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Vacuum System of Beam Irradiation and Monitoring Apparatus

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Vacuum pressure of 1.2×10^{-7} Torr necessary for use of 7 MeV proton from Ion Linear Accelerator has been attained at the vacuum vessel of Beam Emittance Monitor just downstream of the linac. For the purpose of sequence control of the evacuation system, a Penning gauge is used and it is calibrated with an ionization gauge. Total Q-value is estimated to be 3.8×10^{-7} Torr$\cdot l$/sec by the evaluation of the vacuum system. No peak of hydrocarbon is observed in the residual gas spectrum during evacuation.

KEY WORDS: Q-value / Leak / Outgassing Rate / Conductance / End Pressure

1. INTRODUCTION

At Accelerator Laboratory of Institute for Chemical Research, Kyoto University, 7 MeV proton linac consisting of an RFQ and DTL has been constructed and protons are successfully accelerated[1]. Peak beam current reached at 200～300 μA and the vacuum pressure in the cavities of the linac has reached to $\sim10^{-7}$ Torr necessary for beam acceleration. Improvement and evaluation of the vacuum system has been already reported[1,2]. In the present paper, the vacuum characteristics newly attached to the Beam Emittance Monitor (BEM) just downstream of the linac is evaluated.

2. EVACUATION SYSTEM OF THE BEAM EMITTANCE MONITOR

As the proton beam current has been reached at 200～300 μA, beam application has become possible. For this purpose, it is needed to measure the beam characteristics such as emittance and momentum spectrum. The vacuum system of the High Energy Beam Transport (HEBT) of 7 MeV proton linac is expected to be often opened to atmospheric pressure for the beam usage such as beam irradiation. So a roughing system is made and a compound turbo molecular pump is utilized, which can be used from relatively high pressure. At present, it needs almost 30 minutes to reach $\sim10^{-6}$ Torr from atmosphere. A block diagram and specifications of the vacuum system of BEM is shown in Fig. 1 together with that of the linac cavities.

Vacuum pressure is measured by Pirani gauge and Penning gauge to use sequence control of the evacuation system. For sequence control, a programmable controller is to be used.

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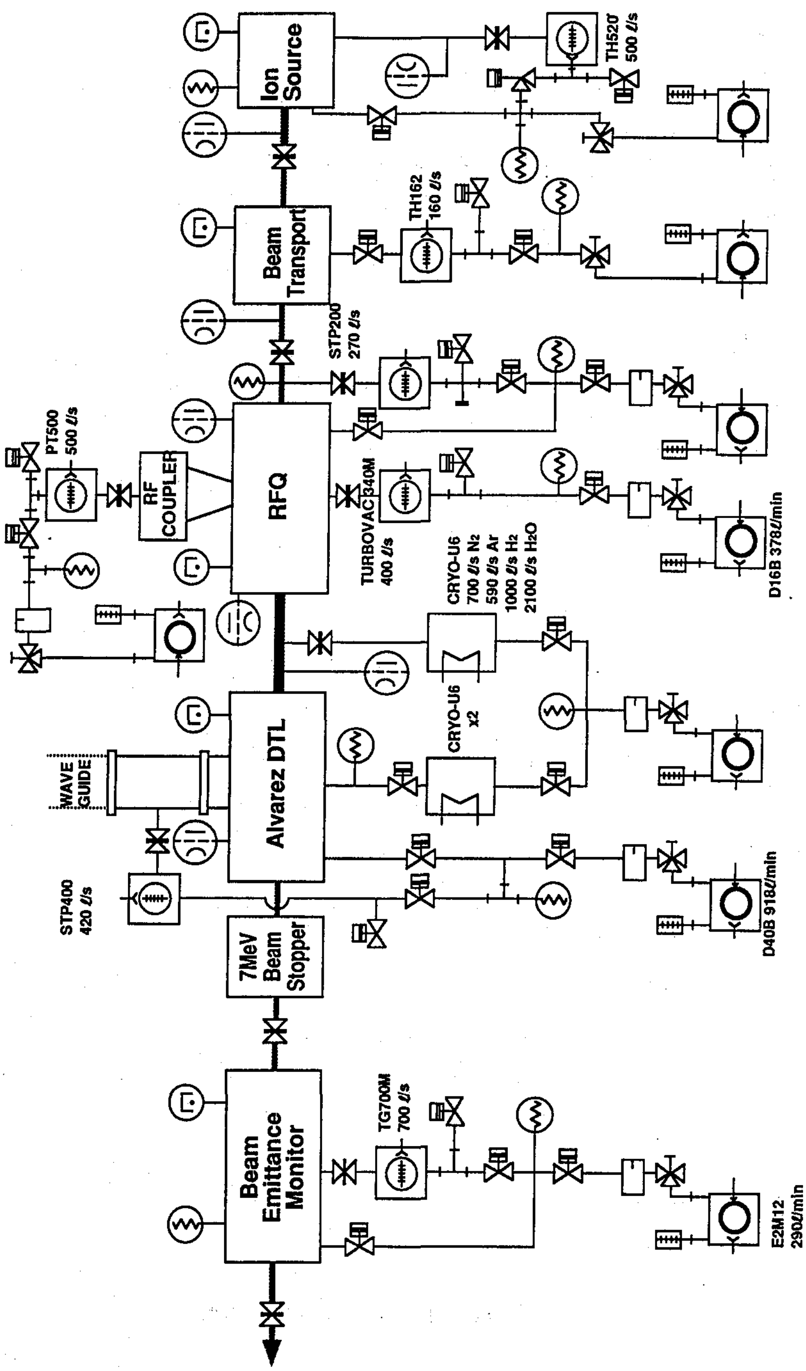
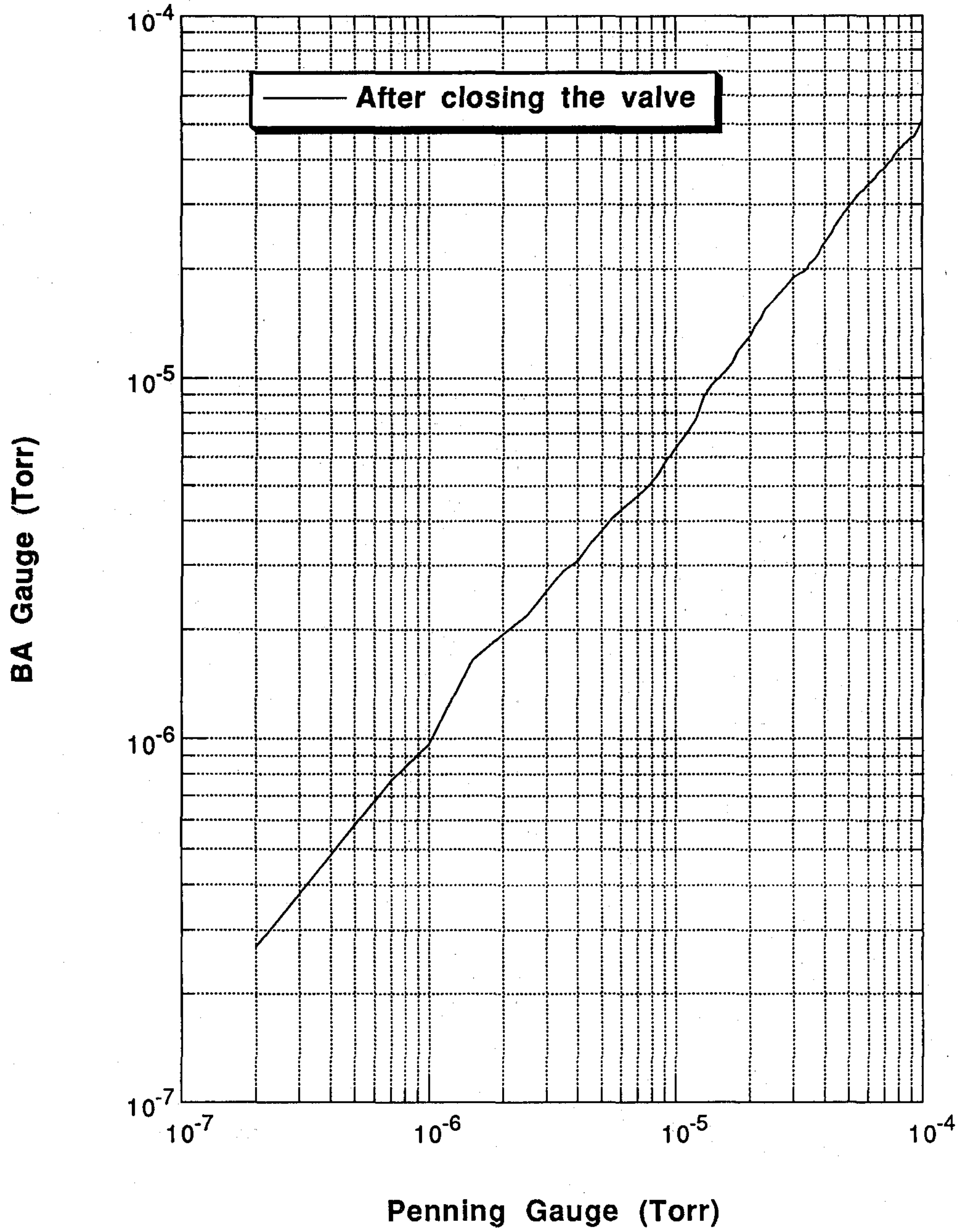
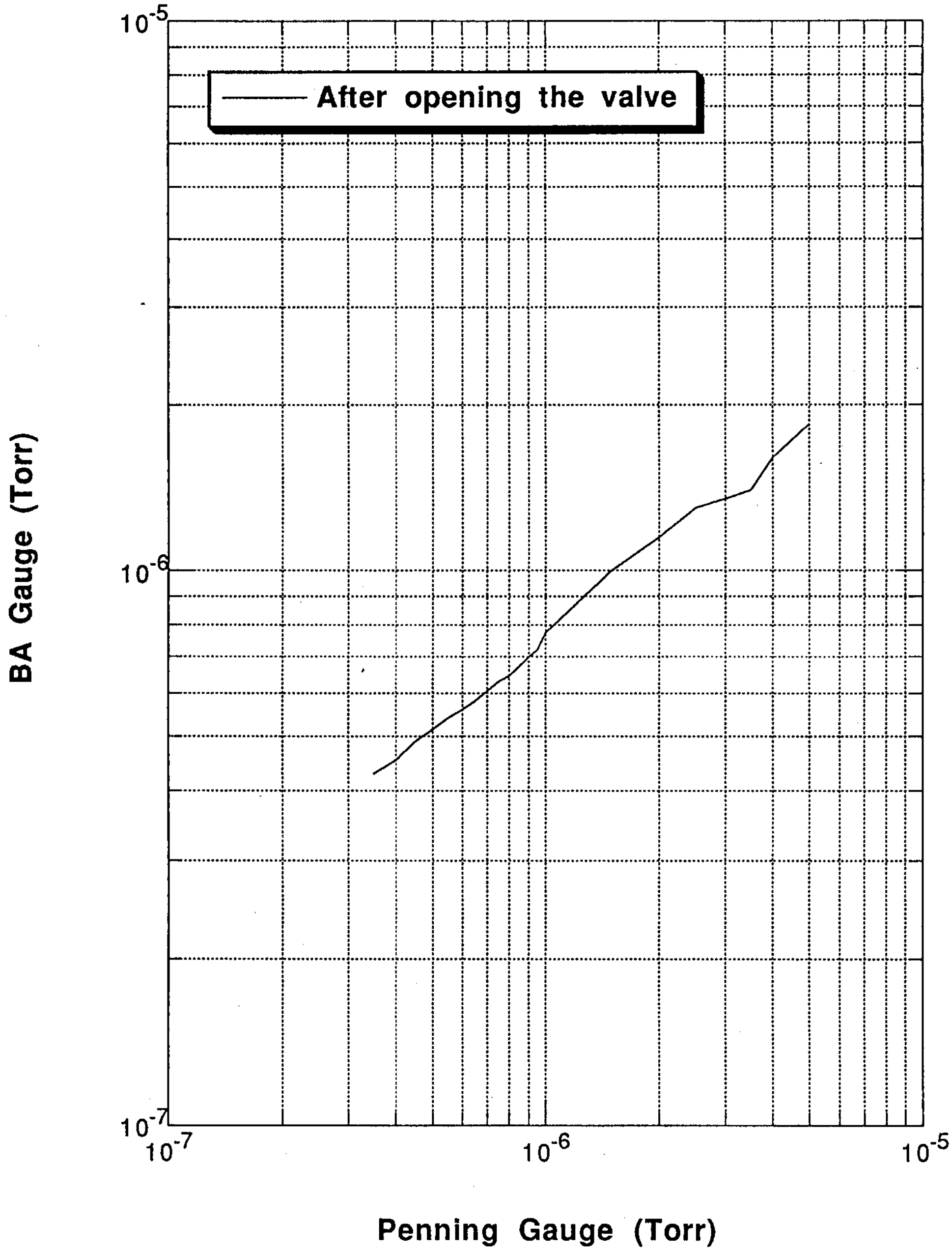


Fig. 1. Block diagram of the evacuation system for the proton linac and BEM at ICR.

Ambiguity of the measurement of a Penning gauge is, in general, larger compared with that of ionization gauge and so calibration with use of BA gauge is applied. Calibration curves are shown in Fig. 2 (a) and (b). Calibration results after closing the valve and opening the


After closing the valve
BA Gauge (Torr)
Penning Gauge (Torr)
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-7}
10^{-6}
10^{-5}
10^{-4}

(a)



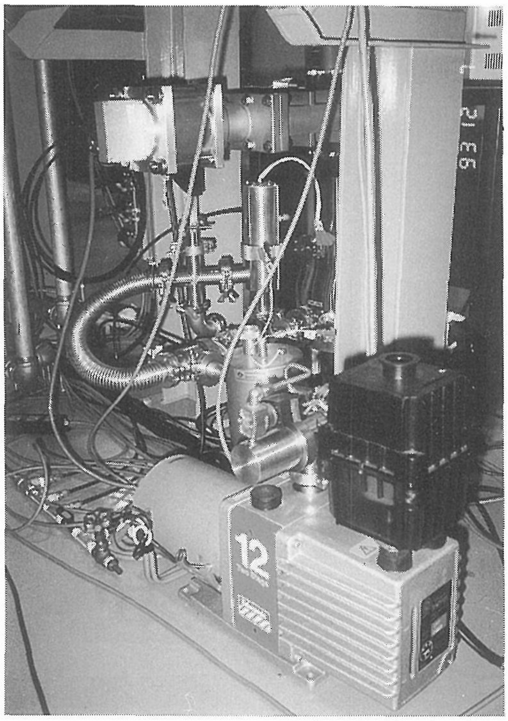
(b)

Fig. 2. Calibration Curves of the Penning gauge with the BA gauge. (a) during pressure rise (after closing the valve), (b) during pressure drop (after opening the valve).

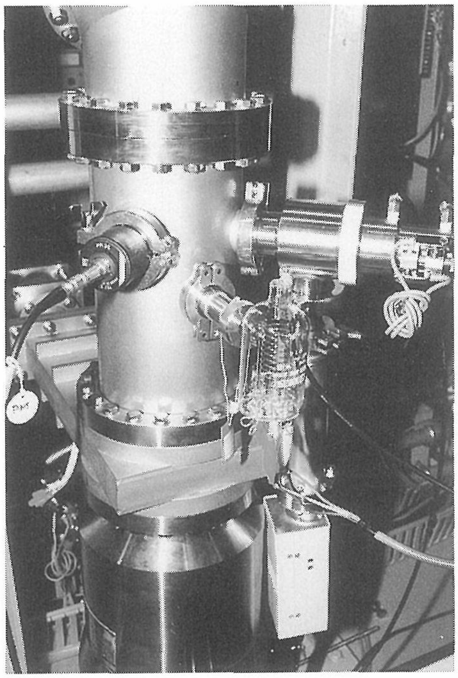
valve are shown in Fig. 2 (a) and Fig. 2 (b), respectively. According to the catalogue of the Penning gauge, the measuring precision is −50% ∼ +100%, which is consistent with our results. The emission current of the BA gauge is calibrated and measurement by the BA gauge is considered to be free from systematic error. The evacuation system and the Penning and BA gauges attached to the chamber are shown in Photo 1 (a) and (b), respectively.

3. EVALUATION OF THE VACUUM PUMPING SYSTEM

It is important to evaluate the Q-value, conductance and effective pumping speed from the point of view of the maintenance of the vacuum system. The main duct of the BEM installed in HEBT is made of stainless steel pipe 9.6 cm in inner diameter and 1.4 m in length and it has an evacuation port at the center. Up and down stream of the duct are connected to aluminum pipe 74 cm and 56 cm in length, respectively both 4 cm in inner diameter. In such a long narrow pipe, its conductance affects the effective pumping speed so much that it should be well taken into account. Total Q-value including leak and outgassing rate is studied by measuring



(a)



(b)

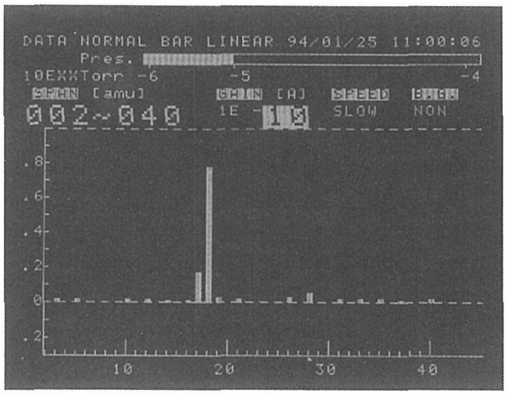
Photo 1 (a). View of the roughing port of the new evacuation system for the BEM.

Photo 1 (b). View of the BA gauge (center) and Penning gauge (left) attached to the vacuum chamber below the BEM.

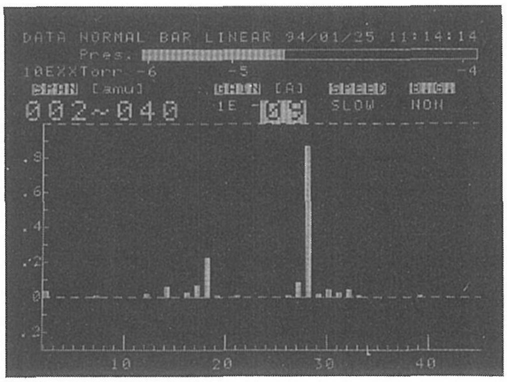
the pressure rise after closing the valve at the pump head. Vacuum pressure is monitored with the ionization gauge for the short time interval (~10 min) after closing the valve. Long term pressure change (3 hours) is monitored with the Penning Gauge. Total Q is estimated to be 3.8×10^{-7} Torr·l/sec and 1.5×10^{-7} Torr·l/sec, for short (BA gauge) and long term (Penning gauge) measurement, respectively, where the evacuated volume of the BEM and pump head is calculated to be 20 l.

Residual gas spectra during evacuation and after closing the valve are shown in Fig. 3 (a) and (b), respectively. As the Q-mass analyzer, ULVAC MASSMATE-100 is used. From the figure, it is known that partial pressure of H_2O (m/e = 18) is 19 times of that of N_2 (m/e = 28) during evacuation. On the other hand, the partial pressure of N_2 is 5 times larger than that of H_2O after closing the valve.

Next, the end vacuum pressure of the BEM is estimated. Total conductance from the BEM to the pump head is calculated to be 7.1 l/sec and effective pumping speed is estimated at 7.0



(a)



(b)

Fig. 3. Residual gas spectra in the vacuum vessel of the BEM. The spectra of the residual gas in the BEM after the end vacuum is attained. Data shown in (a) and (b) are taken with the conditions that (a) the evacuation port is active and (b) the evacuation port is closed by the valve.

l/sec. End vacuum pressure is expected to be 5.4×10^{-8} Torr utilizing the total Q-value measured by the BA gauge in short term. The real attained end vacuum pressure is 1.2×10^{-7} Torr, which is factor 2.2 times larger than the above estimation.

This discrepancy is considered to be due to the fact that real Q-value has the pressure dependence while above estimation assumes constant Q-value.

4. SUMMARY

Evacuation system for HEBT is newly added which utilizes a compound turbo molecular pump and roughing port. The pumping time from the atmosphere to the one applicable for beam irradiation (range of 10^{-6} Torr) is about 30 min. and the end vacuum pressure has reached at 1.2×10^{-7} Torr, which is good enough for the present purpose.

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