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PEELER EXTRACTION OF A SYNCHROCYCLOTRON BEAM*

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A study of a perturbation in the fringing magnetic field of a synchrocyclotron was made using the computed unperturbed orbits of the modified Berkeley 184-inch synchrocyclotron.[1] Instead of a field increase, as is used conventionally in the nonlinear field region of a synchrocyclotron this perturbation is a field reduction.[2] Only median-plane particles were considered, and the perturbation was a δ function of two variables, the radial amplitude and the azimuth of the particle to be extracted. The extraction of the beam with a field reduction function of the radius only was considered previously by Tuck and Teng in the linear field region,[3] but it was discarded because it is not possible to show that the extraction can take place in a finite number of turns. The same is valid for the nonlinear field region.

The peeler extraction proposed here overcomes this limitation by using a perturbation that recedes with increasing radial amplitude. This is shown in Fig. 1, where r is the radial amplitude of oscillation and the base line is the synchronous orbit chosen for the extraction. The recession is measured by the angle ϕ, and its direction is opposite to the direction of circulation of the beam. Figure 2 illustrates a suitable perturbation choice

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† Visitor from the Atomic Energy Commission of Argentina.

1 These were obtained by W. F. Stubbins by numerical solution of Lorentz equations with a digital computer.

2 K. J. LeConteur and S. Lipton, Phil. Mag. 46, 1265 (1955); Warren F. Stubbins, Extraction of Synchrocyclotron Beams Near the Maximum Energy, UCRL-3476, July 1956.

3 J. L. Tuck and L. C. Teng, Institute of Nuclear Studies, 170-In. Synchrocyclotron Progress Report III, University of Chicago, 1950.

for the Berkeley machine.[4] The recession is 15° per inch of radial amplitude.

An extracted particle orbit is shown in Fig. 1. A successful encounter of the perturbed field can be defined as one that results in a gain of radial oscillation amplitude. With a perturbation function of radius only, a particle can encounter the perturbed field at any radial amplitude and consequently at any radial velocity. The recession implies that the encounter can take place at any radial amplitude when the radial velocity is pointing away from the center of the machine, but instead it can take place in a radial-velocity range 0 to $\dot{r}_{limit} < \dot{r}_{maximum}$ when it is pointing towards the center of the machine. It is obvious that the recession ϕ determines $\dot{r}_{limit}$ for every orbit. As the perturbation is a field reduction, the change in radial velocity $\Delta\dot{r}$ points away from the center of the machine. The condition for a successful encounter is $|\dot{r}_{final}| = |\dot{r}_{initial} + \Delta\dot{r}| > \dot{r}_{initial}$ (A), where $\dot{r}_{initial}$ and $\dot{r}_{final}$ are respectively the radial velocity before and after the encounter. The case of interest is precisely the one where $\dot{r}_{initial}$ and $\Delta\dot{r}$ have opposite sign. The recession of the perturbation excludes for particles of large oscillation amplitudes the family of "unsuccessful" encounters, the ones that do not satisfy condition (A) and would therefore reduce the oscillation amplitude. This recession is a way of adequately phasing the perturbation, in order to exclude encounters when the radial velocity $\dot{r}$ points towards the center of the machine and is such that $\dot{r}_{limit} < \dot{r} < \dot{r}_{max}$.

Figure 3 illustrates a property that can be called contraction of the "nodal segment" and is self-explanatory. Several orbits were considered with different initial conditions. For small amplitudes (0.1 to 0.2 in.), it takes some 15 to 20 turns to complete the extraction, with 4 to 5 passages through the perturbation. The action is such that only particles with a particular set of initial conditions are extracted. The ones that do not belong to that set keep circulating until they fall into it (phasing property).

A full report will be published in the future. It is a pleasure to thank Dr. W. F. Stubbins for introducing me to the extraction problems.

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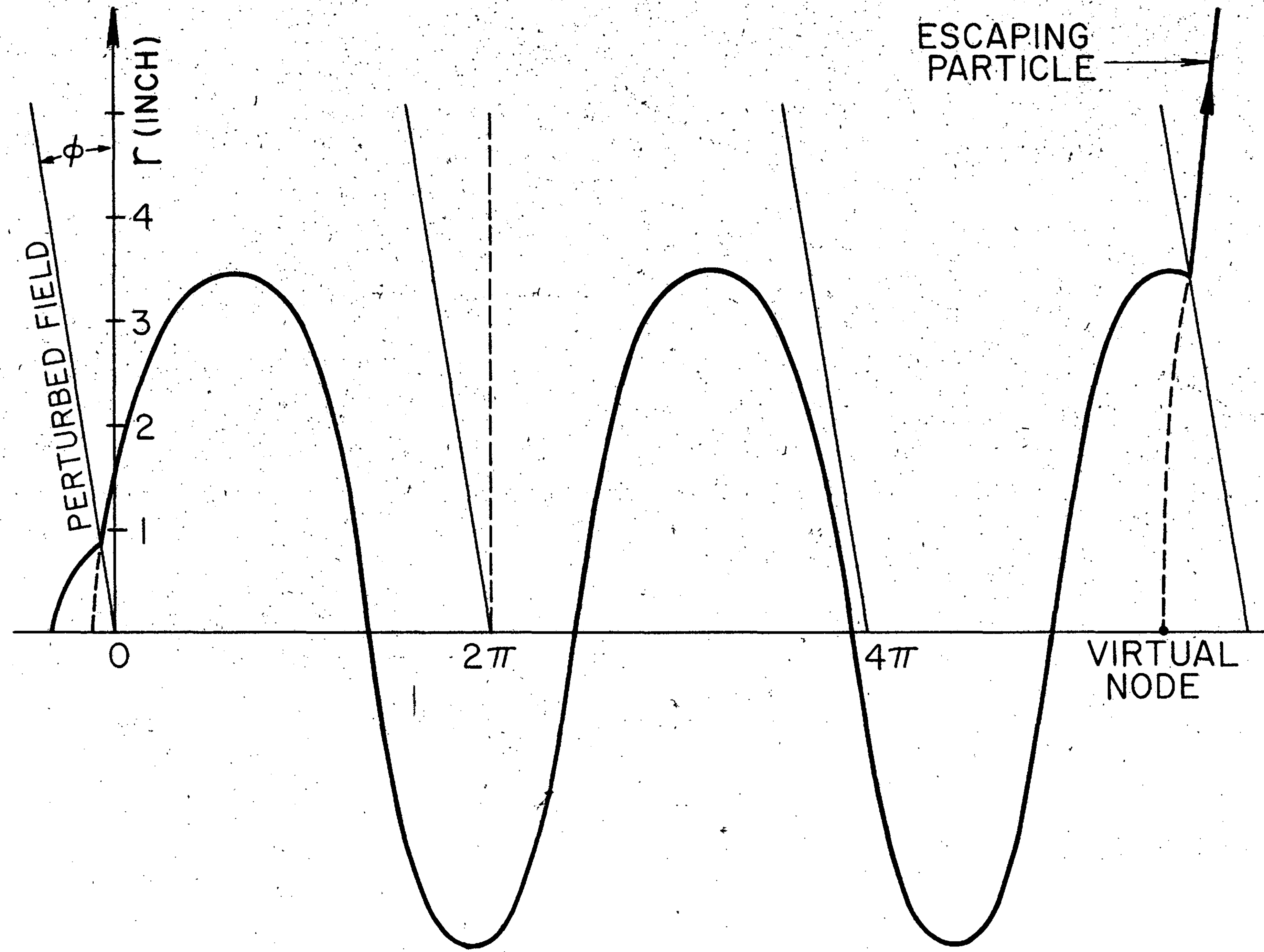
[4]The odd shape is a consequence of the fact that the freedom in the choice of the perturbed field is reduced by the requirement that the beam pass through an existing steering magnet.

Figure Legends

Fig. 1. Example of particle extraction by the proposed procedure.

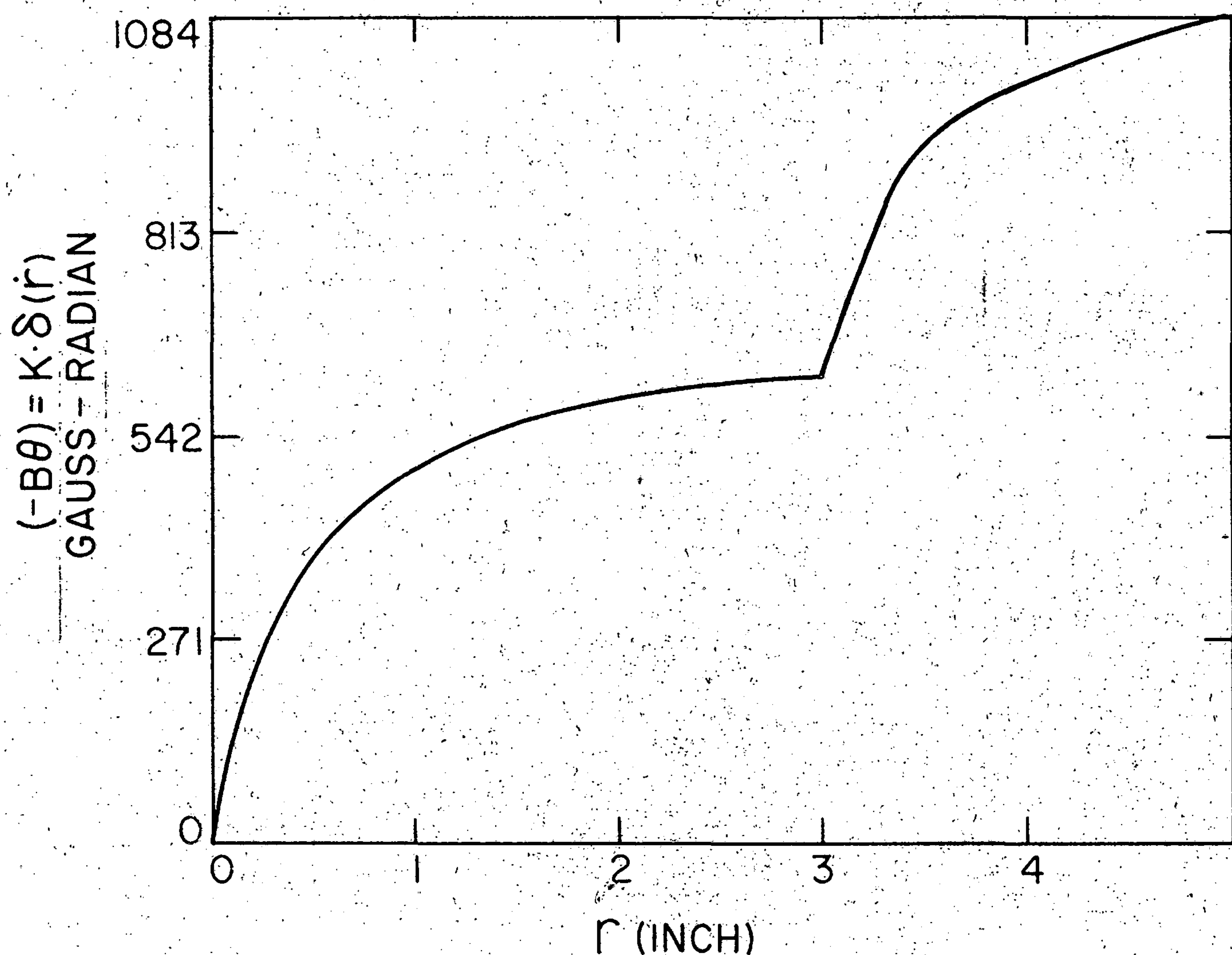
Fig. 2. Perturbation shape for the Berkeley 184-inch synchrocylotron.

Fig. 3. Contraction of a nodal segment.



r (INCH)
4
3
2
1
0
2π
4π
ϕ
PERTURBED FIELD
ESCAPING PARTICLE
VIRTUAL NODE

Fig. 1 50,056-1



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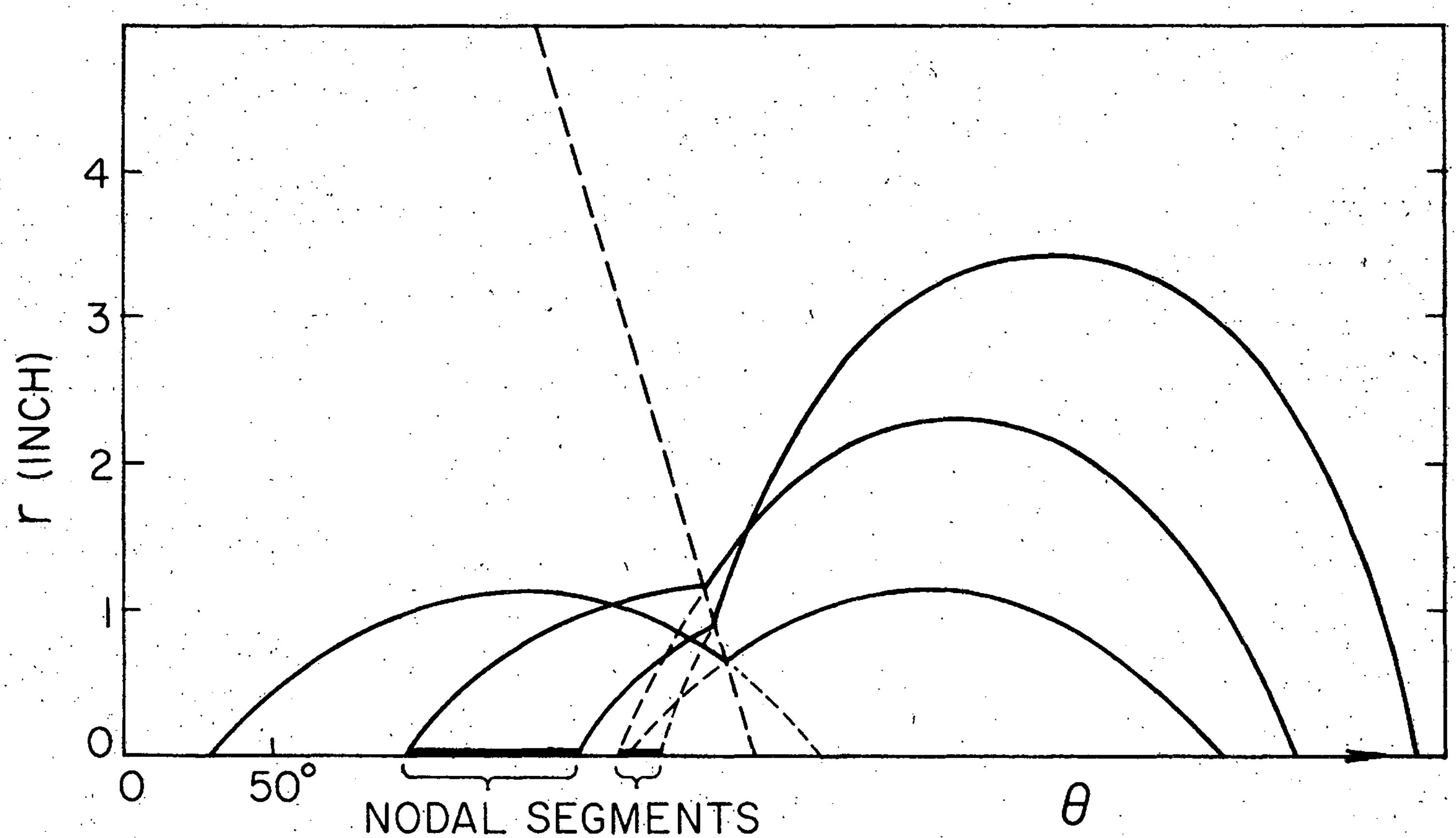

Fig. 3

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