PSR EXTRACTION KICKER SYSTEM IMPROVEMENTS

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Abstract

A program to improve the reliability of hardware required to operate the Los Alamos Proton Storage Ring has been under way for the past three years. The extraction kicker system for the PSR was identified as one candidate for improvement. Pulse modulators produce 50kV pulses 360 nsec in length at up to 24-Hz pulse repetition rate and drive two 4-meter-long stripline electrodes. Sources of difficulty with this system included short switch tube lifetime, drive cable electrical breakdown, high-voltage connector failure, and occasional electrode breakdown. This paper discusses modifications completed on this system to correct these difficulties.

1 Introduction

Extraction kickers for the Los Alamos Proton Storage Ring [1] consist of two sets of 4-meter-long electrodes pulsed to plus and minus 50 kV by Blumlein-configured transmission-line modulators. Each of the pulse modulators utilizes a single hydrogen thyratron to switch two Blumlein-configured transmission lines connected in parallel. The output connection to one of the lines is reversed to provide an inverted polarity output pulse. Ferrite cores have been added over the outer conductor of each Blumlein to increase the nominal inductance of this outer conductor to provide ground isolation for the reversed output. The system produces positive and negative output pulses that are exactly in time with each other since only one switch is used. The system suffered from fairly short main-switch-tube lifetime. In addition to short main-switch-tube lifetime the modulators utilize a pulse-charge system and the charging switch tube also suffered from short lifetime. We have replaced both switches have with EEV thyratrons.

A major part of the problem with main-switch-tube lifetime appears to have been stress from reversed current that occurs when the electrodes break down. The electrodes are 50-ohm strip lines fed at the downstream ends to take advantage of both the electric field and the magnetic field. While the basic design was good we were able to make some mechanical changes to improve the voltage holdoff capability of these structures.

Another weak point in the system was the high-voltage connection at both the modulator end and the electrode end of the drive cables. The original electrode solid connector design was replaced with a gas-insulated version. Connection to the modulator was modified to take better advantage of the insulating oil used for the modulator. In addition the original RG-218 drive cable was replaced with high quality RG-220 cable.

2 Main Switch Tube

The main switch thyratron must switch 4000 amperes in 40 nsec. This translates to a rate of rise of 100 kiloamperes per microsecond. An EGG HY-5353 was initially selected after testing several candidates. This tube cannot handle current reversal and suffered a rather short lifetime when arcing at the electrodes forced the tube to conduct in reverse. We have replaced this tube with an EEV-CX1725 [2]. The CX1725 is a hollow anode hydrogen thyratron capable of di/dt rates of 300 KA/μsec. The hollow anode design allows this tube to conduct up to 6000 amperes in reverse without damage. Arcing in our electrodes will not destroy this tube.

It is customary to supply the heater elements and the reservoir of high di/dt thyratrons with a direct current. This tends to reduce trigger jitter caused by the magnetic fields generated by heater current in the vicinity of the cathode. The CX1725 required a higher heater current than the original HY-5353 and the existing DC power supplies were unable to provide this additional output reliably. Tube specifications for the CX1725 show that one should be able to operate the heaters and reservoir from AC supplies and still achieve very low trigger jitter. Tests we conducted showed that with a large enough trigger pulse (1500 V) we in fact were able to achieve low jitter (4 to 5 nsec) but not wanting to overtax trigger circuitry we chose to use DC current. With DC-powered heaters and reservoir we achieve 1 to 2 nsec trigger jitter. We actually replaced the regulated power supplies with much simpler bridge rectifiers and filter capacitors. Regulation was obtained by installing a regulating-type line transformer ahead of the heater/reservoir supplies.

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3 Electrodes

Occasional arcing at the electrodes was of concern to us not only because it tended to destroy the main switch tube but also because it resulted in a missed kick which spilled beam around the ring. DC corona tests revealed two weak areas in the original mechanical design which lent themselves to improvement. We found considerable corona at the connection of the support insulators and the electrode. We also found trouble at the electrical feedthrough. An investigation into both trouble areas showed conditions in which the local vacuum might be much worse than the nominal ring vacuum of 1e-8 torr.

Fig. 1 shows the mechanical configuration of one of the extraction kicker electrodes. To optimize the kick angle the electrodes are inserted in the housing on a taper that matches the beam size. In addition to the taper one end of the electrode is offset in a direction to follow the displaced beam. To maintain a constant impedance with this taper and positional shift an impedance-adjusting tapered plate is added to the outer surface of the electrodes. Constraints imposed on the mechanical mountings by these offsets and tapers and mechanical tolerances of the housings resulted in a quite complex mechanical design.

Figure 1: Extraction kicker-electrode mechanical configuration.

In the original design of the support insulators connection to the electrode was made by a U-shaped copper bracket with sharp corners. A Pin holds this piece to a copper post which is threaded into the Macor insulator. The standoff insulators were in contact with the housing and only very thin long vacuum pump-out paths were included. Several improvements were made to this design.

Fig. 2 shows details of the improved insulator support structure. We have replaced the U-shaped connecting piece with a stainless steel corona ring that extends beyond the edge of the Macor insulator. This corona ring effectively shields the triple junction at the point the end piece mates with the Macor insulator. In addition, the convolutions have been reduced in diameter, moving the Macor away from the housing and allowing better vacuum pumping. A squared-off stainless steel plug traps the rear of the insulator and the rounded corners provide alignment for this plug and the insulator. Lots of opening is afforded by this squared-off design, allowing good vacuum pumpout of the volume behind the plug.

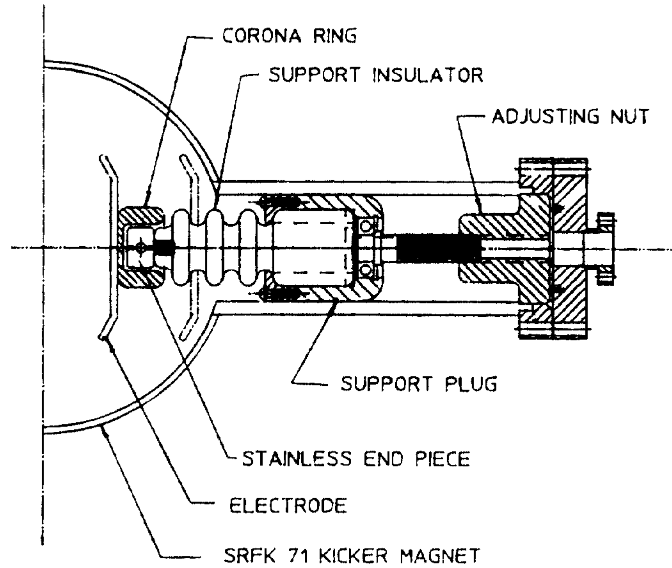

Figure 2: Support insulator.

4 Electrical Feedthrough

The original design utilized a tapered ceramic cone with a metal end cap that mated with a one-inch-diameter connecting rod. There were two major design flaws associated with this design. A corona ring originally planned for the triple junction area at the small end of the ceramic cone was never installed, and to conserve weight the connecting post was constructed as a hollow tube closed at the ends. A small pumpout port was included but was probably insufficient to really clear this volume. As shown in Fig. 3 we replaced this post with a solid titanium post which includes an integral corona ring. We have retained the rather fragile ceramic cones for the time being but plan to develop more rugged feedthroughs in the future.

5 Load Resistors

The original kicker system utilized copper sulfate load resistors. While these were excellent resistors for lab use, maintenance requirements proved to be too great for continued operation. We have replaced the copper sulfate loads with 12-inch-long 2-inch-diameter carborundum resistors immersed in oil. A water-cooled loop of copper tubing is coiled around the inside surface of the housing to obtain cooling.

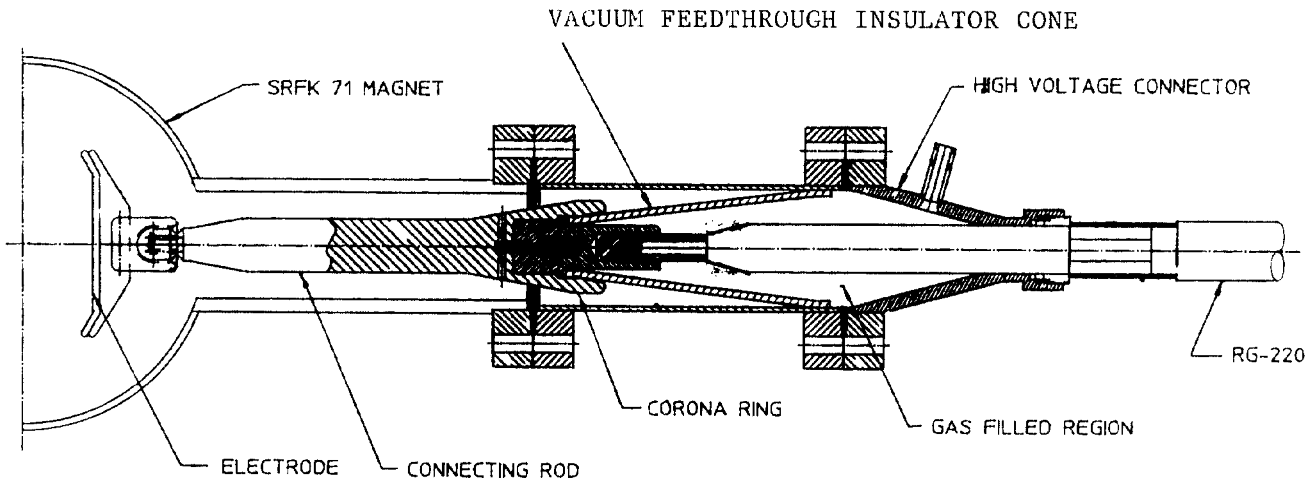

Figure 3: Electrical feedthrough.

6 Cable Connectors

Cable connection to the ceramic feedthrough was initially accomplished with a solid, rubber-filled, connector housing. The area between the air side of the ceramic feedthrough cone and a brass center conductor was filled with a rubber potting compound. The mating connector was machined from Teflon with a gentle cone shape on the mating surface. At assembly a thin coating of transformer oil is applied to the rubber and pressure on the housing deforms the potting compound excluding air. In our present connector design, the housing is filled with Freon 114, which is a high-voltage dielectric used in Tektronix high-voltage oscilloscope probes. Freon 114 provides about a factor of 3 improvement in voltage holdoff over an empty connector and we have DC tested the connectors to 70 kV. Freon 114 has a vapor pressure of 25 psi at 25 degrees centigrade so no pressurizing or manifolding is required. We simply bleed freon from a small can into the connector and close off the port valve.

While we have operated for several years with freon 114 in our connectors, concern for the environment and concern over possible hazardous compounds that could be formed during electrical breakdown have prompted us to replace the freon with dry nitrogen. Though we have not operated with the nitrogen during an actual running period we feel this will be adequate.

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