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RESIDUAL DOSES WITH 400 MEV INJECTION ENERGY AT J-PARC RAPID CYCLING SYNCHROTRON

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Abstract

Last summer shutdown an injection energy of J-PARC rapid cycling synchrotron was upgraded from 181 MeV to 400 MeV to aim for reduction of the space charge effect during injection period.

By the commissioning after the shutdown, 300 kW operation condition was established. In this condition, the doses of most areas were kept at the same level as 181 injection energy operation or decreased except to the injection foil chamber, 100 degrees and H0 dumps.

INTRODUCTION

The Rapid Cycling Synchrotron (RCS) in Japan Proton Accelerator Research Complex (J-PARC) operated since September 2007 [1, 2]. The original design of RCS injection energy is 400 MeV, but first operation was started by 181 MeV for budget reason. New acceleration cavities were installed in J-PARC linac last summer shutdown, and the linac tuning was started last December[3]. The linac achieved 400 MeV acceleration at the end of January 2014, and RCS commissioning was completed 11th February. Finally, the user operation to Material and Life science Facility (MLF) was started from 17th February.

Owing to the beam commissioning with 400MeV injection energy[4], the amount of the beam loss was enough small. Then we tried high power operation at a repetition of 25 Hz. As a result, when the beam power exceeded to 150kW, the vacuum pressure in the beam line chamber rapidly increased and the beam losses occurred all over the RCS beam line. These phenomena were due to the gas (such as a vapour) absorption on the surface of the vacuum chamber. Last summer shutdown period, almost all connections between the vacuum chambers were separated in order to re-align the dipole and quadrupole magnets of RCS[5]. Measurement results of the magnet positions just after the Great East Japan Earthquake indicated that the magnets transversely moved to 10mm and longitudinally moved to 5mm[6] at most. If we fixed those alignment errors, a recovery work from the damage by the earthquake might have been delayed three months. Therefore we estimated the influence of the alignment errors, and the result showed that an increment of the beam loss was enough small to accept[7]. Practically we decided to give user operation the highest priority at that time and to postpone re-alignment work until installation of 400 MeV components[8].

For sudden increment of the beam losses due to the residual gases, the beam power was gradually increased for the conditioning of the vacuum chamber surfaces. After the nine days conditioning by low power, we established 300 kW continuous operation.

In this paper, we report the residual doses with 400 MeV injection energy at J-PARC RCS after 300 kW user operation.

RESIDUAL DOSES WITH 400 MEV INJECTION ENERGY

The residual dose distributions of the RCS after 300kW, 7days operation and 4hr cooling are shown in Figure 1, and the history of the residual dose of typical loss points and output power from RCS are shown in Figure 2.

Before and after injection energy upgrade, the residual doses were concentrated on the injection region. In both cases, there were few doses on another area. This is because the halo which occurred during the acceleration is well localized on the collimator. Thus we consider that the collimator works effectively when the injection energy is up to 400MeV.

In the injection region, the residual dose on the vacuum chamber of the charge exchange foil became higher than the residual dose with low injection energy (black square in Figure 2). The residual dose at this point was about 2 mSv/h before upgrade, and it increased to 7.5 mSv/h after upgrade. As a matter of fact, the flange in 20cm downstream of the point at which we had always watched was maximum dose point. That value was more than 10 mSv/h (Our survey meter cannot measure over 10 mSv/h). We consider this is due to the neutrons which were produced by the interaction between the charge exchange foil and injection/circulating particles.

The doses near the injection H^0 dump were also increased (dark yellow triangle in Figure 2). The injection H^0 dump was prepared to abandon the H^0 and H^- particles by which the electrons around the injection particle were not removed at the injection foil. We measured a profile of the injection beam, and the result indicated that the halo of the linac beam was extended to the outside of the foil. Those were abandoned to the injection H^0 dump and produced more neutrons than the low injection energy case. In order to reduce the halo of the linac beam, we tested the scraper system that was installed at last summer shutdown period[9]. In this study, 1 % of 16 kW beam was scraped during user operation of 1.5 days, and the scraped halo was abandoned to the 100-deg. dump that was set at the halfway of beam transport line. As a result, the residual dose at a vacuum window of the 100-deg. dump was more than 10 mSv/h in spite of measurement after 10 days. This result indicated that we need to put an additional radiation shielding around the vacuum window. Therefore we decided to install the additional radiation

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shielding and monitors in the bema line of the 100-deg. dump.

Meanwhile, the dose at the injection septum magnet was reduced (olive triangle in Figure 2). We think the reduction was due to two reasons. First reason is improvement of vacuum pressure by the installation of additional two vacuum pumps at L3BT line[10], and the other is a decline of the charge exchange efficiency due to the residual gases by the increase of injection beam energy.

Although the doses increased in some points, those were acceptable and we resumed user operation by the same output power as previous injection energy.

CONCLUSION

We increased the injection energy of J-PARC RCS. First result of user operation with new injection energy indicated that:

A) the residual dose on the vacuum chamber of the charge exchange foil became higher.
B) the residual doses near the injection H^0 dump were increased by the halo of injection beam.
C) the dose at the injection septum magnet was reduced due to improvement of vacuum pressure in L3BT line and higher injection energy.

Among these, we will take countermeasures in next summer about B). To achieve further high power output, we will continue to consider the measures of A).

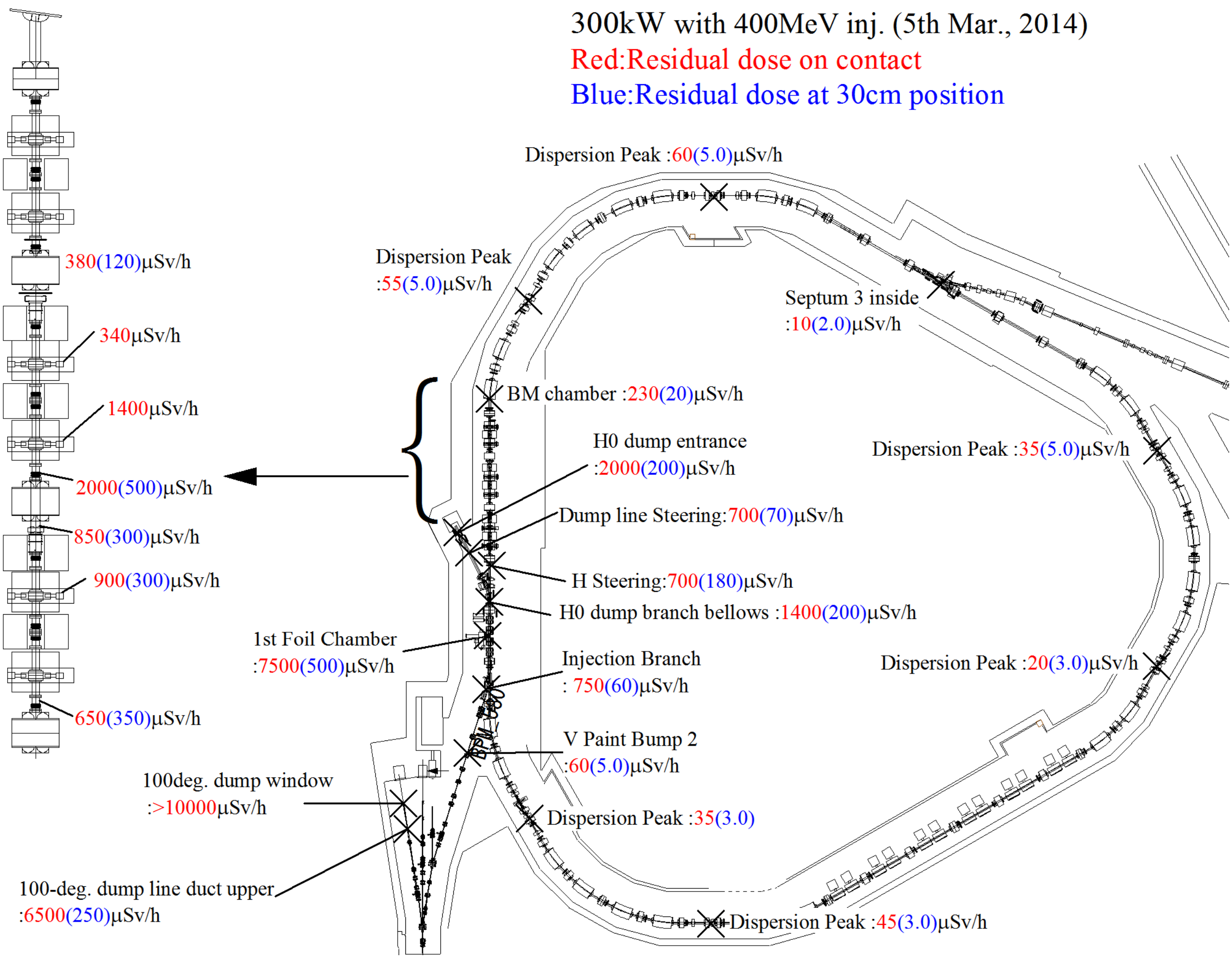

Figure 1: Residual dose distribution at 300kW operation with injection energy of 400 MeV. A left(red) value means a contact dose rate and a right(blue) value in bracket means a dose at “one-foot”(30cm from a vacuum chamber surface) position.

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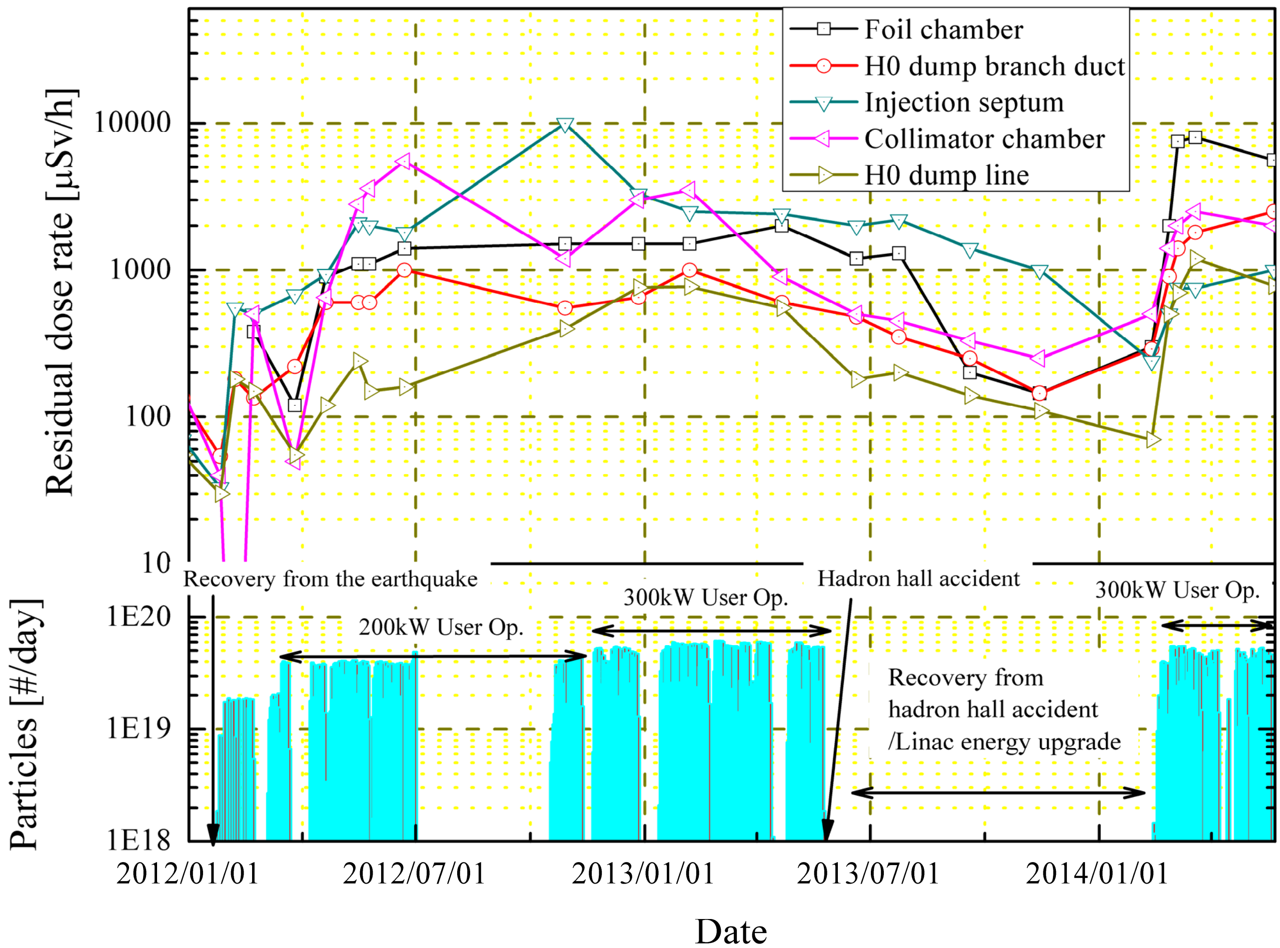

Figure 2: The history of the residual dose of typical loss point and output power of RCS.

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