STATUS OF J-PARC ACCELERATOR FACILITIES AFTER THE GREAT EAST JAPAN EARTHQUAKE

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Abstract

J-PARC was severely affected by the March 11 Great East Japan Earthquake. When the earthquake struck, we had a beam study operation of the linac, and the machine automaticallystopped immediately. Many places particularly around buildings subsided. Underground water came into the linac and the main ring tunnels as well. The water level at the linac reached a depth of 10 cm, but pumping out flooding water with using a diesel generator was succeeded lowering the water level. At the Rapid Cycling Synchrotron (RCS), the surroundingroad got waved, and the yard area for electricity and cooling water devices was severelydistorted. We investigateddamages of each facility, and have beentrying to restore the facilities.

INTRODUCTION

J-PARC, which stands for Japan Proton Accelerator Research Complex,consists of a linac, a 3 GeV synchrotron (RCS) and a Main Ring synchrotron (MR) and a few experimental facilities. A proton beam from the RCS is injected to the Materials and Life Science Experimental Facility (MLF) for neutron and muonexperiments. The MRaccelerates a beam up to 30 GeV. The beam is used for hadron or neutrino experiments.

No user services were coincidentally scheduled in the daytime of March 11. Beam study at the linac, and radiation survey work at the RCS and MR tunnels were carried out, respectively.The earthquake occurred when we suspended a beam for changing a beam destination from the linac to the RCS. The earthquake intensity was 6 lower at Tokai on the Japanese seismic scale of zero to seven. It is extremely fortunate that we had no effects fromtsunami and no one was injured.

STATUS OF LINAC

The linac building is approximately 330 m in length, and 44 -48 m in width. A wide area at the entrance of the linac building subsided~1.5 m, and almost all water supply and drainage pipes were broken as shown in Fig. 1.

We could not get into the building until March 17 due to many strong aftershocks after the earthquake.It was found that there were no severe damages on the accelerator itself, but that water accumulated 1cm in deep on afloorof the linac tunnel.When weenteredthe tunnel again a week later on 24ththe water level increasedto approximately 10cm as shown in Fig. 2. It meant the water level increased more than 1cm per day, and then we decided to pump it out immediately.Since the electricity had yet not been restored for the building, weuseda diesel engine generator.It took two days to drainapproximately 150m^3 of water. Whenthe floor exposed,alarge number of lateral cracks were recognizedon the floor and the wallsmainly in the middle of the tunnel.

Figure 1: Subsidence at the entrance of the linac building.

We were afraid if any component of the linac was damaged by inundation.One of the components was vacuum pump placed on the floor. Werinsed and dried the pumps, and then turned them on after checking insulation resistance.It turned out that eight pumps and four controllers out of 36 pumps were broken down.Small aluminiumboxes for diagnostics pre-amplifiers on the floor had been also submerged, and resulted in being corroded by strong alkali water through the concrete wall.Severalbeam monitorsand bellows welded tobeam transport pipes between cavities were damagedtoo, due to strongvibration[1].

Acceleration cavities,such as an RFQ,a DTL andan SDTL,werechecked through visual inspection, vacuum test, and measurement of resonant frequencies and Q factors.As a result, small vacuum leaksatsome flanges but

Figure 2: Flooding in the linac tunnel.

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no RF property changes were found.Displacement of the drift tubes in the DTL and SDTL cavities was observed by an alignment telescope. The measurement showed that a few drift tubes in the first DTL tank had approximately 0.1 mm displacement.

Damages on the building were more serious. Pillars in theroom called "klystron gallery"inclined,becausetheirbases were damaged. As a result, most of the cranes have notbeen available yet.In addition, air conditioning ducts and plumbing system were also severely damaged. Restorationon the buildingisunderway.

Levelling and horizontal floor surveyswerecarried out to examine displacement of the tunnel floor[2]. It appearedthat there was the deformation of several tens of millimetres in horizontal and vertical directions. It is time-consuming work to move the DTLsby several centimetersbecause a large number of heavy cables for electromagnets are connected. We considered a better scenario for the realignment of the DTLs and also the SDTLs to meet the entire restoration schedule with minimizing an effect on the beam degradation[3]. The realignment work is presently underway based on the scenario.

STATUS OF RCS

The RCS building is located approximately 400m from the shore and 15m above the sea level. The accelerator components are installed on the basement second floor of a main tunnel, and there is a sub tunnel where power supply cables and cooling water pipesare installed. We havemany high power devices, such as chilling refrigerators, cooling towers, capacitors, transformers, rectifiers, power distribution boards, etc., in the yard.

Since the yard subsided by 30 cmto1 m at many places, high voltage distribution boards inclined very badly,and the bus barsfor transmission werealso damaged. Power supply should be cut off until the completion of these repairs.

The accelerator components in the yard suffered from serious damages. Many bases for capacitorsand transformers for resonant power supplies and rectifiers forRF cavities inclined. There were many hollow spaces underneath of bases as shown in Fig. 3.Cable trays installed along the buildingand all 4 cooling towersfor the water systemwerealso damaged.

We evaluated damageson accelerator components with the following two steps. Firstly,we carried out a visual inspection of the components.Secondly, we carried out a low-power inspectionofvacuum pumping system and diagnostic devices, etc.Our biggest concernis a status of ceramic chambers.We visually inspected them from the outside, and then conducteda vacuum test with using six turbo molecular pumps.The vacuum pressuredropped toan order of 10^{-4}~10^{-5} Pa after four hours exhaust, indicating that there werenolarge leaksin the chambers and they werealmost sound.In addition, we tested power supplies and monitors with using alow electric voltage.Although there were some minor malfunctions, no serious damages existed.In order to restore the yard and the high voltage electric boards, we havehad complete power outage from the middle of June to the end of August.After havingthe electricity in September, we will startthe restoration of the cooling watersystem, and will perform the detailed check of the components with usinga high electric voltage.

STATUS OF MR

The MR facility consists of a main tunnel at the circumference of 1.6 km, two carry-in buildings, three power supplybuilding, and three machine building for the HVAC and cooling water system, etc.

More than 30 cracks were foundin the MR main tunnel, and groundwater leaked from these parts.Since the lighting in the tunnel restored on March 25 two weeks after the earthquake, wecouldinvestigatethe status of MR, finding that some electromagnets was continuously hit by leaked groundwateras in Fig. 4.Fortunately, the tunnels, except a part of the sub-tunnel, did not flood because of the presence ofa side ditch. We carried out emergency sealing workat the pointsof heavywater leaks.An attachedbuilding tothe main tunnel subsided, and alevel difference was approximately 5cm at the expansion joint part.

The beam line components were also tested, and vacuum pressure increased to230 Pa within two weeks

Figure 3: Hollow space underneath of a base for capacitor and transformer racks in the RCS yard.

Figure 4: Groundwater leakage in the MR tunnel. The magnet is covered with the sheet.

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after the pump stopped due to earthquake.This pressurewas approximately three orders of magnitude higher than that atnormal stop. There was a relatively large leak at 10^{-4} Pa-m^3/secin a flange joint of the septum electromagnet. After the restoration of the control computer, we examined the pressure history, confirmingthat this leak occurred at the earthquake. We had a detailed test all over the ring,andfortunately, there werenoleaksin the beam ducts. As for the MR, the damage of the infrastructure was relatively lighter than those ofthe linacand the RCS,incoming panels/lines for high receiving voltages, air conditioningsystem, and cooling water systemhad been restored by the end of May.With the test of the main electromagnet power supply on May 30 as a starter, we have testedin operation modeof electromagnets in the beam transport line,steering magnets, devices for slow extraction, an RF acceleration system, injection devices, and fast extractiondevices, sequentially. It was confirmed that there werenoserious problems. A malfunction such as interlamellar short circuits was not recognized even for the electromagnet which got wet with groundwater drops.Inspection of the various beam monitor system has been continued, andnoserious damage has been found to date.

Inspectionof main electromagnets was performedwith using a laser trucker from April 18 through May 30[4].It appeared that there was big displacement in some places as it was concerned. Displacement washorizontally ±10 and vertically±15mm. We are considering aneffective way to align magnets.

STATUS OF EXPERIMENTAL FACILITIES

Regardingthe MLF, an attachedbuilding for a long baseline of the neutron spectrometer sank approximately 15cm compared tothe main MLF buildingand damageswere foundon the beam line.Furthermore, a platform for the mercury target for the neutron production moved, and the connected bellowswas lengthened. We need to replace the target, but the delivery is expected to be in November because the factory of the target vesselalso suffered from the earthquake.Vacuum leak wasfound in half of the neutron shutters. In addition, most of the steel shieling blocks slipped off.The work of draw out and reload of several thousand tons of shielding blockshas beenunderway since June.

There were manysubsidencespots around the building ofNeutrino Experimental Facility. The restoration workhas been carried out.On the other hand, very little damage was found in the main components up to date.Foreign researchers of the T2K group whowent back to theirhome countriesgradually havecome back to J-PARCsincethe middle of May.

Subsidencealso occurredaround the Hadron ExperimentalFacility.All 6 bolts to fixthe north and south beam directionwere broken, and it appeared that there wasa danger of collapse.The restoration work has been completedby the end of August.Abig damagewas not found in the main components, but there are manygapsbetweenshielding blocks.We plan to reload these blocks.

BEAM RESTORATION PLAN

On May 20, the J-PARC Centerannouncedtherestoration schedule[5].The main points are as follows:

- We would start test operation with using beams in December of 2011.
- The user program will start with beam time of about 50 days until the end of March 2012 (within Japanese fiscal year of 2011).

Note that this schedule would be valid assuming the requested budget is usable as we plan. The schedule is also strongly influenced by aprogress ininfrastructural recovery particularly for the linac and the RCS.

J-PARC haddelivered beams progressively since 2008. The accelerators ramped up the beam power, and delivered beams of 145kW and 220kWtoT2K neutrino experiment and MLF, respectively,before the earthquake [6,7].The T2K group announced on June 15 that theyfirst had detected 6 possible events which suggested the transformation from muon neutrinos to electron neutrinos based on the data collected before March 11, 2011[8]. As remarkable resultshave beenpresentedby researchers of the MLF and the Hadron ExperimentalFacility, effects from the suspension of experimentsdue to the earthquake areimmense.We, however,are making the best effort to resume the beam operation as we planned.

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