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A SPIRAL KICKER FOR THE BEAM ABORT SYSTEM*

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Summary

A brief study was carried out to determine the feasibility of a special kicker to produce a damped spiral beam at the beam dump for the beam abort system. There appears to be no problem with realizing this concept at a reasonably low cost.

Discussion

Under any set of parameters adopted for the SSC (circulating beam current, beam emittance, and lattice beta function) the energy per unit area incident on any surface, even 1-2 km from the extraction point, is extremely high. Under no circumstances can this beam be allowed to be deposited within the ring. The beam abort system must be both very reliable and able to reduce the energy/unit area at the beam dump to levels that can be absorbed safely.

To put the problem in perspective the total circulating beam energy might be 1/2-1 GJ and with $\beta = 160$ m at the extraction point and a normalized emittance of 10 π mm-mrad the beam radius, r, at a distance of 1 km from the extraction point would be 2 mm. For smaller emittance of the circulating beam the beam size would be even smaller since it is proportional to the square root of ε. Thus, $r = D\sqrt{\varepsilon/\beta\pi}$, where D is the distance to the beam dump, and the intensity/unit area $\sim\beta/D^2(\varepsilon/\pi)$. Even with D = 2 km and beam radius at the dump 4 mm, the intensity/unit area is too high to be contained safely.

A suggestion by W. Wenzel that the beam could be spread out at the entrance to the beam dump by a pair of coils at right angles excited in quadrature to produce a rotating transverse magnetic field would resolve the problem. The coils would be placed immediately after the extraction system and, with a damped rotating field, would produce a decreasing spiral beam with an initial radius of 20-40 cm at the entrance to the beam dump at a distance of 1-2 km. It is the purpose of this note to examine the feasibility of such a spiral kicker.

Even with this rotation of the beam at the dump the instantaneous spot size might want to be enlarged. This could easily be done with a singlet quadrupole with a focal length of about 33 m as indicated elsewhere.[1]

For the purpose of examining the feasibility of a spiral kicker we assume that an initial displacement of 20-40 cm at the beam dump 1-2 km from the extraction region would be adequate and that a rotating frequency of 100 kHz would provide an angular velocity at the dump sufficient to prevent damage to the window or graphite absorber. Thus, a kicker with an initial dipole field of 3 kg over a length of 20 m would suffice and in a revolution period of 300 μsec in the SSC ring the beam would spiral about 30 turns. In this period the field of the spiral kicker should decay to no less than about 20% of its initial value in order that the last part of the beam not be concentrated in the center of the window. These considerations are shown in Fig. 1.

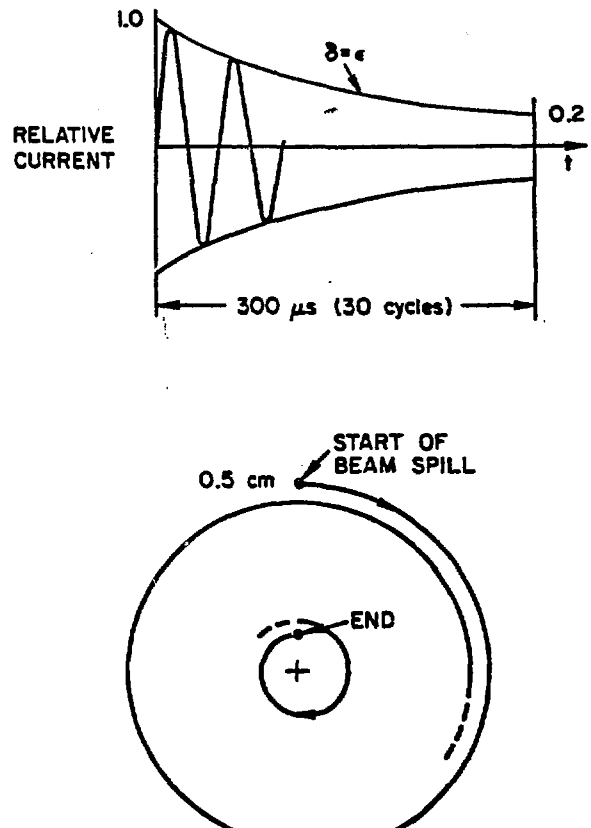

Fig. 1. Spiraling Beam

The simplest rotating field would be produced by 2 sets of coils as shown in Fig. 2a. While the uniformity of the rotating dipole field is not a major concern it is preferable, and not much additional complication, to split each coil into a pair with each displaced by 30° in azimuth from the single coil position as shown in Fig. 2b. With this arrangement the field drops off by no more than 20% at a radius of 0.3 that of the coil circle. Thus, with r = 0.5 cm (much larger than the beam size to accommodate possible deviations during an emergency dump) the coil circle would have a radius of a = 1.67 cm. The required current, $I = a\pi B/\mu\sqrt{3}$, would be 7.24 kA, and for a 20 m coil the inductance would be 36.2 μH, the capacitance 0.070 μF, and the initial voltage 164 kV.

We could easily handle voltages of ±20 kV on the coils so we would construct the spiral kicker of four magnets, each 5 m long. Per 5 m magnet we would then have L = 9 μH, C = 0.28 μF, E = 41 kV (say ±25 kV), R = 96.6 mΩ, and stored energy W = 700 J. The total

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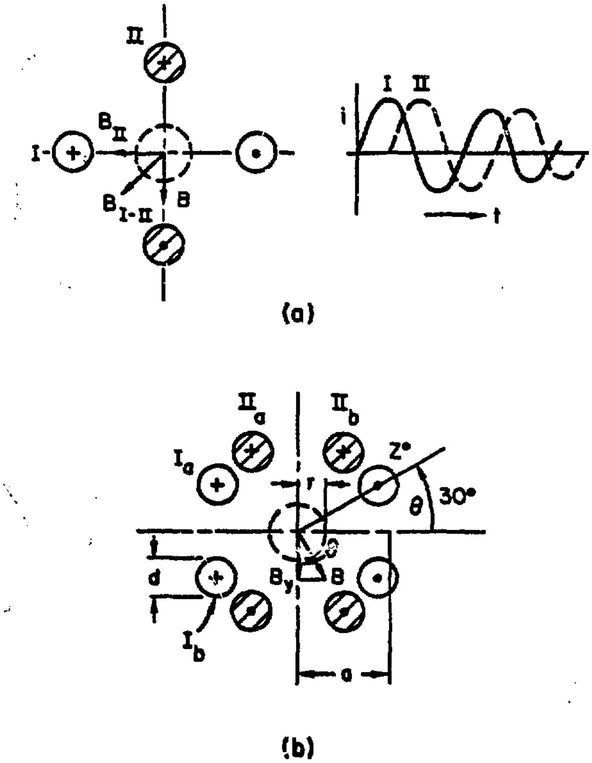

Fig. 2. Coil Placement

stored energy would then be only about 3 kJ. A circuit arrangement shown in Fig. 3 would be suitable where currents are initiated by triggered spark gaps (G). Four such circuits would be required although the power supplies could charge all 4 capacitor banks. Therefore, only 2 power supplies are included. Some redundancy in components, particularly the low level circuitry could be included to provide a high level of reliability.

The major cost of the spiral kicker will be in the magnets. In order to contain the magnetic forces the coils might be constrained by stainless steel laminations which are insulated from each other. For stainless steel the skin depth at 100 kHz is 0.14 cm so stainless steel washers of 0.1 cm thickness would be suitable. The coils would be held in place in holes in these washers with high voltage insulation to isolate them electrically from the steel, and the laminations for each 5 m magnet held together with tie rods. The estimated cost of 4 such magnets fully assembled is less than $100 K. The total cost of the spiral kicker system including the magnets (4), high voltage power supplies (2), high voltage capacitors (16), triggered spark gaps (8), trigger circuits, timing circuits and controls, fail-safe monitoring, construction, supervision, etc., is estimated at less than $200 K.

The feasibility of a spiral kicker system for the SSC thus seems assured and the cost will be a small part of that of the beam abort system.

Acknowledgement

This feasibility study was greatly aided by discussions with W. Praeg. R. Lari suggested the optimum placement of the coils for the kicker.

References

1. W. A. Wenzel, et al., These proceedings.

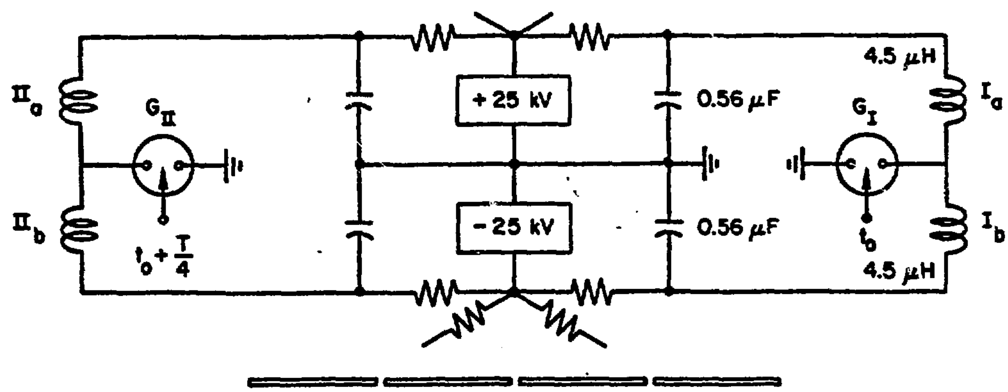

Fig. 3. Circuit Diagram