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IMPROVEMENT OF THE HIGH VOLTAGE PROPERTIES OF THE FERMILAB ELECTROSTATIC SEPTA*

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IMPROVEMENT OF THE HIGH VOLTAGE PROPERTIES OF THE FERMILAB ELECTROSTATIC SEPTA

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Abstract

In the Fermilab Tevatron Switchyard proton beam splits are initiated by a wire array electrostatic septum. At 1 TeV energy, and with fields limited to 50 kV/cm, and electrostatic septum more than 20 meters in length is required to produce the required angular separation between the beams for the Proton and Neutrino/Meson lines. New techniques have been investigated that will allow reliable operation at fields above 75 kV/cm with resultant beam line economy. Changes in construction and conditioning procedures have been studied using a short sample of an electrostatic septum.

Introduction

A Fermilab "splitter" septum consists of an array of 0.1 mm or 0.05 mm diameter wires made of 75% tungsten and 25% rhenium, spaced on 2.54 mm centers. Cathodes are formed from type 304 stainless steel. The electrode configuration has been shown in Ref. 11. The electric field in the gap must be 75 kV/cm in order to achieve the required beam split angle for 1 TeV proton beams. In order to achieve this field strength with a reasonably low spark rate, a lengthy conditioning procedure is necessary. A short test septum, 46 cm in length, has been fabricated and used to study this conditioning procedure.

Theoretical examinations of spark mechanisms[4-3] as well as experimental results indicate that breakdown in vacuum is influenced by electron stimulated desorption from electrodes[4-6], the size of cathode protrusions[2], and the presence of micro particles at electrode surfaces[7-10]. One scenario for breakdown is as as follows[1]: the anode (tungsten-rhenium wires) is heated by electron emission from cathode protrusions and a positively charged macroparticle is detached from the hot spot and accelerated into the gap. Electrons strike the macroparticle during its transit, heating it and producing a neutral vapor. If sufficient heating and evaporation of macroparticles occurs, cumulative avalanche amplification can cause breakdown.

The test septum has been used to examine the influence of anode surface preparation, cathode surface preparation, glow discharge surface cleaning and residual gas characteristics during and after spark conditioning.

Experimental Details

The test septum was placed inside an 11 port 32 cm diameter and 92 cm long aluminum chamber. The lowest attainable pressure, without baking, was 2×10^{-8} Torr. With the exception of two four inch diameter Viton "O" rings, all seals were metal. A quadrupole mass spectrometer and two separated vacuum pump systems were attached to the ports. The two vacuum systems included a cold trapped 400 ℓ/sec turbomolecular pump with two pumping speeds (the fast to start pumping the system and a slow variable speed for DC glow discharge) and a 600 ℓ/sec diode type ion pump. Instrumentation included a Pirani gauge, ionization gage, a viewing window, and an optical spectrum analyzer. Pressure in the system was controllable with a variable leak valve.

The electrodes of the septum were fabricated in the same way as those for beam line use. The first anode examined consisted of electropolished 0.10 mm Tungsten-Rhenium wires. The completed wire frame assembly was cleaned in an ultrasonic cleaner filled with ethyl alcohol for three hours, dried with nitrogen gas and installed into the vacuum chamber. The final stages of cathode preparation were lapping with 14,000 grade diamond paste and with 0.05 μm alumina powder, as it has been experimentally shown[2] that better polished cathode surfaces can reach higher values of the electric field.

Experimental Results

The high voltage between the electrodes was increased in time following a standard low pressure conditioning procedure until the asymptotic value of the voltage was reached. The residual gas analyses and current-voltage characteristics were monitored at the same time. Mass spectra taken during the first rise of the voltage between the electrodes from 60 kV up to 90 kV, at a pressure of 1.4×10^{-7} Torr, showed a dramatic increase of intensity of all gases with H_2,H_2O, N_2/CO, and OH being dominant peaks. The intensity of specific species during this rise at a voltage of 90 kV was 16 times larger for CO_2 and C, 7 times for N_2/CO and N, 6 times CH_4, etc., compared to the intensity when the high voltage was off. When the asymptotic value of 168 kV of the electrode voltage was reached, there was almost no change at 150 kV in the intensity at any mass number regardless of whether the voltage was applied or not. Hydrocarbons, of which masses 41,43,55, and 57 are the largest peaks, were also monitored during the conditioning. Figure 1

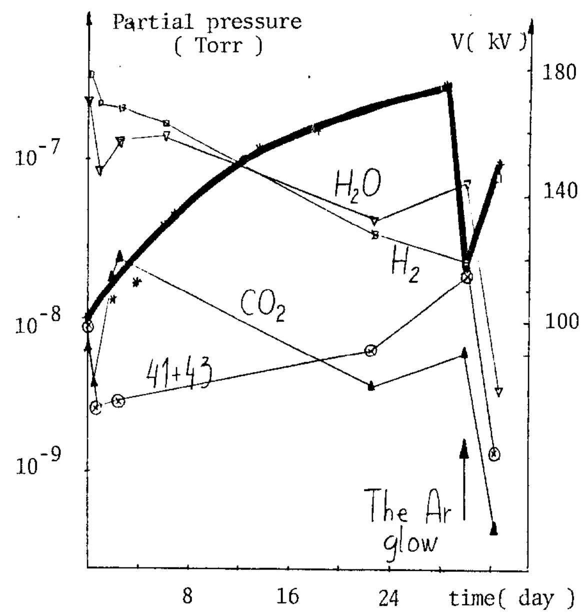

Figure 1. Partial Gas Pressures

*Operated by Universities Research Association, Inc., under contract with the U.S. Department of Energy.

be more susceptible to breakage from sparks or localized heating.

Before the electric field conditioning argon glow discharge was employed for one hour, with the first rise of the high voltage, 110 kV could be reached. The conditioning curve is presented in Figure 5. When the voltage between electrodes of 130 kV was reached a nitrogen glow discharge at a pressure of 110mTorr, with a voltage of 400 V and a current between electrodes of 200 mA was employed. The most important gain obtained by the nitrogen glow discharge was a higher attainable voltage of 160 kV. The residual gas spectrum (Figure 5) showed a change in the partial pressure of hydrocarbons 41 and 43 from 3.2×10^{-9} to 4.5×10^{-10} Torr.

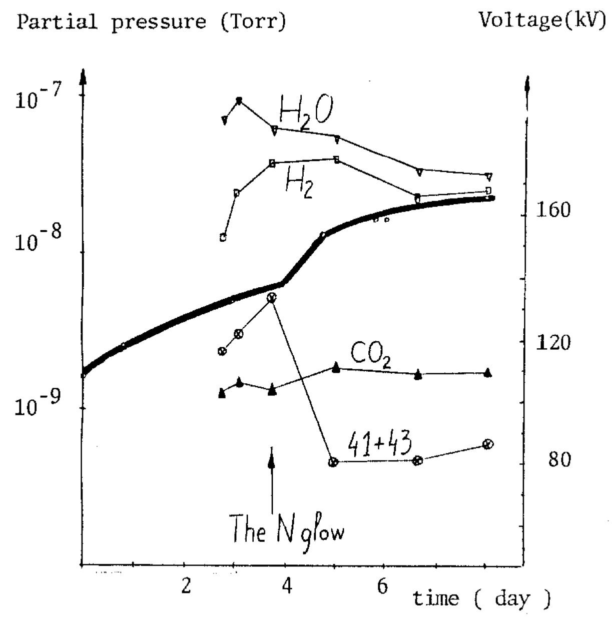

Figure 5. Partial Gas Pressures

Discussion

The conditioning procedure with the electric field of the Fermilab electrostatic septum showed that the gas desorption from electrodes is related to the breakdown mechanism. When the electrode voltage reached the asymptotic value the difference in intensities of analyzed masses in residual spectra with and without applied voltage was not easily observable. Introduction of hydrocarbons, CO_2, and H_2O lowered the value of the operating electric field.

The cold electron emission from the cathode protrusion heated the wires since very often red wires could be seen when micro discharges were not present. Sometimes it was possible to observe a spot of bright light at the aluminum frame which holds the wires. This shows that electron induced desorption was very much pronounced and comparable to the sputtering phenomena.

Argon and nitrogen glow discharge was shown to be a very useful technique for septum cleaning and faster conditioning procedure. The optical line spectra obtained during the DC Ar and N_2 glow discharges showed neutral atoms of residual gases but also of iron, aluminum, and tungsten.

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