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KOMAC/KTF RFQ Linac Vacuum Pumping System

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Abstract

The KOMAC Test Facility (KTF) being constructed at Korea Atomic Energy Research Institute (KAERI) will serve as the prototype for the low energy section of the Korea Multipurpose Accelerator Complex (KOMAC). The design and fabrication of a vacuum pumping system for the KTF Radio Frequency Quadrupole (RFQ) linac were performed. The total gas load consisting mainly hydrogen is on the order of 1.8 $\times 10^{-4}$ Torr-liters/sec, Resulted from the lost proton beam, gas streaming from the LEBT (Low Energy Beam Transport) and out-gassing from the surfaces of the RFQ cavity and vacuum plumbing. The design of this system is that the minimal "operating vacuum level" of 1×10^{-6} Torr is maintained even under abnormal conditions. From the cryogenic pump used, design approach and system analysis were in a good agreement with the calculated value.

Ⅰ. Introduction

The linear accelerator for the KOMAC Project [1,2] will include a 350MHz CW RFQ linac which accelerates a proton beam to a final energy of 3.0 MeV. The first phase of the project, KOMAC Test Facility (KTF), is to demonstrate performance of the RFQ [3] plus a coupled-cavity drift-tube linac (CCDTL) [4] to 20 MeV. A basic parameters of the KOMAC/KTF RFQ are follows: type is a 4-vane type, frequency is 350MHz, beam current is 20mA, and length is 324cm. The KTF RFQ consists of two resonantly coupled 81 centimeter segments in Figure 1. In this paper, the first section of the KTF RFQ was used. The over-riding requirement for the KTF 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 the RFQ cavity and vacuum plumbing. The total gas load will be on the order of 1.8×10^{-4} Torr-liters/sec. The main gas to be pumped will be hydrogen and the system must be able to pump hydrogen. basis.

Vacuum pumps are to be completely oil-free (both high vacuum and roughing) and a single pump type must pump all other species of gas (O_2, N_2 and any out-gassed mixture). The minimal "operating vacuum level" of 1×10^{-6} Torr is maintained in the system. pumps, valves and gauges must be replaceable without bringing the RFQ cavity up to atmospheric pressure.

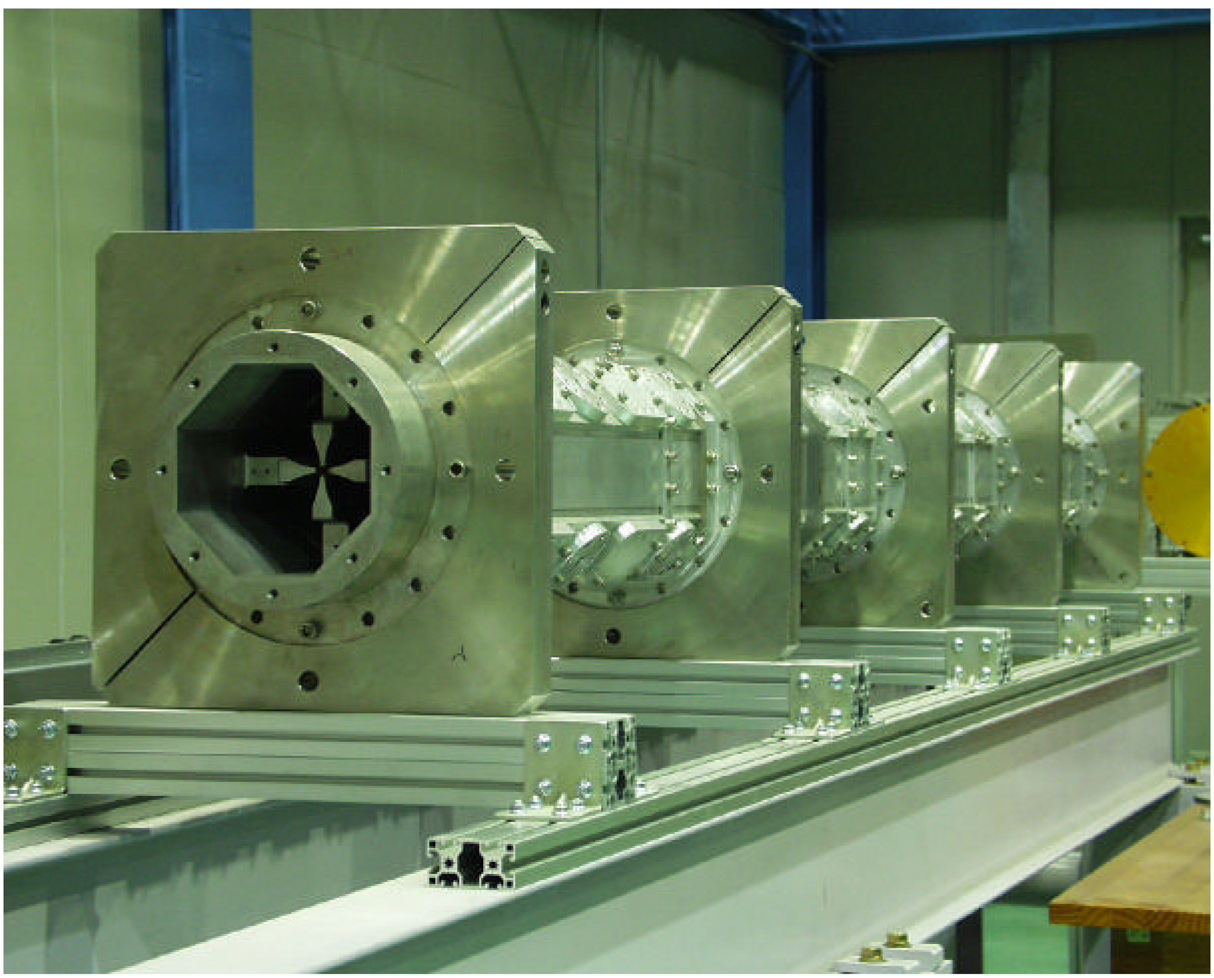

Figure 1. 3.0MeV KTF/RFQ consists of two resonantly coupled segments.

Ⅱ. Design

Ⅱ-1. Design Requirements

Tables 1 and 2 summarize the vacuum parameters and pumping system requirements for the KOMAC/KTF RFQ respectively.

Table 1 : Vacuum Parameters

Parameter	Value
Surface Outgassing Rate	1.0×10^{-5} Torr-liters/sec
LEBT Gas Load (H^+)	5.0×10^{-5} Torr-liters/sec
H^+ Beam Loss (2mA)	4.0×10^{-4} Torr-liters/sec
Total Gas Load	1.8×10^{-4} Torr-liters/sec
Pumping Ports	1 5-slots 140 liters/sec
Pumping Plenums	1 @ Section

Table 2 : Pumping System Requirements

Parameter	Value
KTF Prototype for KOMAC	System must be fully suitable for KOMAC operation
Operating Pressure	$\leq 1.0\times10^{-6}$ Torr
System Time Constant	$\leq$ 0.1 second
Pump down Time	$\leq$ 30 minutes
Standalone Operation	System must operate independently of KOMAC control system
Control system interface	System must accept commands & provide signals to KOMAC control system
RF Window Vacuum	System must allow for vacuum pumping of 1 RF window
Safety / Codes	System must meet all codes & present no safety hazards

Ⅱ-2. Design Approach

Vacuum pumping system for the KOMAC/KTF RFQ must be fully suited for actual operation. In developing the conceptual design for the vacuum pumping system we strove to meet the requirements set forth in the scope of work, and also expanded on those requirements by utilizing design approach. We made a conscious effort to build in a robustness that will guarantee adequate pumping during all operating conditions of the accelerator. In addition, this was accomplished by researching and specifying reliable components in the system to safeguard against possible failures.

Ⅱ-3. System Design

Figure 2 shows the schematic diagram of the pumping stations and roughing system for section of RFQ. We selected to use cryopump based on dynamic analysis of performance during both nominal and abnormal operations, as well as total system pumping speed versus cost. one pump was chosen for the roughing system. This pump provides a total pumping speed of 500 liters/min atmospheric pressure with an ultimate total pressure of 10^{-2} Torr and is totally hydro-carbon free as required. The system can be pumped down to below the cross-over pressure (100 mTorr) of the cryopump in such an arrangement within 30 minutes.

The majority of the pumping is located in first section of RFQ as most of the gas load occurs in the first part. One 3000 liters/sec (for N_2) cryopump and a 500 liters/min roughing pump are attached to the pumpstation at one section. The vacuum header of section is plumbed via an 8" spool.

The port adaptor spool shown in figure 2 is constructed from 304 stainless steel plate and an 8" conflat flange. It provides the transition from the RFQ vacuum port to the plenum. Since the RFQ cavity is fabricated from copper, it is difficult to provide a metal seal between the adapter spool and vacuum port. An o-ring groove, designed to accept a standard sized o-ring, is machined into the mating face of the adapter spool and a viton o-ring will provide the seal. This is the only connection in the high-vacuum system that will not have a metal seal. However, the RFQ vacuum port is water cooled to a temperature suitable for viton use.

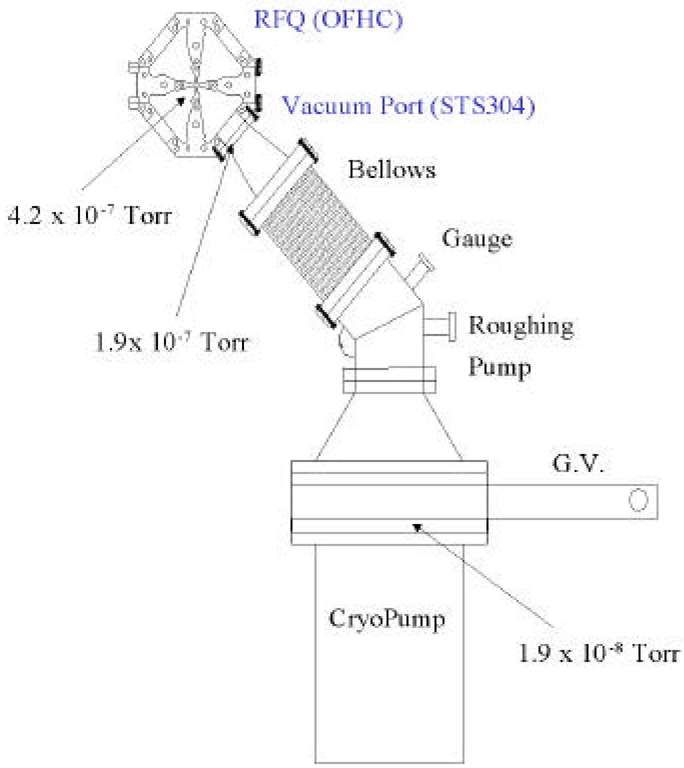

Figure 2. Schematic diagram of the pumping stations and roughing system for section of RFQ.

Ⅲ. System Analysis

The Coupled differential Heat-Load Equations described for each segment can be written as

$$- V_i \frac{dP_i}{dt} = - Q_i + C(P_i - P_j) + K(2P_i - P_{i+1} - P_{i-1}) \tag{1}$$

Where V_i, Q_i and P_i represents the volume, gas load and pressure in segment i respectively. C is the total effective conductance of the RFQ pump ports, and K is the conductance of the coupling plates between two segments. P_j is the effective pressure at the port adaptor described by the equation for pumpstation j as :

$$- V_j \frac{dP_j}{dt} = S_j P_j - Q_j + C(P_i - P_j) \tag{2}$$

Where S_j is the effective pump speed at the pump ports with all the conductance of the plumbing taken into account.

The conductance of an aperture of area A (in molecular flow) is

$$K = \frac{Q}{P_1 - P_2} = 3.64\times 10^3 \left(\frac{T}{M}\right)^{1/2} A \quad cm^3/\sec = 3.64 \left(\frac{T}{M}\right)^{1/2} A \quad \ell/\sec \tag{3}$$

where P_1-P_2 is positive and T, M, A represents Kelvin degree, molecular weight of gases, aperture area respectively. Therefore conductance is independent on pressure.

Pump speed at Pump port is

$$\frac{1}{S} = \frac{1}{S_p} + \frac{1}{C} \tag{4}$$

where S_p is real pumping speed of pump such as

$$S_p = S_t \left(1 - \frac{P_0}{P_p}\right) \tag{5}$$

and S_t, P_0, P_p represents theoretical pumping speed of the pump, the lowest pressure of the pump, pressure at the inlet of the pump respectively.

For the elbows, Conductance C is

$$C = 3.81\left(\frac{T}{M}\right)^{1/2} \frac{D^3}{L_1 + L_2 + 1.33 \cdot D \cdot (\theta/180)} \quad \text{(liters/sec)} \tag{6}$$

where D is a diameter of circle θ is angle between L_1 tube and L_2 tube
For the long tube of constant cross section, conductance C is

$$C = 3.81\left(\frac{T}{M}\right)^{1/2} \frac{D^3}{L} \quad \text{(liters/sec)} \tag{7}$$

To verify the major design parameters, we have started a series of performance tests on the cryopumps procured for the system. Major tests include the measurements of pumping speed and pressure. We have adopted the standard test arrangement (AVS procedure 4.1) [5]. For the cryogenic pump used in the experiment, system design and analysis were in a good agreement with the calculated value.

Acknowledgment

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References

[1] C. K. Park et al., "The KOMAC Project: Accelerator and Transmutation Project in Korea", Proceeding of APAC98, Tsukuba, 1998.

[2] B. H. Choi, "KOMAC", OECD NEA Workshop, 1998.

[3] J. M. Han et al, "Design of the KOMAC H^+/H^- RFQ Linac", Proceeding of LINAC98, Chicago, 1998.

[4] Y. S. Cho et al., "Conceptual Design Study of KOMAC DTL", Proceeding of APAC98, Tsukuba, March 23-27, 1998.

[5] M. H. Hablanian : 'Recommended Procedure for Measuring Pumping Speed', J. Vac. Sci. Technol. A5(4), July/Aug 1987, 25552.