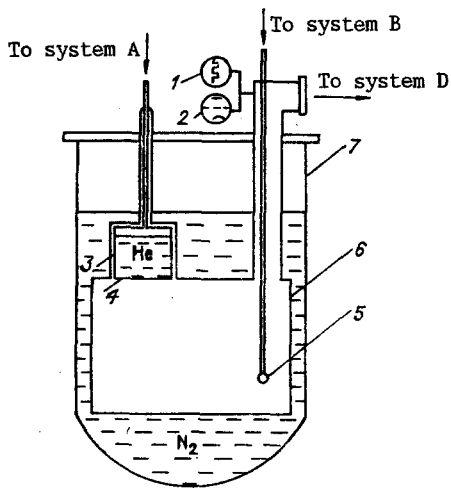


Fig. 1

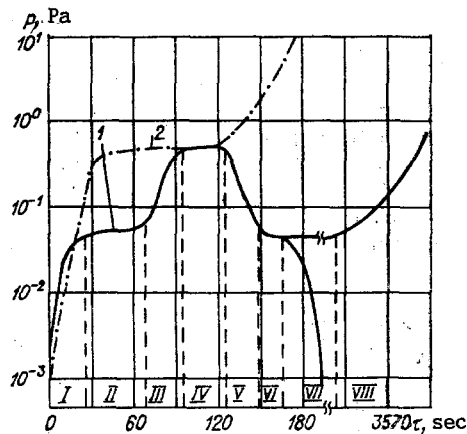


Fig. 2

cases under consideration), the pressure in the vacuum chamber grew to the value corresponding to given j (section I, dependence 1) after a brief time interval. During the delivery the pressure in the vacuum chamber remained constant (section II). If the value of j increases (section III) or diminishes (section V) during nitrogen delivery, then the pressure in the vacuum chamber grows (section IV) or is lowered (section VI), where a definite value of p corresponds to each j . The tendencies noted are related to the specifics of the mass transfer processes on the interphasal surface of the solid sediment. The magnitudes of the mass flux and the nitrogen condensation coefficient β_c are interrelated resulting in the build-up of a completely definite pressure for the specific value of j .

As the delivery ceases the pressure in the vacuum chamber is lowered to the initial value (section VII). If delivery continues, then after a certain time (different for each j) the pressure in the vacuum chamber increases sharply (section VIII), this latter effect is explained by the fact that as the thickness of the cryolayer grows, a rise occurs in the temperature of its surface (since the heat conductivity of the cryosediment is a finite quantity), which means β_c diminishes.

The experimental dependence $j = j(p)$ obtained on the installation described above and quantitatively reflecting the interrelation between the specific mass flux j of the nitrogen delivered to the vacuum chamber and the pressure p that is set up in the stationary condensation mode, is presented in Fig. 3.

Represented for comparison in Fig. 4 are dependences of the rapidity of action of a surface S free of sediment on the pressure in the vacuum chamber during the nitrogen delivery: 1 is the dependence $S(p)$ obtained on the installation described above and computed from the formula $S = jRT_g/p$, where j is the specific mass flux of the nitrogen, $\text{kg}/(\text{m}^2 \cdot \text{sec})$, R is the individual gas constant for nitrogen, $\text{J}/(\text{kg} \cdot \text{K})$, T_g is the temperature of the gas being delivered, $T_g \approx 293\text{-}300 \text{ K}$, and p is the pressure in the vacuum chamber in the stationary mode, Pa; 2 is the dependence $S(p)$ found by the authors of [6] during nitrogen condensation on a surface cooled by liquid neon (the cryosurface temperature was 27.1 K and the nitrogen temperature was 293 K); 3 is the dependence $S(p)$ obtained by the authors of [2] during nitrogen condensation on a surface with the temperature $T_c = (18 \pm 2) \text{ K}$ (nitrogen temperature was 80 K).

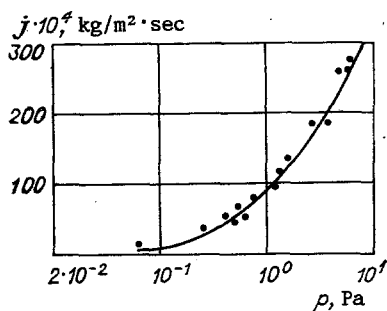


Fig. 3

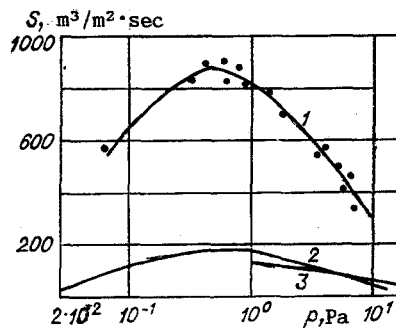


Fig. 4

It follows from an examination of the curves represented that the values of S found in this paper are substantially greater than the corresponding values for the dependences 1 and 2. This is explained by the fact that the pressure was measured in the cryopanel plane and not in the space being evacuated nor the connecting pipeline. No less essential is also the fact that because of the formation of a sufficiently complex gasdynamic flow configuration in the chamber 6 the process of direct spreading on the surface 4 (see Fig. 1) proceeds considerably more intensively than for the traditional delivery scheme. For instance, a strong increase in the intensity of carbon dioxide condensation on a cryopanel is known for jet spreading as compared with free, as noted in [4].

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