MECHANICAL DESIGN OF FAST EXTRACTION KICKER AND PFN FOR SNS ACCUMULATOR RING*

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Abstract

Two kicker assemblies, seven pulsed magnet modules in each assembly, will be used in the SNS accumulator ring to kick the beam vertically to the extraction septum then to the target. These kickers are designed as window frame magnets housed inside a vacuum chamber. Fourteen Pulse Forming Networks (PFN) housed in separate silicon fluid containers are designed to power each kicker module. A single module prototype kicker magnet and PFN modulator have been successfully assembled and tested. In this paper we discuss the mechanical design criteria of these kicker assemblies, the installation layout in the accumulator ring, the structural analysis of the kicker chamber, the magnetic field analysis of the ferrite magnet, the high voltage feedthrough design, the structural design of the modulator container, the cooling and the thermal expansion considerations of the silicon fluids.

1. INTRODUCTION

The extraction from the SNS accumulating ring to Ring to Target Transport Line (RTBT) takes place in one of the accumulator ring's straight sections [1]. There are a total of fourteen kicker magnet modules to kick the circulating beam in a single bunch vertically into septum magnet (Fig.1). The septum then provides the large angle deflection to extract the beam into the RTBT line [2]. Seven kicker magnets in one assembly are located upstream of a quad-doublet, and seven magnets in another assembly are located downstream from the quad-doublet.

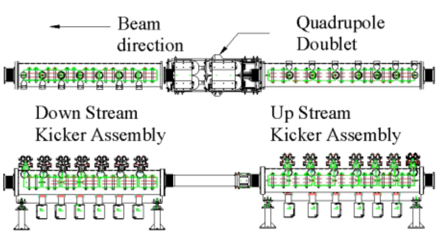

Figure 1. Extraction Kicker Layout

The extraction kicker will be operated at 60 Hz rate with a flat top of 750 ns and a rise time of 200 ns. Fourteen high voltage modulators installed in the modulator building will be used to power the 14 kicker magnets. Two coaxial cables connected in parallel from each modulator transfer current to each kicker magnet in the assembly. Since extraction from the accumulator ring has to have a high level of reliability, the large number of magnet modules, seven in each assembly, is to allow the full beam to be extracted within the acceptance of the RTBT line even when one of the modules in each assembly fails to function.

2. KICKER SPECIFICATIONS

Reflecting the beam acceptance and coupling impedance, the 14 kicker magnets have various apertures, lengths and relative heights to the beam [3]. To simplify the kicker design, the 14 magnets are grouped in 6 different types. The parameters of the kicker assembly with a typical magnet are listed in Table 1.

Table 1: Kicker Magnet Parameters.

Ferrite Gap (cm):	15.1(H), 24.3(V), 34.0 (L)
Ferrite Volume	11760 cm^3
Turns per Coil	1
Max. Field	251 G
Peak Current	2440 A
Peak Voltage	35 kV
Pulse Current Rise Time	200 ns
Current Pulse Flat Top Time	750 ns
Assembly Weight	4465 lb
(7 magnets in one chamber)	

3. KICKER DESIGN

3.1 Magnet

The fast kicker is designed as a ferrite core rectangle frame magnet (Fig. 2).

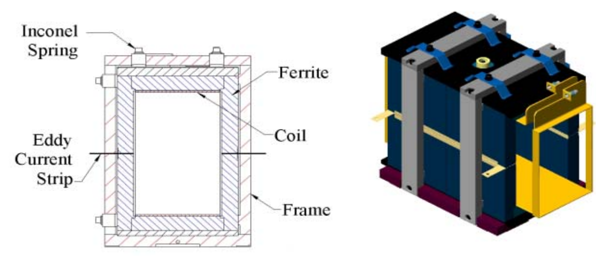

Figure 2. Extraction Kicker Magnet

CMD 5005 Ni-Zn type ferrite is used for this magnet. This ferrite provides high frequency response, low loss and low out gassing rate. These properties are important for pulsed power magnet in high vacuum application. Six ferrite blocks form a window shape frame. These ferrites

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blocks are clamped by inconel springs to a stainless steel structure. In the middle of the back leg, a copper strip is used to carry the beam–induced image current and help to reduce the eddy current heating caused by the beam induced magnetic field in the ferrite. The coil is made of a single-turn copper conductor. High voltage current is fed from one end of the ferrite core.

3.2 Support And Alignment

Seven magnet modules will be installed in a vacuum chamber in series (Fig. 3).

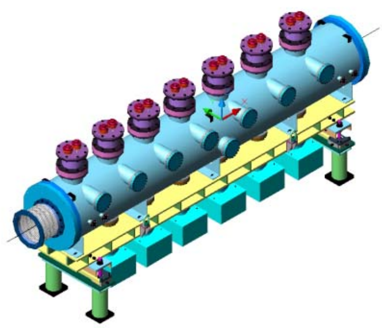


Figure 3. Extraction Kicker Assembly

A sliding fixture will be used to insert these seven modules into the chamber. After insertion, each magnet will be surveyed and supported independently to its final position as determined by the beam dynamics. The adjustments will be done through the access ports in the under side of the chamber (Fig. 4). All magnet supports provide sliding contact except the axial support in the feedthrough end, where the magnet is fixed in the support.

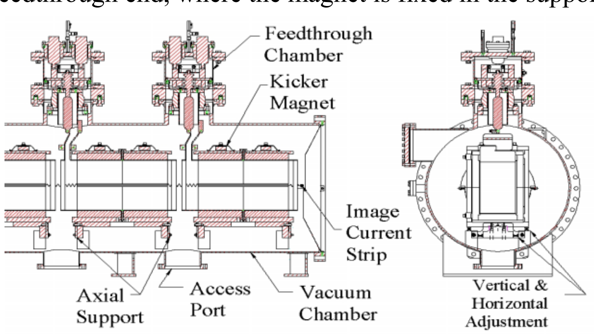


Figure 4. Cross Section Of Kicker Assembly

This design allows the magnet assembly to be baked in the ring. When various temperatures rise in the assembly, the connecting end of each magnet will stay with its ceramic feedthrough and will let the other end expand.

3.3 High Voltage Feedthrough Connection

Each magnet is powered by a modulator. Two high voltage cables from each modulator send the 35 KV pulse into each magnet in the vacuum chamber. Above each magnet, two high voltage connectors are jumped together then connected to the outside terminal of the coaxial HV feedthrough. Inside the vacuum chamber, two adapters are used to connect the terminals of the coil to the high voltage feedthrough. These adaptors can also be used to reverse the polarity of the magnet (Fig. 5). To provide better high voltage insulation, a feedthrough chamber is built around the outside of the HV feedthrough to house these high voltage connecting components. After installation, this chamber will be flushed clean and back filled with 1 atm of insulating dry nitrogen gas. A pressure relief valve will be used to safe guard the feedthrough chamber.

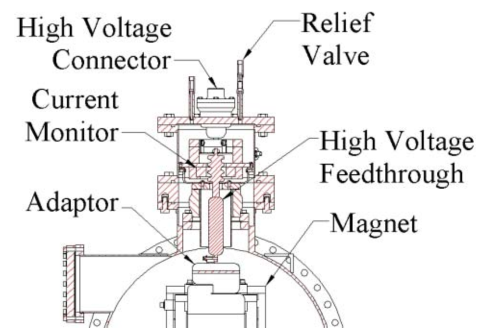


Figure 5. Feedthrough Chamber

3.4 Vacuum Quality Criteria

The required vacuum quality for extraction kicker is in the $1x10^{-8}$ Torr range. Since large quantities of ferrite are used in the system, to overcome the outgassing from these porous ceramics, six ion pumps are installed in the underside of the kicker assembly. The vacuum chamber and flanges are made of 304L stainless steel. End flanges are wire seal type with copper gaskets. All blind holes in machined parts are drilled with venting paths. All fasteners are high vacuum comparable silver plated hardware. Ferrite and all machined parts will be cleaned and baked to 250 ^{0}C before assembly. After installation, the whole assembly can be baked to 250 ^{0}C under vacuum in the storage ring.

4. STRUCTURAL STRENGTH

The total length of the kicker assembly is 170 inches and weights about 4500 lb. From finite element analysis (Fig. 6), the deflection of this structure under its own weight and a side load of 0.5 G is about .034”. Maximum Von Mises stress in the chamber is 13052 psi, which is acceptable for SS304. Shims and support screws will compensate the small deflection to keep all magnets in alignment.

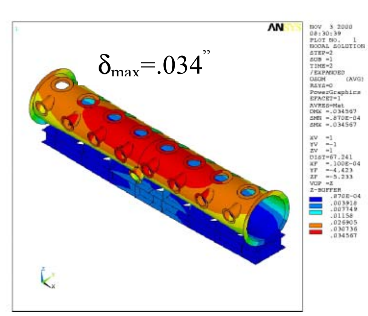
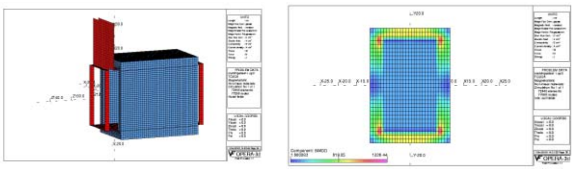


Figure 6. Structural Analysis

5. MAGNETIC PROPERTIES

An OPERA model was used to calculate the properties of the magnet (Fig. 7). When powered by 2000 A current, the center field of the magnet is 160 G. Maximum field in the ferrite is 2433 G, which is acceptable for CMD5005. Inductance of the magnet is .97 µH.



OPERA Model Field Contour Plot
Figure 7. Magnetic Analysis

6. MODULATOR ASSEMBLY

6.1 Design concept

The kicker magnets will be powered by 14 modulators [4][5]. Theses modulators are constructed as a large fluid container. All electric components are submersed in insulating silicon fluid (Fig. 8).

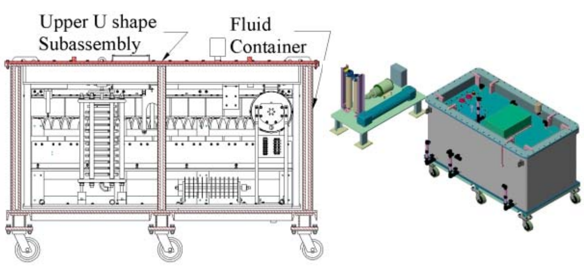


Figure 8. Pulse Forming Network (Modulator)

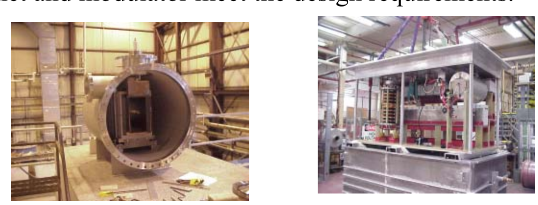
Since the modulator will be operated at 35 KV high voltage, the modulator is designed as a large fluid container to submerse all components into silicon fluid for insulation. The container assembly is a vented system to avoid internal pressure build up. A desiccant filter is installed in the vent pipe, which will keep the air dry and clean when it enters the system. The size of the container is 75”x38”x36” which can hold 400 gallons of silicon fluid. The upper part of the container is a U shape subassembly. A frame structure is built under the lower level of the U shape to house all modulator components. The shoulder of the U shape is the sealing flange. When assembled together, the fluid level will be kept just above the lower level and is enough to keep all components submersed in the fluid. The volume of the air space above the fluid level is 10 gallon. This space is designed as an expansion tank to compensate temperature fluctuation. The thermal expansion rate of the 400 gallons of fluid is about 0.23 gallon/^{o}C. The 10 gallon space will allow 40 ^{o}C temperature fluctuations for operation. The U shape design has two advantages. One is the fluid level will be always below the sealing surface. The possibility of oil leak is greatly reduced. The other advantage is that all external fittings and components that mounted on the top are under the U shape. Any leaked oil will be contained in this U shape.

6.2 Modulator Cooling

The modulator will generate 10,000 watts of heat in total when operates at 60 Hz. Most of the heat is generated in the resistor pack. To remove this heat, a circulating pump will pump water-cooled oil into the tank in four inlets. Flow control valves and meters are installed in these inlets to keep flow rate equal. Oil from the three inlets in the bottom of the tank will flow across all electric components from bottom to the top. One of the inlets in the top of the upper flange will be connected to the bottom of the resistor pack. The resistor pack is designed with vertical cooling path in the center and radial cooling path in each of the copper disk. The warm oil will be pumped back from the three outlets in the upper flange to the pumping station where the warm oil will be cooled by a water cooled heat exchanger.

7. PROTOTYPE TEST

A single module kicker magnet and a full feature modulator (Fig. 9) were built to test all design criteria. Both, magnet and modulator have gone through various measurements and power tests. From test results, both magnet and modulator meet the design requirements.



Magnet Modulator
Figure 9. Prototype Magnet And Modulator

8. CONCLUSIONS

The design and test of the extraction kicker magnet and modulator are completed. The fabrication of the 14 modulators is already started by a contractor. The construction of the two kicker magnet assemblies will be following soon.

9. ACKNOWLEDGEMENTS

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