RESULTS FROM THE DEFLECTOR TEST STAND AT TEXAS A&M UNIVERSITY

D. May, G. Derrig, W. Dewees, P. Smelser, D. Tran and R. C. Rogers
Cyclotron Institute, Texas A&M University, College Station, Texas,
77843-3366, U. S. A.

ABSTRACT

The new room-temperature deflector test stand has recently been put in operation. We are beginning to test new insulator designs, new increased pumping-speed septa, and various conditioning strategies. Results of these tests and experiences with bringing these results to cyclotron operation will be presented.

1. INTRODUCTION

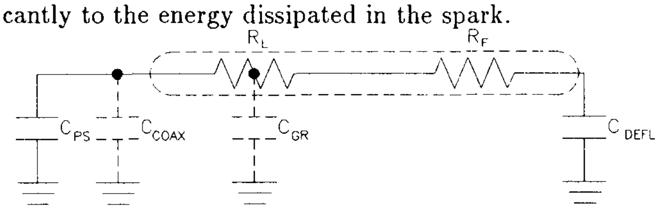
The electrostatic extraction elements (deflectors) for the K500 cyclotron are the primary limitation on the maximum extracted particle energy. This is the direct result of a limited long-term voltage holding capability of approximately 65 kV. At higher voltages sparking inevitably leads to damage to the insulators that results in complete failure to hold voltage without excessive drain current.

The room-temperature deflector test stand was built to provide an opportunity to observe the deflector under sparking conditions and test various techniques for improving the voltage holding capability. Although the magnetic field in the test stand is only 0.7 Tesla, damage similar to that experienced in the K500 has been reproduced.

A few insulator designs, spark shield materials and septa designs have been tested and are discussed below.

2. STORED ENERGY CONSIDERATIONS

Fig. 1 shows the equivalent electrical circuit of the deflector assembly. The power supplies being used are a special low stored energy type, Glassman High Voltage, Inc. model PS/LG100N-0.5X76, with an equivalent output capacitance of 200 pF. With a total distributed capacitance of 372 pF for the complete assembly, the maximum stored energy is 1.86 joules. The spark detection circuitry of the power supply turns the supply output off in less that 10 μseconds, so it does not add significantly to the energy dissipated in the spark.



C_{PS} – POWER SUPPLY OUTPUT CAPACITANCE – 200 pF

C_{COAX} – CAPACITANCE OF FLEXIBLE COAXIAL CABLE – 74 pF

C_{GR} – CAPACITANCE OF GLASS INPUT ROD – 46 pF

C_{DEFL} – CAPACITANCE OF DEFLECTOR ELECTRODE – 52 pF

R_L – DISTRIBUTED RESISTANCE OF LINE – 230 kΩ

R_F – FIXED RESISTOR, 270 kΩ

Fig. 1 Equivalent circuit of deflector, input assembly and power supply.

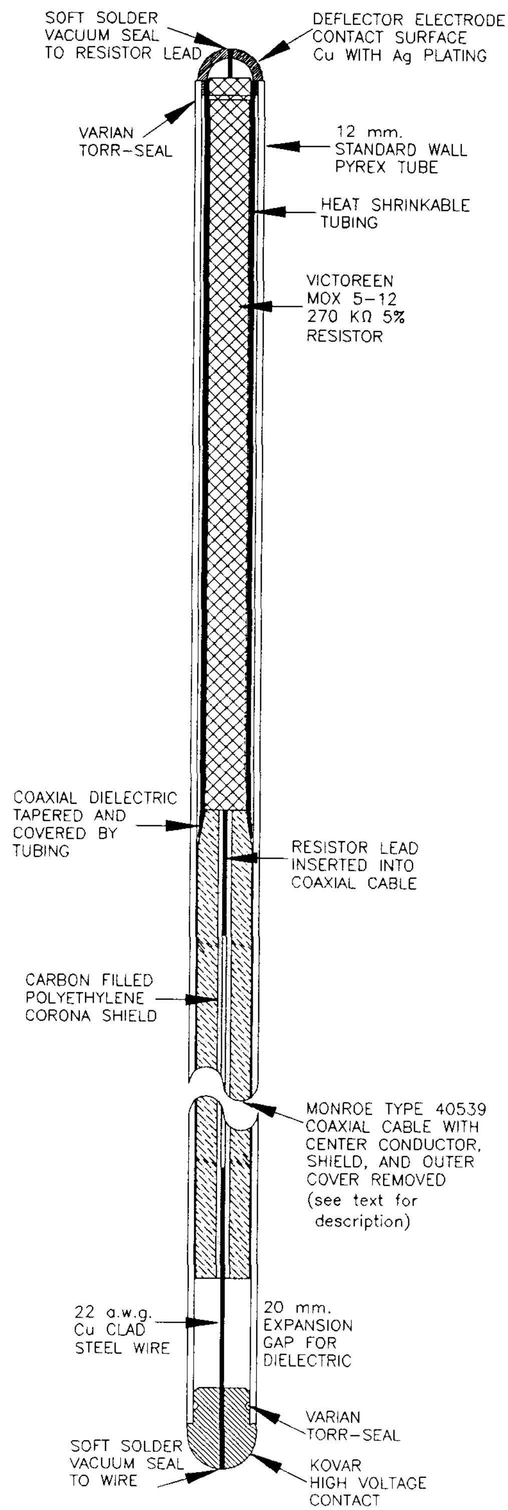


Fig. 2 Glass encapsulated high voltage input rod.

The "glass rod" referred to in Fig. 1 and shown in detail in Fig. 2 is the high voltage input to the deflector. This assembly was developed to cope with the small diameter tube which passes through the cryostat of the main magnet. The small inside diameter of the tube leads to, even with an optimally sized center rod, unacceptably high gradients at the surface of a metal rod that would result in sparking. The assembly consists of a Pyrex tube that encloses a length of high voltage rated coaxial cable, Monroe type 40539, from which the outer sheath and ground braid have been removed. The center lead is almost fully withdrawn from the cable to take advantage of the resistivity of the carbon loaded corona shield. The resistance of the cable plus the fixed resistor at the deflector end of the assembly gives a total resistance of 500 KΩ. This resistance helps dissipate some of the stored energy during sparking. The overall length of the rod is 1.03 meters.

3. FAILURE CHARACTERISTICS

It has been found in the K500 environment that voltages in excess of 65 kV lead to sparking that results in damage to the insulators. This implies that a spark of only 0.75 joules causes enough effluent to be generated at the spark impact point to cause a conductive coating to be deposited on the insulator surfaces. This appears to be the dominant failure mode and can be reproduced in the test stand even at its much lower level of magnetic field.

In addition to the leakage that is caused by sparking, another leakage mechanism seems to be the direct result of coating of the insulators with hydrocarbons. It is thought that this is the result of the use of turbomolecular pumps with poorly trapped backing pumps. Although a cryopanel has been added to the K500, it is used to augment the pumping of the turbomolecular pumps. There is room for two more cryopanels that are scheduled for installation in the latter part of 1992. Improved traps are being added to the backing pumps to reduce the possibility of backstreaming pump oil into the system.

4. INSULATOR DESIGN

The original design of the insulator followed that of the MSUNSCL as shown in Fig. 3. This design performed well in the test stand at MSU but had difficulty in the higher field of the K500. Further, this insulator is difficult to make because of the brazed connection between the sapphire and the metal end electrode.

Fig. 4 is a modification to the original MSU design that features recessed end electrodes. This design was based on a suggestion[1] that leakage along the surface from the high gradient point formed at the junction of the metal to the sapphire would be reduced. This design did not show the expected improvement but performed about the same as the original design. It did give some operating experience using the epoxy bonding technique that showed an inability to accept side loads in this configuration.

Fig. 5 is the present design being used in the K500 and undergoing continued testing. This design continues the idea of recessing the contacts but has a much larger surface area for the epoxy bond for increased strength. It also uses MACOR as the insulator material. This design has shown no particular improvement in resistance to damage but does show some improved ability to in situ cleaning by gas. This process is discussed below.

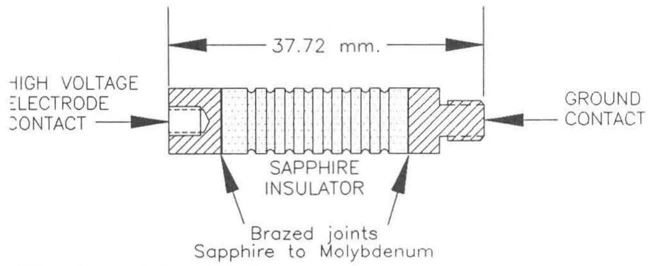


Fig. 3 Original insulator design.

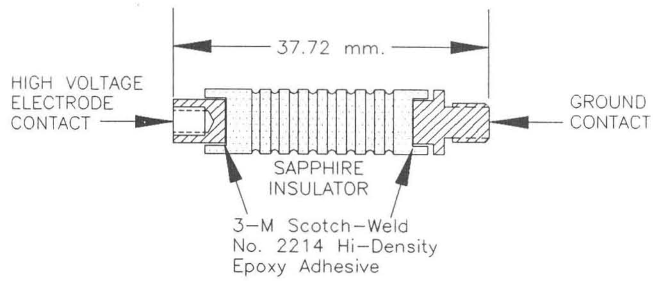


Fig. 4 Insulator with recessed contacts.

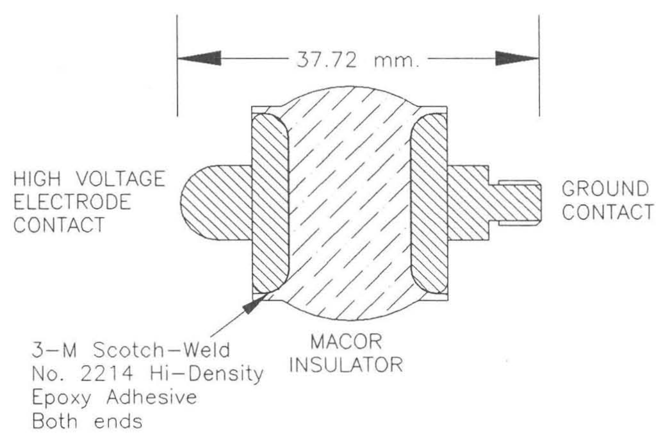


Fig. 5 Insulator now in use in the first deflector of the K500.

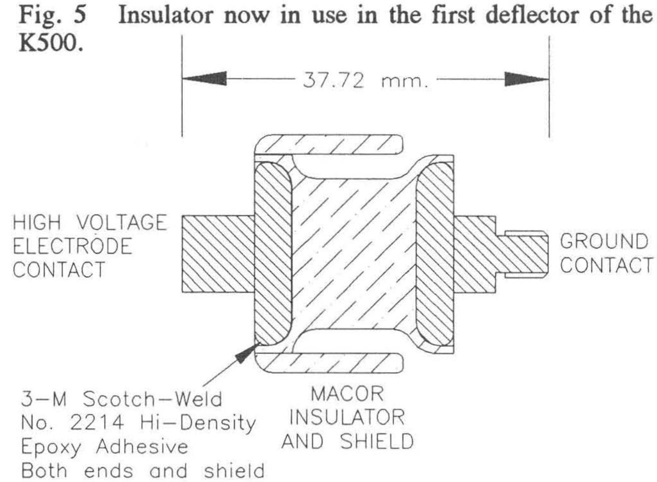


Fig. 6 Proposed self shielding insulator design.

Fig. 6 is a proposed design that attempts to cope with the plating problem by having an integral insulator shield.

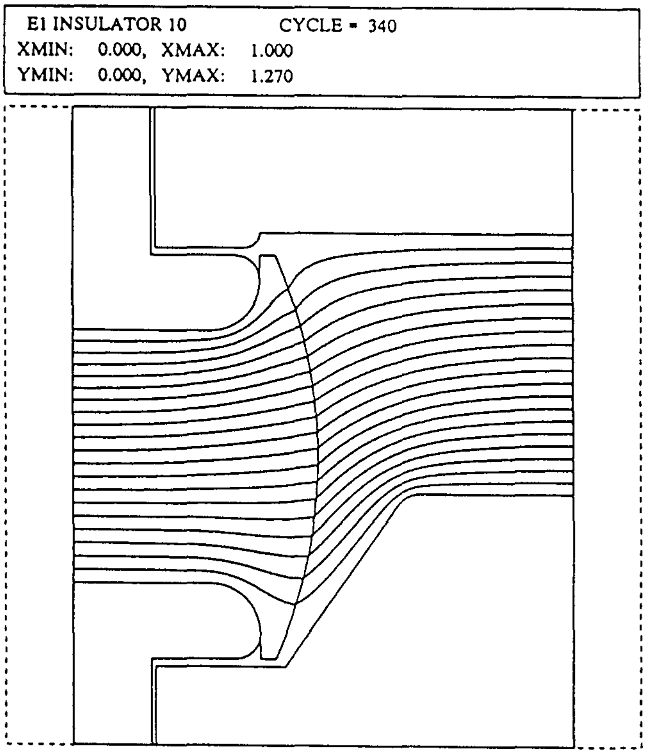


Fig. 7 POISSON field calculation of insulator in Fig. 5.

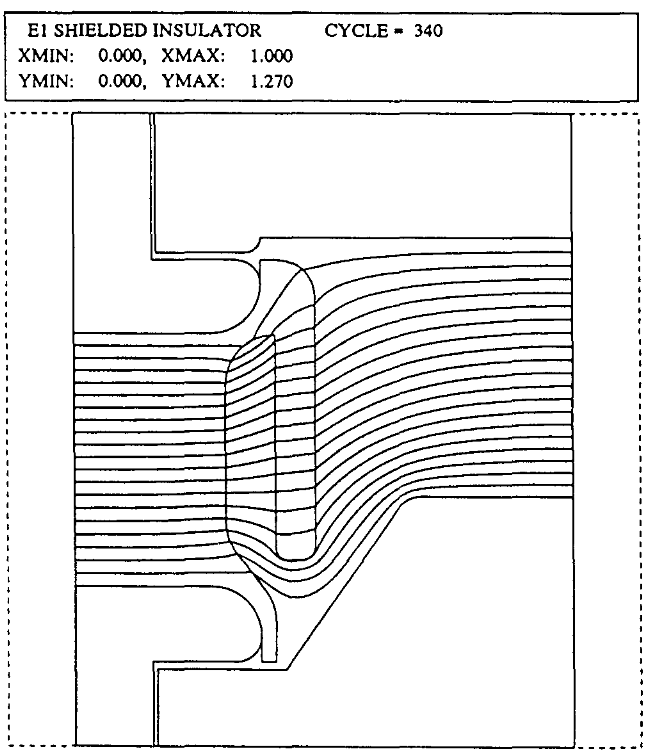


Fig. 8 POISSON field calculation of proposed self-shielding insulator.

Fig. 7 and Fig. 8 show POISSON plots of the fields for the designs in Fig. 5 and Fig. 6, respectively. The equipotential lines are in 5% increments. The shield does not appear to cause serious distortion to the field.

5. SLOTTED SEPTUM

It was suggested[1)] that better pumping in the sparking region might help remove some of the effluent caused by the sparks. To improve the pumping, a slotted septum as shown in Fig. 9 was built. The septum showed no unusual behavior in the test stand so it was installed in the K500. There has been no noticeable improvement with this design but there is some indication that the deflector is more susceptible to the effects of the r.f. fields.

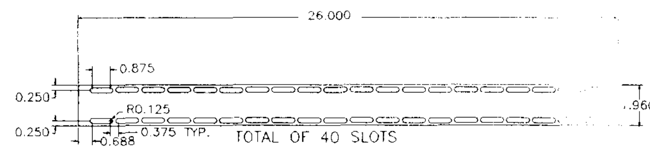


Fig. 9 Slotted system for improved pumping in deflector housing.

6. SPARK SHIELDS

From the beginning of operation, tungsten spark shields have been used above and below the high voltage electrode. Stainless steel shields have been tried in the K500 but seem to damage more easily. Shields made of 97% alumina were tried in the test stand. The maximum voltage that could be attained with no magnetic field was only 90 kV. Further, when the alumina shields were removed it was found that the surfaces exposed to the high voltage had acquired a yellow color. This apparently was not a hydrocarbon coating on the surface because it could not be removed by vigorous scrubbing. It has been suggested that the color may be the result of x-rays produced by the sparking.

7. IN-SITU GAS CLEANING

A technique for in-situ cleaning of the deflector insulators was developed by the MSUNSCL.[2)] This consists of flowing a small amount of gas across the insulators while increasing the voltage and monitoring the leakage current. In practice, the gas flow is set by monitoring the pressure in the cyclotron and typically is about 3 x 10^{-5} torr. Several types of gas have been used: air, N_2, O_2, Ar and H. The higher molecular weight molecules seem to give quicker results in reducing the leakage current. It is possible, for light ion beams which do not require low operating pressures, to allow the gas to flow continuously during operation to suppress the leakage current.

A different technique has been attempted on the test stand. The gas is introduced at a sufficient rate to raise the pressure to the range of 40 to 500 microns. At these pressures glow discharges can be initiated. It has been found that cleaning in this manner with dry O_2 can improve the voltage holding capability of the insulators but only for a limited period of time. Further, it was found that attempting the same technique with H_2 resulted in a film of fine powder being produced throughout the deflector housing. The physical appearance of the deflector after scrubbing with O_2 was extremely clean with no evidence of any residue being created.

8. CONCLUSIONS

Several different approaches to improve the deflector have been tried in the test stand but to this point only marginal improvements have been achieved. The test stand has been a valuable tool in that it allows rapid changes of configuration and has been most successful in duplicating the failure mechanisms of the K500.

9. REFERENCES

1) Proskurovsky, D., FSU Academy of Sciences, Siberian Division, Institute of High Current Electronics, 4, Akademichesky Avenue SU-634055 Tomsk, Russia, private communications.

2) Miller, P., Michigan State University, NSCL, private communication.