INSTALLATION AND RADIATION MAINTENANCE SCENARIO FOR J-PARC 50 GEV SYNCHROTRON

M. Yoshioka, T. Fujino, H. Kobayashi, Y. Hori, K. Ishii, T. Kubo, H. Matsumoto, T. Oogoe, Y. Saito, Y. Sato, M. Shimamoto, Y. Takeuchi, M. J. Shirakata, M. Uota, Y. Watanabe
KEK, 1-1 Oho, Tsukuba, Ibaraki, Japan
M. Hosokawa, THK CO., LTD., 2-2-7 Sasano-cho, Hitachinaka, Ibaraki, Japan
Y. Kuniyasu, Mitsubishi Electric System & Service Co., LTD.,
2-8-8 Umezono, Tsukuba, Ibaraki, Japan
H. Oki, KDC Engineering Co., LTD., 1-58-4 Yayoi-cho, Nakano-ku, Tokyo, Japan

Abstract

This paper describes the installation of the accelerator components and the installation schedule for the 50 GeV J-PARC Synchrotron and the maintenance scenario for the handling of radioactive components.

INTRODUCTION

J-PARC is a high intensity proton synchrotron, which KEK and JAEA are jointly constructing at Tokai [1,2]. The accelerator is composed of a 181 MeV linac, a 3 GeV Rapid Cycling Synchrotron (25Hz, RCS), and a 50 GeV Slow Cycling Synchrotron (0.3Hz, MR) which has a circumference of 1568 m. The RCS primarily provides a 1 MW proton beam to a material and life science experimental facility. The MR receives part of the RCS beam (~5%) through the beam transport line (BT), which is 220 m long; after the MR accelerates it to the maximum 50 GeV, the extracted beam with an intensity of 750 kW is sent to two experimental facilities. Fast extraction delivers a beam for the long base line neutrino experiment T2K, slow extraction is used for the Hadron experiment. This paper describes the installation of accelerator components for the MR and a maintenance scenario for the handling of radioactive components.

Beam loss is the major factor which limits the operation of J-PARC. Once accelerator components become highly activated by any lost beam, it becomes very difficult to maintain components in the area. Our experience with KEK's 12 GeV proton synchrotron (PS), which was decommissioned in March last year, has shown us that the radiation exposure to workers would exceed the permissible level unless the radioactivity at the location where the workers would be is less than 0.5 mSv/h. The beam intensity of the PS was 5 kW, which is less than 1% of the J-PARC design, but beam losses sometimes reached 500 W, producing radiation levels exceeded 10 mSv/h in the immediate area. For the J-PARC MR, the expectation is that the beam losses should concentrate in the five areas shown in Figure 1 and that the beam loss everywhere outside these five areas should be at less than 0.5 W/m. According we designed the aperture of MR carefully considering this scenario. In order to cut the beam halo locally, there will be two collimator systems [3], one upstream in the BT and one in the MR. Septum magnets for beam injection and extraction are the most critical MR components in this regard. Necessarily the septum magnets aperture is ultimately a trade-off where electromagnetic and mechanical requirements are compromised, and we have to accept a certain amount of beam loss. Given that, we have worked out a safe and yet practical maintenance scenario for possible required replacement of the units comprising the two collimators, the beam injection, slow extraction, and fast extraction systems.

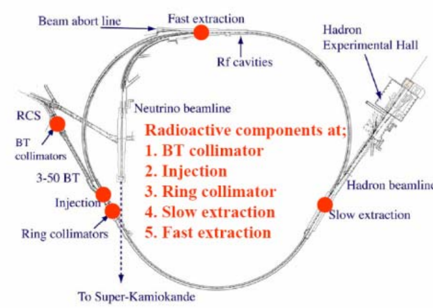

Figure 1: Location of radioactive components

INSTALLATION OF MAGNETS

Installation

The BT and MR magnet quantities and weights are shown in Table 1.

Table 1: BT and MR magnets

	Type of Magnet	Qty.	Weight (ton)
MR	Dipole	96	33
	Quadrupole	216	10~15
	Sextupole	72	2
	Resonant Sextupole	8	2
	Corrector dipole	186	0.3
BT	Pulse dipole	1	16
	Horizontal dipole	3	14~18
	Vertical dipole	2	4.5
	Quadrupole	38	3.5~5.5
	Corrector dipole	14	0.75

The floor level of the accelerator tunnel is excavated ~11 m below the ground surface. Magnets are unloaded at a carry-in vertical shaft by crane and conveyed to the accelerator tunnel by truck. The BT has a crane which is used to install the magnets in the accelerator tunnel. The two straight sections for fast and slow extraction in the

MR also have cranes, but there are no other cranes in the MR. As seen in Figure 2, we used an air floatation transport systems of custom design (the air pallet) to transport and install the bending and focusing magnets which weigh 10~33 tons each. After the magnets are transported to their predefined locations, the bed of the air pallet which holds the magnets is separated from the moving transport part. Finally the magnets are moved on to the beam line and positioned manually. A conventional truck and temporary crane were used to transport and install small correction magnets and other parts. The interior cross section of the standard parts of the tunnel is 5 m wide and 3.5 m high which provides adequate workspace. By now we have almost finished installing magnets everywhere except in the straight sections. We will concurrently be installing cables, completing the vacuum and beam diagnostic systems, and connecting cooling water to the magnets. We will start installing beam injection, fast beam extraction, and the RF acceleration system in September 2007, and finish most of the installation work by the end of November 2007. Off-beam commissioning will start in December 2007, and MR beam commissioning will begin in May 2008. The slow extraction system, however, is scheduled to be installed between July and September 2008.

Figure 2: air float transportation system

Uneven Settlement of Accelerator Tunnel Floor

Two problems have arisen because we are installing magnets as soon as possible after civil construction is completed for each tunnel section; this is necessary to meet J-PARC's overall construction schedule. One problem is the difficulty of managing and scheduling concurrent operations, and the other is the large and uneven settlement of the floor level [4]. Settling of up to a maximum of 40 mm has occurred in places, and there is no sign of stabilization yet. We can solve the first problem through our own effort, but we have no solution for the second but to wait until the ground finally compacts solidly. The subsurface at the site is composed of mudstones, and the topology of both the bedrock and the terrain above are complicated because the work of the rivers that formed the complicated subsurface terrain during the past hundred thousand years is buried. Currently we are adjusting the magnet alignment only as much as needed to connect the vacuum ducts, but we will need to redo the magnet setting and do precise alignment before the beam commissioning which is scheduled to start in May 2008.

MAINTENANCE SCENARIO FOR RADIOACTIVE COMPONENTS

General Description

We need to make the septum magnets replaceable in order to upgrade beam performance, to decrease beam loss, and to improve reliability. However, direct hands-on manual maintenance work may be out of the question because of residual radiation, such as when a septum magnet fails to operate properly. In such a case, workers would have to remain several meters away from the septum magnet in order to decrease their radiation exposure all the while somehow detaching and extracting the magnet from the beam line quickly. The procedure would involve first detaching vacuum flanges, disconnecting the cooling water plumbing and electrical cables, and finally moving the magnet away to where it could be dismantled and worked on. In this paper, we will focus on our concept for detaching the vacuum flange and uninstalling the magnet, as both of these have a large impact on the magnet design.

Vacuum flange and semi-remote handling

To reduce the time required working with the flanges, in cooperation with Cefilac we decided to chose a large aperture quick-disconnect ISO 1609 compliant vacuum flange system. We also selected the Cefilac Helicoflex-delta type for the vacuum seal because its compressive force requirement is small. This Cefilac product line offers several flange apertures ranging from 180 mm to 450 mm. Here, we will describe the common mechanism necessary for semi-remote handling. We focus on the bellows and flange components in the vacuum system. The procedure for disconnecting the vacuum connection is divided into two steps of (a) loosening the chain clamp which releases the flange and (b) compressing the bellows to open a gap between the two flange surfaces of more than 15 mm.

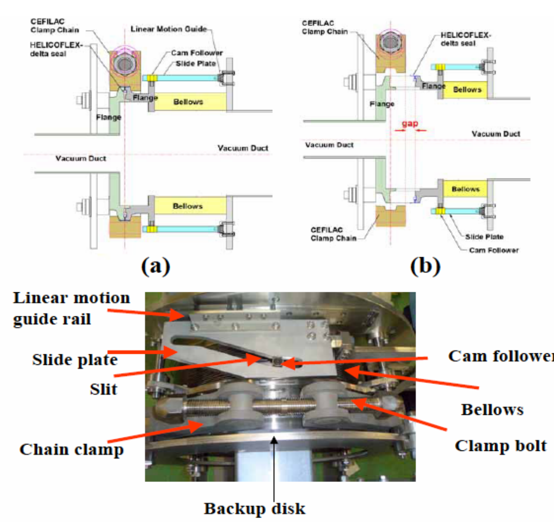

Figure 3: Semi-remote handling vacuum flange(a) Loosen the chain clamp, (b) compress the bellows

As shown in Figure 3, the chain clamp is attached to the backup disk. Depending on the magnet type and where it is situated, the backup disk may be fixed to the vacuum duct, to the magnet itself, or be supported on an independent stand. As the clamp bolts are loosened, the clearance about the flange opens evenly because of a spring set inside the clamp. The clamp bolts can be loosened using a special tool from a position several meters away from the magnet. The other half of the flange is welded to the bellows. Two cam followers are affixed above and below the bellows on the flange side. The linear motion guide rail is fixed perpendicular to the beam axis. One can push the slide plate, which is mounted on the rail, using another long special tool. The plate has a slit at 30 degrees against the right angle of the beam axis, and the cam follower moves inside the slit in the direction of the beam. This allows the bellows to be compressed along to the direction of the beam. Roughly reverse steps are required to reconnect the flange; the flange has a self-aligning design to allow mating the connection even if the original flange centers are off by up to 1.5 mm. Because the guide rail needs a lubricant agent, its radiation resistance is an important design criterion. We have selected a lubricant agent which should have enough radiation hardness.

Detaching magnets and reinstalling them

Next we move on to describe the scenario for moving the magnet away after detaching the vacuum flanges, cooling water, and various cables which tie it to the beam line. We originally planned to use the same air pallet built for the magnet installation but we then concluded that it was not suitable for providing the stable and precise control needed because the distance between the two flange surfaces may be only 15 mm at minimum. Therefore we have worked out an alternatively method. After installing a linear motion guide rail perpendicular to the beam on the tunnel floor, we place the septum magnets and the support table on the linear motion guide rail. In the initial installment, the rail, support table, and septum magnets are fixed after they are aligned to the necessary precision. Locating brackets have a structure that allows for easy detachment by semi-remote handling, making it possible to move the support table and septum magnets perpendicular to the beam line with a small amount of force. Once they come out of the line, they are loaded on a truck using the setup or temporary crane and transported outside through the tunnel. A general purpose truck is sufficient for this. We are currently examining this mechanism for septum magnets for fast beam extraction. Originally developed for a group of final focusing magnets at the collision point of KEKB [5], this method has been used some dozen times during the past ten years without any trouble. In addition, it has location reproducibility that is less than 20 μm, and we can safely say that it is an established technology.

For installing an entirely new septum magnet, away from the hot area we would build up a mock-up simulating the actual beam line and where the new septum magnet could be a pre-aligned. After that, it could be transported to the accelerator tunnel, and installed on the beam line using the semi-remote procedure.

SUMMARY

We are installing accelerator components to prepare for pre-beam commissioning scheduled to start in December 2007. Installation of magnets will finish soon and the installation of cables, vacuum and beam diagnostic systems, and cooling water connections will go on at a quick tempo. Except for the slow beam extraction system, we will start installing RF acceleration, beam injection and fast beam extraction systems in September 2007.

Installation of accelerator components has been carried out concurrently with the civil construction and uneven foundation settlement remains an issue because of the site ground characteristics. It will be necessary to correct and realign to the required alignment precision before the beam commissioning can begin.

The basic idea of maintenance scenario is to localize areas that might become highly activated by using collimator systems in the BT and MR. Since septum magnets for beam injection and extraction are critical components for the reliable operation of J-PARC and yet have to be where beam loss is inevitable, they should be replaceable. Accordingly a semi-remote handling vacuum flange system has been developed. Septum magnets will be mounted on a linear motion guide rail, which is set on the tunnel floor perpendicular to the beam line. The guide rail will allow smoothly transitioning in and out of the beam line the magnets for beam injection and the two beam extraction systems.

ACKNOWLEDGMENT

This paper describes work done in part by the accelerator team of J-PARC. We have consulted closely with the groups doing remote handling for J-PARC's T2K and Hadron experiments. We also appreciate and profited from exchanging very informative ideas with Dr. N. Holtkamp and the Group of Dr. G. Murdock of SNS (ORNL), and Dr. P. Gear of ISIS (RAL).

REFERENCES

[1] T. Koseki et al., "Present Status of J-PARC MR Synchrotron", This conference,

[2] F. Naito, "Present Status of J-PARC", This conference

[3] M. J. Shirakata et al., Proc. of EPAC'06 Edinburgh, Scotland, June 2006, p. 1148,

[4] M. J. Shirakata et al., "The Magnet Alignment Method for the J-PARC Main Ring", This conference,

[5] K. Kanazawa et al., "The Interaction Region of KEKB", Nuclear Instruments and Methods in Physics Research Section A, Vol. 499, Issue 1, 21 February 2003, p. 75