# SNS EXTRACTION KICKER SYSTEM AND FIRST ARTICLE BPFN TEST*

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*Abstract*

The Spallation Neutron Source (SNS) extraction kicker system brings the proton beam from the accumulator ring through a beam transfer line into the target area. The 14 kicker magnets are located in one straight section. The kicker magnets are energized by 14 Blumlein type Pulse Forming Networks (BPFN). The first article of the SNS extraction kicker BPFN was assembled and tested at this laboratory. This paper describes the kicker BPFN system arrangement and parameters. The first article BPFN design and its main components used are explained. High voltage BPFN test results and the load current waveform are illustrated in this paper. Temperature measurements of the kicker ferrite blocks at full power showed only small or no heating. This paper discusses the modifications to the BPFN design, such as a saturating inductor and 25 Ω termination, to minimize the transverse coupling impedance.

## 1 EXTRACTION KICKER SYSTEM INTRODUCTION

The Spallation Neutron Source (SNS) extraction kicker system consists of 14 ferrite magnets, 14 high voltage pulse modulators (HVPM) and auxiliary power supplies. 14 ferrite magnets are separated into two groups. There are 7 kicker magnets in each group. The two magnet groups will be installed in one of accumulate ring straight section. (See Fig. 1) 14 HVPM are installed in the PFN building.

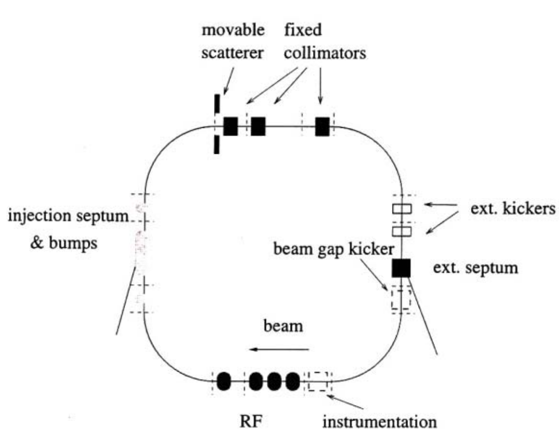


Figure 1: Extraction kicker magnets location [1].

Each of the 14 kicker magnets is energized by one HVPM, which is built as a Blumlein type Pulse Forming Networks (BPFN). Each magnet is energized by one HVPM through two 50 Ω coaxial cables connected in parallel, which transfers the pulse current from the BPFN to magnet situated in accumulator ring tunnel. The coaxial cable length is about 375 feet long.

The service building is next to the PFN building. 14 auxiliary power supplies are positioned in the service building. Each auxiliary power supply consists of a high voltage charging power supply, thyratron filament and reservoir power supplies and others. The high voltage charging power supply charges the PFN capacitor bank. The filament and reservoir power supply heats the thyratron in the PFN tank. Several power supply control units are positioned in the service building.

## 2 KICKER MAGNET PARAMETER AND PFN MAIN DESIGN DATA

According to the beam dynamic requirements and ring beam line layout, 14 ferrite kicker magnets can kick the beam from the accumulate ring through a beam transfer line into the target area. The 14 kicker magnet parameters are listed in table 1. The BPFN parameters are listed in table 2.

| kicker | H(m) | V(m) | FT Length(m) | kick(mrad) | I(kA) | B/sect(Gauss) |
|---|---|---|---|---|---|---|
| K11 | 0.120 | 0.136 | 0.40 | 1.78 | 2.40 | 251 |
| K12 | 0.145 | 0.132 | 0.40 | 1.47 | 2.39 | 208 |
| K13 | 0.145 | 0.132 | 0.40 | 1.47 | 2.39 | 208 |
| K14 | 0.178 | 0.127 | 0.51 | 1.52 | 2.40 | 170 |
| K15 | 0.178 | 0.127 | 0.51 | 1.52 | 2.40 | 170 |
| K16 | 0.211 | 0.133 | 0.51 | 1.28 | 2.40 | 143 |
| K17 | 0.211 | 0.133 | 0.51 | 1.28 | 2.40 | 143 |
| | | | | | | |
| K21 | 0.162 | 0.233 | 0.43 | 1.43 | 2.44 | 189 |
| K22 | 0.162 | 0.233 | 0.43 | 1.43 | 2.44 | 189 |
| K23 | 0.162 | 0.233 | 0.43 | 1.43 | 2.44 | 189 |
| K24 | 0.162 | 0.233 | 0.43 | 1.43 | 2.44 | 189 |
| K25 | 0.151 | 0.243 | 0.39 | 1.40 | 2.44 | 203 |
| K26 | 0.151 | 0.243 | 0.39 | 1.40 | 2.44 | 203 |
| K27 | 0.151 | 0.243 | 0.39 | 1.40 | 2.44 | 203 |

Table 1: Kicker magnet parameters.

| | |
|---|---|
| Magnet operation current | 2.5 kA |
| BPFN operation voltage | 35 kV |
| Current pulse repetition | 60 Hz |
| Kicker magnet inductance | 1.1 uH |
| Magnet pulse current rise time | 200 nS |
| Magnet current pulse flat top time | 750 nS |
| | |
| Pulse transfer cable impedance | 25 ohm |

Table 2: BPFN design parameter requirement

* Work performed under the auspices of the U.S. Department of Energy

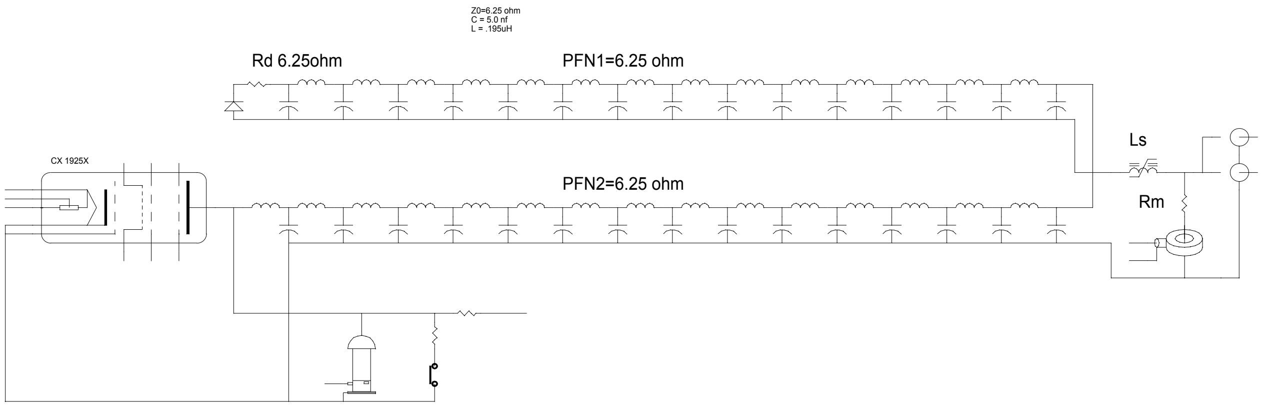


Figure 2: BPFN diagram

# 3 FIRST ARTICLE BPFN DESIGN

## *3.1 BPFN Design*

In order to reduce maintenance radiation risk and to maintain the kicker system easily, the PFN is moved from the accumulator ring tunnel to the PFN building. A Blumlein type Pulse Forming Networks (BPFN) was chosen as the High Voltage Pulse Modulator. Two 50 Ω coaxial cables connected in parallel transfer current pulse to the magnet from BPFN. Figure 2 shows the Blumlein type Pulse Forming Network circuit principle. Two PFNs with 6.25 Ω impedance are connected in series as BFPN. A high power fast switch thyratron is picked to discharge the energy stored in the BPFN. A 25 Ω high power resistor, Rm is connected across the BPFN output to the two 50 Ω cables. This resistor has two functions. One is to match the two 50 Ω coaxial cables in order to present a 25 Ω resistor as required for the damping of the coupling impedance resonance in the kicker magnet. The second function is to absorb the whole BPFN energy. A saturating inductor, Ls is inserted between the matching resistor Rm and BPFN output. This saturating inductor has two functions. One function is to shorten the magnet pulse current rise time [3], and the other is to isolate the coupling between the BPFN and the 25 matching resistor when the beam is accumulating in the ring, in order to minimize the beam transverse coupling impedance.

## *3.2 BPFN Main parts Chosen*

### *3.2.1 BPFN Capacitor*

Two PFNs with 6.25 Ω impedance are connected as Blumlein type pulse forming network. Each PFN consists of a 15 sections of LC network. A high voltage capacitor is chosen as the energy storage capacitor. The PFN capacitors are made by General Atomics, with a very low inductance, around 15nH. The cap capacitance is 5nF. The voltage rating is 50KV with a 50% reversal voltage.

### *3.2.2 High Power Fast Switch*

A Marconi thyratron, model CX1925X, (Figure 3) was chosen as the high power fast switch to discharge energy from the BPFN into the matching resistor Rm and two coaxial cables.

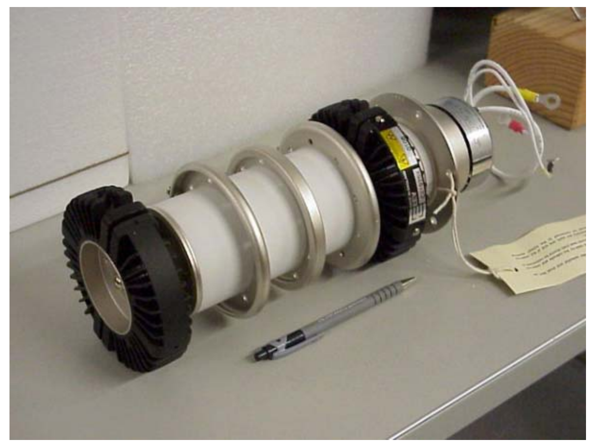

Figure 3: CX1925X thyratron picture.

### *3.2.3 High Power Resistor*

The 25 Ω matching resistor, Rm consists of twelve ceramic resistor discs. Each disc is 125 mm in diameter and 25.4 mm thick. The resistor stack is shown in figure 4.

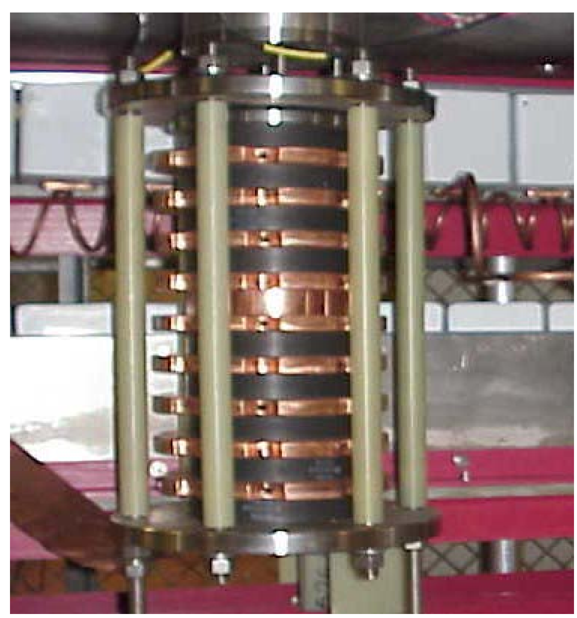

Figure 4: High power resistor stack picture

### *3.2.4 Saturating Inductor*

An assembly of ten-ferrite toroids is positioned at the BPFN output. Each ferrite toroid has a 3.9 in. OD, a 2.1 in. ID, and one half inch thick. The ferrite Initial Permeability, $\mu_i$ is 2300. The Flux Density, B is 4800G at 5 oersted. The ferrite toroids stack is shown at figure 5.

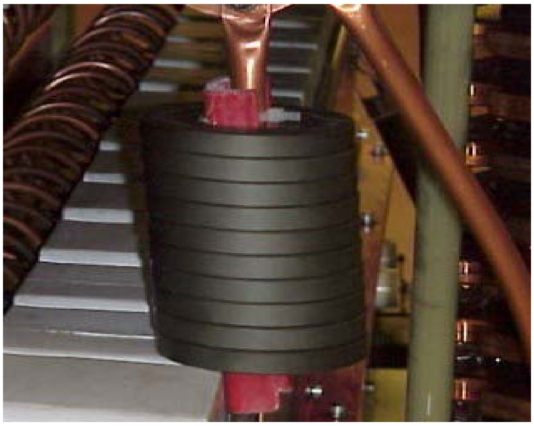

Figure 5: Saturating inductor ferrite toroids stack picture

### *3.2.5 High Voltage Charging Power Supply*

A capacitor charging power supply, model ALE 802L is used to charge the BPFN. This charging power supply rated 50kV can charge the BPFN to 40kV in a 60Hz pulse repetition frequency.

### *3.3 First Article BPFN Assembly*

The BPFN is sitting in a rectangular tank. A Dow Corning 561 silicone Transformer Liquid is used for the BPFN cooling. It provides a combination of dependable safety features and high-performance characteristics. Dow Corning 561 silicone transformer liquid is heat-stable dielectric coolant featuring much greater fire and oxidation resistance than mineral oils, without the environmental hazards of PCB- based askaers [2].

The rectangular BPFN tank is cooled by pumping silicon fluid through a water-cooled heater exchanger. The BPFN assembly and tank picture is shown in figure 6.

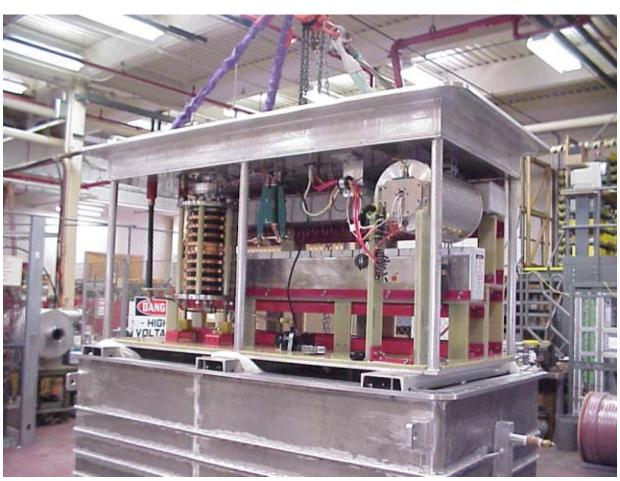

Figure 6: BPFN tank assembly picture.

## 4 TEST RESULT

### *4.1 BPFN Tank High Voltage Test*

The BPFN assembly has been running for more than 200 hours at an operating condition of 35kV, 2.5kA and 60Hz repetition. A continuous 100 hour running without stop has been reached. The assembly has been tested at 40kV for 8 hours. There were no any broken parts found after these test when the tank was opened.

### *4.2 Magnet Load Current Waveform*

A load current waveform is shown in figure 7. The test voltage is 35kV and the load peak current is 2.5kA. The current pulse flat top time is about 780nS. By using the saturating inductor for steeping the current pulse rise, the load current pulse rise time is reduced by about 20 nS. The measured pulse current rise time from 1% to 95 % is less than 200nS. The pulse flat top ripple is about ±2.5 %.

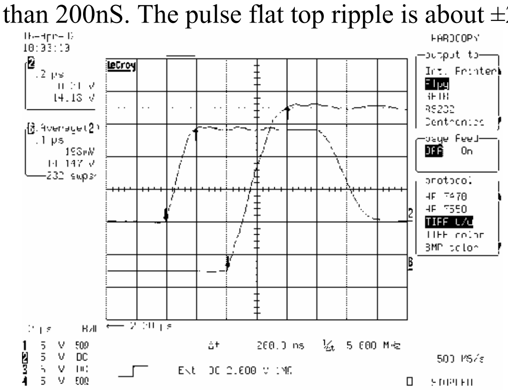

Figure 7: Magnet current pulse waveform, 1kA/div and 0.2us/div

### *4.3 Kicker Magnet Ferrite Temperature Test*

The type of ferrite used in the prototype kicker magnet is CMD5005. In order to understand the heat loss in the ferrite blocks, a ferrite heat loss measurement test was performed. The test was performed at full power, 35kV 2.5kA and 60Hz repetition. The test result shows only small or non-measurable heat created at the CMD5005 ferrite blocks. Consequently, no water cooling structure is need for the kicker magnet.

## 5 CONCLUSION AND THANKS

The SNS Extraction Kicker first article has been assembled and tested. The test results meet the requirement. The authors would like to thank K. Hartmann, S. Perlstein, J. Addessi, R. Zapasek and others who helped with the PFN assembly and test.

## 6 REFERENCES


[1] J. Wei, “ Preliminary Change Request for SNS Ring Hybrid Lattice”, BNL/SNS TECHNICAL NOTE, NO 066, October 12, 1999.

[2] “Information About 561 Transformer Fluid”, Dow Coring Product Information

[3] G. Wait etc, “The Application of Saturating Inductors for Improving the Performance of the CERN PS Kicker System”. CERN