JUL 1 1966

UCD-CNL 49

Conf-660906-1

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CENTRAL REGION STUDIES FOR INCORPORATING AN AXIAL ION SOURCE IN THE DAVIS 76" CYCLO RON

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Davis, California

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UCD-CNL 49
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Central Region Studies For Incorporating
An Axial Ion Source In The Davis 76" Cyclotron

J. A. Jungerman

May 20, 1966

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Prepared Under
Contract AT(11-1)-Gen 10, P. A. #15
for the
San Francisco Operations Office
U. S. Atomic Energy Commission

Davis, California

CENTRAL REGION STUDIES FOR INCORPORATING
AN AXIAL ION SOURCE IN THE DAVIS 76" CYCLOTRON

L. J. Kibbe, J. A. Jungerman and N. F. Peek

The 76-inch Davis cyclotron is essentially a copy of ORIC*, and full scale magnetic field measurements have shown that the fields of the two machines are nearly identical except in the central region (at radii of less than 12 inches)¹⁾. The axial ion source originally designed for the 88-inch cyclotron at Berkeley²⁾, has been installed in the Davis machine from the bottom of the magnet. It is contained in an 8 inch diameter steel plug which passes through the lower pole of the magnet.

Before construction of the Davis cyclotron began, model studies were made on the 0.275 scale model magnet at Oak Ridge to determine if a satisfactory magnetic field could be achieved in the central region using the Berkeley ion source. The results of the model studies³⁾ showed that proper focusing could be achieved at most field levels by locating the "top" of the 8 inch plug 6 inches from the valley floor and removing the upper central ring shim from the ORIC design. This shim is shown by the dotted line in figure 1. However, it was not possible to operate the model magnet at the extremely low (3.5 kilogauss) field levels at which we might like to operate the full scale machine. The full scale magnetic field measurements subsequently showed a depression in the radial profile at low fields which had strong defocusing a poor radial profile might be unimportant, except that the ion source position is limited to a maximum radius of 2.5 inches. This forces operation at comparatively low dee voltages (20-30 kv) in order to center the orbits, and the ions are forced to spend too much time in a defocusing field. (Aside from mechanical design difficulties, the radial position limitation is apparently

* Oak Ridge Isochronous Cyclotron.

the chief disadvantage of the axial ion source.)

Figure 2 shows the full scale radial profiles of the iron field resulting from the original model design compared with the profiles of our final design and the ORIC iron. (The ORIC data shown is from the original full scale field measurements and at present ORIC has some additional iron in the center which would remove the depressions shown.⁴⁾) The final design called for moving the 8 inch plug to 5.5 inches from the valley floor and to extend the caps to a length of 3 1/2 inches. These caps saturate at high levels, but fill in the central "hole" at low fields. The flutter of the two machines is nearly identical, but the installation of the Berkeley ion source had no discernable effect in this regard.

Figure 3 shows the isochronous and operational radial profiles on which the results are based. The isochronous fields are obtained with trim coil settings computed by a linear program, and their greatest deviation from isochronism is less than 15 gauss in all cases. The isochronous conditions used as standards were computed with the formulas of Smith and Garren⁵⁾. Trim coil number 1 was used to provide the radial bump for focusing in the low-flutter region to supplement electrostatic focusing. The phase excursions in the tested fields as computed by the Crocker Nuclear Laboratory orbit code⁶⁾ are shown in figure 4. The medium and high field cases were run with 70 kv on the dee, and the low field cases with 30 kv. In all of the cases the field becomes isochronous where the phase approaches zero. The starting conditions for all cases were estimated by starting the ions on an equilibrium orbit of 12 inch radius and de-accelerating them to the center. The conditions thus obtained were used to start the ions and all data shown is from acceleration tests.

Empirical evidence obtained from recent start-up data from 42 MeV α -particles show that the beam measured at extraction is augmented by possibly 10% by using 22 amps in trim coil number 1 rather than -145 amps. The former produces the central radial bump and the latter produces the isochronous medium field profile in figure 3. Figure 5 shows the axial betatron frequency computed by the orbit code for the fields studied. Figure 6 shows the radial betatron frequencies. The particles pass through the 3/3 resonance at a radius of 6-7 inches. The computer calculations show that the radial oscillation build-up at resonance is not excessive and soon damps to 0.3 inch.

We have not attempted to obtain particle beams for the cases discussed here as we do not plan to accelerate protons until the shielding vault is completed. However, the validity of the calculations and magnetic field data is supported by the fact that we obtained an internal beam of 21 MeV H_2^+ ions using the computed field on the first attempt. It is believed that the installation of the axial ion source will contribute to reproducible operation as well as making possible future axial injection through an identical 8 inch axial hole in the top of the magnet.

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FIGURE 1.
 Ion source & central region iron geometry.

FIGURE 2.

Changes in iron profiles caused by modification of plug position and cap size.

FIGURE 3.
Operational field profiles achieved
by trim coil adjustment.

FIGURE 4.
Phase slip for computed cases.

FIGURE 5.
Axial betatron frequency.

FIGURE 6.
Radial betatron frequency.