## Replacement of power supplies for trim coils in RIKEN Ring Cyclotron

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The RIKEN Ring Cyclotron (RRC) is equipped with 26 trim coils in each of its four yokes, and more than 60 trim coil power supplies are used to supply current to them. The power supplies for six of them were updated in 2014, but 57 were already more than 40 years old and had repeatedly experienced various problems and had to be repaired.

This year, 36 of these power supplies were replaced with newly manufactured ones. The following points were taken into consideration when replacing the power supply.

- 1. Polarity switchers were eliminated for eight power supplies for Coil 6 and Coil 27, which were determined to be unnecessary after several decades of operation.
- 2. One power supply for Coil 9, which required polarity switching for the acceleration of 238 Uranium, was newly equipped with a polarity switch.
- 3. As the distance between Coil 26 and 27 is very small, only Coil 26 was equipped with power supplies and the number of power supplies was reduced from 8 to 4.
- 4. The maximum current value of the four power supplies for Coil 6 was increased from 400 A to 500 A because the current value of Coil 6 was considered insufficient for some particle accelerations as a result of the operation.
- 5. As the current value of the RRC trim coil power supply is frequently changed manually, the current value of the power supply can be changed quickly compared to similar power supplies of the RI beam factory's IRC and SRC. The current can be raised from 0 A to the maximum current value in 10 s.
- 6. We decided to unify the specifications of the power supplies as much as possible and manufacture only four types of current-voltage combinations. For some power supplies, the thickness of the existing wiring from the power supply to the trim coil is insufficient, so the maximum current value is limited by the operation control software inside the power supply.

Table 1 shows the power supplies that have been updated. Chassis RRC-T13 is a special type of trim coil power supply that compensates for slight differences in the excitation currents of the four yokes by bypassing the current for each yoke supplied by a single trim coil power supply. They are called bypass power supplies and are used for coils in areas where the difference in required current per yoke is small.

Chassis	Power Supply	Coil	Max. Current (A) <sup>†2</sup>	Max. Voltage (V)	Polarity Switch
RRC_T1	R_T5W	RRC_5W	600	20	0
	R_T5N	RRC_5N	600	20	0
RRC_T2	$R_T5E^{\dagger 1}$	RRC_5E	600	20	0
	R_T5S $^{\dagger 1}$	RRC_5S	600	20	0
RRC_T3	R_T4W	RRC_4W	-600	20	×
	R_T4N	RRC_4N	-600	20	×
	$R_T4E^{\dagger 1}$	RRC_4E	-600	20	×
	R_T4S $^{\dagger 1}$	RRC_4S	-600	20	×
RRC_T4	R_T6W	RRC_6W	-600 (-500)	20	×
	R_T6N	RRC_6N	-600 (-500)	20	×
	R_T6E	RRC_6E	-600 (-500)	20	×
	R_T6S	RRC_6S	-600 (-500)	20	×
RRC_T5	R_T26W	RRC_26W	600 (500)	20	0
	R_T26N	RRC_26N	600	20	$\bigcirc$
RRC_T6	R T26E <sup>†1</sup>	RRC_26E	600	20	0
	R T26S	RRC 26S	600 (500)	20	0
RRC_T7	R_T27W	RRC_27W	+600 (+500)	20	×
	R_T27N	RRC_27N	+600	20	×
	R T27E <sup>†1</sup>	RRC 27E	+600	20	×
	R_T27S	RRC_27S	+600 (+500)	20	×
RRC_T8	R T28W	RRC 28W	400 (300)	10	0
	R_T28N	RRC_28N	400	10	$\bigcirc$
RRC_T9	R_T28E	RRC_28E	400	10	0
	R_T28S	RRC_28S	400 (300)	10	$\bigcirc$
RRC_T10	R_T8	RRC_8	500 (400)	30	0
	R_T9	RRC_9	500	30	$\bigcirc$
RRC_T11	R_T3W	RRC_3W	-600	20	×
	R_T3N_3E	RRC_3N_3E	-600	20	×
	R_T3S	RRC_3S	-600	20	×
	R_T20_21	RRC_20_21	+600 (+500)	50	×
RRC_T12	R_T12_13	RRC_12_13	+600	50	×
	R_T23_24	RRC_23_24	+600	50	×
	R_T14_15	RRC_14_15	+600	50	×
	R_T22	RRC_22	+600	50	×
RRC_T13	R_T14_15WB	RRC_14W_15W	-50	12.5	×
	R_T14_15NB	RRC_14N_15N	-50	12.5	×
	R_T14_15EB	RRC_14E_15E	-50	12.5	×
	R_T14_15SB	RRC_14S_15S	-50	12.5	×
	R_T22WB	RRC_22W	-50	12.5	×
	R_T22NB	RRC_22N	-50	12.5	×
	R_T22EB	RRC_22E	-50	12.5	×
	R T22SB	RRC 22S	-50	12.5	×

†1 Same type of power supplies replaced in 2014

†2 The values in parentheses indicate the maximum current when there are limitations in the power supply

The stabilities and ripples of the power supply are less than  $\pm 5 \times 10^{-6}$  and  $\pm 5 \times 10^{-6}$ -p-p of the maximum current value. Those of the bypass power supplies are  $\pm 1 \times 10^{-5}$  and  $\pm 1 \times 10^{-5}$  p-p of the maximum current value.

Fabrication and testing of the power supplies were performed from April 2022 to February 2023. Replacement and on-site adjustment were done in March 2023,

## Table 1. List of updated power supply specifications.

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and the power supplies were available for machine time from mid-April. Subsequently, some power supplies were found to have poor stability at certain current values (around 60 A and in the region below 1 A), so readjustments were made from August to November 2023.

Eleven of the remaining RRC trim coil power supplies will be replaced in FY2024, and the final replacement is scheduled for FY2025 or later.