The Operation of Injection Kickers in the SRS

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Abstract

The injection kickers in the SRS have been redesigned for reduced physical length to free up space for installing an additional wiggler. Engineering design details of these kickers are presented together with a description of their high efficiency, pulsed power supplies. These generate the 2.3 μs half sine wave current required by the injection process. The performance of the injection system with these kickers is described.

1. INTRODUCTION

The installation of the 6 T superconducting wiggler magnet in the Daresbury SRS storage ring[1] required a major relocation of one of the families of sextupole magnets[2]. In their new locations, one of the 4 D-sextupoles became adjacent to one of the three injection kicker magnets, and because of limited space available it was therefore necessary to redesign the kicker with a reduced length. It was decided to take the opportunity of redesigning all three kickers to maintain symmetry and also to reduce their broadband impedance.

The electromagnet design and calibration of the new kickers has been reported previously[3]. This paper describes how the new design was realised in practice and gives details of the innovative pulsed power supplies which drive the kickers. Additionally the use of the kickers for optimum performance of the injection process is described.

2. KICKER SPECIFICATION

The injection kickers are required to produce an angular deflection of the storage ring closed orbit of 2 mr at the injection energy of 600 MeV. This implies a field of 10 mT over the 0.39 m active length of the magnet. This field is generated by a 2.3 μs high-current pulse in a pair of copper conductors, one at each side of the beam orbit, as is shown in fig. 1 and fig. 2.

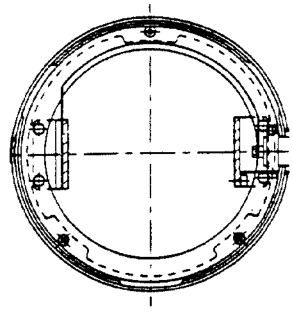

Figure 1. Cross section view of Kicker.

The minimum separation between these conductors, which are uncooled, is dictated by the requirement to prevent synchrotron radiation from impinging on the outer one. Even with a dedicated cooled absorber mounted in the upstream section of the kicker vessel (see fig. 2), a separation of at least 140 mm results. With this separation a conductor height of 60 mm is needed to produce a reasonably uniform field across the aperture. Mounted in a stainless steel vessel of 230 mm inner diameter, this arrangement of conductors gives a substantial reduction in broadband chamber impedance compared with the previous kicker[4] but does necessitate a pulse current of 5 kA to achieve the required deflecting field. This current is fed into the conductors through a coaxial ceramic insulated feedthrough on one side of the kicker vessel in the horizontal plane. The pulsed power supply is mounted immediately adjacent to the feedthrough to minimise the inductance of the connections between the kicker and the power supply.

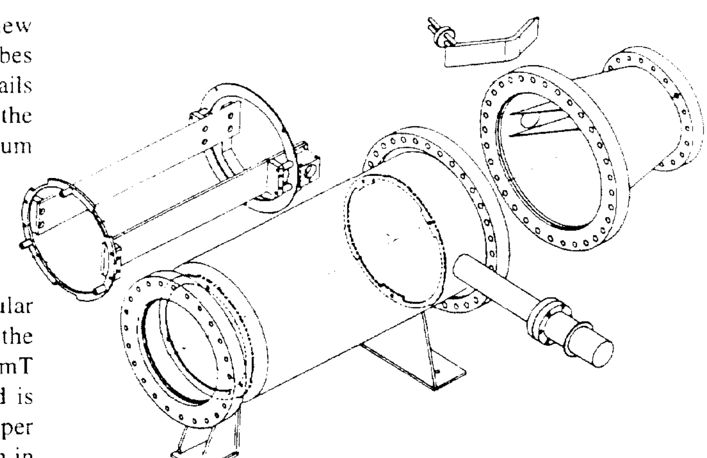

Figure 2. Exploded view of Kicker and its Vacuum vessel.

The kicker vacuum vessels are fabricated from 304 S11 stainless steel. Smooth, gradual changes in cross section are used to minimise the broadband impedance and the only additional flaring required is where the cooled radiation absorber protrudes.

The copper conductors are mounted in the vacuum vessels on electrical insulators manufactured from machinable glass ceramic type Corning 9658.

The mechanical aspects of the kicker are summarised in the following table.

Table 1
Mechanical Details of Kicker

Length of vacuum vessel	790 mm
Inner diameter	230 mm
Outer diameter	236 mm
Material-Stainless steel	304 S11
Conductor dimensions	425x60x5 mm^3
Conductor material	OFHC copper
Conductor gap	140 mm
Ceramic coaxial feedthrough - English Electric type MA54	

3. PULSED POWER SUPPLY

The pulsed power supply energising the kicker is required to produce a 5 kA pulsed current with a half sine wave pulse shape having a base width of approximately 2.3 µS. The maximum pulse repetition rate is 10 Hz but the firing jitter should be of the order of only 10 nS. Because the kicker inductance, together with its connections, is only 0.7 µH, the required pulse current can be produced by discharging through it a 0.75 µF capacitor which has been charged to 5kV. The most reliable device for producing the discharge with the required small jitter is a hydrogen thyratron.

An innovative power supply has been used at Daresbury for this application for a number of years. It has the advantages of low overall power dissipation and excellent stability and it is consequently highly reliable. A simplified diagram of this supply connected to a kicker magnet is shown in fig. 3.

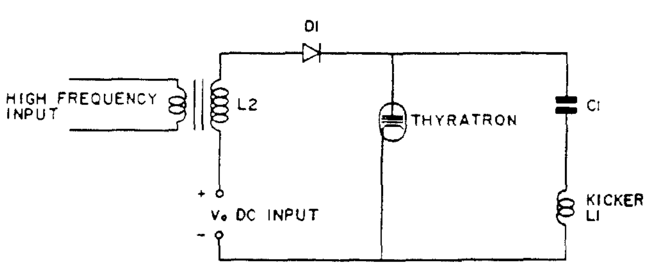

Figure 3. Simplified circuit diagram of pulsed power supply.

The operation of the power supply depends on two mechanisms. Firstly it operates as a conventional discharge circuit with energy recovery. After the capacitor C1 has been charged from the DC supply, triggering the thyratron produces the required half sine wave pulse in the kicker inductance L1. The natural tendency of the pulse to continue oscillating is prevented by the extinction of conduction in the thyratron, and therefore almost all the initial charge on the capacitor is recovered by recharging through the DC supply, the energy recovery choke L2 and the diode D1. If the efficiency of the charge recovery is, say, 90% then after multiple firings the capacitor charged voltage will reach an equilibrium of 10 times the DC supply. At equilibrium the voltage lost after the discharge equals that provided by the DC supply. In this way the circuit can build up discharge voltages of 5 kV from a supply of only 500 V, but the circuit is not suitable for operational use because it is only poorly controllable.

In the configuration used for the Daresbury kickers, a small auxiliary winding is added to the energy recovery choke so that it functions additionally as a transformer. After firing the pulse and the capacitor energy has been recovered as described above, D1 becomes reverse biased. The transformer primary is then driven at its resonant frequency with the stray capacitance. This is typically 8 kHz. D1 acts as a peak rectifier and allows additional and rapid charging of the main capacitor. The voltage on this is measured by suitable additional circuitry (not shown in fig. 3) which switches off the auxiliary excitation when the demanded voltage has been attained.

The advantages of this design arise because only small power is required from the auxiliary drive and because the DC supply can have a high impedance. Thyratron fire-throughs, for example, dissipate little power and this contributes to the overall reliability of the power supply.

Table 2
Power Supply Details

Peak voltage	5 kV
Peak pulse current	5 kA
Pulse repetition	10 Hz
Pulse base width	2.25 µS
Average power consumption	20 W
DC supply	500 V
High Frequency drive	8 kHz
High Frequency amplitude input	60 V
Control stability	0.1%
Thyratron type	CX1154

4. INJECTION IN THE SRS

During injection into the SRS a pair of kickers is used to produce a distortion in the closed orbit which moves it radially outwards towards the injection septum magnet. The orbit distortion is mainly localised to the shorter segme ·' of accelerator circumference between the two kickers. However, there is orbit distortion at other positions because space restrictions prevent the kickers being placed in positions for perfect localisation. Kickers #2 and #3 are used for injection into the more frequently used optic which has a radial betatron tune of 6.2. In the less frequently used single bunch mode, which has a radial tune of 4.2, kickers #1 and #3 are employed.

Each kicker produces a peak angular deflection of the closed orbit of 2 mr, which requires a current of 5 kA in the magnet. The half sine wave shape of the current pulse has a base width of 2.3 µS, and this is sufficiently rapid to move the beam away from the septum after injection has taken place to provide good capture efficiency of the newly injected beam.

The operation of the injection process in the SRS is illustrated in fig.4 and fig.5. In fig.4 the current pulses in both kickers are shown simultaneously with the signal from a horizontal pick up electrode. The pick up electrode is sensitive both to beam current and horizontal beam position.

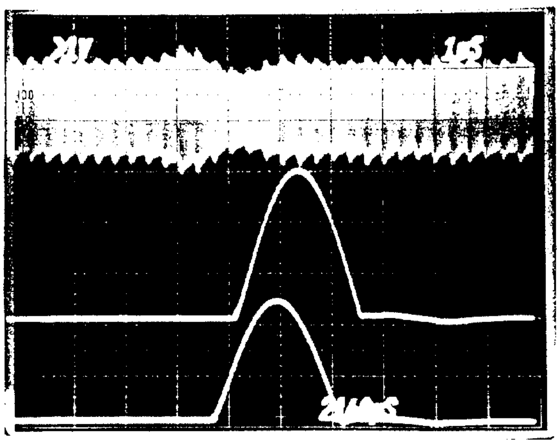

Figure 4. Pulsed kicker currents and a horizontal beam pick up signal during multi-shot injection.

There is an offset between the times of the kicker and beam signals due to differing cable routes, but the orbit shifting action of the kickers can be clearly seen. It can also be seen that there is no coherent oscillation remaining in the beam after injection. The newly injected beam cannot be distinguished because of its small magnitude, 1 mA, compared with the already captured beam of 100 mA. A feature noticeable in fig.4 is that the kickers do not fire simultaneously, there being a delay of about 0.5 μS between them. This is a pragmatically determined condition which has consistently been found to give best injection efficiency, in both optics settings used for the SRS. At the present time it is unexplained.

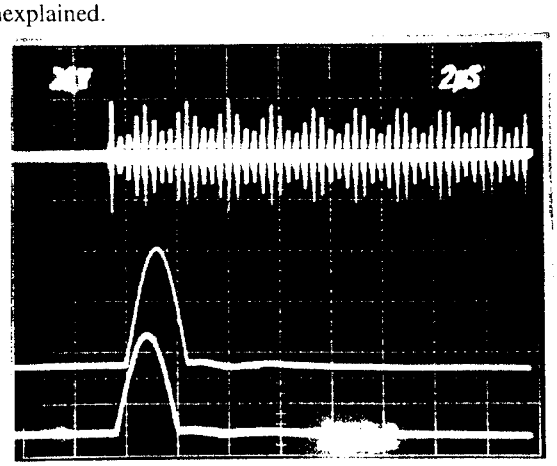

Figure 5. Single shot injection to illustrate the behaviour of the newly injected beam.

Fig. 5 shows the injection of a single beam shot into the SRS without the prescence of previously captured beam. In this case the coherent oscillation of the injected beam can be seen clearly.

5. REFERENCES

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[3] J A Clarke and J N Corlett, Proc EPAC '92, Berlin, 1992, p1469

[4] J A Clarke et al, "Revised SRS Impedance Estimates", in these proceedings.