ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME061

PRESENT STATUS OF J-PARC -AFTER THE SHUTDOWN DUE TO THE RADIOACTIVE MATERIAL LEAK ACCIDENT-

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Abstract

In J-PARC, a radioactive material leak accident occurred at the Hadron Experimental Facility on May 23, 2013. The accident was triggered by a malfunction of the slow extraction system of the Main Ring synchrotron (MR). After seven-month long shutdown due to the accident, beam operation of the linac was restarted in December 2013. In this paper, the most recent status of the beam operation of the J-PARC is presented.

INTRODUCTION

The J-PARC accelerator comprises an H^- linac, a Rapid-Cycling Synchrotron (RCS), a slow cycling Main Ring synchrotron (MR) and related experimental facilities. The RCS provides the 3-GeV proton beam to neutron and muon targets in the Materials and Life science experimental Facility (MLF) at a repetition rate of 25 Hz. A part of the beam extracted from the RCS is injected into the MR, which accelerates the beam up to 30 GeV and delivers the beam to the hadron experimental facility (HD facility) using a slow extraction (SX) system and to the Tokai-to-Kamioka (T2K) experiment using a fast extraction (FX) system.

The maximum beam powers of the MR until the end of April 2013 were 240 kW for the T2K experiment and 15 kW for the HD facility users [1]. On May 13, 2013, the MR started the SX beam study for beam power higher than 15 kW. The beam power was gradually increased and reached to 30 kW in the study. User operation with 24 kW beam power was started on May 18, 2013.

RADIOACTIVE MATERIAL LEAK ACCIDENT

At around 11:55 on May 23, 2013, one of the spill feedback quadrupole magnets, Extraction Quadrupole (EQ), malfunctioned. A beam consisting of $2x10^{13}$ protons was extracted within a very short time of 5 ms and delivered to the gold target in the HD facility, whereas normally a total of $3x10^{13}$ protons were extracted for 2 s. The gold target was instantaneously heated up to an extraordinarily high temperature due to the short-pulse beam and partially damaged. As a result, the radioactive material dispersed from the gold target and leaked into the primary beamline room, because the target container was not hermetically sealed.

Since airtightness of the primary beamline room was not sufficient, the radioactive material leaked into the hadron experimental hall (HD hall) and workers were exposed to radiation. Additionally, due to operation of ventilation fans in the HD hall, the radioactive material was released into the environment outside of the radiation controlled area of the HD facility.

A hundred two persons, including visitors, entered the radiation controlled area of the HD facility on the day of the accident. Out of these, 34 registered radiation workers were found to have received total (internal and external) radiation doses in the range of 0.1 and 1.7 mSv, all below the legal limit. Medical examinations confirmed the absence of any adverse effects due to the radiation exposure.

The total amount of radioactive material released into the HD hall was estimated with a simulation based on actual data of the airborne sample that had been collected at HD hall and readings of the area monitors in the HD hall, being found to be ~20 GBq. The radiation dose of the site boundary at the location closest to the HD facility was estimated below 0.17μSv.

INPROVEMENTS IN 2013

After the accident, all of the J-PARC facilities stop the beam operation. The user operation of the MLF was resumed on February 17, 2014, after a nine-months long effort on preventive measures to the accident. During the long shutdown period, various improvements on the accelerators have been performed. Most of the improvements were planned before the accident.

Linac

In order to achieve designed beam intensity of 1 MW at the RCS and 0.75 MW at the MR, both an energy increase and an intensity upgrade of the linac are required. During the shutdown period, a new accelerating structure system, the Annular-ring Coupled Structure (ACS) linac was installed to increase the beam energy from 181 MeV to the full energy of 400 MeV [2]. Figure 1 shows photographs before and after the installation of ACS cavities. The ACS system has 21 accelerating modules, two bunchers and two debuncher modules. The resonant frequency of the ACS is 972 MHz, three times higher than that of the Separated-type Drift Tube Linac (SDTL) system. The two bunchers are installed in the section between the SDTL and the ACS linac for longitudinal matching. Two debunchers are installed in the Linac to 3 GeV Synchrotron Beam Transport (L3BT) section to decrease the energy spread of the beam to less than the energy acceptance of the RCS.

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Figure 1: Linac tunnel before (left) and after (right) the installation of the ACS linac.

For the intensity upgrade, a cesium-seeded rf-driven negative hydrogen ion source and a Radio Frequency Quadrupole (RFQ) linac for the beam acceleration of designed peak current 50 mA are planned to be installed in the 2014 summer shutdown period. The beam test of the new ion source and RFQ is now in progress in a newly constructed test stand. On February 6, 2014, the first 50-mA H- beam was successfully accelerated by the RFQ. After a test of long-term stability through continuous beam operation, the new front-end system will be installed in the linac tunnel in the 2014 summer shutdown period.

Figure 2: Test stand of the 50-mA ion source and RFQ.

RCS

Since the Great East Japan Earthquake, a large displacement of the magnets due to the earthquake, 10 mm peak-to-peak in maximum, increased beam loss in the collimator section and the 1st arc section of the RCS. In the 2013 shutdown period, re-alignment of all of the RCS magnets and the rf cavities was performed together with the magnets in the beam transport lines from the RCS to the neutron target (3NBT) and to the MR (3-50BT). All of the RCS magnets were re-aligned within error of ±0.1 mm, which is the same level just after the initial installation [3].

For the beam injection at 400 MeV, all of the power supply of four shift-bump magnets was replaced with newly manufactured one in the shutdown period [4]. The new system has 16 capacitor banks in parallel and generates a trapezoidal current pattern. The maximum output current and output voltage are 32 kA and 14.4 kV, respectively, to obtain fast rise and fall time of 150 µs.

For the ceramics chambers of the shift-bump magnet system, a part of capacitors mounted on rf-shield copper stripes was broken by the bump field due to the insufficient withstand voltage in the initial commissioning stage. In the 2013 shutdown, two of four ceramics chambers were replaced with new ones and only capacitors were replaced for another two chambers. The symmetric configuration of the rf-shield is recovered by the replacements. It is important to cancel dipole field ripple driven by resonant currents in the rf-shield loop.

MR

The main subjects of the improvements performed in the shutdown period are upgrade of ring collimator system and replacement of a part of beam duct. Four additional collimator units and additional iron shield walls were installed just downstream area in the beam injection section of the MR to increase the beam loss capacity of the collimator system from 2 kW to 3.5 kW. A part of quadruple and sextupole beam ducts made of stainless steel was replaced with new ones, which were made of titanium, to reduce residual radiation dose. The total 105 ducts in the injection straight section, the upstream half of the first arc section, and the horizontal dispersion peak positions of all the arc sections were replaced.

Preventive Measures to the Accident

After the accident, we have investigated the cause of the malfunction of EQ magnets in cooperation with the manufacturer of the EQ power supply. As a result of the investigation, it was identified that a primary failure occurred in part of the data transmission system of the power supply [5]. The setting value of the magnet current was not correctly transferring. This failure was resulted from voltage drop in a circuit board of the voltage power supply that supplies a fixed voltage of 5V to a circuit board of an interface that converts an external input signal. The EQ power supply had been operated without a failure since 2009. However, a circuit board of the relevant power supply was suffering aging degradation due to insufficient preventive measures against overheating in a three-terminal regulator and it led to the malfunction this time. To avoid having a recurrence of the aging degradation, we changed the configuration of the circuit board of the voltage power supply to have higher heat capacity.

On the other hand, the most important point is to have sufficient measures against malfunction of the system. The EQ system is improved as follows: 1) to stop the operation if anomalous current deviation is detected, 2) to shorten the time of shutdown when abnormality occurrence is detected, 3) to decrease the maximum setting of the current value of the power supply from 340 A (a maximum current of the power supply) to 120 A, which is sufficient for routine users operation.

For the HD facility, reconstruction of the facility including preventive measures against recurrence is now in progress. The main parts of the reconstruction are to make the target container air-tight, to make the boundaries of the primary beamline room air-tight, to make a new exhaust system which can vent the air in the HD hall through filters while monitoring the concentration of radioactivity in the air, and so on.

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BEAM OPERATION

Linac and RCS

The beam commissioning of the linac with the ACS system was started on December 16, 2013. The designed beam energy of 400 MeV was achieved on January 17, 2014. The beam commissioning of the RCS was started on January 30, 2014 and the 400 MeV injection beam was accelerated to 3 GeV on February 5, 2014. At the present time, the new power supply of the shift-bump magnets have a problem of current droop on the flat top. This effect is temporarily compensated by the other injection magnets, two pulse steering magnets in the beam transport line just upstream of the injection straight section, and four paint bump magnets in the injection straight section of the RCS. The problem of current droop will be solved by a modification of control system in the 2014 summer shutdown.

In the accelerator study in February of 2014, the RCS has demonstrated the high beam extraction of 560 kW, the same level of the maximum intensity before the energy upgrade of the linac. The beam losses are drastically improved by the reduced current ripple in the new shift bump magnet power supplies and symmetric configuration of rf-shield stripes on the ceramics chambers. The remaining beam losses are due to the foil scattering in the charge exchange beam injection. This high power demonstration with low beam losses is an important milestone for 1 MW beam operation in the near future [6].

The user operation of the MLF was resumed on February 17, 2014 with the beam intensity of 300 kW after the nine months beam shutdown since May 24, 2013. Figure 3 shows beam power history at the MLF as of June 11, 2014.

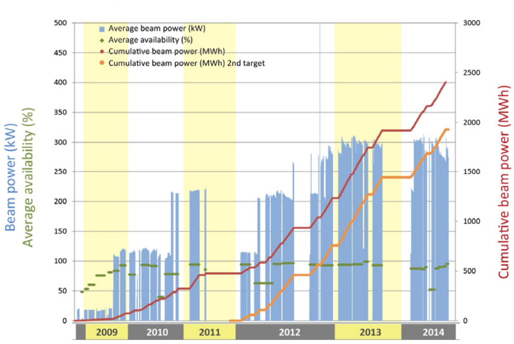

Figure 3: History of delivered beam at the MLF.

MR

Beam study of the MR was restarted on March 24, 2014. The injection beam from the RCS was accelerated to 30 GeV and extracted by the fast extraction system to the abort beam dump on March 30 for the first time after the accident in the HD facility.

To improve the optics correction in the beam transport line between the RCS and the MR (3-50 BT), one multi-ribbon profile monitor, three beam position monitors and three steering magnets have been additionally installed in the collimator section of the 3-50BT in the 2013 shutdown. The dispersion free optics in the collimator section of the 3-50BT has been successfully obtained. This optics correction is necessary to control the balance of the beam losses in the two collimator systems, the 3-50 BT collimators and the MR collimators, for the high power operation in the near future.

Beam delivery to the neutrino beam line has been resumed on May 16, 2014. Figure 4 shows the history of delivered beam to the T2K experiment as of June 12, 2014.

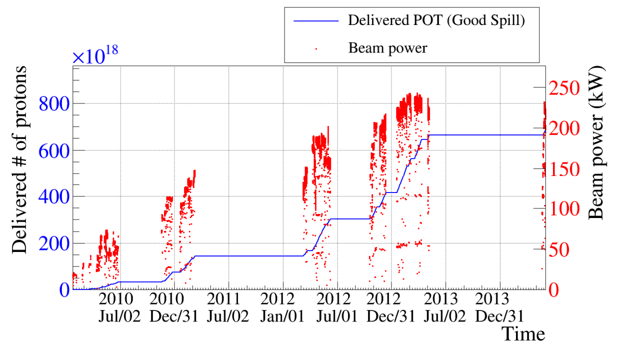

Figure 4: History of delivered beam to the T2K experiment.

NEAR FUTURE PLAN

After three-month shutdown in the summer of 2014, high-power beam study is planned in October to demonstrate 1-MW equivalent beam extraction to the MLF target. For the MR, beam delivery to the HD facility is planned to resume in the winter of JFY2014 after reconstruction of the facility including the preventive measures against recurrence.

The scenario of the MR to achieve the design beam power, 0.75 MW for the FX, is higher repetition rate operation [7]. The cycle time will be shortened from the present 2.48 s to 1.3 s by replacing the main magnet power supplies and the RF cavities. The first prototype power supply will be manufactured and tested within JFY2014. Mass production of the new RF cavities, which have high impedance cores, has been started in companies since 2013. All the nine cavities of the MR will be ready to install in 2015.

REFERENCES

[1] K. Hasegawa *et al.*, Proc. IPAC2013, pp.3830-3832.
[2] H. Ao *et al.*, Phys. Rev. ST Accel. Beams 15, 051005 (2012).
[3] N. Tani *et al.*, IPAC’14, Dresden, Germany, THPME066, *These Proceedings.*
[4] M. Kinsho *et al.*, IPAC’14, Dresden, Germany, THPME064, *These Proceedings.*
[5] M. Tomizawa *et al.*, IPAC’14, Dresden, Germany, THPME060, *These Proceedings.*
[6] H. Hotchi *et al.*, IPAC’14, Dresden, Germany, TUXA01, *These Proceedings*.
[7] T. Koseki *et al.*, Prog, Theor. Exp. Phys., 2012, 02B004 (2012).