Incidents involving the DMT3 magnet in the beam transport line from SRC to BigRIPS

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After the October 2017 incident, wherein the lower correction coil in the DMT3 magnet in the "T-course" beam line was damaged,[1] a new lower correction coil was fabricated at Toshiba and installed in DMT3 in March 2018. In addition to repairing the correction coil, we renewed its water-cooling channels such that the cooling-water lines of correction-coil pancakes are independent from those of the main-coil pancakes. The DMT2 magnet, which is a "2-Tesla" resistive-type dipole magnet identical to DMT3, was also improved in the water-cooling design. A ^{18}O beam at 230 MeV/nucleon and ^{238}U beam at 345 MeV/nucleon were safely transported to the BigRIPS target via the "T-course" beam line with the DMT2 and DMT3 magnets in 2018.

When we improved the cooling-water piping, we flushed all the cooling channels in DMT2 and DMT3 coils. Every pancake of the main and the correction coils was flushed with compressed air and water. We found a considerable amount of black powdery impurities in the water that rinsed all the cooling channels. The composition of the impurities was analyzed using an electron probe micro analyzer (EPMA), and we found that the impurity was mostly copper-oxide crystals. The amount of the impurities we extracted from the non-damaged upper correction coil of the DMT3 magnet was 0.8 g.

We investigated the cooling-water channel in the damaged correction coil by cutting the coil conductor. We cut the damaged coil into 11 pieces. Figure 1 shows, as an example, a cross section of the correction coil cut at a saddle-shaped coil end. Although we found no notable evidence of blockage by impurities, it is likely that a shortage of heat removal due to poor cooling-water flow in the correction coil damaged the epoxy isolation.

A ^{78}Kr beam and ^{124}Xe beam at 345 MeV/nucleon were transported and RI beam experiments were successfully performed in the early summer 2019. However, at the beginning of the uranium beam time in November 2019, we again faced a similar incident, wherein the upper correction coil in the DMT3 magnet was damaged. The DMT2 and DMT3 magnets were excited with currents of 596 A and 594 A, respectively. However, the total excitation voltage of the DMT3 magnet was 131.6 V, which was about 10 V lower than the voltage of the DMT2 magnet (141.2 V). Furthermore, the temperatures of the cooling-water outlet of the upper and lower correction coils of the DMT3 magnet were 20.5°C and 40.1°C, respectively. We concluded that the upper correction coil in the DMT3 magnet was short-circuited.

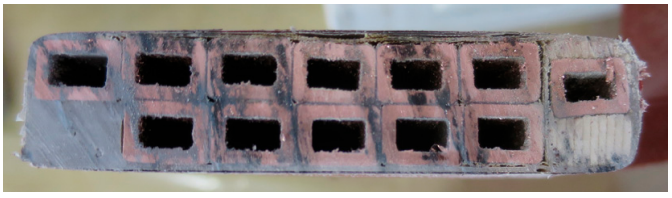

Fig. 1. Cross section of the damaged lower correction coil at the saddle-shaped coil end.

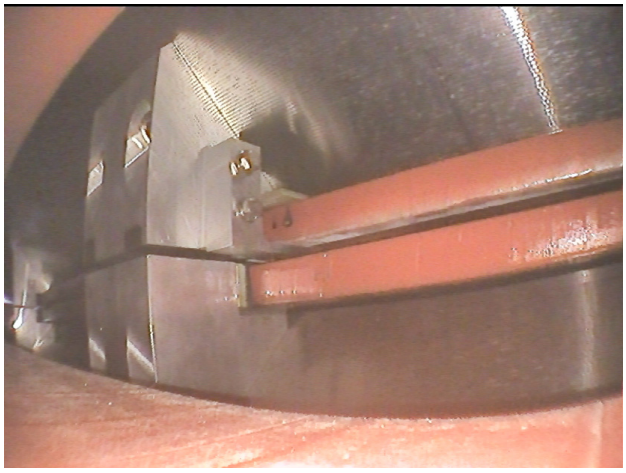

Fig. 2. Damaged upper correction coil of the DMT3 magnet.

In order to complete the beam service successfully, we isolated the upper correction coil from the excitation circuit, as we had done in 2017. The DMT3 magnet was re-excited while monitoring the voltage of each coil pancake.

Furthermore, we introduced an additional auxiliary DC power supply in the DMT3 excitation circuit in a parallel connection. Water-cooled protection diodes were also used for safety. We excited the DMT3 magnet using two power supplies with currents of 110 A and 536 A so that the uranium beam was safely transported to the BigRIPS target from SRC. After 2 days of beam-time suspension, scheduled experiments were performed till December 6. At the end of the beam time, we tested the transportation of the uranium beam using the DMT3 magnet without correction coils. We excited only the main coils of DMT3 magnet using two power supplies with currents of 110 A and 563 A. We confirmed that the uranium beam focused on the BigRIPS target well and the main coils were well cooled with a sufficient water flow.

We investigated the upper correction coil by inserting a fiberscope CCD camera into the space between the main coils of the DMT3 magnet after the beam time. Damage was found at the position of the second coil support from the beam exit side. Figure 2 shows the damage on the outer circumference of the upper correction coil. The origin of the incident is under investigation.

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Reference

1) K. Kusaka *et al.*, RIKEN Accel. Prog. Rep. **51**, 173 (2018).