BEAM SWITCHING SYSTEM for the CEA BYPASS*

H. J. Greenberger
L. A. Law
J. M. Paterson

Introduction

The colliding beam project and the design of the CEA bypass are described elsewhere in this Proceedings.[1,2] It is the purpose of this paper to describe the design of the beam switching system which is needed to bring the stored beams into their new equilibrium orbit through the bypass.

Some General Considerations

The beam switching system is designed to meet the following requirements:

(a) The transition from an equilibrium orbit in the CEA to one through the bypass must be accomplished in a time short compared to an orbital period. As the bypass and switching system occupy 30% of the orbit, the transition time must be less than 150 nsecs so as to maintain 50% filling of the orbit. (For other reasons, e.g., vertical separation of e^+ and e^- beams, 50% orbit filling is considered a practical upper limit).

(b) The new orbit must be maintained for an unlimited time with a stability determined by allowable tune shift or available aperture. This means that the 40 mrad deflection required to establish the new orbit must be maintained constant to better than 0.2%.

*Work supported by the U.S. Atomic Energy Commission

(c) To allow the bypass steering and focusing elements to be adjusted prior to switching a stored beam through it, the system should be capable of switching beams from the normally cycling accelerator into the bypass at the peak of a magnet cycle. This can be done for one pulse in sixty, i.e., once per second, the limitation being the charging rate of a high voltage power supply.

These requirements are met by having a dc septum magnet at either end of the bypass capable of deflecting the beam through the necessary 40 mrad and two pairs of pulsed magnets, of "ultraflectors", to produce the required step function displacement of the beams into the septum magnets. During multicycle injection the septum magnets and "ultraflectors" will be retracted to maximize the available aperture for injection. After transition to dc operation and adjustment to the desired energy, these components will be moved into position, the ultraflectors will be energized and the new orbit through the bypass established.

Septum Magnets and Power Supplies

Each iron cored septum magnet is 527 mm long with an aperture which is 12.7 mm high and 38 mm wide. The aperture is shaped to give a 2%/cm radially focusing gradient in the magnetic field. As 10,000 ampere turns are required to produce a 40 mrad deflection at 4 BeV and the septum is 1 cm wide, the current density is 8000 amps/sq.cm. Although this current density is quite high, the simplification of the requirements on the power supply justified making the septum coil with four turns. Each turn consists of a pancake of three conductors in parallel, to improve heat transfer efficiency, and each turn has a separate water circuit with a pressure differential of approximately 30 kG/cm^2.

The septum magnets will be powered in series by three magnet power supplies in parallel giving up to the required maximum of 2500 amperes at 60 volts. Steering corrections will be applied by a small power supply across one septum magnet.

The Ultraflectors and Current Switches

Each ultraflector consists of a pair of C core ferrite magnets in tandem in one straight section. The magnets are 254 mm long and have an aperture which is 12.7 mm high and 32 mm deep. One magnet has a single turn coil giving an inductance of 1 μH, the other eight turns wilh inductance of 64 μH. The coils are split on the open side of the C core so that the magnet assembly can be moved, after beam storage, into a position where the equilibrium orbit is inside the C.

The one turn magnet is pulsed with a fast rising pulse which decays exponentially while current is switched into the eight turn magnet with a rise time which matches this fall time, c.f., Figure 1. The summed effects of these magnets produces a fast rising step function deflection of the beams.

The ultraflectors are three straight sections away from their corresponding septum magnets. A 5 mrad deflection by the ultraflector produces an orbit which is displaced 30 mm at the septum magnet. Allowing for the 10 mm width of the septum this gives the required 20 mm of horizontal aperture for the beams. As 2400 ampere turns are required for this deflection at 4 GeV, relatively high power switching techniques are needed to generate these current waveforms. The rather simple circuit shown in Figure 2 has been developed for this purpose.

A high power thyratron discharges a 5 μF low inductance capacitor charged to a value between 5 and 30 kV into the one turn magnet. The series resistor, peaking capacitors and the coil inductance determine the minimum rise time of the circuit, the fall time being fixed by the resistor and discharge capacitor. The energy required to obtain the 64 μsec time constant in the 8 turn magnet is stored in the inductor in series with the constant current power supply. Up to 300 amperes flows through this inductor into the shunt leg of the circuit consisting of seven fast recovery diodes in parallel, a silicon controlled rectifier (SCR) and a second inductor. When this SCR is reverse biased or blocked, the current is switched into the magnet and its parallel resistor. This parallel resistance and inductance combination fix the 64 μsec risetime.

To achieve a flat topped step function it is important that the current be switched out of the shunt leg in the order of one microsecond. This is done by interconnecting the two parts of the circuit at the thyratron cathode, thus providing a very low impedance source which reverses the voltage across the SCR and supplies the reverse current required to deplete the SCR of stored charge. The fast recovery diodes prevent this reverse current appearing as a perturbation on the load. To turn off the ultraflector (the SCR is triggered) and the current switches back into the shunt leg.

A prototype switching circuit has been built and tested. It has produced into a simulated load an effective step function with a risetime of 150 nsecs and a top which is flat to 1%. Although this performance is more than adequate, it is believed that as the monitoring techniques are improved the performance will be improved by minor adjustments of the circuit parameters. The ultraflectors and septum magnets are now under construction and the overall beam switching system should be operational before the end of 1967.

REFERENCES

[1]Hofmann, A. et al. The Colliding Beam Project at the Cambridge Electron Accelerator. Proceedings of the Sixth International Conference on High Energy Accelerators, September 1967, Cambridge, Massachusetts

[2]Voss, G.A., Mieras, H. A Design of the CEA Bypass. Proceedings of the Sixth International Conference on High Energy Accelerators, September 1967, Cambridge, Massachusetts.

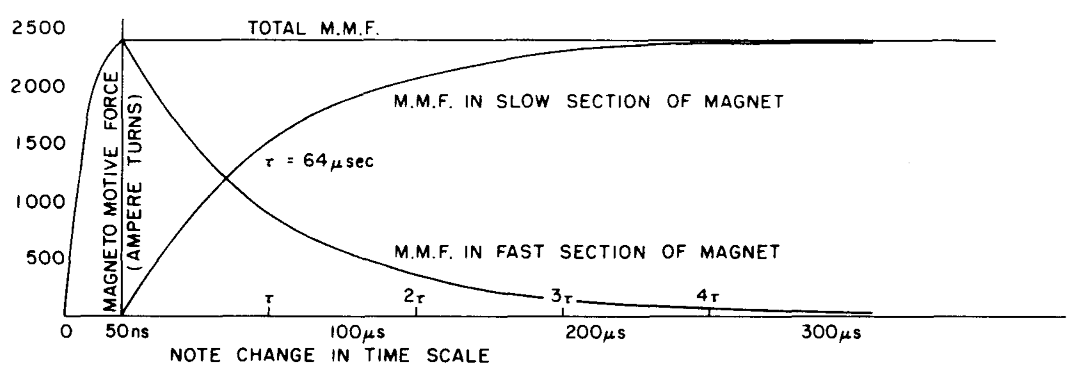

FIGURE 1
WAVEFORMS IN ULTRAFLECTOR CURRENT SWITCH

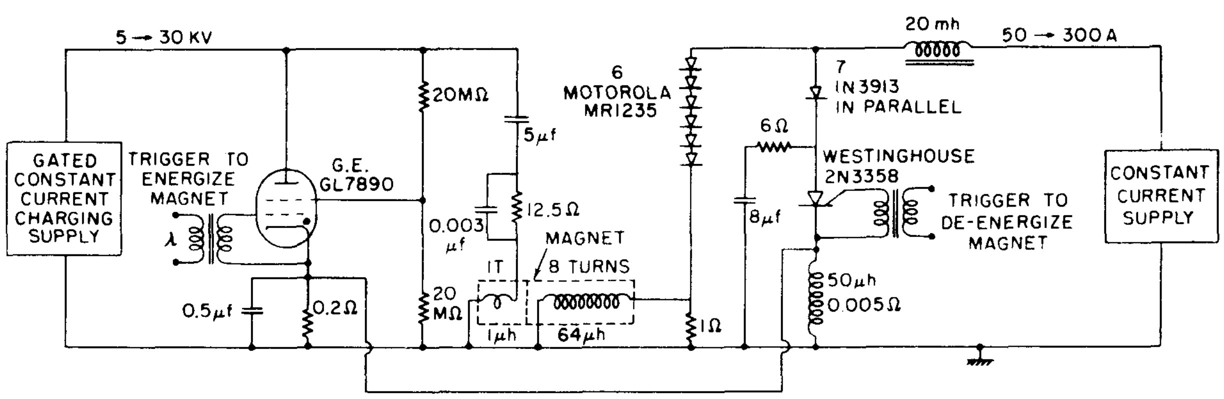

FIGURE 2
ULTRAFLECTOR CURRENT SWITCH