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SPATIAL DISTRIBUTION OF CURRENT ON AN INTERNAL CYCLOTRON TARGET

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ABSTRACT

The spatial distribution of protons over an internal target in the ORNL 86-inch cyclotron was measured by activating carbon strips. Results for several operating conditions are shown, and their interpretation in terms of cyclotron theory is discussed.

SPATIAL DISTRIBUTION OF CURRENT ON AN INTERNAL CYCLOTRON TARGET

In order to measure the spatial distribution of high energy protons in the beam of the ORNL 86-inch cyclotron, a target was designed to hold 17 carbon foils, 1/32" thick by 5 1/2" long, Figure 1. After a 15 minute bombardment with 15 μa, each carbon foil was broken into 1/2" sections, along previously made scorings, and counted in a Geiger counter. The measured activity was due to long-lived impurities in the carbon and the 20-minute activity from C 12(p,pn)C 11, each yielding results in good general agreement. The results for various cyclotron conditions are shown in Figures 2 to 5. Figure 2 shows the total activity on each 5 1/2" foil as a function of distance from the leading edge of the target; and Figures 3-5 show contours of constant current, with intensity proportional to the figures shown on the contour lines.

The theoretical expression for the radial width or the distance between successive orbits may be obtained from the expression for the energy,

$$E = 1/2\ m\omega^2 r^2 \tag{1}$$

where $\omega = eH/mc$, the circulation frequency. Differentiating (1)

$$\Delta E = m\ \omega^2\ r\,\Delta r \tag{2}$$

and dividing (2) by (1) gives

$$\frac{\Delta E}{E} = \frac{2\Delta r}{r} \tag{3}$$

The energy increase per turn is

$$\Delta E = 4\ V_0 \cos\theta \tag{4}$$

where V_0 is the maximum dee-to-ground voltage and θ is the phase of the ions with respect to the dee voltage. Then (3) can be written

$$\Delta r = r\,\frac{2\ V_0 \cos\theta}{E} \tag{5}$$

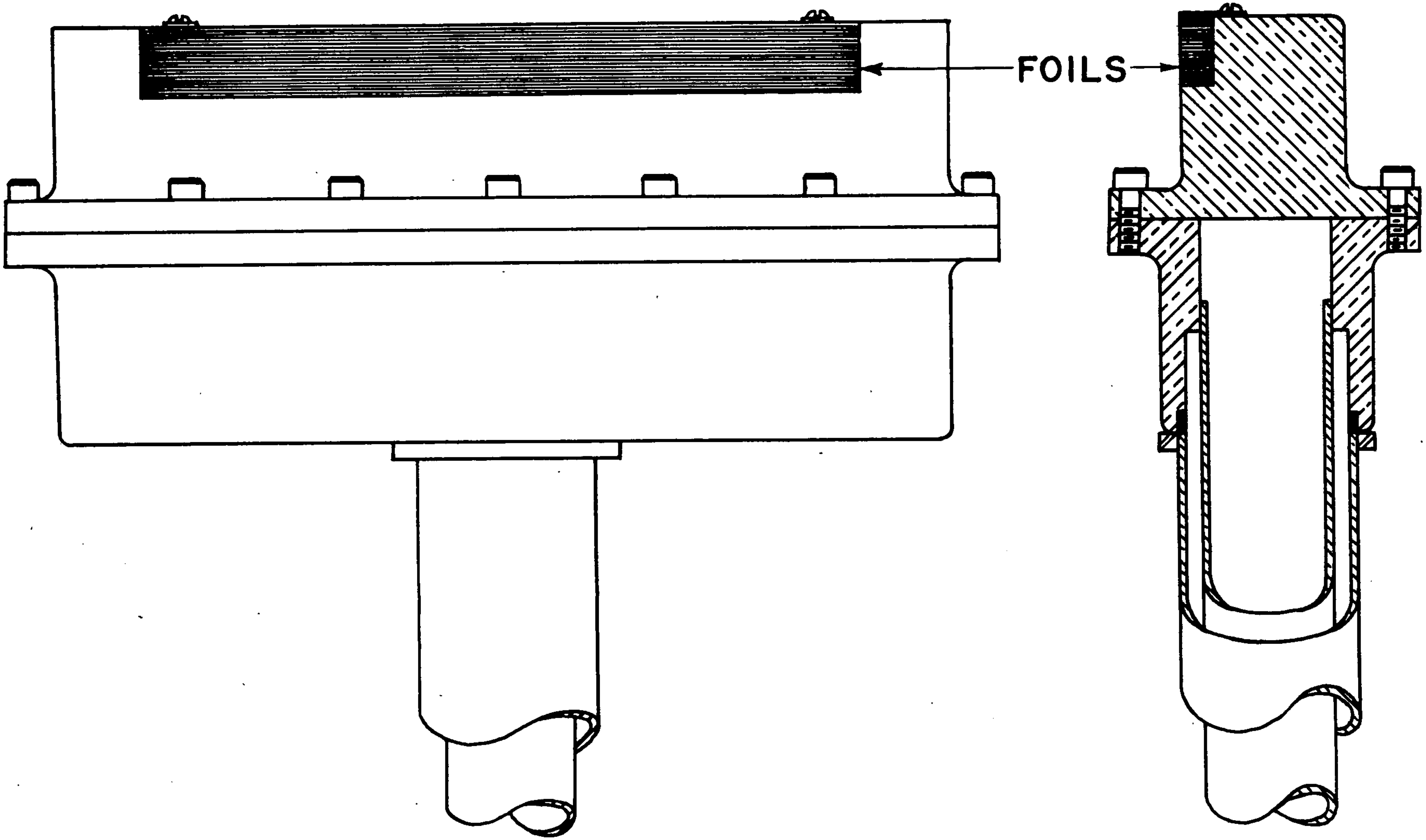

FIGURE 1. TARGET FOR MEASURING SPATIAL DISTRIBUTION
of current on cyclotron target

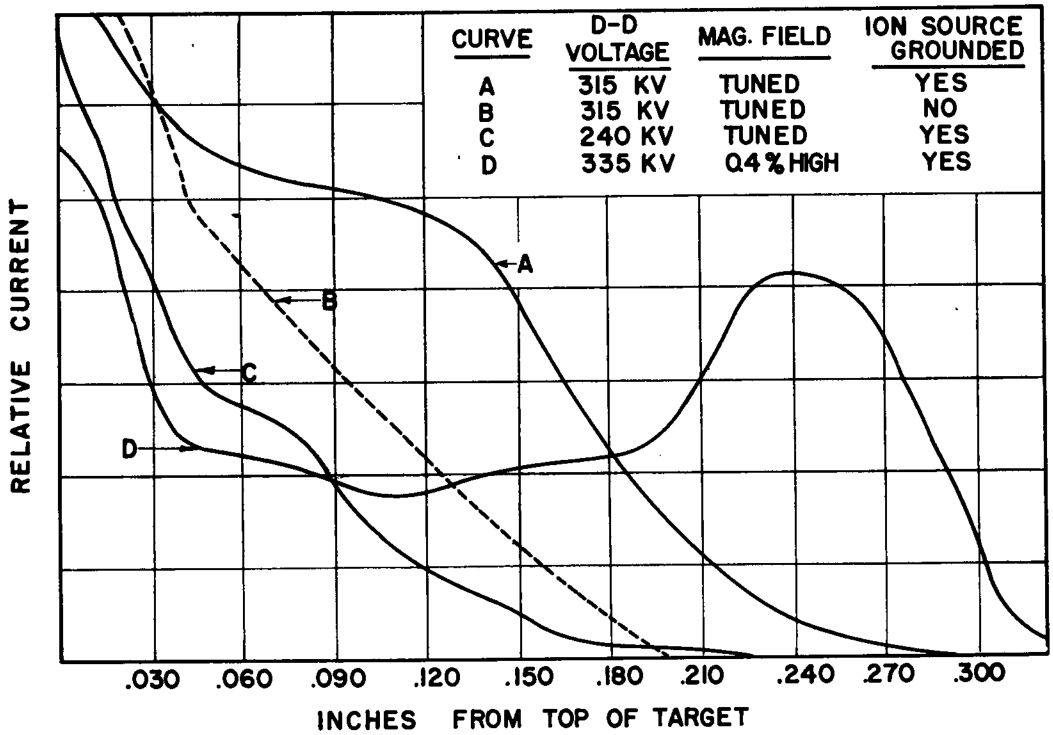

FIGURE 2. BEAM INTENSITY, as a function of distance from inside edge of target

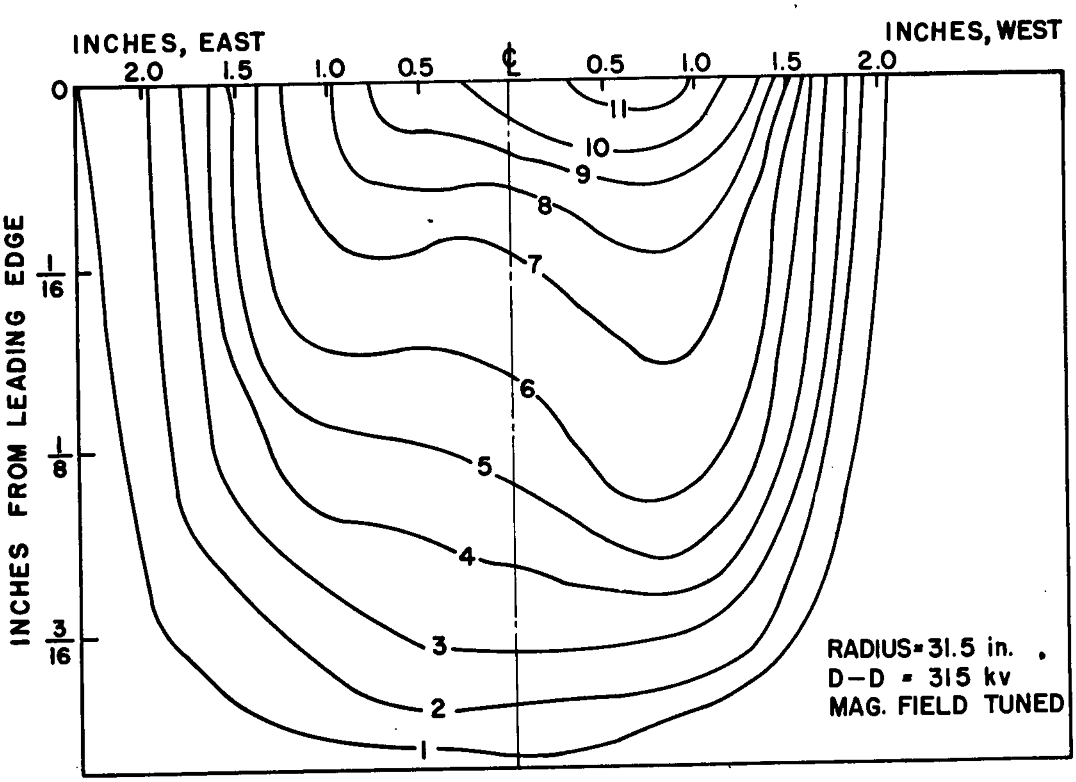

FIGURE 3. SPATIAL DISTRIBUTION FOR CONDITIONS FOR CURVE A (FIGURE 2)

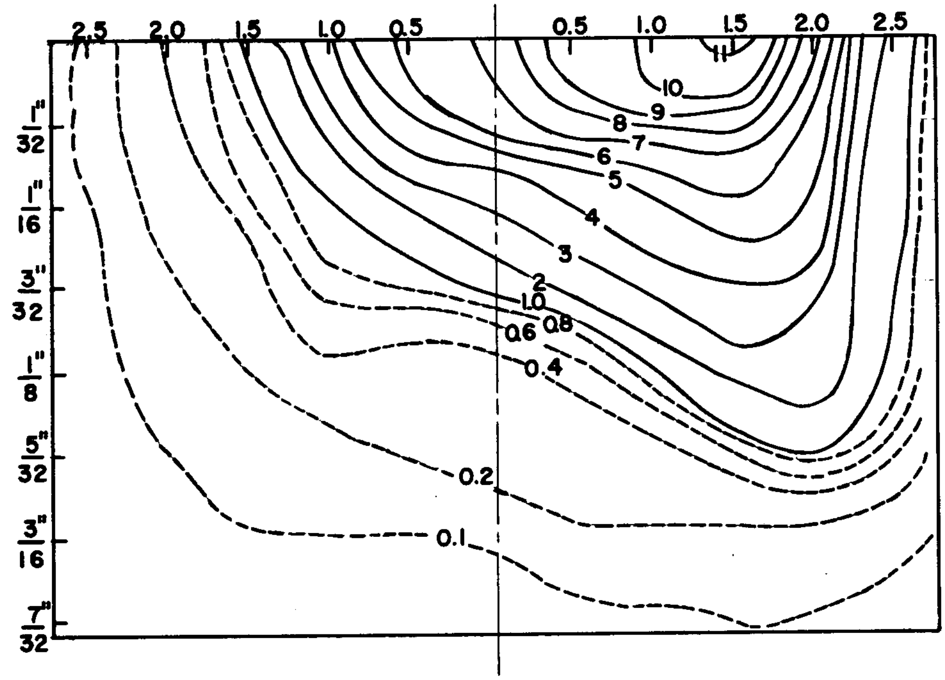

FIGURE 4. SPATIAL DISTRIBUTION FOR CONDITIONS OF CURVE C. (Figure 2)

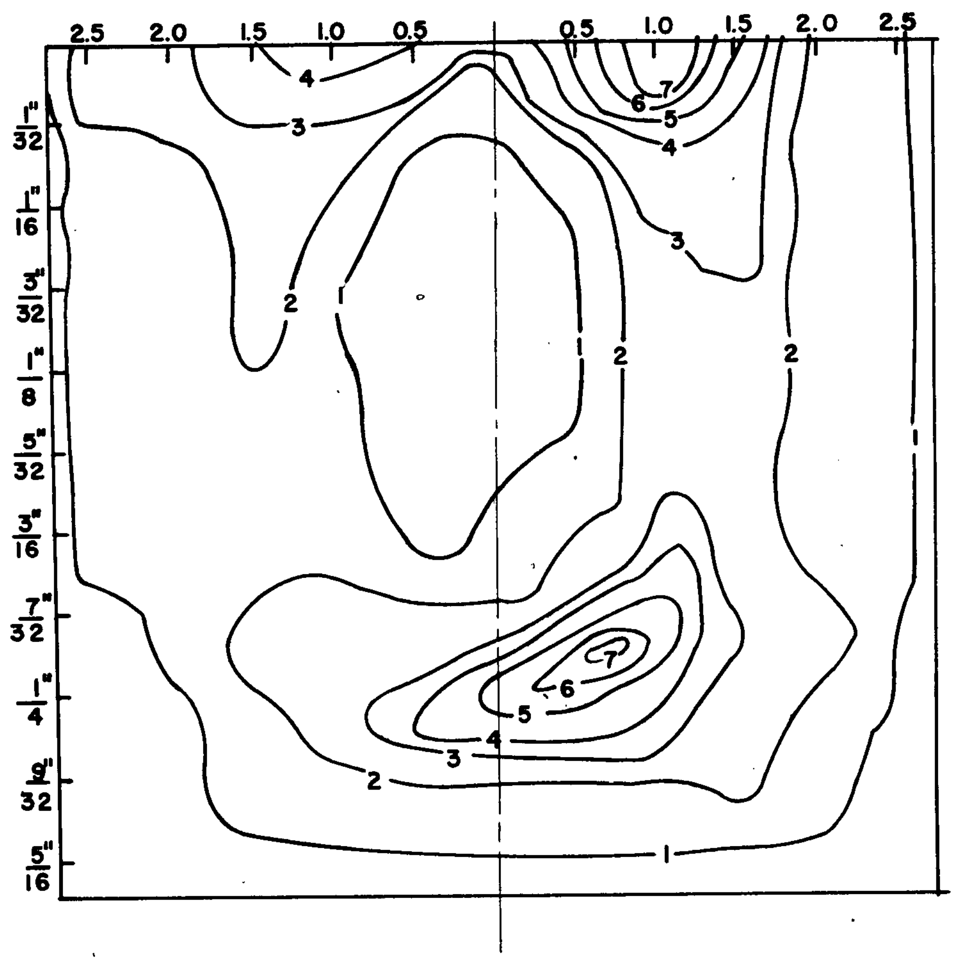

FIGURE 5. SPATIAL DISTRIBUTION FOR CONDITIONS OF CURVE D (Figure 2)

From (5) the measurement of Δr is essentially a determination of the phase. The table below shows the results of applying (5) to Figure 2.

Curve	Δr (exp)	V_{D-D} (kv)	θ_{min}
A	0.29"	315	60°
B	0.19	315	72
C	0.22	240	60
D	0.40	335	50

These phases are in general agreement with the predictions of cyclotron theory.[1] In addition, Figure 2 indicates that leaving the ion source ungrounded has a very substantial effect, since it then floats nearer the potential of the accelerating slit which is attached to the dees. This reduces the effect of the latter and the radial width approaches the theoretical predictions for a cyclotron without an accelerating slit.[2]

The theoretical effect of detuning by 0.4% is to reduce the final phase by 0.004 x 360° x number of turns. For the conditions of Figure 4, this amounts to 45°. Actually, the phase from Curve D is only about 10° less than the phase from Curve A. This is probably due to the fact that the ions which were the chief contributors to the current at resonance are lost by defocusing[3] and ions of more positive phases are now the chief contributors.

A striking feature of Curve D and to a lesser extent of Curve A is the residual effect of radial grouping.[4] Assuming that tuning the cyclotron includes setting the group on the target edge, the phase of the principle part of the group is, from (5), 74° for Curve A and less than 65° for Curve D. These are in good agreement with the theoretical predictions.

1. Cohen, B. L., AECD-3301, p. 21, p. 48.
2. Ibid. p. 19.
3. Ibid. Part II
4. Cohen, B. L., Article submitted to Review of Scientific Instruments.