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

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Abstract

The accelerator tunnel of the J-PARC 50 GeV Synchrotron is still under construction, and will be completed at the end of 2006. Installation of accelerator-components is scheduled to start in July 2005 in parallel with civil and utility construction, and beam commissioning will be started in January 2008. This document describes how to install accelerator components in the tunnel and a radiation maintenance scenario.

INTRODUCTION

The J-PARC is a joint project between KEK and JAERI. It is composed of the Linear Accelerator (LINAC, 181MeV at the beginning), the 3-GeV Rapid-cycling Synchrotron (RCS), and the Main Ring (MR, a synchrotron with the maximum energy of 50 GeV) as shown in Figure 1 and 2 [1,2].

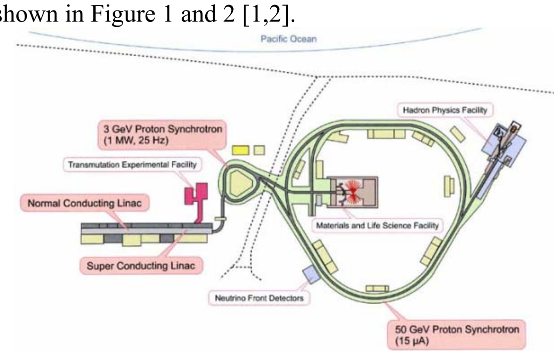

Figure 1: Layout of accelerators of the J-PARC [1].

Figure 2: Construction view.

JAERI and KEK are respectively in charge of construction of the LINAC and the RCS, and the MR. In this year civil and utility construction of the LINAC and the RCS are nearly completed, and those of the MR are nearly 40% completed and are scheduled to be finished at the end of 2006. As for the MR, installation of its components in the completed portion of the tunnel is started in July 2005 without waiting for the completion of its civil and utility construction. Start of the integrated beam commissioning of the accelerators is aimed for in January 2008. We decided the installation method of the components considering a radiation maintenance scenario, which are described in this report.

ACCELERATOR TUNNEL, BEAM LOSS AND RADIATION SHIELDING

A beam extracted out of the RCS is divided into 2 beam-lines using a pulse-bending magnet, which is located 225 m away from the MR; one is sent to a neutron facility, and the other to the MR, whose circumference is 1567.5 m. In order to reduce and localize beam-induced activation of the components, collimation systems are arranged both in the beam transport section (3-50BT) from the RCS to the MR and in the straight section of the ring just after injection, respectively. The downstream beyond the collimation system in the 3-50BT is shielded with 1.5 m-thick concrete walls (BT shield) except for the beam-duct portion. Because the beam level of the MR is 4.3-m lower than that of the RCS, the downstream beyond the BT shield has a slope of 2.86-degree. The following 5 areas (called the active areas in the following) where large beam losses are anticipated is shown in Figure 2: (1) 3-50BT collimation system (450 W), (2) beam injection system (135 W), (3) MR collimation system (450 W), (4) slow extraction system (7.5 kW), and (5) fast extraction system (1.13 kW). The numbers in the parentheses are beam losses on which the shield design is based [3]. The cross-sectional geometry of the standard section of the accelerator tunnel is as follows: width between inner surfaces = 5 m, height = 3.5 m, and floor level is 2.1 m below sea level. The concrete frame structure is as follows: floor thickness = 1.2 m, wall thickness = 0.8~1.0 m and ceiling thickness = 1 m. The tunnel is covered with soil with a thickness of 8.4 m on the upper side. The maximum beam loss at the standard section is assumed to be less than 0.5 W/m, and the design dose rate at the surface of the mound is 0.25 µSv/h or less. As for the tunnel frame structure of the active areas, concrete thickness is increased, and furthermore beam-induced activation of the tunnel walls is prevented by employing concrete with a reduced Na element, which generates a long-life radioactive isotope in the inner surfaces. The maximum beam losses were assumed in the

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respective active areas as the design criteria for the thickness of the concrete and the mound. These numbers are just the criteria for the shield design, and losses of these numbers are not allowed at all times in the actual operation, but the ALARA (=As Low As Reasonably Achievable) principle of the International Commission on Radiological Protection is followed [4]. Beam emittance, and acceptance and aperture of the accelerator which serve as yardsticks for the beam loss estimation are as follows (unit: π mm mrad): (a) RCS beam: 216, (b) BT collimator: 54, (c) BT line aperture: 120, (d) MR aperture: 81, (e) MR collimator: 54, (f) 30 GeV MR beam: 10, (g) 50 GeV MR beam: 6, and (g) fast extraction septum aperture: 16.

INSTALLATION OF COMPONENTS AND RADIATION MAINTENANCE

Transportation of components

The numbers and the weights of the magnets are summarized in Table 1.

Table 1: Nnumbers and weights of magnets

	Magnet	Total number	Weight
MR	Bending	96	35 ton
	Focusing	216	~15
	Sextupole	80	~3.5
	Steering	186	~0.24
3-50 BT	Pulse Bending	1	16
	DC Bending	5	8~18
	Focusing	38	3.5~5.5
	Steering	14	0.7

Figure 3: Mock-up of the tunnel.

Figure 4: Air pallet

The cross-sectional sizes of the tunnel in the standard section were decided in consideration of an economical efficiency. Cranes for transporting the magnets were not installed also by the same reason, but air pallets were made as an alternative method. All components to be set up in the downstream beyond the BT shield and in the MR are installed through the vertical shaft shown in Figure 2. The components to be set up in the upstream of the BT shield are installed through the carry-in entrance for the RCS. The air pallet can travel stably with the aid of the guide rails set up along the walls in the tunnel. The reason for choosing the air pallet is twofold: first, it is suitable for transporting heavy load, and secondly, it can perform tasks in a short time in an environment with a high activity level when failed components are carried out in the case of failure. Figure 3 shows the mock-up of the standard section of the accelerator tunnel. Figure 4 shows photographs of the air pallet for transporting the bending magnets. Cranes with capacities enough for hoisting components are set up in (1), (4), and (5) ampong the 5 active areas in consideration of the radiation maintenance, and maintenance work is performed by combining the cranes and the air pallets.

Policy for radiation maintenance in active areas

As for the activity-level of the components in the active areas, it can possibly be over 10 Sv/h at portions, which beam halos directly hit. As an example for the BT collimator, when the worst scenario is assumed where the beam loss of 450 W occurs at 1 site, beam-induced radiation at the Ta-made collimator section is over 10 Sv/h. However, because 50-cm-thick iron-made blocks cover the collimator section, the radiation level on the block surface does not exceed 50 mSv/h. We decided to employ a hands-on method for the maintenance work at the active areas instead of remote handling, which is necessary for target sections. However, in order to suppress exposure doses of workers low enough, 3 elements—Time, Distance, and Shielding, which are standard methods for radiological protection—are combined. The Time here has 2 meanings. One is to wait for 10–20 days during which the beam-induced radiation rapidly decays until start of maintenance work after stopping the accelerator. The other is to shorten the work time as short as possible. The Distance means that works required for maintenance such as moving of components, attaching and removing of vacuum flanges, cooling-water ports, and current-terminals, and work with a crane are conducted at least several meters away from components to be worked on. The Shielding means putting shielding blocks between workers and components. We have decided to make easy-to-move blocks, learning lessons from experiences of ISIS [4].

Work procedure for changing components

Quick disconnect system (Cefilac/Garlock Sealing Technologies), and Helicoflex delta type, were employed for vacuum flanges and gaskets, respectively. Standard products are used as they are in the standard section where the beam loss is estimated to be 0.5 W/m or lower. Because duct diameters in the active areas are bigger in many cases than those in the standard section, and clearances between neighbouring components are narrow, connecting and removing work of flanges and moving of components are difficult. An explanation is made taking removing work of a 35-ton septum magnet, the heaviest in the fast extraction system, as an example. The flange diameter of the septum magnet is as large as 450 mm, and in addition the clearance between flange faces of neighbouring ducts is as narrow as approximately 15 mm when bellows are shrunk. Therefore, it is set up on the linear motion guide rails set up on the floor so that instruments can be easily pulled out in the direction perpendicular to the beam line. The work procedure is shown in Figure 5.

(Step-1) Movable shielding blocks are properly arranged. The obstructing septum magnet is temporarily removed. Removal of vacuum flanges, couplers of cooling-water pipes, and current leads is conducted several meters away by hands-on work.

(Step-2) The magnet separated from neighbouring components is pulled out by sliding on the linear motion guide rails.

(Step-3) The instruments are loaded on the air pallets using a crane, and carried out.

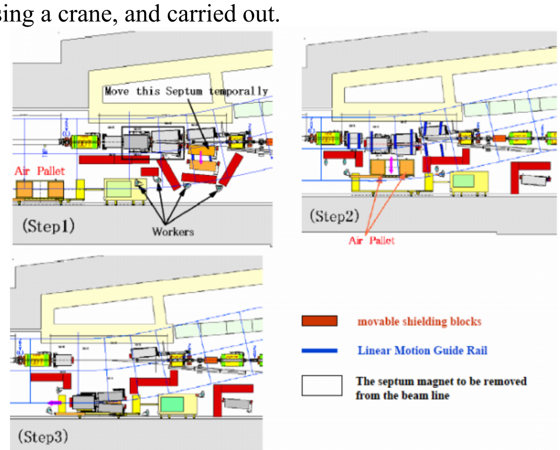

Figure 5: Carryout procedure for the septum magnet, the heaviest in the fast extraction system.

A mechanism required for detaching vacuum flanges from a distance has been prototyped and tested. As for attaching and removing of cooling-water pipes, commercially available products shown in Figure 6 can be used practically as they are.

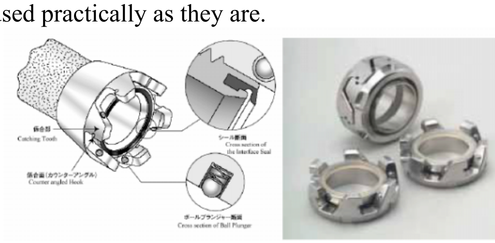

Figure 6: Cooling-water pipe couplers capable of remote attachment and removal [5].

Although Silicon rubber is used as a sealing material in them, a sealing material made of EPDM rubber is under development within whose permissible range the degree of hardening by radioactive exposure dose up to approximately 5 MGy exists.

SUMMARY

Installation of instruments for the MR starts in July 2005 in parallel with civil engineering and construction of conventional facilities. Start of integrated beam commissioning is aimed for in January 2008. Air pallets are used for transporting components and maintenance work in the tunnel. Cranes are set up at the locations (1), (4), and (5) shown in Figure 2 among the 5 active areas where large beam losses are anticipated, and maintenance work is conducted by combining cranes and air pallets. Although maintenance work in the tunnel is basically conducted by a hands-on method, maintenance work in the active areas is conducted by quick working away from instruments utilizing movable shielding blocks based on 3 principles of Time-Distance-Shielding. Components requiring fine position adjustment are set up on the linear motion guide rails. A mechanism capable of attaching and removing vacuum flanges, cooling-water pipes, and current leads from positions several meters away in as short a time as possible is under development.

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