BEAM MONITOR DEFORMATION BY TOHOKU EARTHQUAKE AND ITS RECOVERY PROJECT*

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Abstract

On March 11, 2011, the great earthquake occurred off the Pacific coast of Tohoku. This earthquake and related ones caused the big damage of the J-PARC accelerators. As for the beam monitors in J-PARC Linac, some commissioning tools had damage and the vacuum leakage was observed. In the recovery work, we inspected the damage and put the emergency steps for the vacuum equipment. In this paper, detailed inspection results of beam monitors are described and also the recovery work is introduced.

INTORODUCTION

The great earthquake occurred on March 11, 2011 at 14:46 JST off the Pacific coast of Tohoku. The seismic intensity was 6^- (JMA scale) at J-PARC [1]. Although tsunami came to the Tokai-site coast, well below the ground level of J-PARC. No injuries were observed for J-PARC related persons. Also the tsunami came to the Tokai-site, but no damage occurred.

Alignments of the accelerators in J-PARC were deformed [2-3]. Vertical level variation of ~40 mm was observed in the linac. And the level has been slightly shifted after the quakes. Detailed inspection had been completed. This paper focuses on the detailed inspection results of beam monitors and the recovery work for it.

OVERVIEW OF BEAM MONITORS

In the present situation, an RFQ (Radio Frequency Quadrupole), three DTL (Drift Tube Linac) cavities and fifteen pairs of SDTL (Separated-type DTL) cavities are employed for the beam acceleration to obtain the beam energy of 181 MeV. The SDTL cavities are installed on the trestle tables. As described in Fig. 1, fifteen A and B pairs of SDTL cavities are installed in each common trestle. Three phase monitors (FCT: Fast Current Transformers) are delivered to the exit of all SDTL cavities and the entrance of the A (upstream) cavities. Beam transport and bellows are connected with the FCT, and beam current monitors (SCT: slow current transformer) with beam position monitors (BPM), also BPM with the endplate of the cavities.

J-PARC LINAC presently employs the following beam monitors; 38 SCT monitors, 61 FCT monitors, 36 beam profile monitors (WSM: wire scanner monitor), 102 BPMs and 124 beam loss monitors (BLM) [4]. Twenty SCT monitors and forty-five FCT monitors will be additionally installed in the future ACS (Annular Coupled Structure) section [5].

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INSPECTION AFTER THE QUAKE

During the short interval between the Linac beam operation and the preparation of the RCS beam operation, the quake occurred. Faraday cup had already inserted to stop the operation temporally, but any other devices and infrastructures were working.

One week after the quake, some delegations accessed to the accelerator tunnel to check the accelerator and its related infrastructures. At the time, no collapse of the accelerator components was found but approximately 1 cm depth of the water flooding was found. Because of the no electric power and no ventilation, we couldn't inspect the detail of the damage of the accelerator. After two-week intervals, we started again the damage inspection of the facility.

According to the detail inspection, we found the deformation of the several beam monitors and bellows welded with beam transport pipes (Fig. 2, 3, 4). Because the alignment of the acceleration cavities and the beam monitors should be required, the devices installed in the drift space which is located between the cavities were

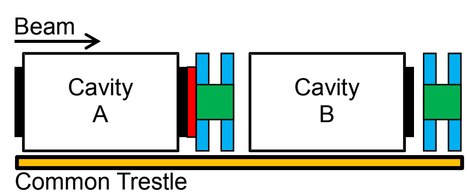

Figure 1: General Layout of the Beam Monitors in SDTL section. This describes a pair of SDTL cavities on a trestle, i. e. both A cavity (left) and B (right) cavity are installed together on the same trestle. The linac has 15 pairs of the SDTL cavities. Beam comes from the left side. Black boxes are FCT monitors, red one is SCT and green ones are BPMs.

Figure 2: Deformation of the bellows with CT monitor installed on the endplate of the SDTL cavity.

dismounted. Vacuum leakage of all removed devices is inspected by helium leak test.

Damage in the Accelerator Tunnel

Vacuum leakage was found at the MEBT1 and SDTL section. Because the MEBT1 is a matching section between RFQ and DTL cavities, there are many tuning magnets and beam monitors. As the result of the helium leak test, leakage was found at the welded point between the bellow and the BPM.

Due to the damage of the FCT monitors, vacuum leakage occurred at the accelerator cavities and beam transport pipe. The monitors had experienced many quakes until then, but there had had no damage on them. After the quake on 11, March, we found the deformation of the SCT and FCT monitors. Ceramic parts could be seen from outside of the beam line (Fig. 3). In the FCT monitor, thin magnet core and ceramic block to keep insulation are enclosed in the vacuum case. Also in the SCT monitor, magnet cores are doubly enclosed in the case (Fig. 5). After the damaged FCT monitors were dismounted to be observed carefully, detachment of the ceramic parts was confirmed. Damage was mainly observed at the part where the ceramics and metal parts are brazed (Fig. 6). Seventeen FCT monitors were damaged and thirteen of the seventeen ones were deformed by the detachment between the brazed parts. This is because the cavities might be waving with the unit of the trestle during the quake.

Corrosion due to the flooding water was observed on the several pre-amplifiers which were on the floor. Based on the chemical analysis result, the distilled water had strong alkali property which was originally from the concrete contents (Fig. 7).

Numbers of Deformed Monitors

Beam monitor deformation was mainly observed at the MEBT1, DTL and SDTL section. Numbers of installed and damaged monitors are listed in table 1. In the MEBT1 section, vacuum leakage was found at only one point on the monitor. And one carbon wire of the head of WSM was cut, because the wire was very thin (7μm) and frangible.

In the DTL section, SCT and FCT monitors are packed inside the flanges of the gate valve due to the narrow space. The bellows are welded with the flanges. Deformation and leakage were found on the two bellows.

In the SDTL section, deformation was found on 13 FCT monitors and 4 bellows welded with BPMs and FCTs.

No damage of the beam monitors in the following future ACS section and downstream section to inject the beam to RCS (L3BT section) was observed.

Residual Activities of Deformed Parts

Residual activity of all dismounted devices was measured. Because the residual activity was not abnormally high but reached around several tens of μSv/h, damaged devices are newly fabricated.

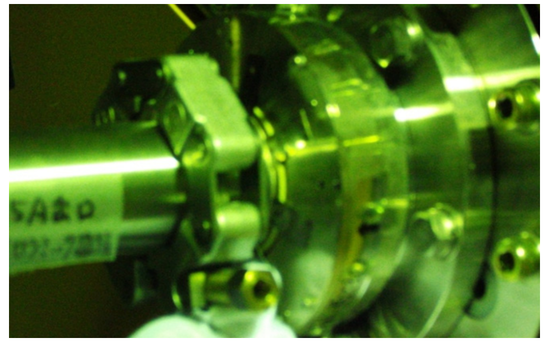

Figure 3: Deformation of the FCT Monitor installed behind the SDTL05A. Ceramic part (white part) which is used inside the vacuum chamber can be seen.

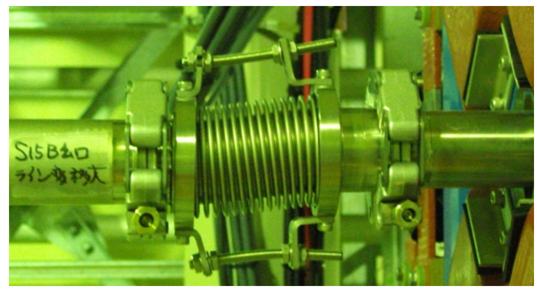

Figure 4: Deformation of the bellows installed after the SDTL15B. This part is an exit of the SDTL cavities and the beam line is shifted with a few centimetres horizontally.

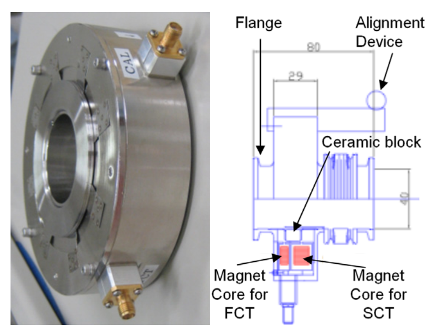

Figure 5: Beam Current and Phase Monitor (SCT/FCT). A small ceramic block is used for RF signal to be transmitted through (toward the inductive core) while a vacuum enclosure is tightly kept.

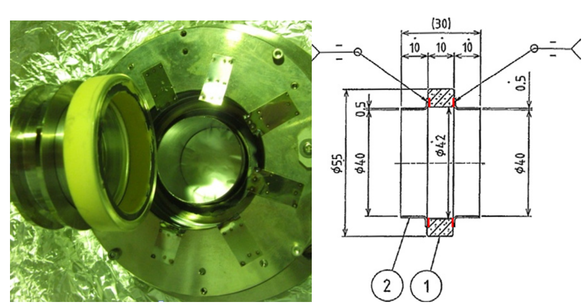

Figure 6: Deformation of FCT Monitor. Number 1 is the ceramic part and number 2 is the stainless parts in the right figure, they are brazed at the surface of the ceramic part (red points). Damage is mainly observed at the part where the ceramics and metal parts are brazed (red points).

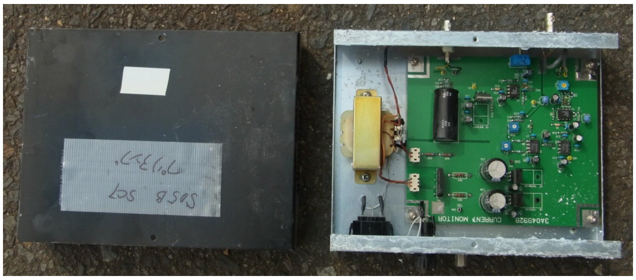

Figure 7: Corrosion by the leaked water. This electrical circuit was submerged and it was corroded by the flooding water which had strong alkali property from the cement contents.

Table 1: Numbers of Installed and Damaged Monitors

Section	Number	BPM bellows	SCT	FCT
MEBT1	Installed	8	6	5
	Damaged	1	0	0
DTL	Installed	0	3	3
	Damaged	0	2*1	2*1
SDTL	Installed	32	15	44
	Damaged	6*2	0	17*2

*1: Only the welded bellows were deformed.
*2: Because four FCT monitors were welded with BPM, four were doubly counted in the FCT monitors.

RECOVERY WORK

After primary inspection, emergency treatment was conducted for the vacuum leakage. In the treatment, damaged components were dismounted, the air in the cavities was exchanged with the nitrogen gas and the endplates of the cavities were sealed with blank flanges.

In the detail inspection, tiny vacuum leakage was confirmed from the invisibly small cracks. Because of the residual radioactivity, damaged monitors couldn't be repaired but were required to be exchanged with new ones.

Sequence of the Recovery

On May 20, the J-PARC center announced a restoration schedule [6]. It implies that the Linac beam commissioning will start since December 2011. We set this target as the goal of the recovery and made a fine schedule for each facility. The main sequence of the schedule of beam monitor recovery is as follows:

1: Preliminary inspection at a week after the quake
2: Detail inspection, emergency treatment for vacuum leakage and clarification of the number of damaged components from two weeks after to a month after the quake
3: Order and fabrication of the damaged components before the reinstallation
4: Confirmation of the cable and connector impedance during a fabrication
5: Replacement and reinstallation of damaged or undamaged components to the beam line after the beam line alignment
6: Calibration of all monitors before the beam operation
7: Connection to the control devices and preparation of the beam operation until the operation start

Reinstallation and Calibration

Fabrication of damaged monitors requires five months including four months for manufacturing the parts which are employed for the exchangeable monitors. It is required longer time to manufacture the parts than usual due to the damage of a factory of the company and planned blackout of the electricity. During the fabrication of the monitors, we checked the impedance of all cables and connectors because the corrosion of the part of the connectors was found. The connectors which had abnormal impedance were exchanged and the impedance of new ones was measured again.

BPMs should be calibrated at the bench test to match the impedance of all striplines. After this, BPMs will be installed. On the other hand, both SCT and FCT monitors are calibrated after installation. SCT monitor has signal line and calibration line. We put into the simulated beam pulse from the calibration line and we obtain the signal from the signal line through the electrical circuits. Impedance of the cable and connector should be essentially considered with the FCT monitors as the offset to the phase measurement.

All signal gain of BLMs was confirmed by the measurement of radiation from gamma-ray source. If the system of all beam monitors has something wrong, we can easily notice it through the calibration.

SUMMARY

We have inspected the damage by the quakes and forwarded the recovery work. This is still continued in order to resume the beam operation along the announced schedule.

ACKNOWLEDGMENT

We would like to express thanks to the engineers of Mitsubishi Electric System & Service Co., Ltd. for their help.

REFERENCES

[1] Japan Metrological Agency, http://www.seisvol.kishou.go.jp/eq/shindo_db/db_map/indexemg.html (Japanese).
[2] T. Morishita et al., in these proceedings.
[3] K. Hasegawa et al., in these proceedings.
[4] S. Sato et al., "Installation of Beam Monitor Sensors in the Linac Section of J-PARC", Proc. of EPAC2006, TUPCH061, Edinburgh, Scotland.
[5] A. Miura et al., "Beam Diagnostics in the J-PARC Linac for ACS Upgrade", Proc. of DIPAC2010, MOPD08, Hamburg, German.
[6] http://www.j-parc.jp/en/topics/2011 ./ en.html#Recovery_schdule .