THE EXTRACTION KICKER SYSTEM OF THE RCS IN J-PARC

J. Kamiya#, T. Takayanagi, JAERI/J-PARC, Tokai, Naka, Ibaraki, Japan
T. Kawakubo, S. Murasugi, E. Nakamura, KEK, Tukuba, Ibaraki, Japan

Abstract

The kicker magnets are installed in the vacuum chamber at the extraction section of the RCS (Rapid Cycling Synchrotron) in J-PARC (Japan Proton Accelerator Research Complex) facility. They kick the 3GeV proton beam to the extraction septum magnets followed by a downstream beam transport line. The RCS is designed to achieve the 1MW beam power with minimum loss. Therefore, the kicker is required to have a wide aperture, UHV (ultra-high vacuum) in its chamber, and uniformity of magnetic field. The wide aperture requires large exciting current and the use environment of the thyratron is very tough. Therefore aging run was found out to be needed. And the uniformity of the magnetic field was improved by changing length of the conductors. In order to achieve the UHV, we succeeded in reducing outgas from components of the magnet.

In this paper, we will introduce the specification of the extraction kicker system in the RCS, and report countermeasure against the technical challenge described above.

SPECIFICATIONS OF THE KICKER SYSTEM

The conceptual diagram of a kicker system is shown in Fig. 1. A kicker system mainly consists of a power source and a magnet. There are eight sets of kicker systems in the extraction section of the RCS. As shown in Fig. 1, one power source consists of two units of same power supplies, and they are operated by one control panel. Each unit supplies the current through the load co-axial cable to both sides of the conductors in the twin-C typed magnet. The high voltage plate of the final unit is shorted, which makes the exiting current double. The reflected currents are consumed by matching registers in the power source. The characteristic impedances of the components, i.e. matching registers, PFN (Pulse Forming Network), thyratron setting, load cable, and magnet, are designed to have the same value, to avoid the reflection of the current due to the impedance mismatching. Eight sets of magnets are installed in two vacuum chambers, which contain three and five sets of magnets, respectively.

Specifications of the kicker system are summarized in Table 1. The following sections present the specification of the power source and magnet.

Power Source

Rectangle pulses of 25 Hz repetition are supplied by the kicker power source which is produced by IDX ltd [1]. One power source contains two power supplies. Each unit consists of the charging unit, PFN, thyratron, load co-axial cables, and matching registers. The maximum voltage of 80kV can be charged in the PFN, which consists of parallel co-axial cables FHVCX-80 from Fujikura ltd [2] whose characteristic impedance is 20Ω each. Thyratron CX1193C produced by e2V technologies ltd [3] is used as the switching device. The load cable is the same co-axial cable as the PFN. Figure 2 shows the output signal from the current transfer which was installed in the shorted end of the load cable. The current rise time of the power source without magnet was about 80nsec (10-90%).

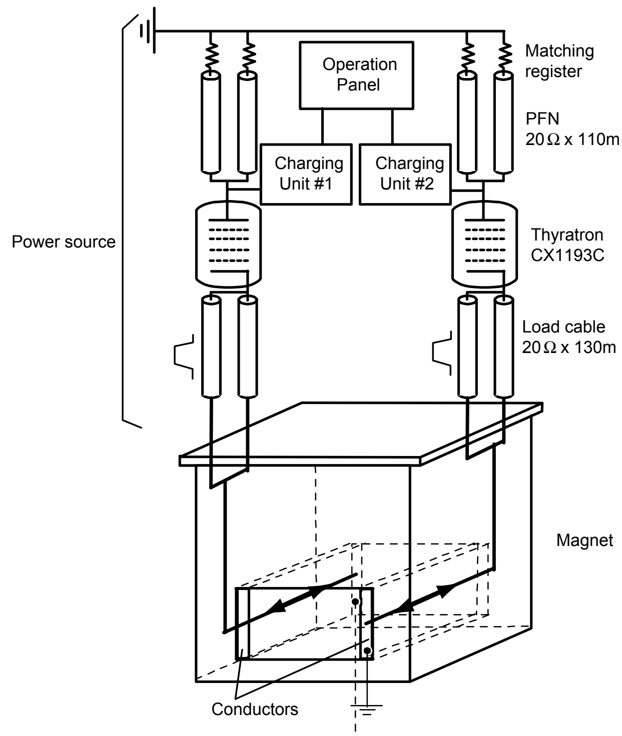

Figure 1: Conceptual figures of the kicker system.

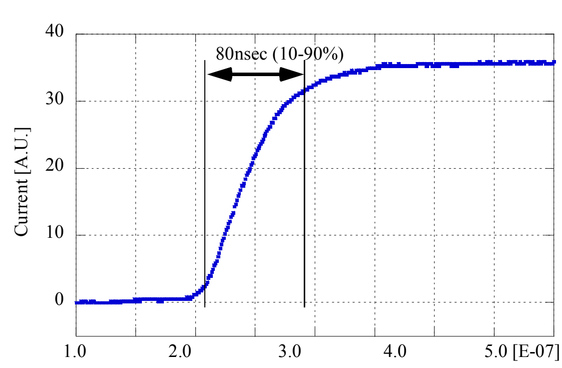

Figure 2: Rise time of the load current (without magnet).

#kamiya@linac.tokai.jaeri.go.jp

0-7803-8859-3/05/$20.00

Table 1: Kicker System Specifications

Power source [IDX ltd]		
Numbers		8
Output pulse shape		Rectangle
Maximum repetition rate		25Hz
PFN		Co-axial cable (~110m) [FHVCX-80, Fujikura ltd]
Switching device		Thyratron [CX1193C, e2V technologies ltd]
Load cable		Same as PFN (~133m)
Maximum charging voltage		80kV
Maximum exciting current		8000A
Characteristic impedance		10Ω
Magnet [NEC/TOKIN ltd]		
Numbers		8 (S:3, M:2, L3)
Configuration		Twin-C distributed magnet
Dimension	Vertical	960mm
	Horizontal	776mm
	Length	638mm
Aperture size	Vertical	186mm (S), 206mm (M), 232mm (L)
	Horizontal	360mm
	Length	638mm
Magnet core		Ferrite [PE14, TDK ltd]
Unit number		20units/magnet
Characteristic impedance		10Ω
Vacuum chamber [NEC/TOKIN ltd]		
Dimension	Vertical	885mm (A,B)
	Horizontal	1080mm (A,B)
	Length	2495mm (A), 4065mm (B)
Magnetic field (requested specification)		
Integral (Kick angle)		0.023~0.030Tm (1.8~2.4mrad)
Rise time		350nsec
Flat top length		850nsec

Magnet

Figure 3 shows a conceptual figure of the magnet of our kicker system. A magnet mainly consists of ferrite core and aluminium alloy, which is used as high voltage plates, earth plates, and conductors for exciting current. Ferrites are put together into C core facing each other. The ferrite core is put between aluminium high voltage plates and an earth plate is inserted between them. These parts form one unit of a distributed-parameter line and twenty units constitute one magnet. As described before, the final high voltage plate is terminated to an earth plate and exciting current becomes double. The upper panel in Fig. 4 shows measured current at the entrance into the magnet. It should be noted that this figure be the superposed current of forward and reflected ones. The time difference between a rise point and a bump by superposition is about 190nsec, which corresponds to a round-trip propagation time of exciting current in the magnet.

There are three types of magnets, S, M, L, corresponding to their aperture sizes as listed in Table 1. Magnets are installed in two vacuum chambers to prevent them from discharging. Dimensions of each vacuum chamber are listed in Table 1. Magnets and chambers are produced by NEC/TOKIN ltd [4].

Requested specifications for magnetic field are also shown in Table 1. The lower panel in Fig. 4 shows integrated magnetic field measured by a long search coil. The rise time and flat top length were within the requested specifications.

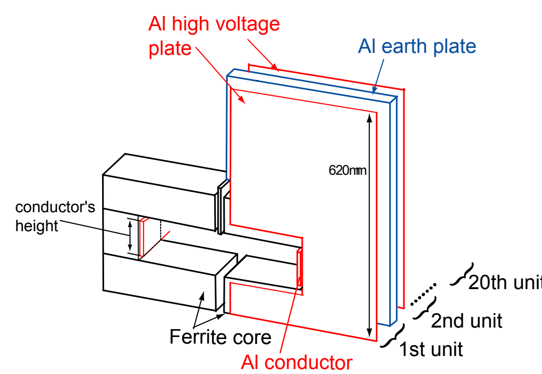

Figure 3: Configuration drawing of the kicker magnet.

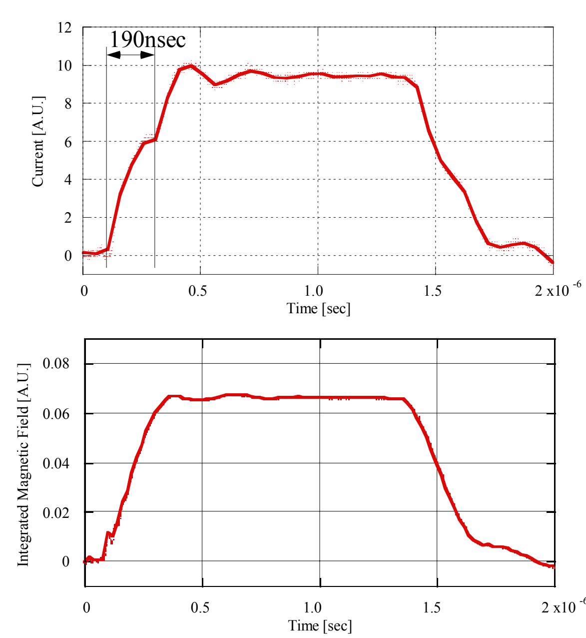

Figure 4: Exciting current at the magnet entrance (upper panel) and integrated magnetic field (lower panel).

TECHNICAL IMPROVEMENT

Thyratron aging

The power source of this system is used in very tough circumstance for thyratrons. That is high peak current, high peak voltage, and high repetition rate. Although the thyratron CX1193C's ratings were within allowable range for this system, some self-breakdown without discharge trigger occurred at the beginning stage of tryout operation. It was noticed that an aging run was needed for new thyratrons. In an aging run, charging voltage is set to start at low level about 50kV. And it is increased gradually up to 80kV over ten hours. Then, run is gone through at 70~80kV, until self-breakdown is suppressed. Figure 5 shows the number of self-breakdown through an aging process. In this aging run, the power source was operated about twelve hours a day. The number of self-breakdown was reduced by the aging effect.

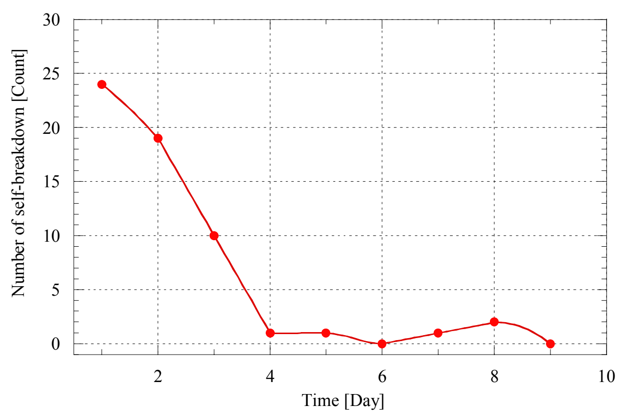

Figure 5: Number of self-breakdown through aging run.

Outgas reduction

Outgas from magnet components have large effects on the vacuum and beam itself. For components made of aluminum alloy, the surface is finished by pit-free electropolishing [5]. And they are baked at 150deg C about 70 hours in vacuum to reduce water which is a dominant component of the outgas. Figure 6 shows outgassing rate through the backing. Ferrite core is also baked in vacuum at 200deg C about 200hours. The outgassing rate of each component has been reduced by two or three order of magnitude.

Magnetic field measurement

Distribution of the integrated magnetic field is requested to have ±1% flatness within ±90mm in the horizontal axis. Integrated magnetic field distributions measured by a long search coil are shown in Fig. 7. Open squares represent integrated magnetic field with conductors of default height (see Fig.3). Open and filled circles correspond to the measurement results when shortening conductors' height every 10mm. When shortening conductors' height, magnetic field enters from a transverse direction. As a result, magnetic field distribution flats more.

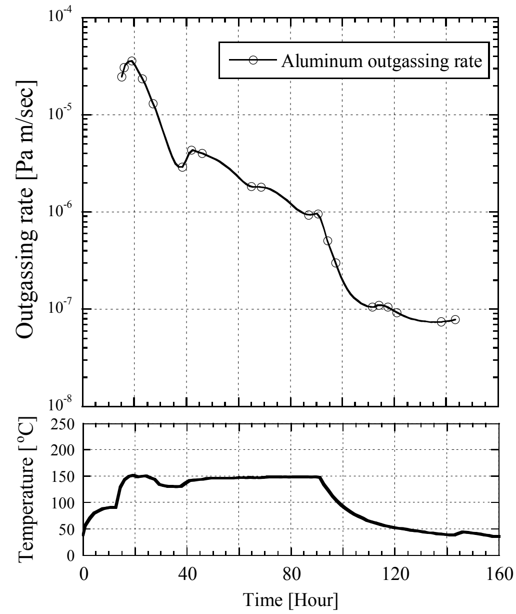

Figure 6: Outgassing rate of aluminum components.

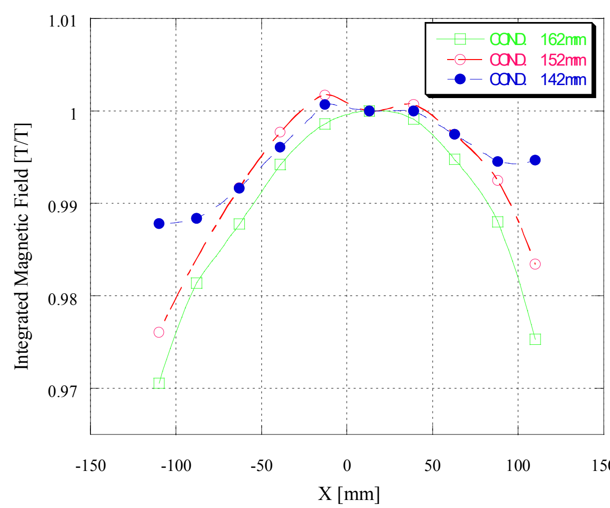

Figure 7: Distribution of integrated magnetic field.

CONCLUSION

The specifications of the extraction kicker system in the J-PARC RCS facility are reported comprehensively. Although there are many difficulties to manufacture this system, the technical improvements have been made from all viewpoints of a power source, magnet, and a vacuum and so on.

REFERENCES

[1] IDX Corporation, http://www.idx-net.co.jp/
[2] Fujikura Ltd., http://www.fujikura.co.jp/
[3] e2V technologies, http://e2vtechnologies.com/
[4] NEC/TOKIN Corporation, http://www.nec-tokin.com/
[5] K. Tajiri, Y. Saito, Y. Yamagata, Z. Kabeya, Journal of Vacuum Science & Technology A, A16(3), May/June 1998, pp.1196-1200

0-7803-8859-3/05/$20.00 ©2005 IEEE