Study of Hydrogen Pumping through Condensed Argon in Cryogenic pump

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Objective of Hydrogen Pumping

- Pumping of hydrogen is limited with widely used UHV pumps.
  - TMP: Pumping limitation of lighter gases, like H_2, He
  - CRYO: Pumping limitation of non condensable gases, H_2, He, Ne & Low capacity to pump hydrogen

- Hydrogen, as fuel gas in tokamak ADITYA, to produce various discharges like, high temperature plasma discharge, Glow discharge cleaning (GDC) & others.

- For wall conditioning, GDC is operated with high pressure of hydrogen and for long duration. As a result, high background pressure of hydrogen perturbs the high temperature plasma discharge. (As a Recycling effect of hydrogen in hot plasma).

- Thus, an experimental study of **cryosorption using argon adsorbent to increase pumping speed and capacity of hydrogen** has been carried out to improve pumping efficiency of ADITYA vacuum vessel.

Cryosorption of Static Adsorbents

- Cryosorption pumping : to achieve high pumping speed and capacity of non condensable gases **(H_2, D_2, He, Ne)** & to produce highly cleaned vacuum condition to achieve UHV.

- The static adsorbents like, activated charcoal, molecular sieves are mostly used for cryosorption pumping.

- The static adsorbents have large surface area to capture non condensable gases below 20°K temperature. (i.e. activated charcoal: 1000m^2/g)

- But all cryogenic pumps are designed with limited static adsorbent material for particular application. Thus these adsorbents have limited capacity to pump non condensable gases at saturation level.

Cryosorption of Condensed Gas Adsorbents

- To improve the pumping limitation of static adsorbents.
- Cryosorption by condensed gases like Ar, CO_2, SF_6 below 20°K temperature for non condensable gases.
- Argon gas is more preferable for condensed gas adsorbent, has effective properties for cryosorption, like high thermal conductivity, heat removal efficiency of adsorbed gases, high throughput, non reactive, etc.

- There are two types of gas filling of adsorbent gases in cryopump

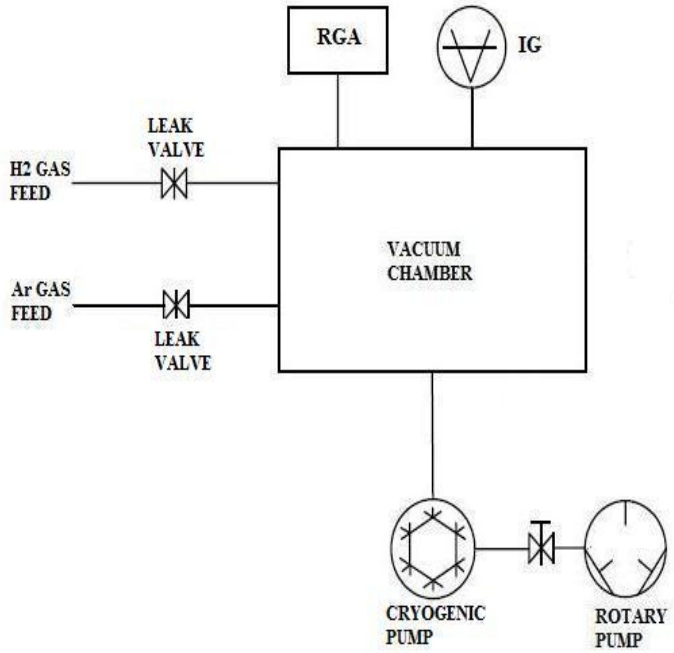
(1) Pre condensed, adsorbent gas is filled sufficiently in cryopump to create porous structure before actual pumping of main vacuum chamber.

- to achieve extreme vacuum condition,
- to improve vacuum of main vessel without affect
- optional pumping of saturated static adsorbents
- Gradually, the pumping efficiency is reduced with time due to blockage of pores

(2) Continuous condensed, adsorbent gas is filled continuously in cryopump with actual pumping of the vacuum chamber.

- To realize the cryosorption effect of condensed gas.
- To determine cryosorption pumping effect on non condensable gases.
- Provide continuous pumping of non condensable gases with fresh frost.

Schematic view of the experiment setup & parameters



- In this Experiment, **Continuous condensed (frost) of Argon gas** is used to determine hydrogen pumping at temperature 14 °K of 2nd stage cryopanel of refrigerator cooled cryopump.

- Important parameters of this cryopump are:

(1) pumping speed (liters/sec): 9500 for water vapor,
(2) crossover: 250 Torr liters for N_2
(3)capacity: condensable gases greater than 2200 standard liters at 5 x 10^{-6} torr and hydrogen 30 standard liters at 5 x 10^{-6} torr
(4) Maximum argon throughput at 20°K: 11 torr.liter/sec
(5) Minimum temperature on 2nd stage: 14°K

Calculation of sticking coefficient

- Sticking co-efficient (α), which is the ratio of number of particles stick on cryo surface to number of particles impinge on it. (To get between 0 to 1)
- For refrigerator cooled cryopump sticking co-efficient (α) derives by

$$1/\alpha = 1/c - 1/w + 1$$

- Capture coefficient (c) is the ratio of actual pumping speed (S) to theoretical pumping speed (S_{id}), derives by

$$S = c.\ S_{id} = c.\ A\ [R_0T/2\pi M]^{½}$$

The pumping speed of cryo pump depends on geometry as inlet area, types of gas being pumped.

- The pumping speed (S) is measured using general formula of throughput in vacuum system.

$$S_{measured} = Q/P$$

- *w* = transmission probability, *w* depends on baffle designed to restrict gas particles movement to cryopanel. *w* is taken as 0.25 for hydrogen pumping of standard refrigerator cryopump.
- The **hydrogen sticking coefficient (α_{H2})** on condensed argon can be determined for 14°K temperature of refrigerator cooled cryopump using above equations with different gas load of argon.

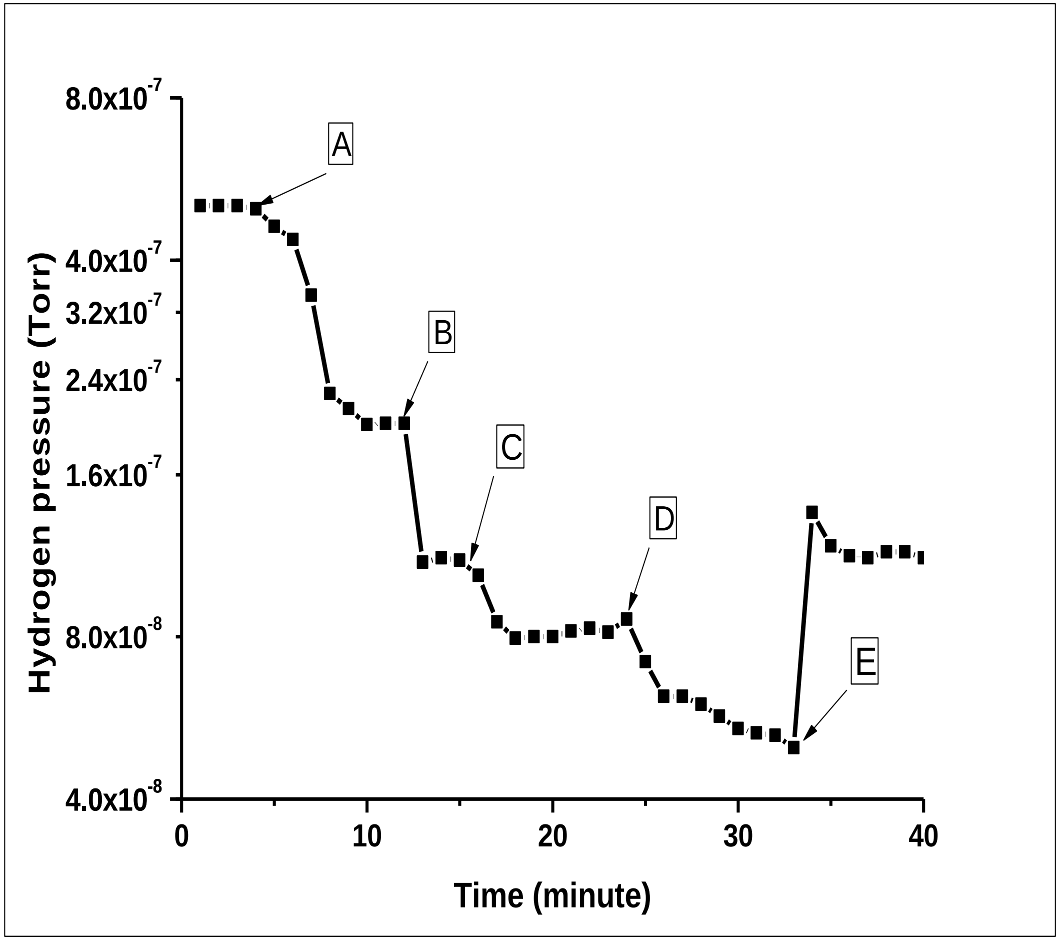
Cryosorption Effect of Continuous Condensed Argon

(I) Cryosorption of saturated level of hydrogen

(II) Cryosorption of constant filled hydrogen

(III) The sticking coefficients of hydrogen (α_{H2}) with various argon gas loads

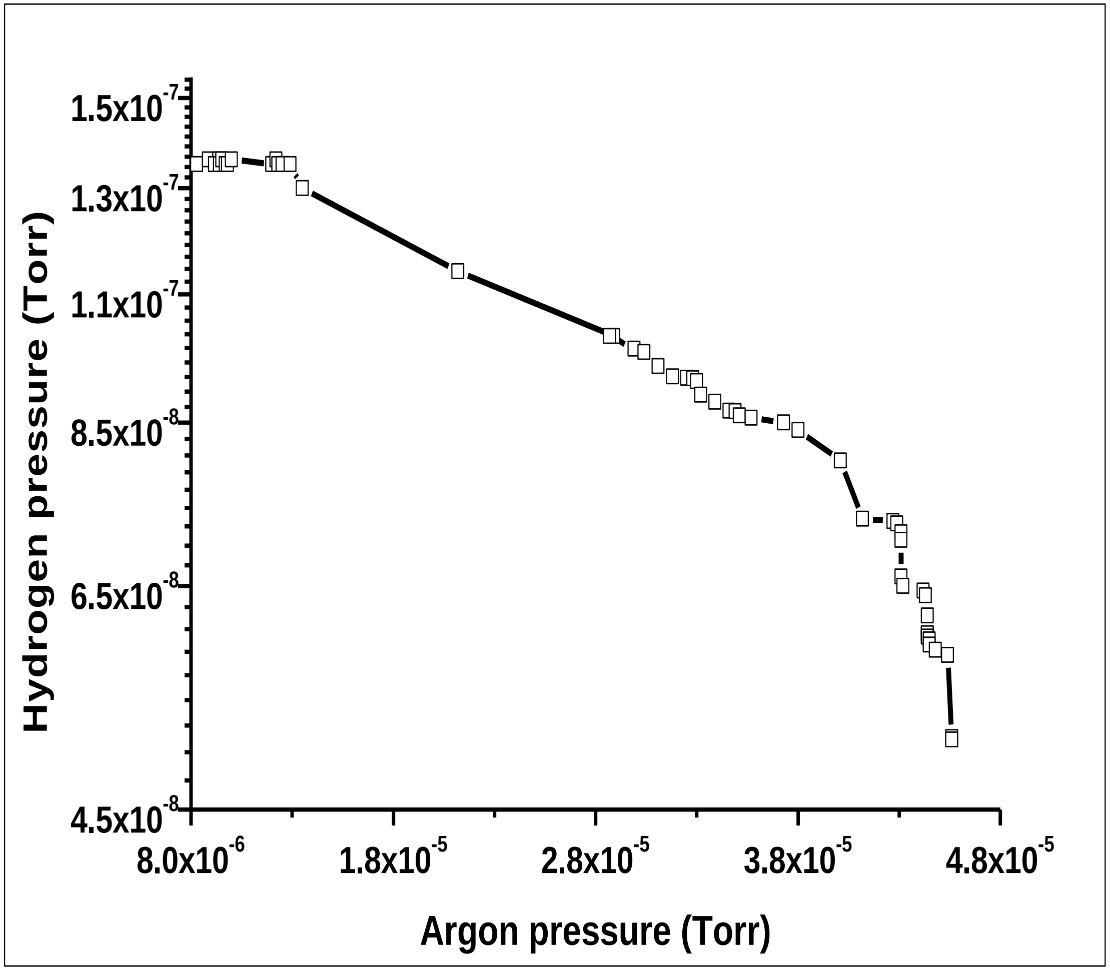
(I) Cryosorption effect of continuous condensed argon on saturated level of hydrogen



Various pressure levels of argon are shown as points A to E, where argon pressure at (A) 1 x 10^{-5} torr (B) 5 x 10^{-5} torr (C) 6 x 10^{-5} torr (D) 8 x 10^{-5} torr (E) Argon gas feed off

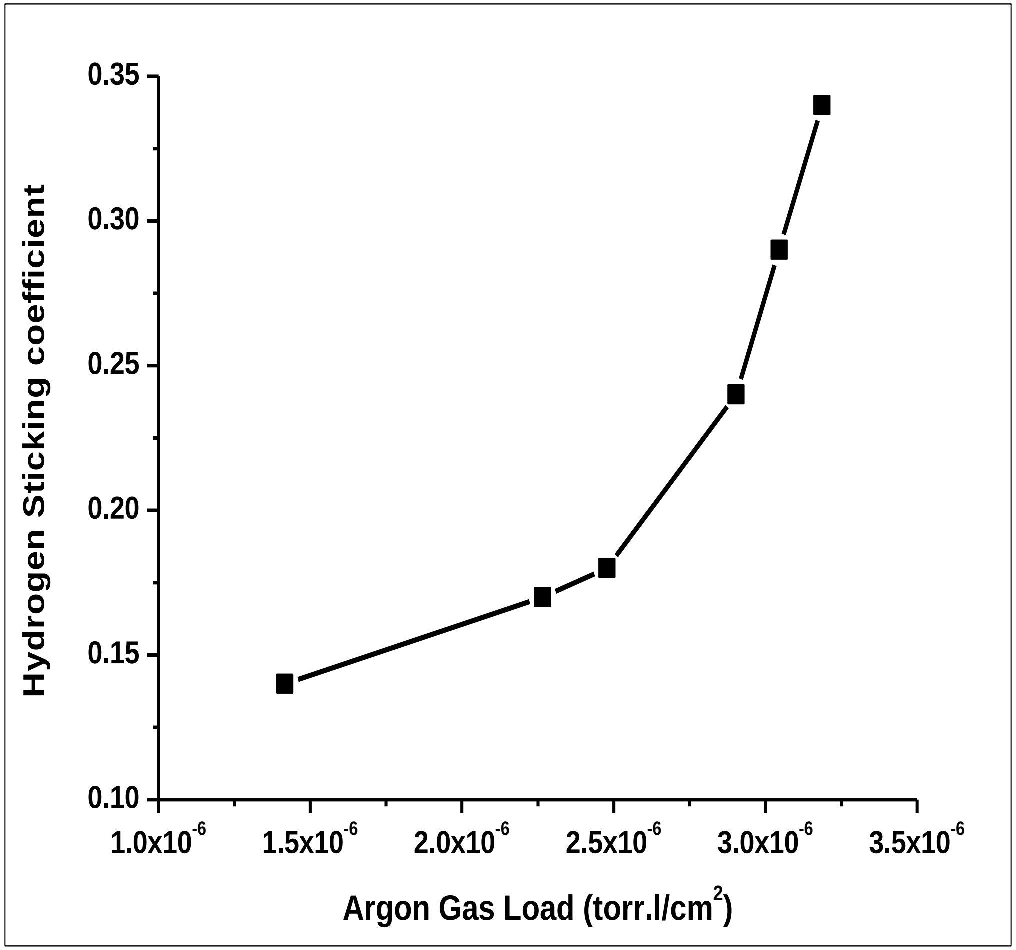
- Hydrogen is pre filled in cryopump as more than 10 liters to achieve saturated condition as H_2 pressure stable on 5 x 10^{-7} torr
- Argon pressure is reached at 1 x 10^{-5} torr (point A), the hydrogen pumping is started on enough argon frost structure
- Argon gas feed is stopped at point E, the hydrogen pressure stable on 1 x 10^{-7} torr, which is reduced in **factor of 5** from the initial saturated pressure

(II) Cryosorption effect of continuous increasing of argon pressure on constant filled hydrogen



- simultaneously filled argon and hydrogen in cryo chamber at temperature 14°K
- Hydrogen filled at constant pressure **1.3×10^{-7} torr**, when argon reaches at pressure **1.3×10^{-5} torr**, hydrogen pressure starts to reduce. Due to creation of sufficient porous structure of argon frost.
- H_2 pressure decrease up to **5×10^{-8}** torr with Argon pressure **4.6×10^{-5}** torr.
- Cannot distinguish H_2 pumping limitation due to RGA operation limit.

(III) The sticking coefficients of hydrogen (α_{H2}) with various argon gas loads with constant filled hydrogen



- sticking coefficients of hydrogen (α_{H2}) at temperature 14°K with steady gas feed of hydrogen as **1.3×10^{-7} torr (previous data)** for various Ar gas loads.
- Calculation of α_{H2} : maximum as **0.34** on argon gas load 3.2×10^{-6} torr.liter/cm^2 & minimum as **0.14** on argon gas load 1.4×10^{-6} torr.liter/cm^2
- Cannot distinguish final value of α_{H2} due to RGA operation limit.

Conclusion

- The cryosorption effect of argon frost on hydrogen is started on argon gas feed pressure near **1×10^{-5} torr** in this cryopump system.

- The sticking coefficient of hydrogen (α_{H2}) at temperature 14°K is determined to be **0.34** on argon gas load 3.2×10^{-6} torr.liter/cm^2 for steady gas feed of hydrogen at pressure 1.3×10^{-7} torr.

- The final value of sticking coefficient of hydrogen (α_{H2}) at temperature 14°K in this cryopump can be determined with changing in experimental setup of measuring instruments.

- It is noticed that the 2nd stage temperature of this cryopump is decreased up to **12°K** from its standard temperature as 14°K after sufficiently filled argon (pre condensed effect). This effect is useful to increase pumping capacity and speed of non-condensable gases.

- These experiments more depend on cryo surface temperature, so experiments must be carried out at lower temperature of cryo pump. This initial study is motivated us to further experimental studies of pre condensed argon effect, increasing hydrogen pumping in actual vacuum vessel of ADITYA Tokamak.

- This method is applicable for the system where additional hydrogen pumping is required.

Thank You