VACUUM STATUS DURING THE BEAM OPERATION OF RCS IN J-PARC

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Abstract

Since the start of the beam commissioning on October 2007, we have succeeded to increase the beam power of the Rapid Cycling Synchrotron (RCS) in the Japan Proton Accelerator Research Complex (J-PARC). The effect of the high power beam on the vacuum had become visible above the beam power of 20 kW. When the high power beam was operated at 25 Hz, the vacuum pressure became higher. Quadrupole mass filters as the residual gas analyzer were installed in order to investigate which kinds of outgassing were desorbed by the high power beam. The hydrogen and hydrocarbon compound mainly increased with the high power beam in the area. The increase of the pressure is considered to be the outgassing emission from the surface of the vacuum duct by the ion, which are made and accelerated by the proton beam. The conditioning effect by the continuous beam operation has been confirmed.

INTRODUCTION

J-PARC is a high intensity proton accelerator facility. The 3 GeV RCS is a keystone of J-PARC facility since it plays a role of both the main accelerator for the Material and Life Science Facility (MLF), which uses the world highest intensity pulsed neutron and muon beams, and the injector to the Main Ring (MR), which is a 50 GeV synchrotron for high energy particle physics. The RCS aims to achieve the proton beam power of 1 MW, which corresponds to each cycle 8.3×10^{13} protons accelerated up to 3 GeV at the repetition rate of 25 Hz. Effect of the high current beam on the vacuum had been a big problem in the ISR at CERN [1]. There, beam storage induced a ”pressure bump” and an instability of the beam. The beam power of RCS is uniquely so high that we have been carefully investigated the variation of the pressure and outgassing components induced by the high power beam. In this report, variation of the vacuum pressure during the high power beam operation is described. We focus the distribution of the pressure around the ring and outgassing components measured by mass filters.

RCS vacuum system

Vacuum chambers of RCS have large size of aperture in order to accept such a high intensity beam. The normal diameter is 200 mm, while the largest diameter is 500 mm in the injection and extraction section. Alumina ceramics chambers are used in the aperture of the bending and quadrupole magnets, whose repetition rate of the magnetic field is 25 Hz, in order to prevent the eddy current heating [2]. Other vacuum chambers and bellows are made of titanium because of its small residual radioactivity. The allocation of the pump and gauge is shown in Fig. 1. The 24 turbo molecular pumps (TMP) and 20 spattering ion pumps (SIP) are used to evacuate RCS. As shown in Fig. 1, many turbo molecular pumps are used for the devices in vacuum like collimators and kicker magnets. Cold cathode gages (CCG) and B-A gages (BAG) are used to measure pressure. CCG are located at the same position as TPM and SIP in the ring, although they are not shown in Fig. 1. Pressure has been about $10^{-7} \sim 10^{-6}$ Pa. Quadrupole mass filters was installed at the injection and RF sections in order to investigate the outgassing components.

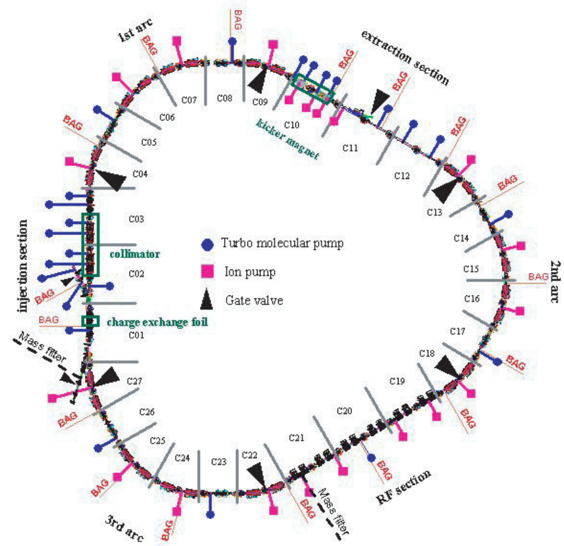

Figure 1: RCS vacuum system. RCS is conveniently divided into three straight and arc sections, which consist of 27 cells.

EFFECT OF THE HIGH POWER BEAM ON THE VACUUM

Pressure increase in the high power operation

Table 1 shows the performance of the J-PARC beam run from the start of the RCS beam commissioning. RCS starts its beam commissioning test in October 2007, Run 10, and accomplished 3 GeV on October 31. The beam-on-demand operation with no beam repetition or 1 Hz, which are shown as 1shot in Table 1, has been employed during the RCS

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	Oct.07		Feb.08		Sep.08				Feb.09
Run Number	10	← →	14	← →	18	19	20	21	22
Contents	Accelerator beam commissioning						User operation		
Beam power	1shot		1shot 50kW	1shot	1shot 210kW		100kW 20kW	20kW	

Table 1: Contents of J-PARC beam run since RCS starts its beam commissioning. 1shot means the beam-on-demand operation.

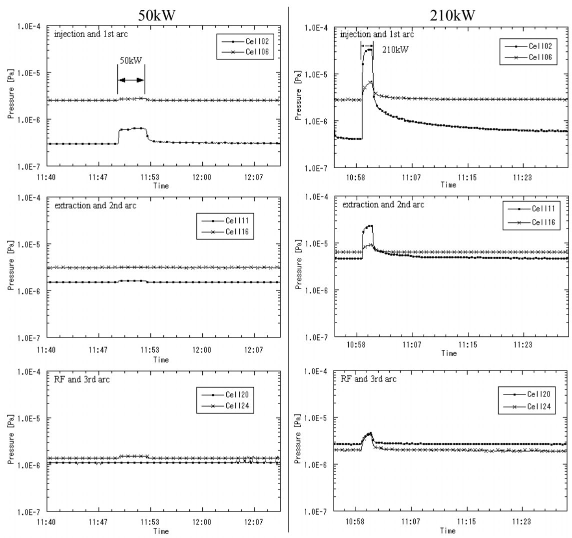

Figure 2: Variation of the pressure during the 50 kW and 210 kW beam operations.

beam commissioning. There are no variation of pressure during the beam-on-demand and 1 Hz operation. Its beam power has been gradually increased as a result of the cautious parameter search [3]. In Run 14 and 18, we achieved the high power beam test of 50 kW and 210 kW at the repetition rate of 25 Hz. Each operation time was 5 min and 70 sec, respectively, which was limited by the capacity of

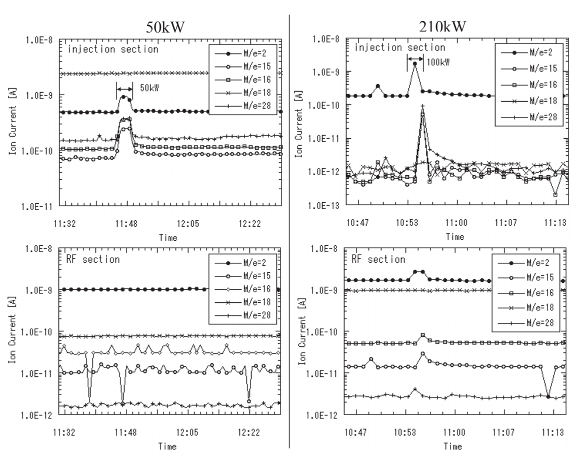

Figure 3: Variation of the outgassing components at injection and RF sections during the 50 kW and 210 kW beam operations.

beam dump. Left side graphs in Fig. 2 shows the pressure, measured by CCG, during the 50 kW beam operation in Run 14. The variation of the pressure was almost not observed at this beam power except the injection area. It may be mainly due to the carbon foil for charge exchange, which is located at the center of the injection section. Left side graphs in Fig. 3 describes the results of the mass filter during the 50 kW beam operation. The components like hydrogen (M/e=2) and carbon-hydrogen (M/e=15, 16, 28) compound increased by 50 kW beam at the injection section. Quantity of the outgassing component at RF section did not change. Right side graphs in Fig. 2 and 3 shows the pressure and outgassing components during the beam power of 210 kW in Run 18, respectively. The variation of the pressure by the beam was seen at almost all sections in the ring. Data of the mass filter shows the same outgassing components as in the case of 50 kW beam increased in the injection section but the amount was larger. In the RF section, the only hydrogen increased by 210 kW beam. It can be said that the RF section was relatively clean.

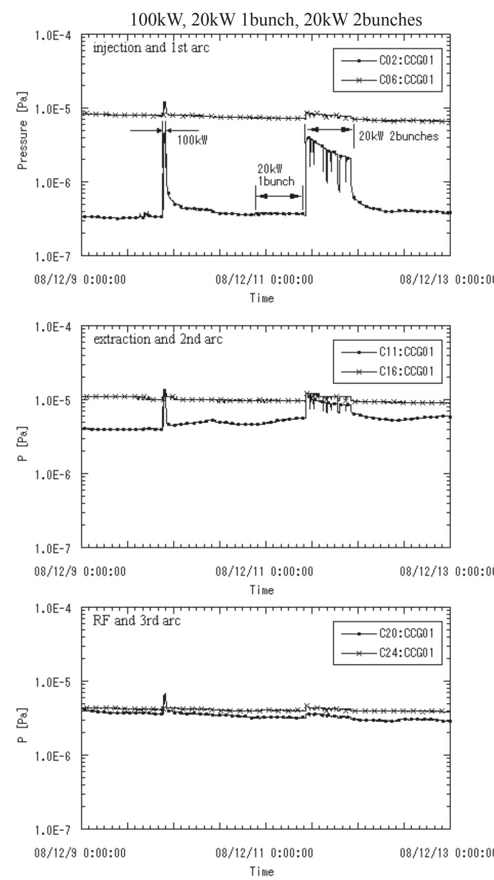

Figure 4: Variation of the vacuum pressure at each beam condition in Run 20.

In December 2008, Run 20, we operated at the beam power of 100 kW for one hour and started the continuous operation at 20 kW beam for users of the MLF. In terms of 20 kW operation, we provided the 2 beam bunches for 10 hours and 1 beam bunch, particular to this Run, for

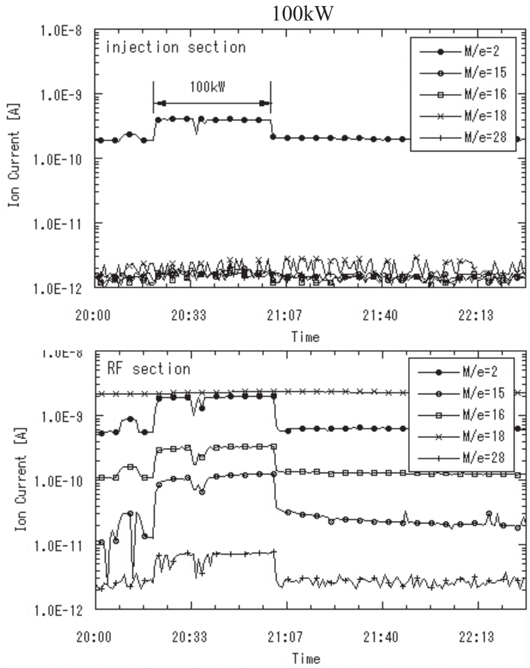

Figure 5: Variation of the outgassing components at injection and RF sections during 100 kW beam operation in Run 20.

other 15 days. Fig. 4 shows the pressure around the ring in each beam power. The variation of pressure in injection and extraction area was larger than other areas, which may be due to carbon foils, collimator and kicker magnet, which are the in-vacuum components. The effect of the 2 beam bunches was much larger than that of 1 beam bunch even when the beam power was the same. The reason is briefly discussed in the next section. Fig. 5 shows the outgassing components at 100 kW beam operation. In the injection section, only hydrogen increased unlike the case in Run 14 and 15 as shown in Fig. 3. In contrast, hydrogen and carbon-hydrogen compounds increased in the RF section. Because the vacuum ducts are decomposed between Run 19 and 20 in order to install the 11th RF cavity, surface of the chamber may have become soiled.

Conditioning effect

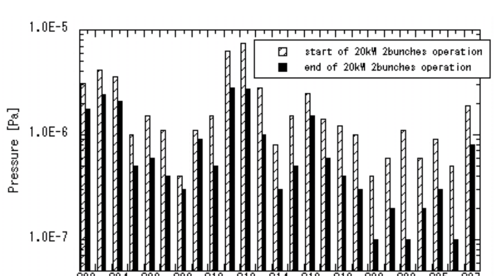

Figure 6: Comparison of the pressure between the start of the 20 kW 2 beam bunches operation and 10 hours later.

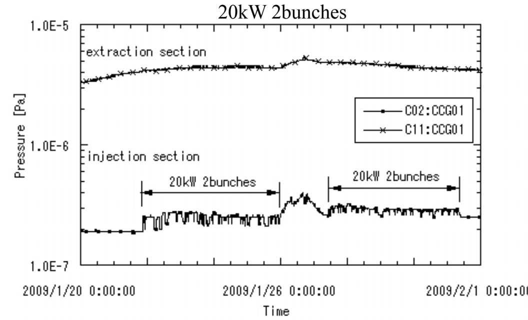

Figure 7: Pressure at injection and extraction section during 20 kW 2 beam bunches operation in Run21. Pressure increase between the beam operation is effect of a stop of the main magnet.

As can be noted from Fig. 4, the pressure decreased during the 10 hours 20 kW 2 beam bunches operation . Fig. 6 shows the comparison of the pressure at the start of the 20 kW 2 beam bunches operation to that of 10 hours later. The pressure values are subtracted by the vase pressure at each cell. There is a conditioning effect by the long time high power beam operation. Fig. 7 shows the pressure at the injection and extraction at Run 21 (January 2009). Conditioning has proceeded and there is not a large increase of the pressure like in Run 20.

DISCUSSION

Increase of the vacuum pressure by beam is considered to be the same process as the ISR [1]. First, residual gas molecules are ionized by proton beam. Next, the ions are accelerated by the potential made by the beam current. They attacked the surface of vacuum chamber and caused outgassing emission. As a result, the pressure increased. Space charge potential, which is made by beam current and accelerates the ions, is given by the formula,

$$V = \frac{I}{2\pi\varepsilon_0 c} \log\left(\frac{D}{d}\right) \tag{1}$$

where $I, D,$ and d are the beam current, a diameter of the vacuum chamber, and a diameter of beam. The space charge potential is about 20 V in the case of 20 kW beam, which is about a thirtieth of ISR's case. Therefore the increase of the pressure has not become a big problem in this phase. The process described above is a feed back process. Therefore it is considered the variation of the pressure in the 2 beam bunches is larger than that in the 1 bunch.

REFERENCES

[1] R. S. Calder, Vacuum, Vol. 23, No. 10, (1974), 437.

[2] M. Kinsho, Y. Saito, Z. Kabeya and N. Ogiwara, Vacuum, Vol. 81, Issue 6, (2007), 808.

[3] H. Hotchi, to be published in Phys. Rev. ST Accel. Beams.