SUPPRESSION OF LEAKAGE FIELDS FROM DC MAGNETS IN J-PARC 3 GeV RCS

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Abstract

In the Japan Particle Accelerator Complex (J-PARC) 3GeV Rapid Cycling Synchrotron (RCS), we found that DC leakage fields from the extraction beam line significantly affected the beam. For this issue, we installed additional shields and got the 40% reduction of the DC leakage field. Thus the circulating beam loss was successfully reduced.

INTRODUCTION

From the early beam commissioning of the J-PARC 3GeV RCS, it was confirmed that there were the DC leakage fields from the extraction beam line and they affected the beam dynamics significantly [1]. The main source of the DC leakage fields were the extraction septum magnets (ESEPs) and 3NBT bending magnet (3NBT-B01). The leakage field strength could be estimated from both the COD measurements and the field measurements in the RCS tunnel [2]. The result of the COD measurements estimated that the leakage field from the ESEPs was 1.4×10^{-3} Tm, and the one of the 3NBT-B01 was 1.8×10^{-3} Tm. On the other hand, the leakage field from ESEPs and 3NBT-B01 were estimated from field measurements at 1.7 $\times 10^{-3}$ Tm and 1.9×10^{-3} Tm respectively.

In order to suppress the DC leakage field, we had installed additional magnetic shields which made with silicon steel for high magnetic permeability and workability. And then leakage field strength was estimated by COD measurements. Moreover the circulating beam loss due to the leakage field was measured. In this paper, we report the detail of the shield structure and the results of the beam studies.

ADDITIONAL SHIELDS AGAINS THE DC LEAKAGE FIELD

ESEPs, and 3NBT-B01 were located at the RCS extraction area as shown in Fig. 1. ESEP [3, 4] and 3NBT-B01 [5] were designed and developed as stand-alone units. But the leakage fields after the installation were not investigated until the beam study results. Then the DC leakage field distributions from ESEPs and 3NBT-B01 were measured, and then the strength, the location, and the passing route of the leakage field were made clear to suppression the leakage. The leakage field measurements had been carried out with 1-dimentional Hall probe along s-axis on the vacuum chamber of the RCS ring. Fig. 2 and Fig. 3 show the results of measured field distributions leaked from the ESEPs and 3NBT-B01 excited at 3-GeV mode respectively.

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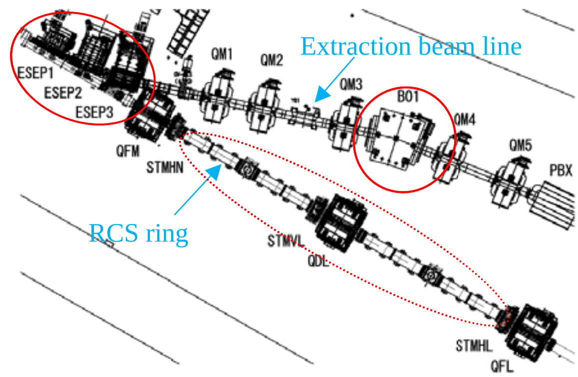

Figure 1: The schematic diagram of the RCS extraction area.

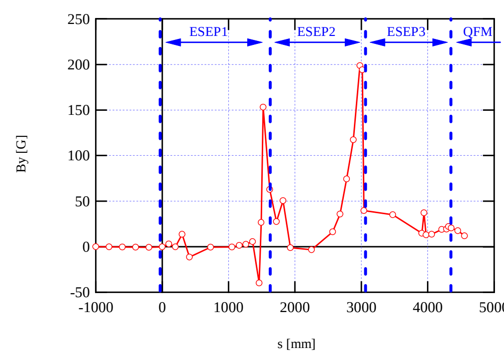

Figure 2: Measured leakage field distribution from the ESEPs along the s-axis on the top of the vacuum chamber, in which the origin of s-axis indicates the upper-stream flange of the ESEP1.

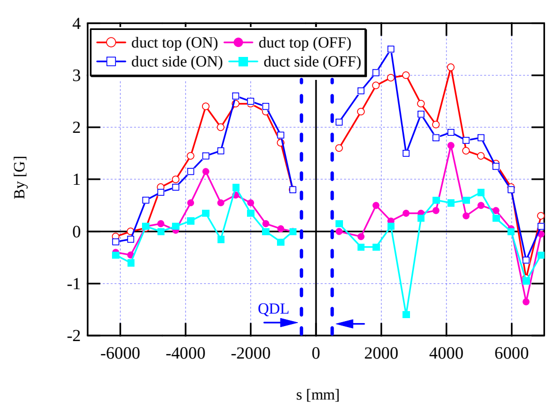

Figure 3: Measured field distribution leaked from the 3NBT-B01 along the s-axis on the top and side of the vacuum chamber, in which the origin indicates the center of the QDL.

In the case of the ESEPs, there are two types of the field distributions, as shown in Fig. 2. One is the narrow area and high peak distribution, and there are the two distributions between every ESEP. The other is the broad area and low peak distribution, and it exits at outside of the ESEP3. These results indicate that there were two passes of the leakage field from the ESEPs. In the former case, the leakage field due to the coil passed through two gaps between each magnetic shield on the ESEP. In the latter case, the field was leaked from the body of the ESEP3 because the magnetic shield is saturated. Therefore additional shield plates were installed between each magnetic shield on the ESEP to fill the gaps and were attached on the ESEP3 additionally to reduce the saturation in the magnetic shield.

The leakage fields from the 3NBT-B01 were very weak with peak field of about 3Gauss, but it spread over the very broad area with length of about 10m as shown in Fig. 3. The vacuum chambers at the RCS ring were made of titanium and then the leakage fields can permeate into the chamber thoroughly. Thus the titanium ducts were wrapped with additional shielding covers at long area as possible. Then the shielding covers made with silicon steel were wrapped on the only straight ducts as shown in Figs 5. The shielding covers can be separated vertically were fixed with support rings, then the covers don't attach on the vacuum ducts directly. The shield for other components, which are T-ducts, bellows, and flanges, are future problem to be solved.

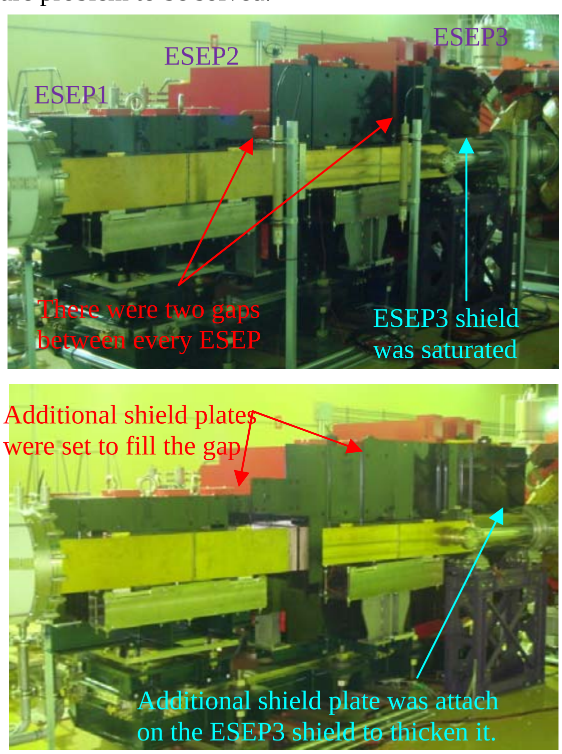

Figure 4: Photo of the ESEPs assembled with the additional shield plates. Upper and lower shows the comparison between before and after shielding.

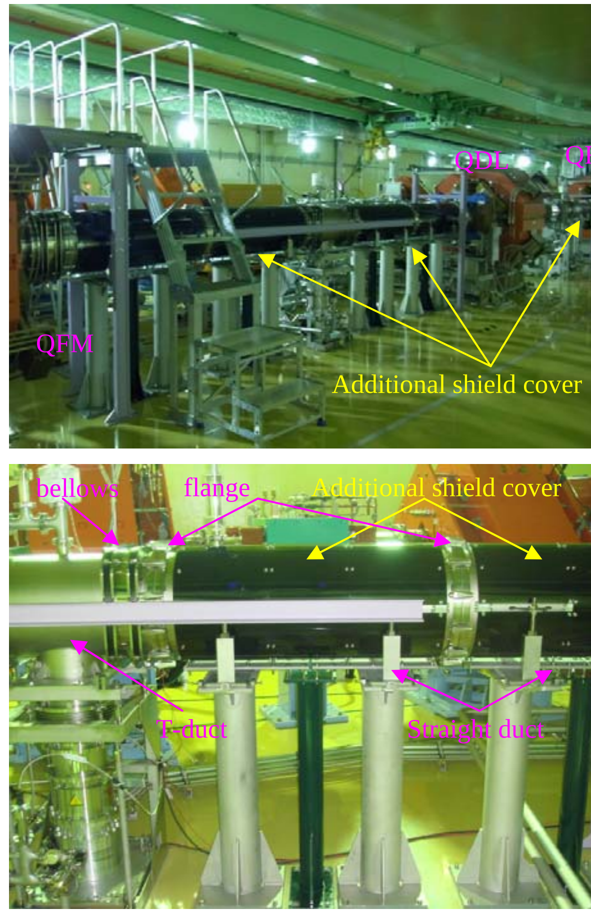

Figure 5: Photo of the RCS ring duct wrapped with the additional shield covers.

COD AND CIRCULATING BEAM LOSS MEASUREMENTS

In order to estimate the DC leakage field after shielding additionally, horizontal and vertical COD were measured at 181MeV beam storage mode where ESEPS of 3NBT-B01 were alternately excited at 3GeV mode. Fig. 6 and Fig. 7 show the COD measurement results. (Note: beta function after additional shielding is different from before.) The amplitudes of the horizontal and vertical CODs with ESEPs excited at 3GeV mode is 5 mm and 0.7 mm, and the leakage fields, which is estimated with the beam simulation, is 9.6×10^{-4} Tm and 0.9×10^{-4} Tm respectively. And in the case of the 3NBT-B01, the amplitude is about 5mm and 0.6mm, and the leakage field is 1.1×10^{-3} Tm and 5.8×10^{-5} Tm. Table 1 shows the summary about the COD measurement results, we got the 40% reduction of the DC leakage field with additional shield. Fig. 8 shows the beam survival rate at 3GeV beam acceleration measured before and after shielding additionally. From the results, the circulating beam loss was successfully reduced.

Table 1: Comparison with or without the additional shield

	Before shielding	After shielding
CODx from ESEP	12mm	5mm
CODy from ESEP	0.8mm	0.8mm
BL from ESEP	1.4×10^{-3} Tm	9.6×10^{-4}Tm
SBL from ESEP	0.9×10^{-4}Tm	0.9×10^{-4}Tm
CODx from 3NBT-B01	9mm	5mm
CODy from 3NBT-B01	1.4mm	0.6mm
BL from 3NBT-B01	1.8×10^{-3}Tm	1.1×10^{-3}Tm
SBL from 3NBT-B01	1.6×10^{-4}Tm	5.8×10^{-5}Tm

SUMMARY

At the early beam commissioning of the J-PARC RCS, we found that DC leakage fields from the extraction beam line significantly affected the beam. And the main sources of the leakage fields were ESEPs and 3NBT-B01. In order to suppress the leakage field, the field distribution was measured and additional shields were installed with various methods according to difference leakage field situation. As a result, we got the 40% reduction of the DC leakage field. Thus the circulating beam loss was successfully reduced.

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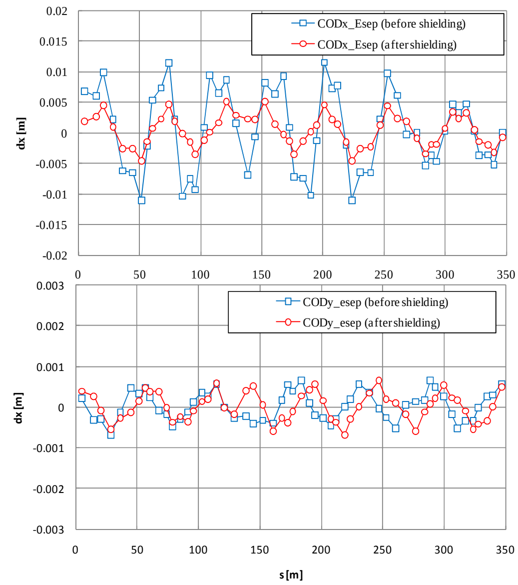

Figure 6: Horizontal and vertical COD measurements at 181MeV storage mode where the ESEPs excited at 3GeV.

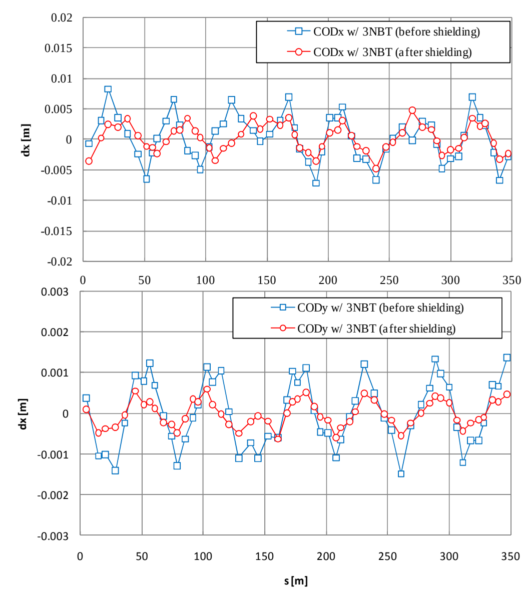

Figure 7: Horizontal and vertical COD measurements at 181MeV storage mode where the 3NBT excited at 3GeV.

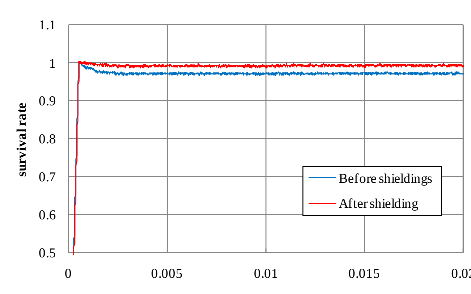

Figure 8: The beam survival rate at 3GeV acceleration mode was measured before and after additional shielding.