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Title: TESTING OF VACUUM PUMPS FOR APT/LEDA RFQ

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Testing of Vacuum Pumps for APT/LEDA RFQ *

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Abstract

Two vacuum systems were designed and built for the RFQ (Radio Frequency Quadrupole) cavity in the APT/LEDA (Low Energy Demonstration Accelerator) linac. The gas load from the proton beam required very high hydrogen pump speed and capacity. The gas load from the high power RF windows also required very high hydrogen pump speed for the RF window vacuum system. Cryopumps were chosen for the RFQ vacuum system and ST185 sintered non-evaporable getter (NEG) cartridges were chosen for the RF window vacuum system. Hydrogen pump speed and capacity measurements were carried out for a commercial cryopump and a NEG pump. This paper will discuss the test procedures and the results of the measurements.

1 INTRODUCTION

Cryopumps and NEGs are known for their high hydrogen pumping speed and capacity and are used widely in accelerators applications. Cryopumps were selected for the RFQ cavity due to the very high hydrogen gas load from the proton beam loss. A cost analysis showed that for the same cost, cryopumps could provide twice the pumping speed compared with turbomolecular pumps. NEGs were selected for the RF windows because in addition to the high hydrogen pumping speed, they are relatively small in size and lightweight. Size and weight were important requirements in the RF window vacuum system since space in the waveguide area was very limited.

The Ebara ICP200 cryopump was selected for the RFQ vacuum system because of its reasonable cost, very large hydrogen capacity and its flexible interface for remote operation. The SAES CapaciTorr B1300 NEG cartridge pump utilizing the sintered ST185 blades was selected for the RF window vacuum system. The manufacturer claims that the sintered ST185 blades has increased pump speed and capacity at room temperature over other types of NEGs.

Since LEDA is a demonstration facility for APT, beam availability must be high to prove that APT production goals can be met. Therefore, it was important to verify the performance of the cryopumps and NEGs to ensure they would support the operational requirements for LEDA.

2 TEST SETUP

The pump speed and capacity for the cryopump and the NEG pump were measured using test domes built to American Vacuum Society Standard 4.1 [1]. The pumps were tested using only hydrogen, since it is the primary gas load in APT. A schematic of the test setup is shown in Figure 1.

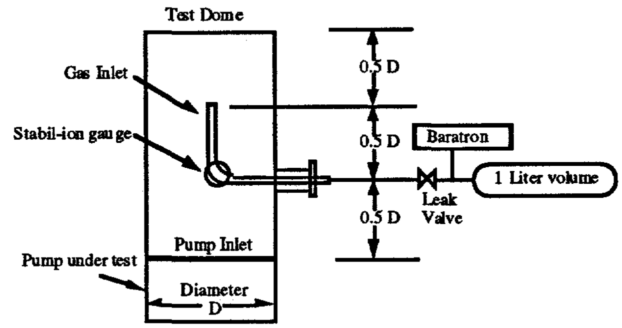

Figure 1. Test setup for pump speed measurement.

The pressure in the test dome was measured using Granville-Phillips 370 Stabil-ion gauges. These gauges were supplied with individual calibration data on memory modules that were downloaded into their controller. Granville-Phillip claims the measurement uncertainty is 3%. The gauges were calibrated at the factory for Nitrogen. All measurements were taken using the factory calibration and then corrected for hydrogen.

Gas flow into the test dome was established by charging a known volume to a set pressure, then measuring the change in pressure with respect to time. The gas flow into the test system was controlled by a Varian variable leak valve. The pressure in the known volume was measured using an MKS Baratron. The Baratron is a capacitance manometer with an accuracy of 0.5%.

The measurement of pump speed was similar to the flowmeter method as outlined in AVS Standard 4.1. However, this method varies from AVS Standard 4.1 in that

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the flow rate drops off as the pressure in the known volume drops. The LabView data acquisition system measures the pressure change in the known volume via the Baratron and the vacuum pressure via the Stabil-ion gauge at prescribed time intervals. For a given short time interval, we assume that the flow rate is constant. The pump speed can then be calculated using the equation $S = Q/(P - P_0)$ where the throughput Q is the change in pressure in the known volume during the sample time interval and P is the Stabil-ion gauge pressure in the test dome. P_0 is the base pressure in the test dome before the test gas is introduced.

For the pump speed measurements, a certified 1 liter volume was used as the known volume. By substituting the 1 liter volume with a larger volume and changing the Baratron to a higher range we used the same LabView system to measure pump capacity. LabView then calculated the total Torr-Liters of gas sorbed versus pump speed.

3 RESULTS AND DISCUSSION

Pump speed and capacity were measured for both the cryopump and the NEG. LabView recorded a timestamp, pressure in the test dome, and pressure of the test gas in the 1 liter volume.

3.1 Cryopump Data

The cryopump reached a base pressure of 1.78×10^{-10} Torr in the test dome. The pump speed was measured at over 2700 liters/sec. The pump speed test was repeated 5 times after the pump was conditioned as stated in the AVS Standard 4.1. (Pump Conditioning = pump speed x 0.03 Torr-liters. Using the manufacturer's specification of 2200 liters per second [2], the pump was conditioned after 66 Torr-liters.) See Figure 2 for a typical plot of cryopump pump speed versus sorption. The measurement shows that the manufacturer's specification is very conservative.

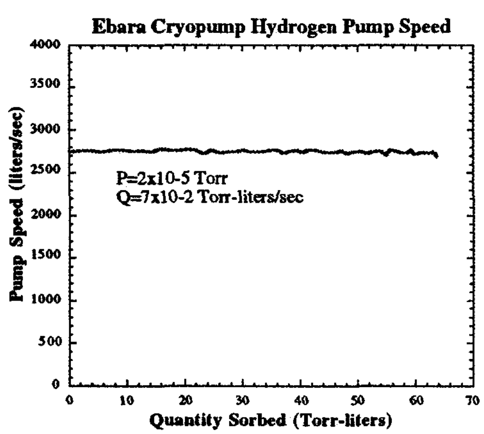

Figure 2. Measured Cryopump Pump Speed Versus Sorption.

The hydrogen capacity of the cryopump was measured to be over 30 standard liters at an operating pressure of 1×10^{-4} (H_2) Torr and a throughput of 2×10^{-1} Torr-liters/sec. This flow rate is over two orders of magnitude higher than the predicted gas load in APT/LEDA. Figure 3 shows the sorption plot at the high flow rate. At this very high flow rate the test took 33 hours.

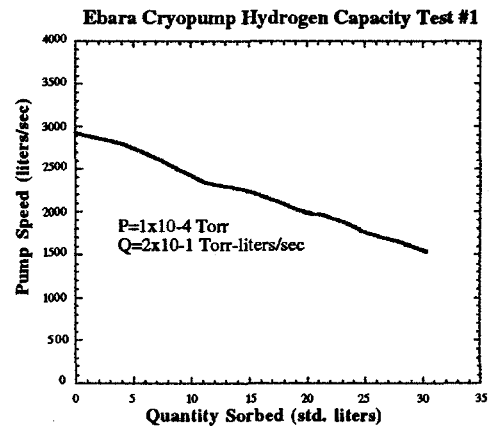

Figure 3. Measured Cryopump Capacity at High Flow.

The cryopump was then regenerated and after regeneration the cryopump reached a base pressure of 1.90×10^{-10} Torr. The hydrogen capacity of the cryopump was re-measured and found to be 32 standard liters at an operating pressure of 1.0×10^{-5} (H_2) Torr and a throughput of 2.0×10^{-2} Torr-liters/sec. This flow rate was still at least an order of magnitude higher than the predicted gas load in APT/LEDA. Figure 4 show the sorption plot at the lower flow rate. At this flow rate the test took 12.8 days and the results agreed very well with the previous test at the high flow rate.

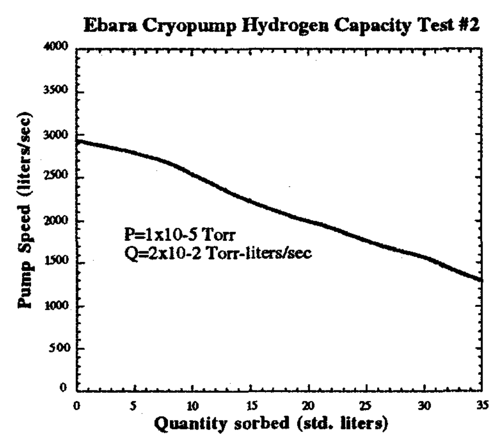

Figure 4. Measured Capacity at the Lower Flow Rate.

3.2 NEG Data

The ST185 NEG, like all NEG pumps, does not pump inert gases, therefore a small turbo pump was added to the system. The turbo was a Varian V70LP and has a specified hydrogen pump speed of 45 liters/sec. The hydrogen pump speed was measured in the test dome before the NEG cartridge was inserted and found to be 51 liters/sec.

The NEG cartridge pump was mounted in the optional 6" diameter body rather than the standard 4" body. According to SAES, this would increase pump speed from about 700 liters/sec to 1200 liters/sec [3].

It was observed during installation of the cartridge pump in its heater assembly that the thermocouple used by the NEG regeneration controller to control the heater was mounted very near the heater element and free standing. There was concern that the actual temperature of the NEG pump would not be what the thermocouple was reading since the ST185 blades are mounted radially outward and the view factor of the blade to the heater is small. It was felt that a thermodynamic analysis was not in the scope of this study, but it would have been interesting to mount thermocouples directly on NEG blades and measure the temperature gradient. Pump speeds could probably be further optimized by knowing this temperature gradient.

After the initial activation recommended by SAES of 500 C for 45 minutes, several pump speed measurements were made, followed by a regeneration. It was found that by increasing the regeneration to an indicated 550 C for 90 minutes produced higher pumping speeds. This agrees with tests performed by others [4]. Subtracting the pump speed of the turbo, the average speed of the NEG was 1380 liters/sec. Figure 5 shows a typical sorption plot for the NEG.

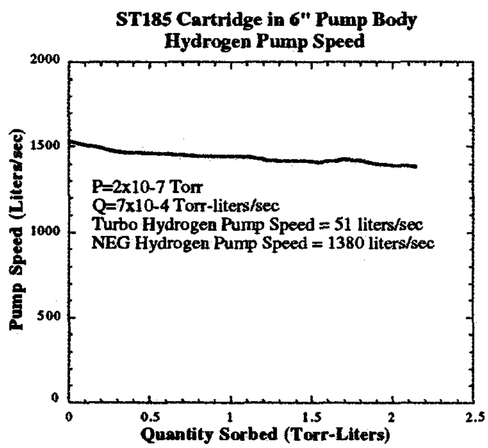

Figure 5. Measured Speed of ST185 Cartridge Pump.

A test of the hydrogen capacity of the NEG pump was performed after a regeneration. The objective of this test was to show that the NEG pump was capable of sorbing one standard liter of hydrogen at the rated pump speed. One standard liter was an arbitrary value that represents several months of normal RF window operation.

As the data shows in Figure 6, the pump speed was 1150 liters/sec after 700 Torr-liters. The hydrogen capacity of ST185 according to SAES is 10 Torr-liters/gram. The CapaciTorr B1300 cartridge pump has 600 grams of ST185 NEG for a total capacity of 6000 Torr-liters.

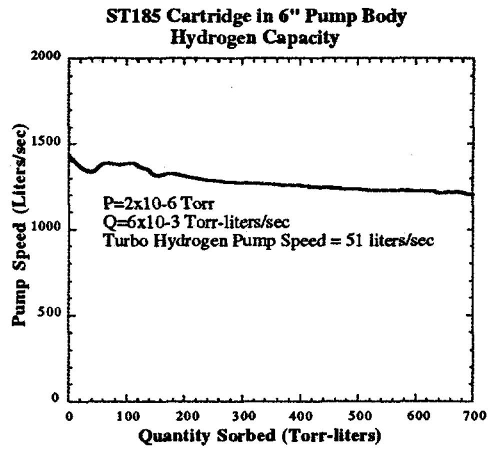

Figure 6. Measured Capacity of ST185 Cartridge Pump.

4 SUMMARY

We have measured the pump speed and capacity of the cryopump and NEG that are proposed for use in the RFQ vacuum system for APT/LEDA. The results verify the manufacturer's specifications and gives us confidence that these commercial pumps will provide the necessary vacuum performance for the operation of LEDA.

ACKNOWLEDGMENTS

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