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A HOODED ARC ION SOURCE WITH A MAGNETIC MIRROR FEATURE

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The ion source used for hydrogen and deuterium ions in the variable energy cyclotron at the University of Rochester is of the hooded arc type.* For the past year it has been operating with a new feature which has greatly improved its performance.

The new feature is a magnetic mirror built into the upper end of the arc hood by the simple insertion of a steel bearing ball 1/8" in diameter. (See the drawing.) The magnetic field gradient near the ball provides a magnetic mirror action on electrons moving up the arc channel toward the ball, reflecting many of them.

Before the steel ball was added the top of the graphite hood glowed a bright orange color when the arc was operating, because of the intense electron bombardment. After the ball had been added the top of the hood was found to remain black when the arc was operating. This result is taken as evidence of a strong mirror action. In view of the fact that according to an approximate expression for magnetic mirror action the critical cone outside of which an electron entering a mirror field is reflected is given† by

$$\sin^2 \theta_0 = \frac{B_o}{B_{max}}$$

where B_o = the field far from the mirror, θ_0 = the (critical) angle between the field direction (vertical) and the direction of motion far from the mirror, and B_{max} = the maximum field which the electron can encounter before striking the top of the arc channel, the strength of the mirror effect should perhaps be taken as an indication that most of the electrons approach the mirror moving in fairly tight helical orbits. Just why this should be is not apparent, but it may be due to conditions near the filament. In this connection there should be mentioned

* H. W. Fulbright, Contributions to the Washington University Cyclotron. Master's thesis, Washington University (1942).

† Lyman Spitzer, The Physics of Fully Ionized Gases. Interscience Publishers (1956).

the fact that a brief attempt to use a magnetic mirror consisting of a steel ball embedded in a tantalum button in the top of a different ion source was unsuccessful. The most obvious difference in geometry between the sources is in the filament arrangement. The filament of the second source, in this case also a hairpin-shaped 60 mil tungsten wire, is mounted with its plane vertical, parallel to the magnetic field of the cyclotron, rather than perpendicular as in the first source. However, since no detailed study of the mirror type of source has yet been made its operation is not very well understood.

The mirror feature has led to several important improvements in the operation of the cyclotron.

1) The arc current required to produce a satisfactory current of hydrogen ions has been reduced severalfold, presumably because the electrons oscillate, being reflected by the magnetic mirror at the top and by electrical repulsion from the filament structure below.

2) Filament lifetime has been increased severalfold, presumably because of reduced temperature requirements for adequate emission. Typical lifetimes of filaments had ranged from 15 to 30 hours. The first filament installed in the new source was intact, though thin, when removed after 109 hours of operation.

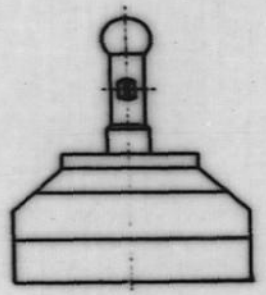
3) The stability of the arc has improved.

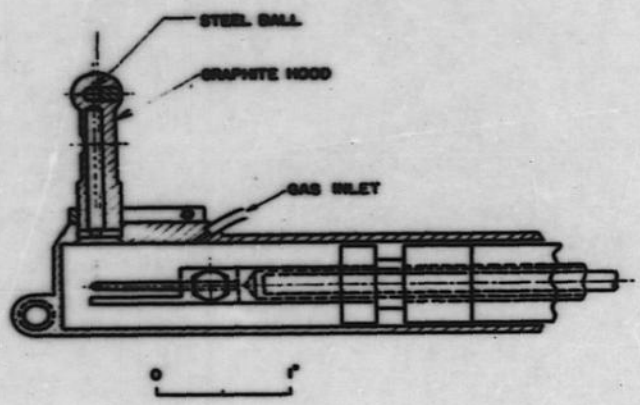
4) The gas pressure in the cyclotron tank is lower. This came about partly because the opening in the hood (through which the ions to be accelerated are pulled by the electric field of the "puller" electrodes mounted on the dee) was reduced in size to about 1/32" x 3/16" when the mirror feature was added. (However, after a few days of operation, it was found to have become somewhat enlarged in the direction of ion rotation.)

The source has been operated with magnetic fields ranging in strength from 7,000 to 14,000 gauss. Arc currents up to 2 amperes and arc voltages up to 250 have been used. For deuterium operation a current of about 0.75 amperes and a voltage of about 100 are usually sufficient. Raising the arc current from 1.0

to 2.0 amperes produces a relatively small increase in beam current.

The source has been tested briefly with alpha particles. Cyclotron beam currents were found to be of the order of 1/10 those obtained with our standard helium ion source, which is also of the hooded type, having a tantalum button supported by a short piece of quartz tubing at the upper end of a tantalum tubing hood. For these tests a hood with a larger hole, about 1/8" x 3/8" was used.





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