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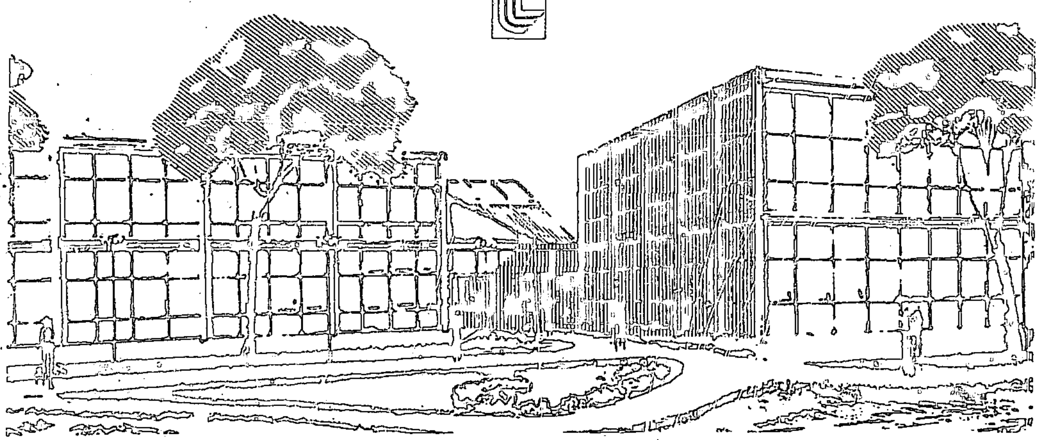

DEGASSING A LARGE LHe CRYOPUMP*

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Summary

A method has been developed and successfully tested, to degas a large LHe cryopump. Use of this method inhibits the normally excessive pressure rise during the degassing cycle when the degassing rate exceeds the external pumping capabilities of the system.

A small appendage pump, installed close to the main cryopump, absorbs all the gas, as it is desorbed from the main cryopump, with no rise in the system pressure. The appendage pump can then be isolated from the main vacuum system and degassed at high pressure. We pumped 15 to 20 × 10^3 Torr·l of H_2 on a 1.25 m^2 panel. During the degassing cycle the system pressure never rose above 1 × 10^{-4} Torr.

In large vacuum systems for future fusion machines that contain cryopump panels as well as cryogenic magnets, this method is a unique and very useful tool. It will allow the degassing of cryopumps without affecting the temperature equilibrium of cryogenic magnets.

Introduction

Present and future magnetic fusion experiments, require large quantities of D_2 gas to be pumped at 10^{-6} Torr pressure or lower. These very large gas loads are created from the operation of intense neutral beam injectors for heating and sustaining plasma. Very high pumping speeds are required (>10^5 l/sec) to keep pressure below 10^{-6} Torr at flow rates of tens of Torr-l/sec. Because of the large gas loads that are pumped, conventional appendage pumps are not feasible, necessitating some other method of "vacuum wall" pumping. The most practical solution is to use cryocondensation pumps that have LHe-cooled panels on the chamber walls. Three such schemes, shown in Figs. 1, 2 (Ref. 1) and 3 represent only a few of the schemes proposed or currently being used in fusion research devices that maintain the desired base pressure in the experimental space. Cryopumping panels, or any other pump that does not actually remove the gas from the system but rather immobilizes it in the solid state, requires periodic degassing to allow the gas to be removed from the system.

A new method has been developed to degas a large heavily loaded cryopanel (>30,000 monolayers) within several minutes. The gas can be transferred to a smaller properly positioned cryopanel while keeping the system pressure below the gas conduction regime.

Conventional Methods of Degassing

For safety reasons an upper limit is placed on the amount of gas accumulation on the cryopanels to prevent the development of an explosive mixture of D_2 and air in case of an up-to-air accident. The gas load on the cryopanels should be kept below an amount that would produce ~13 Torr[2] pressure at room temperature in the vacuum system. The available data[3] on the explosive limits of D_2-air mixtures indicates that as the inleaking air dilutes the hydrogen, no combustion can occur, if the initial hydrogen pressure is ≲12 Torr (Figure 4). We estimate that if combustion occurs and if the initial hydrogen pressure is ≳50 Torr, t system pressure will stay below 2 atm absolute. The ventional method of degassing the cryopump by depressi he cryogenics fluid and raising the panel surface te rature needs improving. If the cryopanel temperatur is raised for degassing, the external pumping capacity must be comparable to prevent excessive pressure rise d minimize the amount of time at high pressure (>1 r).

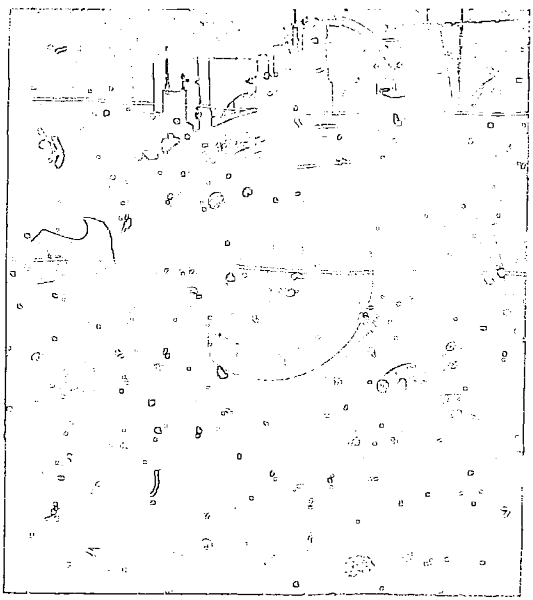

Fig. 1. Cryopump for the Lawrence Livermore Laboratory High Voltage Test Stand (HVTS).

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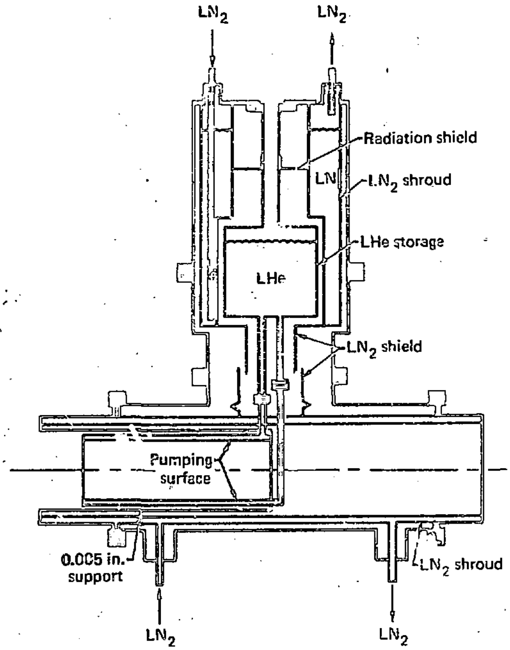

Fig. 2. Beamline cryopump used on Baseball I.

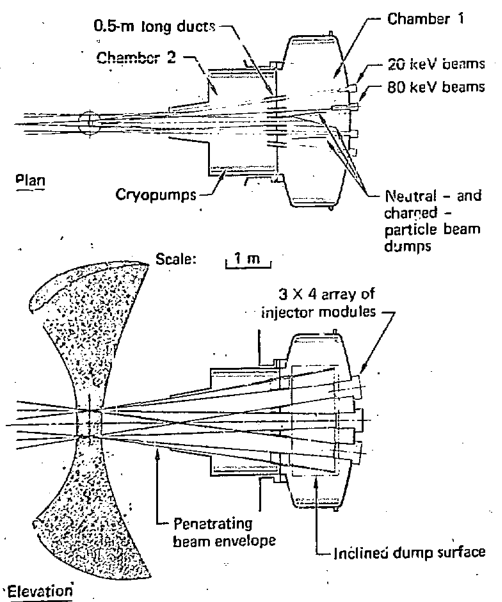

Fig. 3. Proposed cryopanel arrangement for the Mirror Fusion Test Facility (MFTF) beam line.[3]

On the present cryopump for the High Voltage Test Stand (HVTS) used at the Lawrence Livermore Laboratory, we observed that in the initial stages of degassing, the pressure remained fairly steady at 4×10^{-5} Torr for H_2. The pressure then rises very slowly to 10^{-3} Torr until the cryopanel is nearly empty. However, in the last 100 sec it rises several decades to 10-20 Torr. On the HVTS we also observed that when the system pressure climbs above $\sim 10^{-3}$ Torr, occurring when the panel is 80% defrosted, the cryopanel is warmed by gas conductance and the remaining condensate comes off rapidly. Figure 5 shows the P vs t behavior of a panel during this condition. The plot was drawn using parameters from an analytical solution of a panel placed in a system with a volume of 1000 l and a pumping speed S_0 of 150,000 l/sec^{-1}. The panel had absorbed 12,000 Torr·l of hydrogen and was defrosted by depressing the liquid level at a constant rate for a time period of τ_0 equal to 2,000 sec. This experimental behavior of the HVTS panel agreed very closely with the analytical solution plotted in Fig. 5. We further observed on the HVTS that the panels continued to warm up with the chamber at 12 Torr, and it took about 1 min to boil the LN_2 out of the shielding panels. The temperature rose at a rate of about 0.07 K/s^{-1}. The vacuum chamber volume[4] of the HVTS was 20×10^3 l. To conserve refrigeration the chamber was pumped to $\gtrsim 10^{-3}$ Torr within a few minutes, by using a combination of Roots blowers and diffusion pumps.[5]

Experimental Degassing Test

To avoid a runaway pressure rise during the defrosting of a large system such as the Mirror Fusion

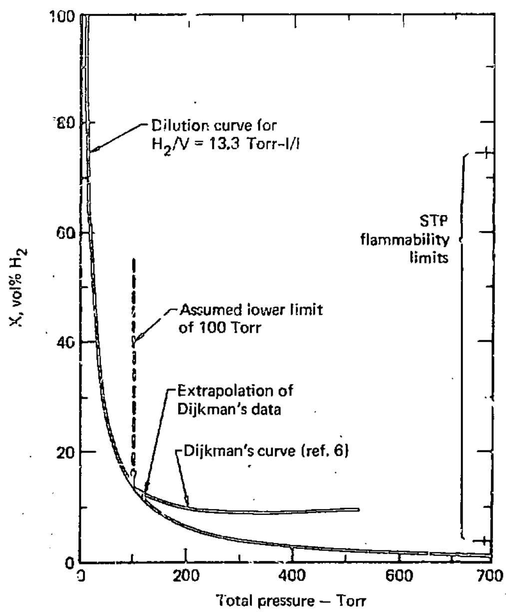

Fig. 4. H_2 partial pressure for safe operational limits.[6]

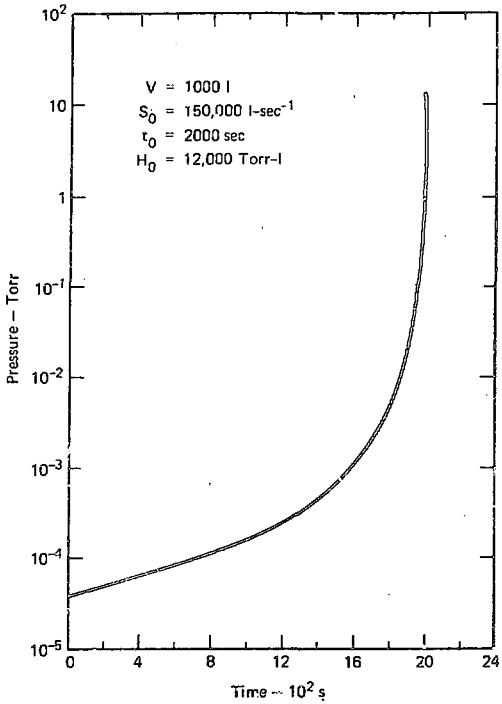

Fig. 5. A plot of the pressure versus time behavior of a High Voltage Test Stand (HVTS) cryopanel during cryopump degassing.

Test Facilities (MFTF), a new technique has been devised. This method requires a small appendage pump at cryogenic temperature, placed in the vicinity of the cryopumping panels. The appendage pump will condense the gas as it comes off the main pump with very little pressure rise. It can then be isolated by a valve into a small high pressure degassing chamber.

Mechanical Design Features

The main components and parameters of the test stand are shown in Fig. 6. Surface temperature sensors are used to measure the panel temperature and liquid level indicators measure the LHe level. The LN_2 liner and heat shields are made of copper. The cryopumping panel and appendage pumps have a quilted surface design and are made of 316 stainless steel with 0.015 in-thick walls. Each panel has its own LHe reservoir. The chevron heat shield is cooled by He boil-off from the panel. The surface temperatures of the appendage pump, heat shield and cryopumping panel are monitored by carbon resistors. These resistors are calibrated before installation and are bonded to the surface with a nickel band, spot welded over the resistor and epoxy c er that. Each resistor has a small heat shield of its own to keep it in temperature equilibrium with the surface.

Testing Procedure

The following step by step procedure should be followed to perform the test:

1. Pump the vacuum system down to $<10^{-5}$ Torr.
2. Chill the LN_2 liners in the vacuum tank to 80°K.
3. Fill the LHe reservoir of the cryopump panel until the cryopump heat shield (chevron) temperature has been stabilized at 20°K. Top off the cryopump panel reservoir.
4. Valve off the external vacuum pumping system.
5. Record the system base pressure.
6. Take a base line spectograph of the residual gas.
7. Record the panel and chevron heat shield temperatures.
8. The appendage pump should be empty.
9. Add the H_2 or D_2 gas through a gas metering system. Record the total amount of gas pumped on the panel and the system pressure history during this operation.
10. Stop the gas bleed and record the system recovery pressure.
11. Fill the appendage pump with LHe.
12. Start depressing LHe in the main cryopump and desorbing the gas. Record the surface temperature and system pressure until all LHe has been transferred out of the main cryopump and it is totally degassed.

Table 1 shows the experimental test results.

From our experimental tests, we found this method of degassing a large cryopump to be extremely useful. No pressure rise was noted during desorption, nor was there any change in the temperature equilibrium.

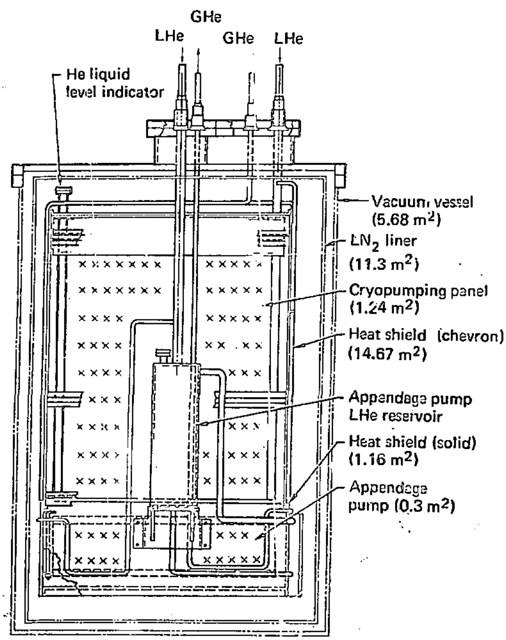

Fig. 6. Experimental test apparatus used for the degassing operation. Surface area of the component parts are in parentheses.

Table 1. Experimental test results for degassing a large LHe Cryopump.

Test Run	Gas Flow Rate (Torr-l/sec)	Total Gas Added (Torr-l/sec)	System Pumping Speed (l/sec)	System[a] Recovery Pressure (Torr)	Peak Transfer[b] Pressure (Torr)	System[c] Pressure (Torr)	System Base Pressure (Torr)
1	2.4	1.0×10^{4}	66,000	8.8×10^{-7}	4.0×10^{-4}	>10	1.0×10^{-9}
2	2.4	1.7×10^{4}	66,000	8.0×10^{-7}	1.3×10^{-3}	>20	1.2×10^{-9}

[a]Pressure after terminating gas flow.

[b]Pressure during transfer of gas from main cryopanel.

[c]Pressure after LHe was transferred from appendage pump.

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