CONSTRUCTION AND POWER TEST OF THE EXTRACTION KICKER MAGNET FOR SPALLATION NEUTRON SOURCE ACCUMULATOR RING*

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Abstract

Two extraction kicker magnet assemblies that contain seven individual pulsed magnet modules each will kick the proton beam vertically out of the SNS accumulator ring into the aperture of the extraction Lambertson septum magnet. The proton beam then travels to the 1.4 MW SNS target assembly. The 14 kicker magnets and major components of the kicker assembly have been fabricated by BNL. The inner surfaces of the kicker magnets were coated with TiN to reduce the secondary electron yield. All 14 power supplies have been built, tested and delivered to ORNL. Before final installation, a partial assembly of the kicker system with three kicker magnets was assembled to test the functions of each critical component in the system. In this paper we report the progress of the construction of the kicker components, the TiN coating of the magnets, the installation procedure of the magnets and the full power test of a kicker magnet with the power supply.

INTRODUCTION

The beam extraction from the SNS accumulating ring to Ring to Target Beam Transport (RTBT) Line takes place in one of the accumulator ring's straight sections (Fig.1) [1].

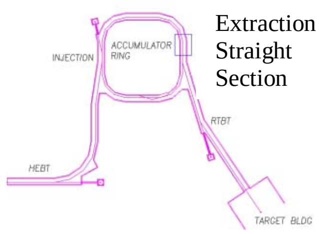

Figure 1: Extraction Kicker Location in the Ring.

The extraction scheme is a "single turn", "two step process". In the first step, a set of fourteen kickers will deflect the beam vertically into extraction channel of a Lambertson septum magnet. Then the septum magnet will bend the beam horizontally into the RTBT transfer line and the target [2]. To optimise the kick delivered by each of the kickers, the 14 kickers were separated into two groups with a ring lattice quadrupole-doublet assembly in between (Fig. 2).

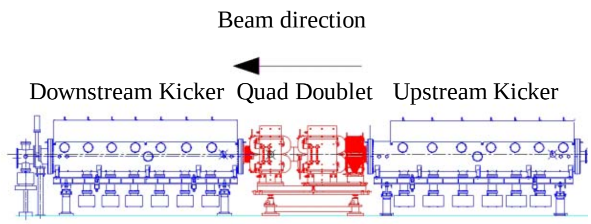

Figure 2: Extraction Kicker Layout.

KICKER SPECIFICATIONS

The aperture of the extraction kickers depends on the acceptance of the accumulator ring and the acceptance of the extraction channel in the septum. To maintain a safe margin and minimize beam loss, the 14 kickers were designed with increasing apertures. To simplify the kicker design and make the installation and maintenance easier, the 14 magnets are grouped in 6 different types. The parameters of the 14 kicker magnets are listed in Table 1.

Table 1: Kicker Parameters

Magnet	Width H(cm)	Height V(cm)	Length L(cm)	Beam Center to top of kicker (cm)
K1-1	12.0	16.6	35.0	8.30
K1-2	14.5	20.0	35.0	10.00
K1-3	14.5	20.0	35.0	10.00
K1-4	17.8	19.5	46.0	9.75
K1-5	17.8	19.5	46.0	9.75
K1-6	21.1	23.3	46.0	11.65
K1-7	21.1	23.3	46.0	11.65
K2-1	16.2	23.3	38.0	8.71
K2-2	16.2	23.3	38.0	8.60
K2-3	16.2	23.3	38.0	8.48
K2-4	16.2	23.3	38.0	8.39
K2-5	15.1	24.3	35.0	8.30
K2-6	15.1	24.3	35.0	8.22
K2-7	15.1	24.3	35.0	8.16

The location of each of the kicker was optimised to minimize the required voltage and to make the required voltage the same. The length of each kicker was optimised with the aperture to reduce the ratio of inductance to kick. Each extraction kicker will be excited by a pulse forming network (PFN) operated at 60 Hz repetition rate with a flat top of 750 ns and a rise time of 200 ns [5]. Since the extraction kicker is a fast and high repetition rate system, the kicker magnet is designed to have high reliability in operation and maintenance.

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KICKER DESIGN CRITERIA

Reliable and Cost Effective Design

To simply design and reduce cost, all magnets in the same group use the same ferrite and support frame to form the window frame aperture. The different beam height for each magnet is compensated by adding top and bottom ceramic plates with various thicknesses. In this design all magnets have the same support frame and have the same base height for installation.

Bakable System

The required vacuum quality for extraction kicker is in the $1x10^{-8}$ Torr range. With large quantities of porous ferrite used in the magnet, the kicker assembly is designed to be bakable to 200^{o}C in the ring under vacuum. Inside the long vacuum chamber, the 7 kicker magnets are individually supported and connected to a brazed ceramic coaxial high voltage feedthrough. It is very important to have enough flexibility for thermal expansion between the magnets and the long vacuum chamber.

High Voltage System

The kicker magnet is powered by a fast pulse of 35 KV, 2400 amp in 60 Hz repetition rate. High voltage insulation is critical for magnets inside the vacuum chamber and power cable terminations on the outside. Minimum space between charged parts is critical to avoid breakdown. All metal parts used in the magnets were machined with smooth surfaces and round corners. In order to reduce the secondary electron yield, the inner surfaces of the magnets were coated with a thin layer of Titanium Nitride film (TiN) about 100nm thick [3]. Because the TiN film is conductive, the coating pattern of the TiN film has gaps between magnet coil and the coating surface on the ferrite to prevent any high voltage break down.

Structure Strength and Shipping

The length of the kicker assembly is 170 inches and it weights about 6500 lb. The structural strength of the kicker has a special requirement for shipping. The two magnet assemblies were constructed at BNL then shipped to ORNL by truck. Since the core of the magnet is ferrite and the insulator of the HV feedthrough is ceramic, both are very brittle in nature. The support of the magnet assembly was designed to take a 1G acceleration during transportation (Fig. 3,4)[4]. Using a shock absorbing frame both assemblies were successfully shipped to ORNL.

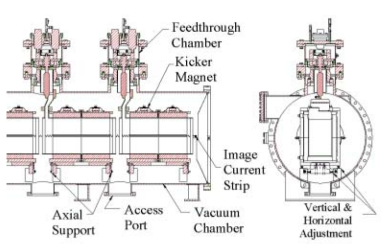

Figure 3: Extraction Kicker Assembly.

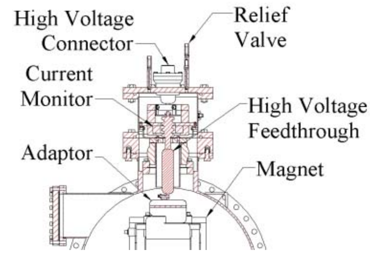

Figure 4: High Voltage connection.

PULSE POWER SUPPLY

Each kicker magnet will be powered by a pulsed high voltage modulator, Pulse Forming Network (PFN) (Fig. 5) [5]. After an extensive prototype test and improvement, the design of the PFN was finalized and 14 of these PFN's have been built and tested [6]. One improvement during production is in the circulation pump. The transformer fluid used in the PFN for cooling is Dow Corning 561. This is a Polydimethysiloxane (PDMS) silicon fluid. The viscosity of the fluid is about 50 cSt, which is higher than mineral oil. Unlike mineral oil, PDMS fluid is not a good lubricant for metal-to-metal contact. A circulating pump for cooling with steel gears is not suitable for this fluid. However, PDMS fluid is one of the best lubricants for fiber and plastic gears. After an initial failure of a steel gear pump, a Polyphenylene Sulfide (PPS) plastic gear pump was used to circulate this fluid. With this pump all 14 production PFN were successfully tested.

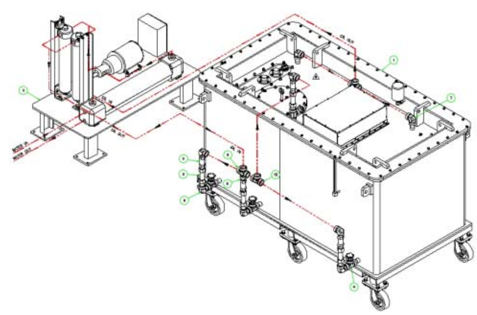

Figure 5: Pulse Forming Network (PFN).

MAGNET CONSTRUCTION

The construction started with building the 14 window frame ferrite magnets. Then each magnet was placed into a vacuum chamber and baked to 250^{o}C for TiN coating (Fig. 6).

Figure 6: Extraction Kicker Magnet.

After TiN coating, a resistance measurement was done and then seven magnets were linked together as a train and inserted into the vacuum chamber with a sliding tool (Fig. 7).

Figure 7: Kicker Magnet Installation.

Finally, the 7 sub-assemblies of the feedthrough chamber that house the high voltage feedthrough were installed on the top of the vacuum chamber and connected to the coils inside the chamber (fig. 8).

Figure 8: Extraction Kicker Assembly.

MAGNET PULSE POWER TEST

Before final installation, 3 of the kicker magnets in the downstream kicker were assembled and powered to the operating voltage of 35 KV to check its waveform and performance. The current waveforms of these 3 magnets and a waveform from dummy load for comparison are shown in the Fig. 9.

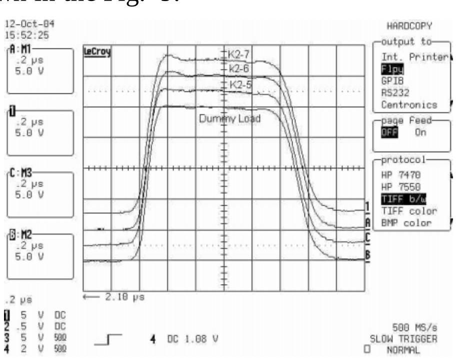

Figure 9: Current Wave Forms.

From top to bottom, the 4 current wave forms are taken from magnets K2-7, K2-6, K2-5 and dummy load. Among them K2-5 is the magnet with TiN coating. These three waveforms from the magnets are almost identical to the dummy load. The performance of these magnets is consistent with the prototype [6] and meets the design specifications. The TiN coating did not affect performance.

KICKER ASSEMBLY BAKE OUT

The kicker assembly is designed to be bakable for good vacuum quality. Sets of custom made heating blankets were built to fit on each kicker assembly. Both kicker assemblies were baked to 200°C under vacuum to verify their integrity and the performance of the bake out system. During the bake out test, temperatures of critical parts were recorded. Electrical power required to heat the chamber was determined too. The temperature curves of these critical parts during bake out are shown in Fig. 10.

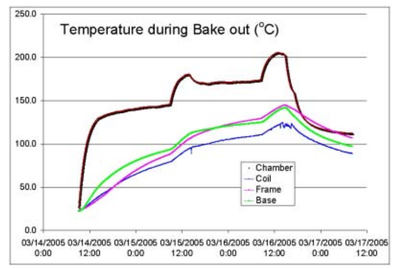

Figure 10: Temperatures during Bake out

CONCLUSION

Two extraction kicker assemblies, upstream and downstream, each with 7 kicker magnets were successfully built, baked to 200°C and 3 of the 14 magnets were full power tested in the BNL. With extra shipping arrangement, these two magnet assemblies were safely delivered by Air-Ride truck to ORNL and installed in the SNS accumulator ring.

ACKNOWLEDGEMENT

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