

THE VACUUM SYSTEMS FOR PEFP LINAC*

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Abstract

The frontier project for high power proton accelerator including the proton injector, LEBT, RFQ and DTL has been launched in Sep. 2002. The fabrication and installation of the front-end system completed and the engineering design of the DTL has been ended. Now we are fabricating the 1st tank and RF components for the DTL. The purpose of this paper is to overview the installed vacuum systems of the front-end system, and to check out the designation of the DTL vacuum system.

- Output current : 20 mA
- RF power : 225/225/224/221 kW

FRONT END

The layout of the front-end vacuum system is presented in figure 1. The PEFP linac is designed to accelerate to 20 MeV both H⁺ and H⁻ beams and at the front-end the beam energy is 3.0 MeV. As showing in the figure, every structure has respective vacuum system and they'll be operate independently.

INTRODUCTION

The high power proton accelerator has been developed at KAERI (Korea Atomic Energy Research Institute) for basic researches and industrial applications. In the 1st step of the project we're plan to develop the system for acceleration to 20 MeV until 2005 and will provide beam to users in the middle of 2007[1-2].

The main design scope of the vacuum system is to select the proper vacuum components and install locations to lower the system pressure efficiently. At first for this, we understood the vacuum characters and estimated the gas loads for respective accelerating structure. And then we selected the pumps in which have the sufficient pumping speed in order to overcome the gas loads evolved from the beam loss, surface out-gassing and leak, etc. The required pressures of respective structure are decided to limit the beam losses by resident neutral gases. The main gas loads on front-end are hydrogen gases from beam losses amount of 10 mA, and are surface outgassed and leaked gases on the DTL. Another factor to select the components is the easiness of operation and maintenance. Also the counter-plan for problems of sudden failure of the pumps is to be prepared.

LINAC PARAMETERS

The main parameters of the linac are listed in table 1.

Table 1. The Linac parameters

	- Energy : 50 keV
Injector	- Current : 30 mA
	- Proton ratio : > 80%
	- Energy : 50 keV
LEBT	- Current : 10 ~ 40 mA(variable)
	- Transfer efficiency : > 92%
	- Energy : 3.0 MeV
RFQ	- Output currnt : 20 mA
	- RF power : 417.9 kW
DTL	- Energy : 20.0 MeV

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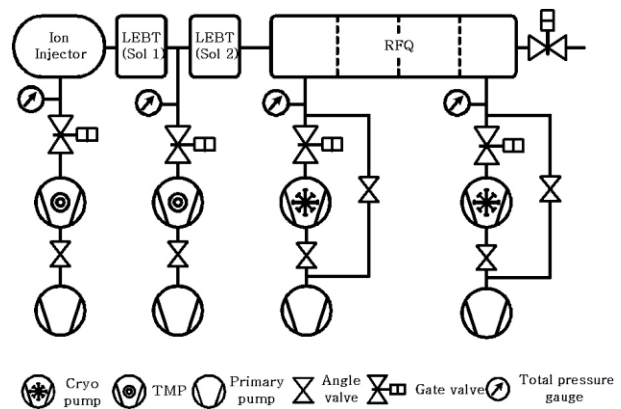


Figure 1 : The layout of the front-end vacuum system

Injector and LEBT

The duo-plasmatron type proton source to produce the H⁺ beam is installed (refer to the figure 2). The neutral hydrogen gas is injected into the source through the MFC (mass flow controller) about 4 sccm. The large amount of the proton and H₂⁺, H₃⁺ beam about 7 mA vanishes at the end of the source and the LEBT. The demanded pressure on these parts is about 1x10⁻⁵ mbar, we installed pumps at the injector and LEBT respectively. The stainless steel chamber was fabricated to evacuate the hydrogen gas evolved from these beam loss and installed at the end of the source. The LEBT is the long stainless steel pipe having two solenoid magnets. Inner diameter of the LEBT is 160 mm and the total length is 2.2 m. The conductance of the entire pipe is 887.3 L/sec. We installed the TMPs on injector of 720 L/sec pumping speed of H₂ and on LEBT of 370 L/sec of H₂. We selected the TMP for these parts in spite of the high H₂ loads since the required pressure is a little high about 10⁻⁵ order and the regeneration process of the cryo pump will give rise to the problems during the beam operation in this operational pressure range.



Figure 2. Picture of the installed ion injector. The vacuum system consists of gate valve, TMP with rotary pump and penning gauge.

RFQ

The pumping efficiency of the RFQ is not good because of the low conductance in the accelerating space, large surface area and high rate of beam loss. The PEFP 3 MeV RFQ divided into 4 sections, and all sections are bolted with fluorocarbon sealants [3]. The total length of the RFQ including a coupling plate located between 2nd and 3th section is 324 cm and aperture diameter is 6 mm. The OFHC copper was machined and brazed to shape the 4 vane cavities, and the 16 elements of the vacuum ports are located in 1st and 4th section.

Due to the particular geometry of the RFQ, we installed the pumping station made of stainless steel pipe at the respective cavities to raise the pumping speed at the cavity wall (refer to figure 3).

We performed the He leak tests on the fabricated systems and the leak rate were measured below 2×10^{-10} mar L/sec at every joints except the o-ring parts.

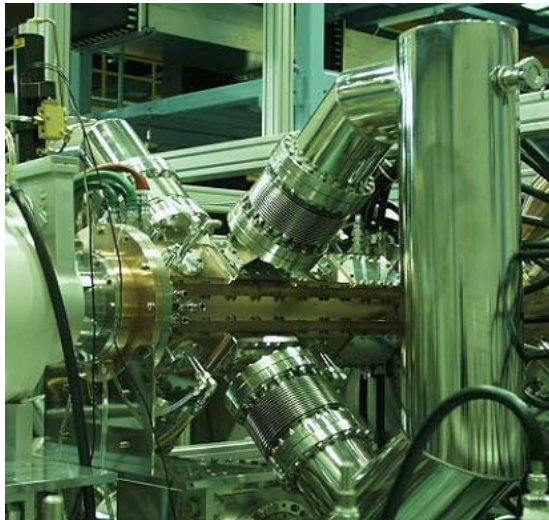


Figure 3. Installed RFQ vacuum pumping station.

- The expected gas loads on the RFQ are estimated.
- Outgassing ($41,500 \text{ cm}^2$) : $>8 \times 10^{-6}$ mbar L/sec
 - Joint leaks : $>2.8 \times 10^{-6}$ mbar L/sec
 - Beam loss (H⁺, 3 mA) : 7.2×10^{-4} mbar L/sec

The main pump for the RFQ is cryo-pump. The cryo pump has several advantages such as high H₂ pumping

speed vs. inlet flange and pumping performances of other gases are also excellent. For PEFP RFQ, 2 sets of 5000 L/sec (H₂ speed) cyro pumps are installed at the 1st and 4th section. The regeneration period is calculated as 65 days when operate the pump at 1×10^{-6} mbar, so we're planning to install a concurrent cryo pump in parallel in each pumping station. The 2 sets of the 250 L/min scroll pumps are used to rough the system from atm. to 2×10^{-2} mbar and to back up during cryo pump regeneration.

DTL

The goal of the project is to end the development of the 20 MeV DTL in the first step. We finished the DTL engineering design and now fabricating the 1st tank [4]. The PEFP DTL consists of 4 tanks – each tank divided two sections – made by Cu plated steel pipes. The total length of the DTL is 18.61 m and inner diameter is 54.44 cm. Ports for the DTL are mentioned in the table 3.

The pressure requirement of the DTL is calculated from the minimizing the beam loss due to the residual gases [5-6]. In table 2, the calculation results are presented.

Table 2. Beam loss due to stripping in the DTL

Tank (No.)	Exit beam energy (MeV)	Tank length (m)	Beam loss due to stripping		Max. allowable pressure (mbar)
			$\mu\text{A/m}$	μA	
1	6.9	4.45	0.882	3.66	3.00E-07
2	11.4	4.61	0.488	2.25	3.00E-07
3	15.7	4.54	0.406	1.84	3.00E-07
4	20.2	4.74	0.364	1.72	3.00E-07
Total loss (μA)			9.47		

Seal

We divide the vacuum and RF seal as fluorocarbon and canted coil spring. The compression set of the viton is about 20% at below 200 C, and required compression force is about 1.6 kg/cm. The force for compression for viton is higher than the coil spring, so we considered to

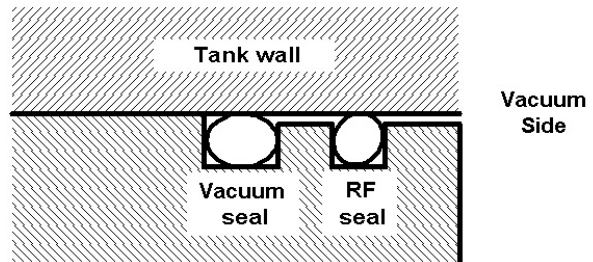


Figure 4. RF and vacuum seal groove design of ports

this point when designing the groove. The material of the coil is silver coated BeCu produce by Bal Seal engineering. Seal geometries of each port are similar to figure 4.

Gas loads

In the table 3 and 4, the gas loads due to outgassing and leak on the DTL are presented. The outgassing rate of the OFHC copper is assumed to reach 1.33×10^{-10} mbar L/sec/cm² after 100 hrs of vacuum and RF conditioning [5]. Despite of the low outgassing rate of the copper, the main gas loads on DTL was the outgassed gas on the large surface area as shown in the table. So we choose the PR (periodic reverse) method to plate the inner surface of tank [7].

Table 3. Gas loads on DTL due to the surface outgassing

	Qty.	Area (cm ²)	Outgas load (mbar L/sec)
Tank	1	75739.10	1.01E-05
End wall	2	341.88	4.55E-08
Drift tube	50	18809.86	2.50E-06
Stem	50	8449.74	1.12E-06
Post coupler	17	2872.91	3.82E-07
Slug tuner	8	3818.24	5.08E-07
Vacuum spool	1	1431.84	1.90E-07
			1.48E-05

Table 4. Summary of ports for 1st tank and gas loads due to the leaks

Seal Name	Qty.	Nominal seal dia.(cm)*	Gas load (mbarL/sec)	Remarks
Tank	2	55.8(54.2)	8.27E-06	Endwall
	1	57.1(55.5)	4.24E-06	Intertank
Stem	50	2.6(2.6)	6.75E-06	
Post couplers	17	2.6(2.6)	2.30E-06	
Slug tuners	8	15.8(14.5)	9.56E-06	
Vacuum ports	4	17.6(15.8)	5.31E-06	
RF coupler	1	14.9(13.1)	1.12E-06	
RF pick up	5	3.5(2.2)	8.55E-07	
Pump spool	1	15.24	1.36E-07	
Total			3.85E-05	

Viton O-ring (Coil spring)

Vacuum components

The SIP (sputter ion pump) is adopted as the main pump for the DTL. Ion pump is reliable, has no moving part, using the low outgassing material, and has long life. We plan to install the 3 sets of 300 L/sec SIP per one tank, and a set of TMP and scroll pump will be used to rough the a cavity to 1×10^{-5} mbar.

The pirani gauges and penning gauges will be installed at the pumping spool pipe to measure the total pressure of the cavity. They cover the range from atmospheric pressure to 1×10^{-10} mbar.

RF GRILL DESIGN

RF grills for RFQ and DTL are showed in the figure 5. These grills are installed to less the RF attenuation through the pumping ports, but they also reduce the conductance. The calculation results are listed in table 5.

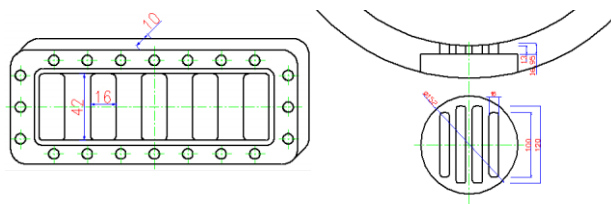


Figure 5. The RF grills for RFQ and DTL

Table 5. Conductance calculation of the RF grills.

	RFQ	DTL	
		SIP	TMP
Pumping speed (L/sec)	3,000	300	400
Grill conductance (L/sec)	4,224 (16896)	2,854	
Spool conductance (L/sec)	2,822	-	1,945
Effective pumping speed (L/sec)	1339	271.5	297

CONCLUSION

- The status of the vacuum systems of PEFP proton linac was overviewed.
- The expected difficulties of DTL vacuum system are the stem installation of vacuum tight and the plating of the copper to reduce the outgassing
- We will design the vacuum systems for the RF window region for next plan

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