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CRYOCONDENSATION PUMP WITH ADVANCED COEFFICIENT OF BY H_2 AND He

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Abstract:
In this work a cryocondensation pump is presented, which has original design with advanced coefficients of capture for H_2- 3.0 and for He- 1.8 times higher than in the existing cryopumps of other authors. Operating speed of this pump is 8 m^3/s for N_2, 6 m^3/s for Ar, 12 m^3/s for He and 22 m^3/s for H_2, diameter 500 mm. The pump is made of Ti and Al. The described cryopump is the most effective at pumping gas with the adhesion coefficients less than 1 (^4He, ^3He, H_2, D_2, T_2 and others) and can be successfully used for pumping from physical chambers or installations: thermonuclear synthesis, implantation etc. as well as there, where are the specific requirements for vacuum.

Keywords: *cryopump, condensation, coefficient, vacuum, chamber.*

The given work presents a design of the filled cryopump with enveloped pumping zone CCP-8D, results of thermophysical calculations and results of the pump testing.
Fig.1 shows the section of a CCP-8D cryogenic pump general view. The cryopump has casing 1, connection flange 2 (∅500) with metallic compaction joining the transition flange to commutating vacuum elements.

In an inner upper part of the pump a vessel with long cavity 4 of the circular section is located and in the operation mode is filled with liquid nitrogen (LN_2). Vessel 3 is suspended to the casing lid with three suspension tubes 5. These suspension tubes serve for LN_2 filling and release of its vapor.

An external surface of cavity 4 is enveloped with good thermal contact by the shell cool conductor 6 which is connected with a blackened chevron screen. The screen is made of cylindrical 7 and disc 8 optically nontransparent chevron.

Between vessel bottom 3, the inner shell of cavity 4 and the chevron screen helium vessel 9 is located which joins suspension tube 10 which at the same time is a tube for liquid helium filling and release of its vapor.

A lower part of vessel 9 lateral surface of which and vessel 9 bottom are pumping surfaces. Between casing 1 and nitrogen vessel 3 thin-walled screen 12 is located and has tight contact with a lower part of the casing. There are technological branch pipes with flange 13 in casing 1 and are destined for control-measurement apparatus and pump testing.

Titanium and aluminium were chosen as main design materials. Surfaces of the chevron screen are blackened with enamel of thickness not less than 0.3 mm. Surfaces of pump junctions oriented in to vacuum volume are polished up to the 11 roughness class of R0.16 and an external surface of the helium vessel up to R0.03 and have aluminium film coating not less than 1 μm in thickness deposited with special technology in helium flow.

When calculating thermophysical parameters of the CCP-8D cryopump we can ignore convection due to low pressures and heat conductivity.

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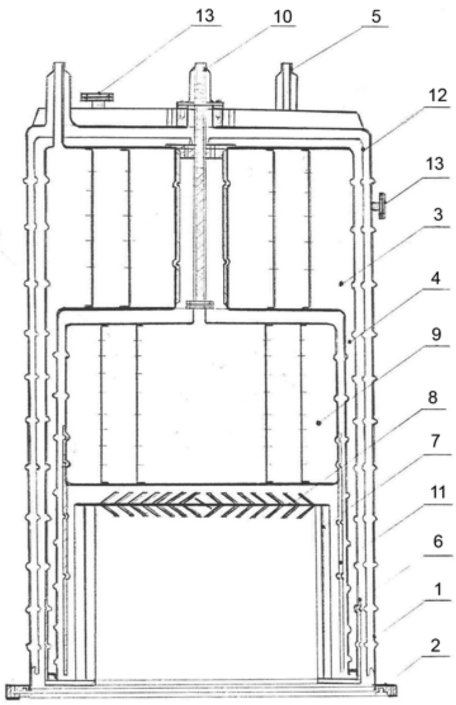

Fig.1. Section of a general view of the CCP-8D cryocondensation pump with the enveloped pumping zone.

Thermal afflux by radiation was calculated by the known formula [1]:

$$Q_{rad} = \varepsilon_r\ \sigma(T_2^4 - T_1^4)A \qquad (1)$$

where ε_r — is the reduced degree of blackness of the surfaces with T_2 and T_1 which is expressed by the following relation:

$$\frac{1}{\varepsilon_r} = \frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1 \qquad (2)$$

where ε_1 and ε_2 are degrees of blackness of surfaces with T_2 and T_1, $\sigma = 5.77 \cdot 10^{-8}$ W/($m^2 \cdot$ K) is the constant of the absolute black body radiation, T_2 - temperature of the radiation surfaces, T_1 - temperature of the adsorbing surfaces, A – area of the surfaces with.

Thermal afflux through the walls was calculated according to the known Hogg formula [2]:

$$Q_T = \frac{mC_p\Delta T}{\exp\left[\frac{lmC_p}{F\lambda}\right] - 1} \qquad (3)$$

where Q_T - thermal afflux entering walls of a suspension tube, $m = Q_{tot}/(r \cdot \mu)$ - number of moles of a gas flowing in the channel of the suspension tube, in 1 s, Q_{tot} – total thermal afflux at the expense of all other thermal affluxes, r = 20.3 J/g -heat of liquid He evaporation, μ – He molar mass, C_p - molar heat capacity of a gas (for He =21.2 J/(mol·K)), ΔT –temperature gap between heated and cool ends of a suspension tube, l - suspension tube length, λ-average specific heat

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Calculations of thermal afflux perception by the surfaces with Helium temperature give the following values: fluxes of heat radiation on the shell and helium vessel of 7 and 6 mW respectively, heat flux entering a suspension tube by heat conductivity does not exceed 0.5 mW. So the summery heat flux is 15 mW. Which corresponds to the length of continuous operation of CCP-8D after a single filling with LHe of up to 4 months.

After eight hours of cooling the pump is ready for operation. On the pumping surfaces of the cryopump cryocondencation of gas-sorbent Ar of the purity or gasified from the liquid phase of N_2 is performed through the leak-in unit during 30-100 min at $P \sim 10^{-2}$ Pa. 1-10 normal liters of Ar ($10^2 \div 10^3$ m^3Pa) is condensed on the cryopanel and the condensate layer of $\sim 10^4 \div 10^5$ monolayer is formed and only 0.5-1 liters of liquid helium is spent during this process.

After this the cryopump can pump 10-100 m^3Pa of H_2 and 1-10 m^3Pa of He at the cryopanel temperature of 4.2K, and equilibrium pressure of H_2 and He is 10^{-7} Pa and 10^{-6} Pa, while operation pressure $10^{-8} \div 10^{-9}$ Pa, respectively.

With the help of the described cryopump were taken isotherm of adsorption of H_2 and He (Fig.2) on the Ar condensate $\sim 10^{-4}$ monolayer thick at T=4.2K.

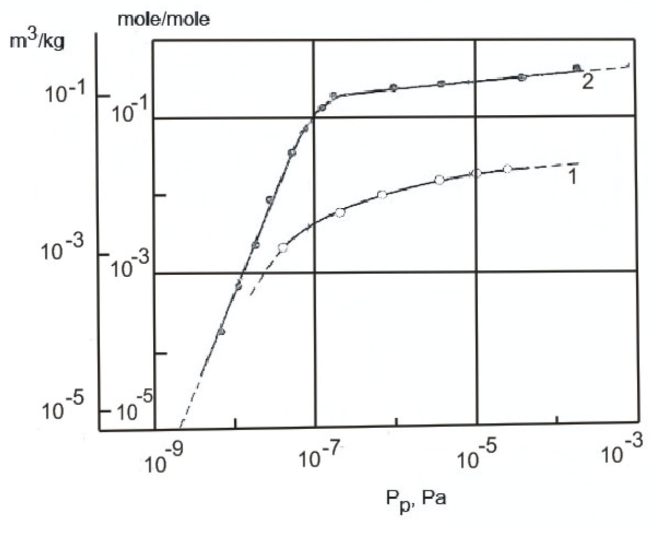

Fig.2. Isotherms of adsorbtion of He (curve 1) and H_2 (curve 2) on Ar condensate $\sim 10^{-4}$ monolayer thick at T=4.2K.

Fig.2 shows that in range of equilibrium pressures $10^{-7} \div 10^{-4}$ Pa any of 100÷300 condensed atoms of Ar at T=4.2K in the layer $\sim 10^{-4}$ monoatomic layer thick is able to adsorb 1 He atom. If we condense 1.2 normal liters of Ar on the cryopanel of CCP-8D, this amount of sorbent is able to adsorb 10÷40 normal cm^3 of He. Isotherm of H_2 and He adsorption on Ar condensate of $\sim 10^{-4}$ monoatomic layer in a more narrow range of equilibrium pressure of $10^{-6} \div 10^{-4}$ Pa obtained by authors [3,4] agree with curves 1-2 of fig.2.

Action rapidity of CCP-8D cryopump measured by the method of constant pressure by N_2 is equal to 8 m^3/s, Ar - 6 m^3/s, He and H_2 on the Ar condensate at T=4.2K - 12 m^3/s and 22 m^3/s, respectively.

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Calculated coefficients of seizure of the described cryopump by N_2, He and H_2 are higher than those of pumps [5,6] of the same diameter of casing and incoming flange 1.4, 1.8, and 3.0 times respectively and are equal to: $Y^{N2} = Y^{H2}$=0.5; $Y_{4.2}^{He}$=0.42.

Thus the described design of CCP-8D with the enveloped zone of pumping is most effective at pumping gases with coefficients of sticking <<1 (^{4}He, ^{3}He, H_2, D_2, T_2 and others) and can by successful applied in installations of thermo-nuclear fusion, space imitators, monocrystal growing, implanters, accelerators and others.

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