ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-TUPTS036

OPERATION STATUS OF J-PARC RAPID CYCLING SYNCHROTRON

K. Yamamoto†, J. Kamiya, Accelerator Division, J-PARC Center, Japan Atomic Energy Agency (JAEA), Tokai-mura, Japan

Abstract

The 3 GeV rapid cycling synchrotron (RCS) at the Japan Proton Accelerator Research Complex (J-PARC) provides more than 500 kW beams to the Material and Life Science Experimental Facility and Main Ring synchrotron. In such a high-intensity hadron accelerator, even losing less than 0.1% of the beam can cause many problems. Such lost protons can cause serious radio-activation and accelerator component malfunctions. Therefore, we have conducted a beam study to achieve high-power operation with less loss. In addition, we have also maintained the accelerator components to enable stable operation. This paper reports the status of the J-PARC RCS over the last japan fiscal year.

INTRODUCTION

The Japan Proton Accelerator Research Complex (J-PARC) aims to deliver very high intense proton beams for the various physics programs. Among them the 3 GeV rapid cycling synchrotron (RCS) was constructed to supply 1 MW, high-power proton beams to the Main Ring (MR) synchrotron and Material and Life Science Experimental Facility (MLF) [1].

In proton accelerators, the most important issue is radio-activation caused by beam loss. High beam losses increase the failure rates of accelerator components and worker radiation doses during maintenance work. Therefore, the output beam power has to be limited to keep the exposure dose for the workers by the residual dose within acceptable levels. To keep such a condition, it is necessary to reduce beam losses.

We have thus continued the beam study and the hardware improvements to reduce beam losses. Now the RCS beam power for neutron targets is 500 kW. On the other hand, the RCS simultaneously delivers the proton beam to the MR, and since this requires the beam with smaller emittance than the MLF, we have continued to investigate beam conditions that are suitable for both facilities. We are continuing the beam study, improvement and development of the accelerator components to achieve much higher capability and stability.

IMPROVEMENTS OF ACCELERATOR COMPONENTS IN RCS

Foil Production

In J-PARC RCS, The Hybrid type thick Boron-doped Carbon (HBC) foil[2] was used for charge exchange injection. It had been produced in KEK laboratory since the beginning of RCS commissioning. However, due to retirement of the expert of the HBC foil production, it became difficult to produce the HBC foil in KEK anymore. Therefor the foil deposition system in KEK was moved to J-PARC site to continue the HBC foil production. By using this system, we started research and development to produce more robust foil.

With some trial-and-errors, we produced new HBC foil. The performance of the new HBC foil was evaluated by using the heavy ion beam facilities in Takasaki Advanced Radiation Research Institute of National Institute for Quantum and Radiological Science and Technology before installing in the RCS. The test result indicated that the new HBC foil would be durable as almost same as the original KEK HBC foil. Finally, one new foil was tested during 10-day user operation on June 2018[3], and it endured during this period. As a result, we have been using this new HBC foil from October for full user operation. Figure 1 shows the new HBC foil before and after 2-month operation.

Figure 1: The new HBC foil before (upper) and after 2-month operation (lower).

† Email : kazami@post.j-parc.jp

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2019). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-TUPTS036

Movable Collimator Installation

The beam collimation system removes the beam halo and localizes the beam loss to preserve the other accelerator components. The collimation system comprises one primary collimator, which scatters the halo particles, and five secondary collimators, which absorb those scattered particles. The radiation shielding around the collimator chamber was designed such that the collimator system could absorb a halo up to 4 kW.

In April 2016, a malfunction occurred in the VME system, i.e., the collimator's control system. We performed a performance test to remedy this but a vacuum leak occurred during the test. The vacuum pumps stopped abruptly due to sudden vacuum deterioration, and the area around the vacuum deterioration point was immediately isolated by the gate valves.

After an investigation, it was found that the fifth secondary collimator was the source of the leak, which was caused by a collision of the collimator blocks. We needed to repair it quickly, but it was highly activated and we did not have a spare of the fifth secondary collimator. We then looked for a temporary solution, and the numerical simulation results indicated that the beam loss without this collimator would be acceptable. We therefore installed a spare straight duct instead of repairing the broken collimator[4].

After the resumption of user operation, the residual dose was not as high as expected. Thus, we continued user operation till summer shutdown 2016 under this condition. Following our temporary repair, we made a fixed collimator to replace the spare duct, and this was put in place during the summer shutdown period 2016. During JFY 2017, we improved the collimator movable system as much reliable one. The control system was changed from VME to PLC, and it included redundant limit (software and hardware). Hardware was also improved to separate support point and vacuum boundary, and horizontal and vertical collimator positions are alternating to prevent hitting each collimator blocks. Finally, we installed new fifth movable collimator system in the summer shutdown period 2018.

OPERATIONAL STATUS

In the JFY 2018, the operation beam power to MLF was started at 400 kW. The power of the beam to the MLF was immediately increased to 500 kW at the end of April. Meanwhile, the MR output power was steadily increased as MR commissioning progressed. Figure 2 shows the change in RCS output power with respect to time.

This year, there were no serious problems in the RCS. The major problems were the discharge of Pulse Forming Network (PFN) cables in the kicker magnet system. The discharges occurred twice and we were not able to recover quickly. Therefore, after the second discharge phenomena, the bump orbit made by the correction magnets near the extraction area compensated the shortage of the kick angle. Although the loss at the septum magnets increased several times higher than usual operation, it was usually a dose rate of 100 mSv / h or less, so we judged to be acceptable and continued operation under this condition. The dose after operation was within the expectation.

The availability of the RCS was summarized in the table 1. The operation time for MLF over the year was approximately 4130 h, excluding the commissioning time, and downtime of approximately 64 h; therefore, its overall availability was 98.4%.

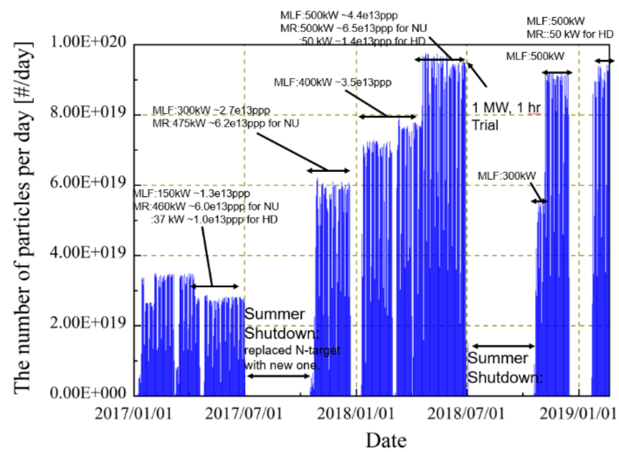

Figure 2: The change in RCS output power with respect to time.

Table 1: Summary of Availability

Facility	User time (hr)	Trouble in RCS (hr)	Availability of RCS(%)
MLF	4129:46	53:52	98.4
Neutrino	1053:32	8:28	99.2
Hadron	1089:28	3:06	98.9

EXPOSURE DURING MAINTENANCE

Since the output power to the MLF was increased, the residual doses in the RCS were relatively larger than that of previous years.

Table 2 summarizes the radiation doses received by the workers during the summer shutdown period in 2018. A total of 49 workers were exposed to doses of more than 0.01 mSv, and their collective dose was 2.50 man-mSv. Eight workers were exposed to residual doses of more than 0.1 mSv, and the maximum dose received by any one worker was 0.24 mSv. Both the collective and maximum doses were increased compare to the previous years. This is due to the increase of the output power for MLF and MR.

Table 2: Summary of Worker Radiation Doses During the Summer Shutdown Period in 2017

Dose (mSv)	Number of workers
0.01-0.05	36
0.06-0.10	5
0.11-0.20	6
0.21-	2

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2019). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-TUPTS036

1-MW TRIAL

At the end of June 2018, We carried out the trial of the 1-MW continuous operation. As a matter of fact, just before the 1-MW trial, we had a failure of the turbo molecular pump at the arc section. This trouble caused contamination near the TMP failure point. Therefore, at 1 MW operation, the pressure rises were slightly more than one order of magnitude, but three orders of pressure rise was found at TMP failure point. Because of this vacuum deterioration, the signals of the beam loss monitors around the TMP failure point were increased and some time beam was stopped due to the machine protection system. However, actually those signals were brought about the interaction between the beam and gas. Thus, there were no significant changes of the residual dose values before and after 1-MW operation. Figure 3 shows the residual dose around the RCS tunnel before and after 1-MW continuous operation.

CONCLUSION

RCS is almost continuing stable user operation. At present, RCS delivers 4.4e13 ppp (500-kW) beam to the MLF and 6.5e13 ppp (780-kW equivalent in RCS) beam to the MR. It will be further increased step by step with carefully monitoring the neutron target status and the beam loss.

We achieved 1-MW, 1-hr continuous operation at the end of June 2018. 1-MW trial indicated some issues to establish stable 1-MW operation. We will improve those issues.

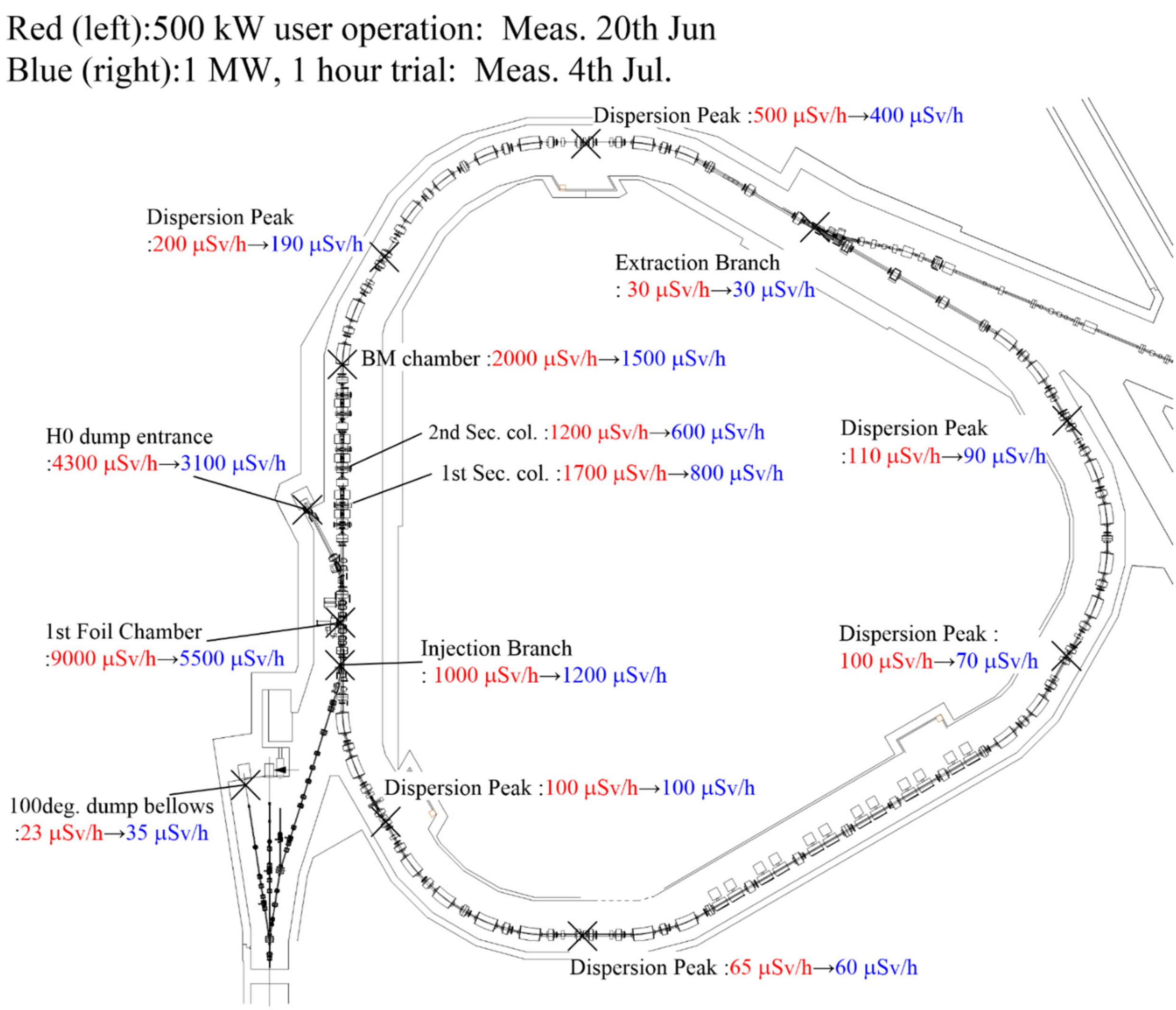

Figure 3: RCS residual dose distribution after 500-kW user operation and 1-MW trial.

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2019). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-TUPTS036

REFERENCES

[1] Y. Yamazaki ed., "Accelerator Technical Design Report for High-Intensity Proton Accelerator Project, J-PARC", KEK Report 2002-13 and JAERI-Tech 2003-44, 2003.

[2] I. Sugai *et al.,* "Double-layer effects on the lifetime of newly developed HBC-foils for RCS of J-PARC", *Nucl. Instrum. Methods Phys. Res., Sect. A* 613, 457 (2010).

[3] Y. Yoshimoto *et al.,* "Progress Status of Fabrication of Stripper Foils for 3 GeV RCS of J-PARC in Tokai-site", *Proc. INTDS conference 2018*, (2018).

[4] K. Yamamoto and P. K. Saha, "Recent Status of J-PARC Rapid Cycling Synchrotron", in *Proc. 9th Int. Particle Accelerator Conf. (IPAC'18)*, Vancouver, Canada, Apr.-May 2018, pp. 1045-1047. doi:10.18429/JACoW-IPAC2018-TUPAL020

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2019). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI