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K1200 Deflector Insulator High Voltage Tests

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Introduction

In this report we will describe voltage holding tests of various K1200 cyclotron deflector support insulators, performed in the TASCC high voltage materials test stand at Chalk River Nuclear Laboratories (CRNL). Instances of these insulator types are either now in use, or have previously been used to support K1200 deflector cathodes. The purpose of the present effort is to compare the voltage conditioning characteristics and the voltage holding limit of each insulator type. It is hoped that we will be able to establish which insulator design has the best performance, and how close this performance is to K1200 design requirements.

For comparison purposes, we also tested a 'greened' alumina insulator not of K1200 design, but having very good performance. This surface treatment of alumina is a promising new technique that has been developed at CRNL.[1] The results of this test will also be reported.

Test Insulator Set

Figure 1 shows the K1200 insulator designs to be tested. Insulator type-A is a 0.312 diameter Macor insulator with titanium end caps. The end caps are attached via a solder-glass fusion. The end caps fill the deflector shoe counter bores to give a 'planar' transition from metal to insulator. At present, type-A insulators are the most commonly used type in the K1200 cyclotron E1 and E2 deflectors. Insulator type-B is dimensionally the same as type-A, but using alumina insulator material and molybdenum end caps. The molybdenum end caps were attached to the alumina by brazing in a 50 torr argon atmosphere using active metal brazing alloy. We had two type-B insulators fabricated for these tests. We found that during brazing, the end caps could be displaced off axis about 10-20 mils, resulting in sharp projection of part of the end cap over the insulator end. We also found that brazing material crept up the sides of the alumina

The test stand cathode and anode have detachable end pieces. For these tests a set of end pieces were modified to hold the ends of the 0.312 inch diameter NSCL insulators, with the end caps recessed, so that the insulator end is tangent to the end piece surface, as shown in Fig. 2. To make contact, the spacing of the anode to cathode is adjusted by moving the anode toward the cathode through a sliding vacuum seal. The chamber is pumped by a turbomolecular pump and achieves a base pressure of about 10^{-7} Torr.

The test chamber has a number of available diagnostics. The upper and lower sparking plates and the anode are isolated from ground, permitting current monitoring. Externally, sparking plate currents are converted to voltages which are then displayed on an oscilloscope. In the plane perpendicular to Fig. 2, x-ray and visible light emission from the high voltage region are monitored.

Operation of the Test Stand

With floating spark plates and anode, it is possible to observe collected emission currents and their correlations with x-rays and photons. During HV ramping, the sparking plates generally had low average currents, ($\leq$ 10 microamps) but cathode sparks to ground would cause large excursions of the current on the sparking plates, and thus became a convenient way to separate average emission from sparking. During sparks, large increases in x-ray and visible light flux were also observed.

Visible light versus x-rays--these two detectors behave similarly. Raising the cathode voltage above the present conditioned level generally resulted in an increase in both visible light and x-rays, indicating increased cathode emission, <u>even when sparking was not observed</u>. Over a period of a few minutes, this emission would tend to die down. But in all tests, at the highest attained voltage, frequent cathode sparking was observed.

was observed and the test was halted. The insulator was then removed for inspection. No visible damage or discoloration was observed, but a small crater in the surface near the HV end was observed under a microscope, which one of us (W.D.), considered to be a likely cause of the failure.

The insulator failure after shutting off the magnet was a surprise. At NSCL, we often re-condition failed deflectors *in situ* by raising the voltage with the magnet off. (It is thought that spark plate damaged induced during sparking at high field can be 'healed' by B=0 conditioning, but this has not been confirmed.) Here we have a situation where B=0 conditioning was clearly deleterious. What is probably important here is the B=0 insulator conditioning is different from B=6 kG conditioning, because the insulator is mounted perpendicular to the magnetic field. So, with some magnetic field, electron motion across the insulator surface to the anode is impeded. With B=0, electron motion across the insulator surface to the anode is actually preferred, making insulator tracking possible. The failure of the type-A insulator in our test would imply that B=0 conditioning is the more difficult case for insulator conditioning.

Insulator Type-B Testing

As mentioned previously, the brazing of the molybdenum end caps to the alumina rod resulted in a slight misalignment of both end caps and some wetting of the alumina. We hand filed these areas to reduce the sharpness of the insulator/vacuum/metal interface regions prior to installation in the test stand, but significant imperfections in the joints remained. (Since these fabrication alignment difficulties would be intrinsic to routine use of this type of insulator, we saw no reason to bypass testing).

A series of three high voltage test cycles were obtained for this insulator; these are shown in Figure 4. This insulator was installed in the test stand at about 9:00 on 3 Dec 92 and high and overall lower emission current. (Perhaps the longer time in vacuum was advantageous?) The conditioning cycle is shown in Figure 5.

The planar mounting scheme of these insulators, as exemplified by the standard mounting arrangement in Fig. 2, was intended to minimize emission at the junction of cathode to insulator. [4] As tested, insulator type-C did not meet the design criteria, because the type-C end caps do not fit into the electrode tips. Since the exposed insulator end caps effectively become a cathode projection, the field at the high voltage insulator end is enhanced, and a degradation of performance would be expected. The contrary was observed--at least, if there was some degradation, it occurs above the 100 kV operating level.

Insulator Type-D Testing

The grooved sapphire insulator is a previous NSCL design and was included for testing completeness. Leakage current versus applied voltage is shown in Fig. 6. As can be seen, this insulator reaches the 100 kV power supply limit, but with about twice the emission current as the fluted macor insulator. The grooves in this insulator are designed to reduce electron transport across this insulator, and that is evidently not as successful as fluting for reducing emission current. No evidence for the 'glow discharge' failure mode was observed.

'Greened' Alumina Insulator Testing

The support insulators and the high voltage vacuum feedthru insulator of the Chalk River cyclotron deflector are 'greened' alumina. Insulators are painted with CrO_3 and heat treated--the resulting baked-on green CrO_2 layer is resistive. It is believed that this coating inhibits charge accumulation on insulator surfaces that can lead to electron cascades, tracking and sparks. A small sample insulator of 0.25 inch diam. x 27/32 inch long of this type was

References

1. W. Diamond, 13th Int. Conference on Cyclotrons and Their Applications, Vancouver, (1992), to be published.

2. J. Nolen, NSCL; B. Rodgers, TAMU--private communication.

3. B. Rodgers, Workshop on High Voltage Deflectors for Superconducting Cyclotrons, MSUCP-66, (1992).

4. T. Kuo, private communication.

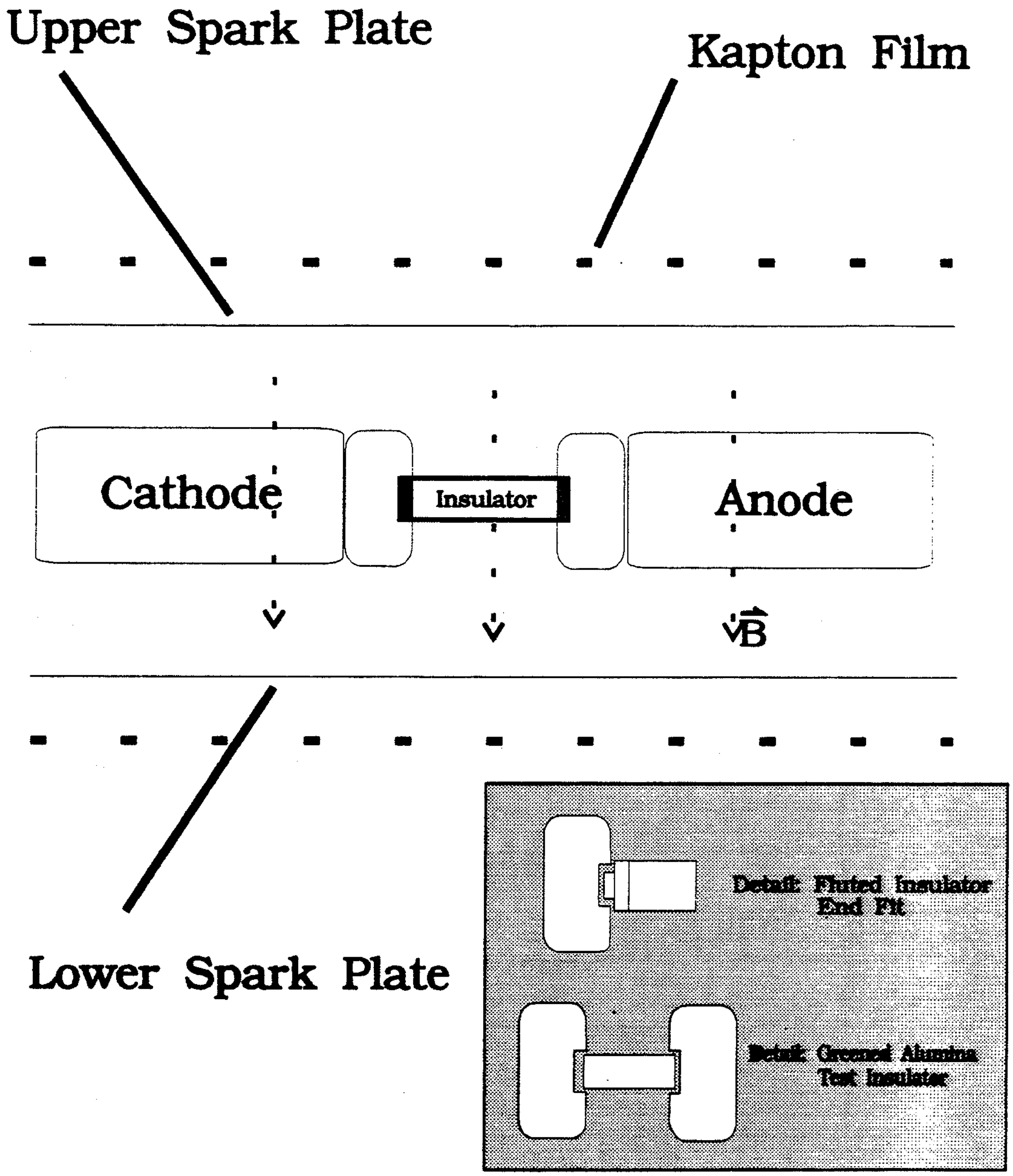

Figure 2. The TASCC Deflector Materials Test Stand is shown in schematic form for the testing of K1200 style 1.24 inch x .312 dia. macor or alumina insulators. The inset shows non-standard test configurations--see text for details.

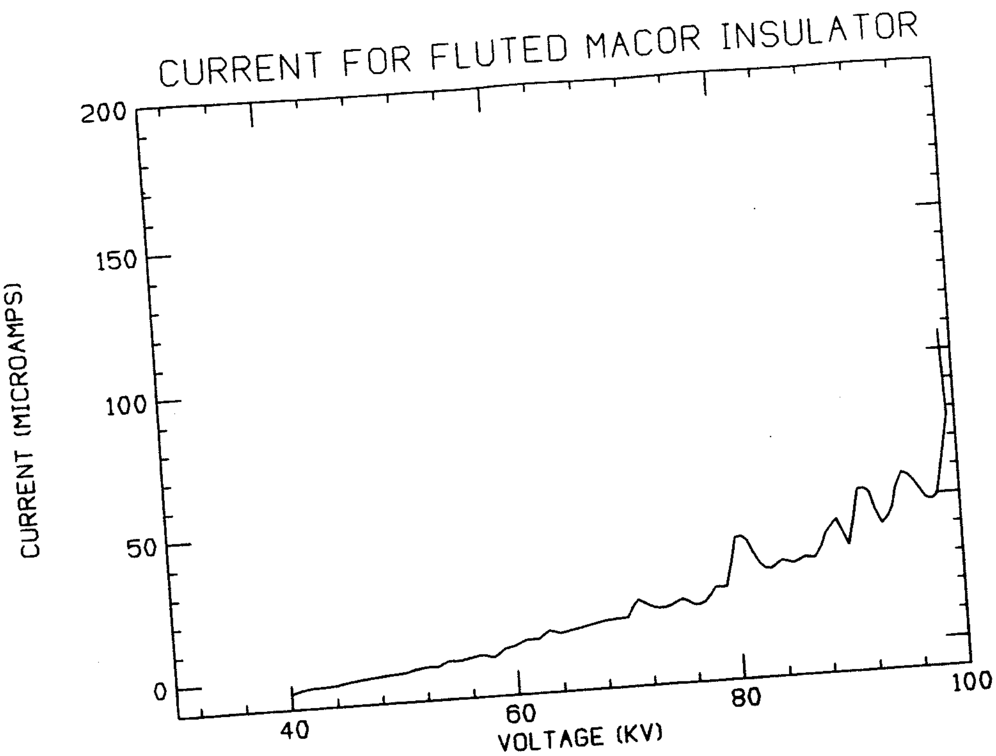

Figure 5. A single 'magnet on' training curve was obtained for the type-C fluted Macor insulator.

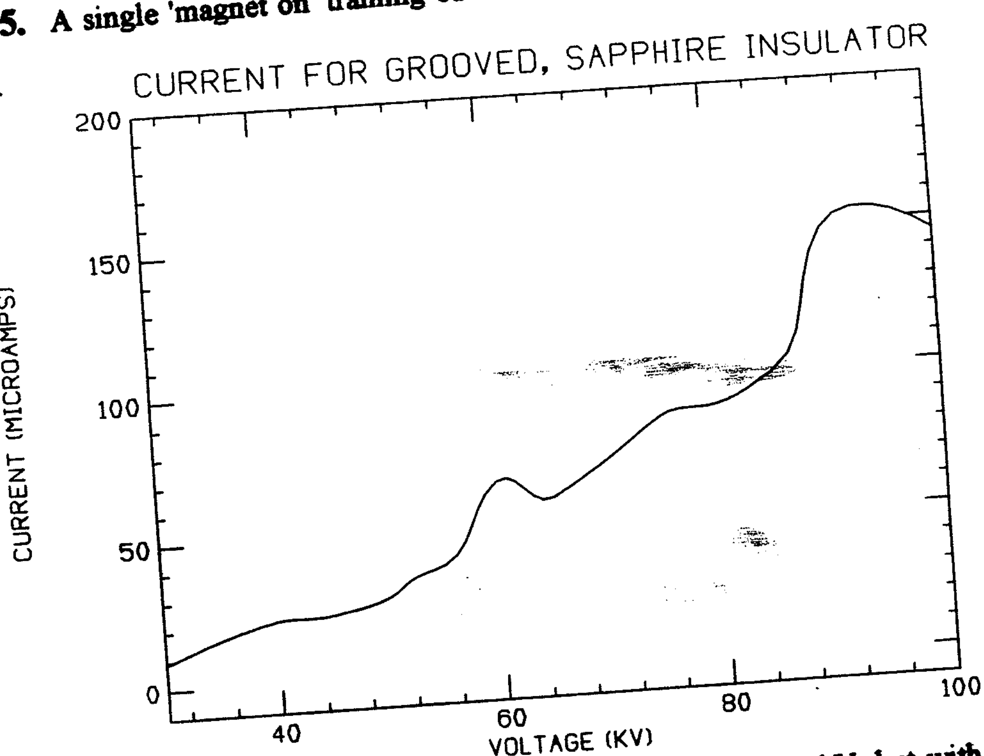

Figure 6. The fluted sapphire insulator type-D also reached 100 kV, but with very high leakage current over the whole training cycle.