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HYDROGEN ARC DISCHARGE CLEANING OF ACCELERATOR TUBES

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ABSTRACT

Accelerator tubes manufactured by NEC were cleaned by the hydrogen arc discharge method and tested on the NEC 3-MV test accelerator. We will discuss the results of this testing program. Generally, we confirm the favorable experience previously obtained by Korschinek, et al.[1] The familiar micro-discharges exhibited by normal tubes are largely eliminated in arc discharge cleaned tubes. Thus, the arc discharge process has the same observable effect as voltage conditioning. This result suggests that the hydrogen discharge is effective in removing carbon and hydrocarbons from the surface of the accelerator tube.

1. Introduction

Korschinek et al.[1] have shown that NEC accelerator tubes can be more effectively conditioned by the use of a low-voltage hydrogen arc discharge than by the standard methods used previously. Results from tests in a small accelerator showed substantial improvements in voltage gradients from typical values of 20-25 kV/cm to values of over 40 kV/cm.

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With Korschinek's advice and help, we assembled equipment to carry out hydrogen arc discharge conditioning at ORNL. After a period of familiarization, the equipment was transferred to the NEC 3-MV test accelerator where voltage tests could be carried out. However, the NEC accelerator could not achieve the column voltage gradient of 40 kV/cm of the Munich test accelerator but was limited to a maximum value of slightly under 30 kV/cm.

2. Some Experimental Details

Our electron emitting filaments were prepared in the same way as those used in the Munich work. A fine nickel wire mesh was coated with a mixture of nickel powder and $BaCO_3$+$SrCO_3$. These filaments gave months of satisfactory service when used to produce electron currents of 6 A. In our work, we always used two bias voltage power supplies. One power supply provided a voltage between the filament and the filament housing (ground potential). The second power supply provided the voltage for running the arc in the accelerator tube. With this arrangement, the filament provided a constant 6 A of electron current and a variable fraction of that current could be drawn through the accelerator tubes for arc conditioning. We generally used between 2 and 4 A for tube conditioning.

Our accelerator tube was conditioned while in a vertical orientation which was different from the horizontal orientation used at Munich. The orientation of the tube affects the convective cooling of the tube. When in a vertical orientation, the tube insulators experience appreciably less convective cooling. Temperature equilibrium was obtained about 30 minutes after initiating the arc discharge. With an arc current of 4 A, the outside surface of the insulators attained a temperature of 150°C.

A hydrogen pressure of at least 20 mTorr is required to maintain the arc in the accelerator tube. Arcs run very smoothly at hydrogen pressures of 50 mTorr. The arc can also be operated at higher pressures of 200-300 mTorr but instabilities are more prevalent. These instabilities can be reduced by putting a resistor (5 to 10 Ω) in series with the arc resistance.

We believe it is quite important to condition the accelerator tubes with arcs operated at 200-300 mTorr. The higher pressure helps in two ways: (1) it increases the throughput of hydrogen gas which facilitates removal of reaction product gases and (2) it reduces the mean-free-path of $^{+}H_2$ ions in the arc discharge. At 200 mTorr hydrogen pressure the mean-free-path of the $^{+}H_2$ ion is a fraction of a millimeter. This short mean-free-path reduces the average energy of ions striking the electrodes and thus reduces the sputtering of electrode metal onto the insulators. We have found barely detectable changes in the resistances of the tube insulators after running arc discharges at these higher pressures.

There is not much hard evidence on how long the arc should be run in conditioning accelerator tubes. Probably a minimum time is one hour. We typically ran the arc for two hours. More recent experience suggests that six hours may be desirable in a long tube. With regard to the magnitude of the arc current, we feel that 2 A may be marginally low and that

6 A may be too high (producing uncomfortably high insulator temperatures). We have generally worked with an arc current of 4 A.

3. Conclusions

With the reservation that accelerator tube tests suffer from very limited statistics and many variables, we summarize our results with the following points:

1. The difference in the initial behavior of arc discharge conditioned tubes and normal tubes is striking. The familiar microdischarges exhibited by normal tubes are largely eliminated in arc discharge conditioned tubes. There is essentially no vacuum activity.
2. The maximum voltage gradient is quickly achieved with tubes conditioned by the arc discharge. The column gradient proved to be the limitation.
3. Continuous X rays were frequently observed when high-voltage gradients were applied to arc discharge conditioned tubes. The intensity of these X rays could abruptly change. Once the continuous X rays were initiated, they persisted at lower voltage gradients, where they had not initially been observed. It is not clear whether these continuous X rays will prove to be troublesome in the use of arc discharge conditioned tubes to accelerate ions. However, experience with operation of the HHIRF tandem accelerator, which is equipped with accelerator tubes which also show continuous x-ray activity, suggests that continuous

x-ray activity does not adversely affect operation of the accelerator.

4. The deterioration of accelerator tube insulators by sputtering of electrode material by the arc discharge was very slight. It is important to operate the discharge at a pressure of about 200 mTorr in order to keep the mean-free path of the ion short so that they strike the electrodes with lower energies, thus reducing the sputtering yield.
5. Arc discharge conditioned tubes may be exposed to air with no obvious degradation of the voltage gradient performance.

An explanation for the effectiveness of the arc discharge in conditioning accelerator tubes is that it causes the inner parts of the tube electrodes to be heated to temperatures as high as 500°C, and that these high temperatures promote outgassing and cleaning of the electrode surfaces.[1] However, based on our test results, we prefer a somewhat different explanation. The most clear-cut result from our tests is the almost complete elimination of microdischarges following arc discharge conditioning. Although hydrogen gas was originally chosen to minimize electrode sputtering, it has other important virtues. From Tokamak wall-cleaning research, it is known that the hydrogen discharge is a very effective way to clean carbon and heavy hydrocarbons from surfaces by chemically producing methane, whereas, simple heating of surfaces does not remove these substances.[2] The good removal of carbon and hydrocarbons from the electrode surfaces eliminates the most likely source of negative ions needed to initiate the familiar microdischarge.

References

1. G. Korschinek, J. Held, A. Isoya, W. Assmann and A. Münzer, Nucl. Instrum. Methods, Phys. Res., 220, 82 (1984).

2. G. M. McCracken and P. E. Stott, Nuclear Fusion 19, 889 (1979).