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Regeneration of Cryoadsorption Cryopump

Mayur Joshi
PG student, A. D. Patel Institute of Technology, New V. V. nagar, Anand, Gujarat, India

Abstract
A cryopump is a vacuum pump that pumps the gases and vapours by condensing, them on a cold surface, by adsorption on porous surfaces or by trapping mechanism. Helium gas which is very light can only be pumped by Cryoadsorption cryopump. Cryoadsorption cryopump cannot be used when working for continuous operation as it pumps the effluent till the saturation state is achieved. Then the absorbed gases are to be removed by desorption process and evacuation system. Regeneration is a phase where the heating of cryopanel of cryoadsorption cryopump takes place. Hence, regeneration of cryopanels of cryopump is very important to make cryopump in continuous pumping mode. Various methods of regeneration of cryopumps are proposed. This review paper focuses on the different proposed regeneration methods and concludes the best possible regeneration method for cryoadsorption Cryopump.
***Keywords**:* Cryopump, regeneration

I. INTRODUCTION

A tokomak is a device uses a magnetic field to confine plasma in the shape of a torus. The fusion reaction of hydrogen isotopes takes place inside of tokomak, where in result producing high throughput of He and DT mixtures. Hence, there is a great requirement of pumping system capable of pumping at very speed.

Mechanical pumps are not capable to pump such huge load of tokomak throughput of He and H2 isotopes. Also, Helium gas throughput cannot be pumped by other than cryoadsorption cryopump.

Cryoadsorption mechanism, Gas particles impinging on a surface of sufficiently low temperature lose so much of their incident kinetic energy that they stay attached to the cold surface by weak intermolecular forces, resulting insignificantly higher molecular concentration on the surface than in the gas phase. This phenomenon is called physical adsorption or physisorption. Cryosorption denotes the physical adsorption process under vacuum conditions and low temperatures. The equilibrium pressure of adsorbed gas particles is significantly lower than the corresponding saturation pressure for cryocondensation. This is due to the fact that the dispersion forces between the gas molecule and the surface are greater than between the gas molecules themselves in the condensed state. Hence, gas can be retained by adsorption even in a sub saturated state, i.e., at considerably higher temperatures than would be required for condensation. This fact is essential in cryopumping helium, hydrogen, and neon, which are difficult to condense. When this occurs, a sorption pump will either need to be "regenerated" or replaced.

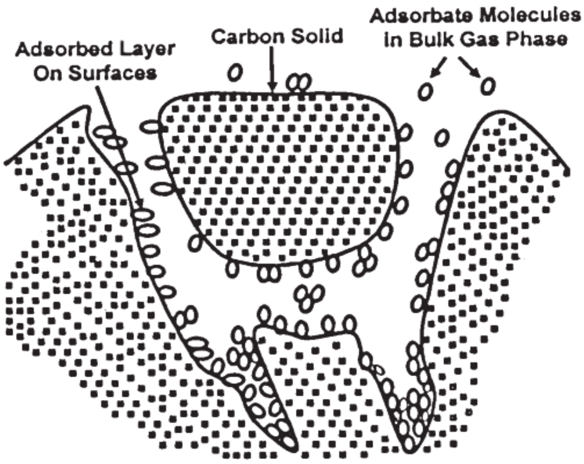

Figure 1 Cryoadsorption on ACs[S. M. Manocha, 2003]

Desorption, if a molecule is physically adsorbed (if a chemical bond has not been formed between the surface and the absorbate), then the molecule maintains its gas-phase structural features. By heating the surface, the molecule can be desorbed or freed from the surface. The thermal Energy added to the system causes the breaking of valence bond between surface and gaseous molecule. This create excitation of molecule and escaped from surface, this phenomena called as desorption.

Regeneration, when the cryoadsorption surface of the cryopump will become saturated after the adsorption of gases, this will causes the reduction of pumping speed. When this occurs, regeneration may be performed by simply heating and evacuating system. Gases will be desorbed from the adsorption surface, and will escape the pump body through the vent or pressure relief valve.

II. REGENERATION METHODS OF CRYOPUMP

There are different methods of regeneration are suggested by different authors.

H J Mundinger et al., in his research paper "A new cryopump with a fast regeneration system" in 1992, proposed different types of possible methods of regeneration of cryopump. The possible regeneration method includes; natural heating regeneration, electrical heating regeneration, purge gas regeneration. It also explains another regeneration method called as fast regeneration. For industries like semiconductors, the regeneration time is very important in aspect to cryopump operation. Author has compared all the regeneration methods in aspects of time of regeneration.

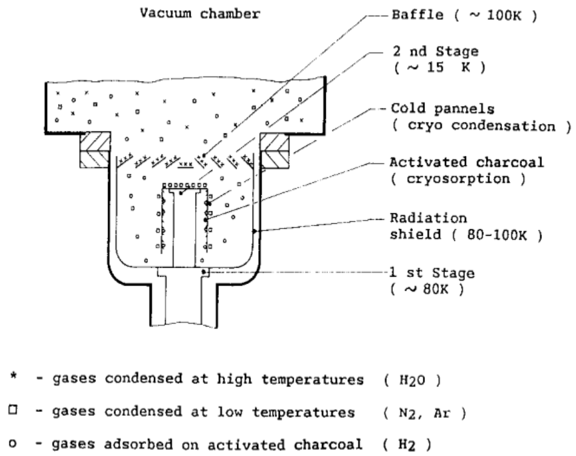

Figure 2 The principle of the cryopump pumping mechanism. [H J Mundinger et al, 1992]

Natural warm up regeneration, In the very beginning this only takes place via radiation and heat conduction in the material. After some time, part of the gas starts to sublimate or to desorbs and the pressure rises to the 10^{-3} — 10^{-2} mbar-region. Heat transfer via convection then leads to a faster warm up. It has drawback of condensing of water at outside of housing of cryopump.

Purge gas regeneration, an inert gas is lead into a cryopump for increases the rate of natural heating, but it also show same effect of natural warm up regeneration.

Electrical regeneration, natural regeneration and purge gas regeneration having some drawbacks, which are resolved by electrical regeneration. Electrical power is used for heating of surface. It gives rapid regeneration than above methods, but sudden pressure rise me damage the system so electrical regeneration has carried out in pulse heating.

Fast regeneration, the fast regeneration is taking advantage of the local heating with electrical heaters and is furthermore regeneration above the triple point of the gases pumped on the second stage of the cryopump. Therefore, the temperature and the pressure have to rise above some special limits depending on the type of gases. To avoid a transposition of the evaporating condensed gases onto the activated charcoal this temperature has to be even higher than the triple point temperature. At the same time the radiation shield and the baffle have to stay cold, thus the vapour pressure of the water which is condensed there remains at very low limits.

All the methods of regeneration are compared in figure 3, comparisons of methods has done on aspect of regeneration time.

A. Möbius et al., in his paper "Regeneration of cryosorbing exhaust gas panel by means of gyrotron radiation" in 2 002, proposed a regeneration of cryosorbing surface by gyrotro radiation. Gyrotron radiation may refer as good technique for regeneration. It gives uniform heating to the cryosorbing surface, but this method is highly influenced by material heat capacity and thickness of material for infrared penetration.

C. Day, in his paper "basics and applications of cryopump" in 2007, also mentioned different kind of regeneration methods and related aspects. Author has a also explained the regeneration of cryopump like ITER cryopump with fluids.

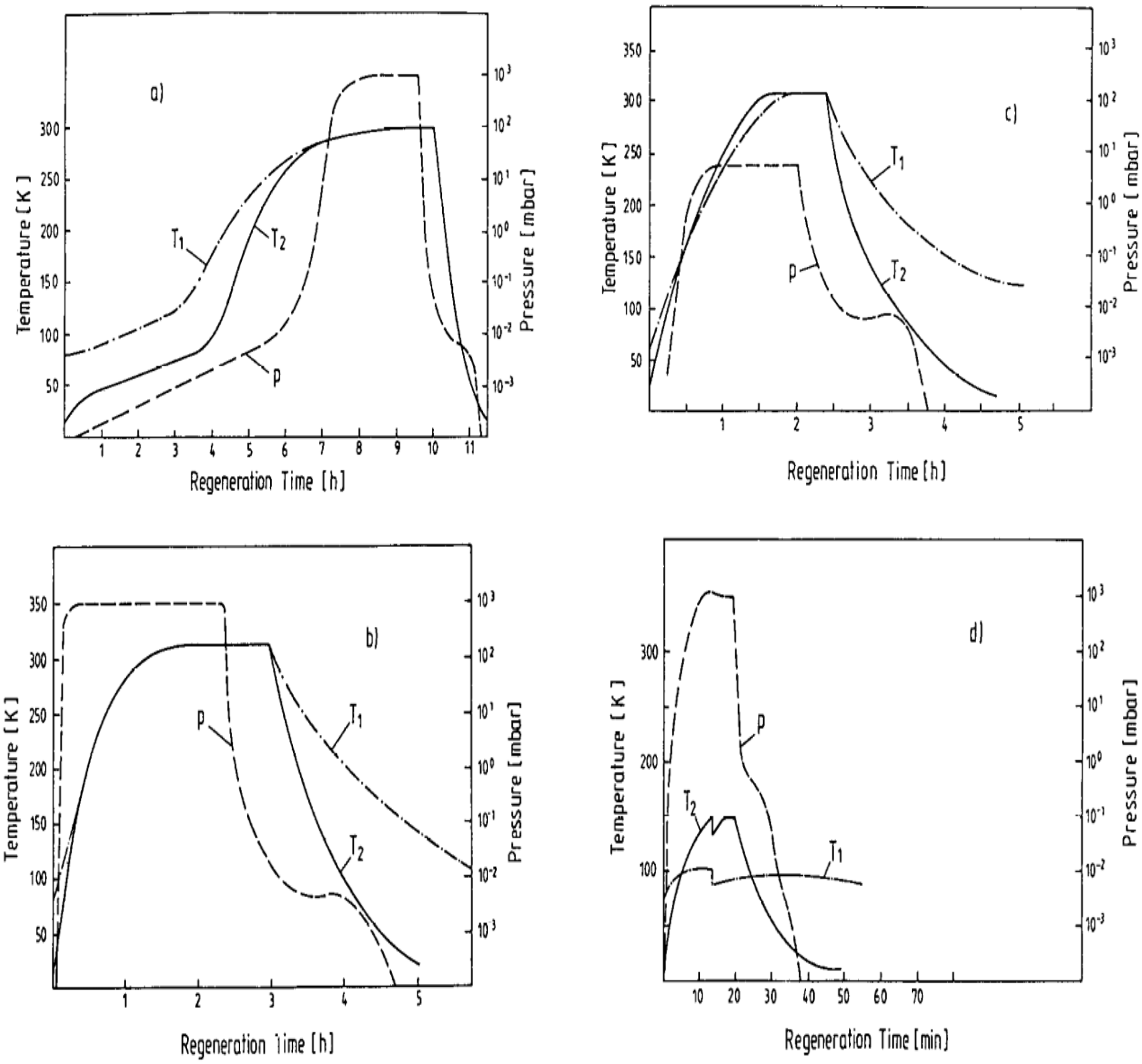

Figure 3 The temperature and pressure dependence during the regeneration of 400 bar.1 Ar (a) via natural warm up (b) purge gas regeneration (c) electrical regeneration; and (d) fast regeneration [H-J Mundinger, 1992].

III. CONCLUSION

Among all above methods of regeneration, natural regeneration and purge gas regeneration having disadvantages of heat transfer by convection to outer chamber. The electric regeneration method having great advantage over regeneration time, but sudden pressure rise of chamber takes place. So to overcome this problem electrical heating is perform in pulse heating and this causes increasing in regeneration time. It is also difficult to apply for regeneration of hydrogen.

As shown in figure 3, fast regeneration having less time as compared to other methods of regeneration, but it is very difficult to perform with its criticality.

The regeneration of cryopump with fluid is best possible way of regeneration. Regeneration time can maintained or vary with fluid flow rate.

IV. FUTURE SCOPE

Develop a test facility for testing and analysis of regeneration behavior, time and related parameter with help of fluid flow regeneration method. Test regeneration method for different gas regeneration.

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