TESTING OF VACUUM SYSTEM FOR APT/LEDA RFQ *

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Abstract

We have designed, built and operated two vacuum systems for the RFQ (Radio Frequency Quadrupole) in the APT/LEDA (Accelerator Production of Tritium/Low Energy Demonstration Accelerator) linac: a cryopump system for the RFQ cavity and a non-evaporable getter (NEG) pump system for the RF window system. They were designed to provide very high hydrogen pump speed (>$2x10^4$ L/s) and sorption capacity. Both systems underwent performance tests in mock assembly before the installation. This paper presents the mock test results of both vacuum systems. It also discusses the preliminary test results from the commissioning of the APT/LEDA RFQ.

1 INTRODUCTION

The APT/LEDA RFQ consists of four resonantly coupled two-meter segments and 12 RF windows connected via ridged waveguides to 3 sections of the RFQ [1]. The over-riding requirement for the APT/LEDA RFQ vacuum pumping system is that it be capable of pumping the combined gas load from the lost proton beam, gas streaming from the LEBT (Low Energy Beam Transport), and out-gassing from the surfaces of both the RFQ cavity and the RF window system. The total air-based gas load from the cavity will be on the order of $7.2x10^{-4}$ Torr-liters/sec, and $8x10^{-5}$ Torr-liters/sec are expected from each RF window. The main gas to be pumped will be hydrogen and the system must be able to pump hydrogen on a continual basis. Vacuum pumps are to be completely oil-free (both high-vac and roughing) and a single pump type must pump all other species of gas (O_2, N_2 and any outgassed mixture). For the RFQ cavity, redundancy must be provided in the pumping and gauging systems to ensure that the minimal "operating vacuum level" of 1×10^{-6} Torr is maintained despite pump failures in the system. All pumps and gauges must be replaceable without bringing the RFQ cavity up to atmospheric pressure.

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2 SYSTEM DESCRIPTIONS

For the RFQ cavity, there are 36 vacuum pumping ports connected to 3 distributed manifolds. Five Ebara ICP200 cryopumps are used to handle all the gas loads [1][2]. For the high power RF windows which also required very high hydrogen pump speed, non-evaporable getter (NEG) cartridges were selected. This is mainly because they are relatively small in size and lightweight. The SAES CapaciTorr B1300 NEG cartridge pump that utilizes the sintered ST185 blades, can provide hydrogen-pumping speeds of more than 1000 L/s for each RF window. Both cryopumping and NEG systems are built with automatic pumping and regeneration systems. As reported earlier [3], hydrogen pump speed and capacity measurements were carried out for both types of pumps. From these component tests, we have verified the manufacturer's specifications and thus validated the major design parameters

3 MOCK SYSTEM TESTS

Since LEDA is a demonstration facility for APT, beam availability must be high to prove that APT production goals can be met, it was important to ensure the performance of the vacuum system would support the operational requirements for LEDA. Therefore, in addition to the pump verification tests, we also have carried out mock assembly system tests for both cavity and window systems before the shipment. These tests turned out to be extremely useful in developing procedures for installation and system commissioning tests.

3.1 Mock Cavity Testing

A mock cavity was fabricated to simulate the cavity conductance and the volume. As depicted in Fig. 1, the whole cavity vacuum system was then assembled and connected to the mock cavity at LLNL. A series of performance tests were carried out; the results were satisfactory and can be summarized in Table 1.

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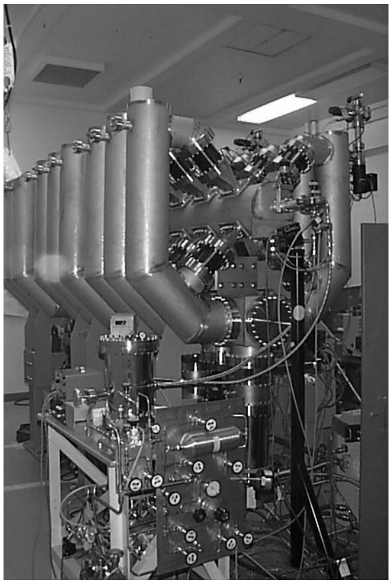

Figure 1: RFQ Mock Cavity Vacuum Assembly

Table 1: Results of Mock Cavity Vacuum Tests

Test	Results
Pumpdown	From atmosphere to 10^{-6} Torr in 30 minutes
Instrumentation & Control	Gauges calibrated and all control functions verified.
Base Pressure	10^{-8} Torr (> 50 hrs)
Transient Gas Pulse	Time constant ~ 5 sec.
Abnormal Condition Tests	Measured pressures with simulated gas loads agreed with calculation. Measured pressures with one and two pumps off agreed with calculation.

The results of the "Abnormal Condition Tests" listed in Table 1 are also illustrated in Fig. 2 for Segment A. A direct comparison with the calculation results shown in Fig. 3, indicates that measurement results are in good agreement with the design analysis. (The Sequence of Events are described in Table 2.)

Table 2: Sequence of Abnormal Condition Tests

Time Interval Fig. 2 (min)	**Time Interval** Fig. 3 (sec)	**Descriptions**
0-7	0-5	Base pressure
7-14	5-10	With simulated gas loads
14-23	10-15	With one pump off
23-40	15-25	With two pumps off

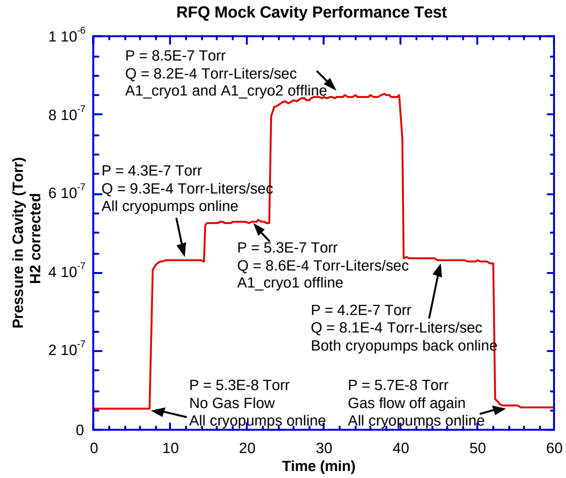

Figure 2: Measured Vacuum in Mock Cavity Assembly

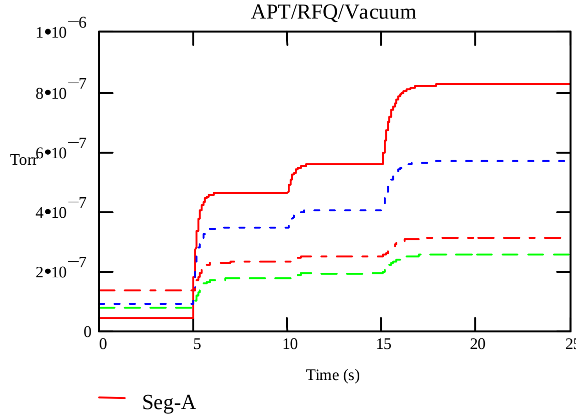

Figure 3: Analytical Results for Comparison

3.2 Mock Window Testing

A mock window cavity (see Fig. 4) simulating the RFQ cavity was used to assemble all four arms of one section of the RF window vacuum system. The purpose of this assembly was to conduct integrated tests on the RF window vacuum control system. In the stand-alone mode, the control system consisted of a Modicon PLC and a PC running Labview. Once installed and commissioned on the actual RFQ, the PC was replaced by an interface to EPICs.

All the valves, pumps and instrumentation on the mock cavity used the actual cables that were to be used on the real RFQ. In this way, both the hardware and PLC software of the control system were validated on the

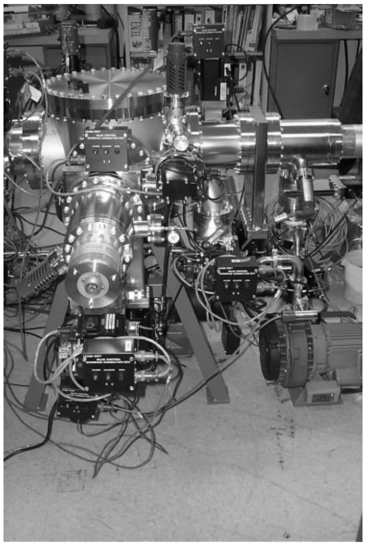

Figure 4: Mock RF Window Vacuum Assembly

mock cavity. It was also used to develop the interlocks and controls for the safe operation of the high temperature regeneration of the NEG pumps. The mock cavity provided an easy and safe method to completely test the entire vacuum system before delivery. The cost of testing with the mock cavity was necessary to guarantee the system will be fully operational immediately after installation was completed

4 COMMISSIONING TESTS

The high RF power conditioning of the RFQ began when the first klystron had been connected to the RFQ via 4 window and waveguide sets. The base pressure in the RFQ cavity and window/waveguide sets prior to the start of conditioning was in the $1x10^{-7}$ to $5x10^{-7}$ Torr range. First, RF power at approximately the 1 kW level was introduced into the waveguides and RFQ cavity, producing a vacuum level of approximately $3x10^{-6}$ Torr in the waveguides. For purposes of reconditioning the RF windows, a vacuum level of $5x10^{-6}$ Torr was set as the limiting pressure. Pressure in the RFQ cavity remained at about $5x10^{-7}$ Torr. Within the first 2 hours of high RF power conditioning, the power level was increased to 3 kW while the waveguide pressure remained at approximately $5x10^{-6}$ Torr. During the next 10 hours of high RF power conditioning the power level was increased to 71 kW with waveguide pressures remaining in the $3x10^{-6}$ Torr range. Once the RF power was increased over the 10 kW range, some multipactoring bands were encountered in the RF window/waveguide sets. These multipactoring regions required steady RF power level operation for various amounts of time in order to break through them. Even with occasional multipactoring having occurred, the operating RF power level that was attained in the first 12 hours is significant. At approximately the 50 kW RF power level the RFQ cavity began to be excited. At power levels of 50 kW and higher, the RFQ cavity and waveguides were alternating as to which would dictate the operating power level in order to remain below the pressure set point of $5x10^{-6}$ Torr. After a conditioning period of approximately 40 operating hours, a power level of 950 kW was reached. Subsequently, another set of 4 RF windows and waveguides was connected to the RFQ. However, this new set was not connected to a klystron immediately. The initial conditioning of these window/waveguide sets was carried out by operating the first klystron and reflecting power into and out of the 4 new window/waveguide sets via the RFQ cavity. The behavior of this new set of windows and waveguides during the initial conditioning was about the same as with the first set of windows and waveguides.

The second klystron was connected to the RFQ via the 4 new sets of windows and waveguides. Power levels in the 900 kW range were used to condition primarily the RFQ cavity. The limiting pressure in the cavity was lowered to $2x10^{-6}$ Torr. The cavity was conditioned to the 1.2 MW power level. Once this conditioning level was reached, the base pressure in the RFQ cavity and window/waveguide sets was about $2x10^{-8}$ Torr with no RF power being conducted. RF power in the 1.0 MW range could be fed into the RFQ with pressures stabilizing in the $1x10^{-7}$ Torr range in both the cavity and waveguides.

The vacuum levels attained during high RF power operation provide further verification that the RFQ cavity and RF window vacuum systems will meet the operational requirements for proton beam operation of 6.7 MeV at 100 mA.

5 CONCLUSIONS

The APT/LEDA RFQ vacuum system performed successfully in the mock assembly as well as in the commissioning tests. The test results presented in this paper validated the design of the vacuum system. It is also demonstrated that the vacuum system is capable of providing comfortable vacuum levels for conditioning the high power RF windows.

6 REFERENCES

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