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PEELER EXTRACTION OF A SYNCHROCYCLOTRON BEAM

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April 2, 1957

Printed for the U.S. Atomic Energy Commission

## PEELER EXTRACTION OF A SYNCHROCYCLOTRON BEAM\*

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April 2, 1957

The study of a perturbation in the fringing field that is a field reduction (peeler or degenerator) instead of an increase, as is conventionally done in the nonlinear field region of a synchrocyclotron,<sup>1</sup> was made by using the computed unperturbed orbits of the modified Berkeley 184-inch synchrocyclotron.<sup>2</sup> Only median-plane particles were considered, and the perturbation was of a  $\delta$ -function type.

The regenerator is a function of radius only and defines a stationary node for adequately phased particles (Fig. 1). The degenerator instead has to recess in angle with increasing radius in order to adequately phase the perturbation (Fig. 2). Another feature is that the perturbation does not take place on each turn (the particle illustrated in Fig. 3 misses it for two turns). Figure 4 illustrates the field perturbation necessary for the Berkeley machine.<sup>3</sup> The assumed recession is  $15^\circ$  per inch of radius. Figure 3 is an example of an extracted particle. Considering a group of particles of a given radial amplitude and different phases, their "nodal segment" (Fig. 5) is reduced as a consequence of the action of the perturbation--in the particular case of

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† Visitor from the Atomic Energy Commission of Argentina.

<sup>1</sup> K. J. LeCouteur and S. Lipton, *Phil. Mag.* 46, 1265 (1955); Warren F. Stubbins, *Extraction of Synchrocyclotron Beams Near the Maximum Energy* UCRL-3476, July 1956.

<sup>2</sup> These were obtained by W. F. Stubbins, numerically solving Lorentz equations with a digital computer.

<sup>3</sup> The odd shape is a consequence of the fact that the particles ought to go through a pre-existing steering magnet, which reduces the freedom in the choice of the perturbed field shape.

Fig. 5, by a factor of 4. Several orbits have been considered with different initial amplitudes. For small amplitudes (0.1 to 0.2 in.) it takes some 15 to 20 turns to complete the expulsion, with 4 to 5 passages through the perturbed field. It is worth while to point out that a perturbation in the field, positive or negative, indistinctly increases or decreases the oscillation amplitude. The action is determined only by the phase of the particle. If the extraction radius is  $R_0$ , and  $r_i$  is the maximum radial oscillation amplitude for particles of energy corresponding to a radius  $R_0 - r_i$ , the particles enter the perturbed field by a small gain in energy. In general, they miss the perturbed field for 0 to  $k$  subsequent turns;  $k$  is related to the precession velocity. A passage through the perturbed field means an increase or a decrease of the oscillation amplitude with equal probability. The particles that increase their amplitudes belong to the radius  $R_0 - r_i$ , and as they are not phased again, they can lose or gain amplitude. It follows, therefore, that a decrease of the average oscillation amplitude occurs when the particles gain energy and approach the extraction radius. The degenerator action for the extraction is such that it accepts particles with a particular set of initial conditions. The particles that do not belong to that set keep circulating until they fall into it, and then they are extracted.

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

LEGENDS

- Fig. 1. Regenerator action
- Fig. 2. Recession of the reduced field
- Fig. 3. Example of a particle orbit extracted by the proposed procedure
- Fig. 4. Perturbation shape for the Berkeley 184-inch synchrocyclotron
- Fig. 5. Contraction of a nodal segment











