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A DIVERTER FOR USE WITH PLASMA GUNS

M. H. HUGHES
R. G. MONTAGUE

Culham Laboratory
Abingdon Berkshire

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by

M.H. HUGHES
R.G. MONTAGUE

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A B S T R A C T

A diverter system for use with a plasma gun injecting into a guide field is described; it can be used to attenuate any unwanted plasma from the gun following the initial injected plasma. The operation of the diverter involves passing current through the plasma orthogonal to the guide field by means of a pair of electrodes in contact with the plasma. The plasma is given momentum in a direction perpendicular to the field and is then stopped by an aperture limiter. It is shown experimentally that this diverter attenuates unwanted plasma with high efficiency.

U.K.A.E.A. Research Group,
Culham Laboratory,
Abingdon,
Berks.

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C O N T E N T S

		Page
1.	INTRODUCTION	1
2.	PRINCIPLE OF OPERATION	1
3.	APPARATUS TO TEST THE DIVERTER	2
4.	RESULTS	3
	REFERENCES	4

1. INTRODUCTION

Plasma guns have been developed for controlled thermonuclear research as a means of filling magnetic traps with dense hot plasma ($n \sim 10^{13}$ cm^{-3}, $T_i \sim 1$ keV); the plasma is guided into the trap by injecting along a magnetic guide field matched to the trap and the gun. However, in addition to hot plasma most guns produce a comparable quantity of cold plasma which can enter the trap and interfere with the confinement of the hot component. Consequently, various schemes have been devised for separating the hot and cold plasma employing, for instance, magnetic stoppers (FRANCIS et al., 1968) or curved guide fields (COLOMES and VERON, 1969). This paper describes a simple alternative device which diverts plasma with high efficiency.

2. PRINCIPLE OF OPERATION

The diverter, which is shown schematically in Fig.1, comprises a pair of parallel plate electrodes in contact with the plasma. Momentum is imparted to the plasma in a direction perpendicular to the guide field, B, by passing a current, I, through the plasma orthogonal to the field. The velocity component of the plasma perpendicular to the field is given by

$$v_{\perp} = \frac{E}{B} = \frac{V}{Bd} \qquad \dots (1)$$

where V is the voltage dropped across the plates and d is their separation. The diverted plasma is then intercepted and stopped by an aperture limiter whose diameter is somewhat less than the separation of the plates.

The current, I, necessary to produce a perpendicular velocity $v_\perp$ is given by the momentum equation

$$IB = \rho v_\perp \; v_\parallel \; \ell \qquad \ldots (2)$$

where ρ is the mass density, $v_\parallel$ is the velocity component along the unperturbed field lines and ℓ is the dimension of the plates perpendicular to the field (Fig.1).

3. APPARATUS TO TEST THE DIVERTER

The diverter was tested in the apparatus shown schematically in Fig.2. Hydrogen plasma from a thetatron gun (ALLEN et al., 1965) was directed into a uniform DC guide field of 350 G and detected some 3 m from the gun by biased ion-collecting probes and by the attenuation of 3 cm microwave radiation. The diverter plates, which comprised two stainless steel electrodes 15 cm square and 12 cm apart, were located 2 m from the gun. Between the electrodes and the diagnostic instruments there was a glass aperture limiter 12 cm in diameter.

To investigate the possibility that conductors cutting the field lines which pass through the volume between the diverter plates might "short circuit" the plates and provide an alternative current path, a copper disc probe P cut to the shape shown in Fig.2 was placed beyond the aperture limiter. The Rogowski coil R on this probe would detect current flowing along the field lines from one diverter plate, across the field via the copper plate and back along the field lines to the other electrode.

4. RESULTS

Fig.3(a) shows the signal from a biased ion-probe placed on axis 2.75 m from the gun and the same signal after integration, thus showing the total number of ions detected. The longitudinal ion energy at the peak of this signal, obtained from time-of-flight, is 1.0 keV and the corresponding density is 5×10^{12} cm^{-3}. Fig.3(b) shows the ion probe signal when the diverter system was energised. The integrated output of the ion-probe with and without the diverter shows that some 97% of the plasma was prevented from passing through the aperture while the disc probe P mentioned in Section 3 above showed that no significant depolarising current flowed along the field lines to the probe. The microwaves were unable to detect any plasma beyond the aperture when the diverter was used.

The diverter current and the voltage across the plates are shown in Fig.3(c). The voltage of $\sim$ 1 kV corresponds to $v_\perp = E/B \sim 3 \times 10^7$ cm sec^{-1} and the current corresponding to the peak density is 12 kA which compares with the value of 5 kA predicted by equations (1) and (2).

A diverter system similar to that described above has been installed on the M.T.S.E. II mirror machine (FRANCIS et al., 1968) which is filled by injecting plasma from a coaxial gun along a guide field. The gun on M.T.S.E. II produced, in addition to a burst of energetic plasma, large quantities of cold plasma which subsequently entered the trap where it interfered with the confinement of the hot plasma and confused the measurements of density and temperature. Fig.4 shows the line density, $\int n d\ell$, as a function of time when the mirrors were not energised, measured from the attenuation of a beam of high energy neutral potassium atoms (HILL et al., 1967) traversing the mid-plane of the trap. When the diverter was not energised the beam was cut off for about 150 μsec and continued to indicate the influx of cold plasma for a further 500 μsec; energising the mirror nearest the gun did not produce a significant reduction in the amount of cold plasma entering the trap.

The diverter on M.T.S.E. II was located midway between the gun and the trap in a field of about 200 G. Fig.4 shows the reduction in the amount of cold plasma entering the trap when current was switched to the diverter plates following the initial burst of energetic plasma.

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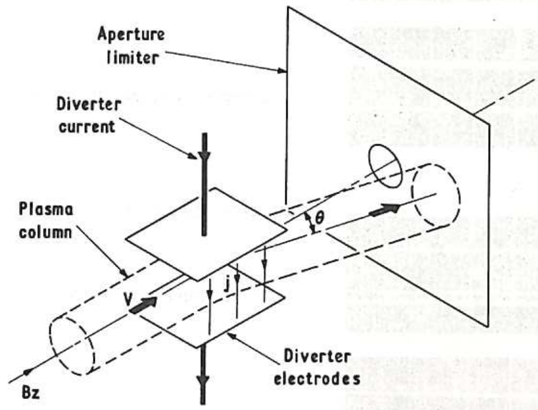


Fig.1 Schematic of cross field diverter

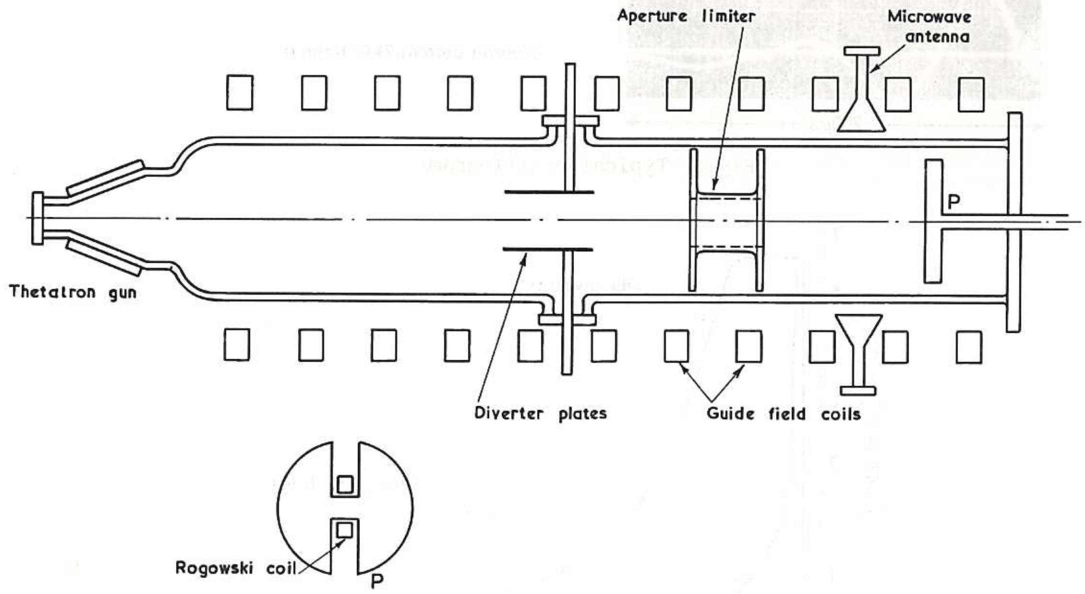
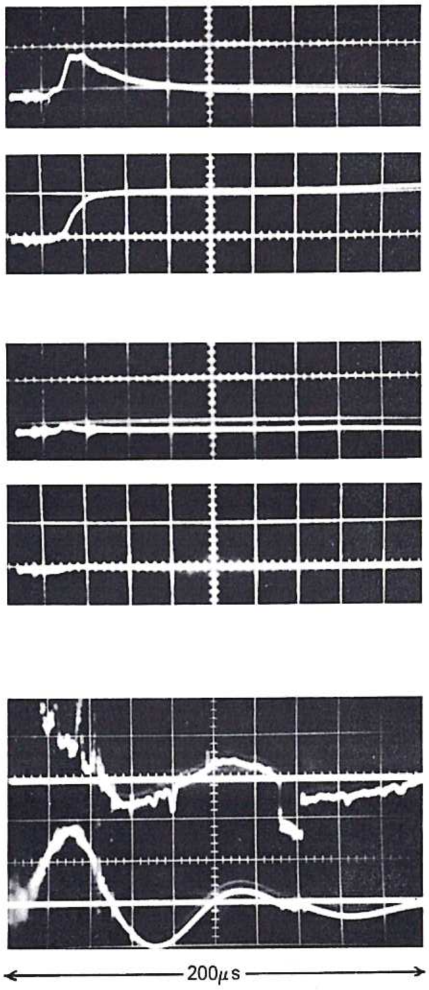


Fig.2 Experimental assembly used to test the diverter CLM-P249



(a) NO DIVERTER

Axial Ion Probe 0.5V/large div.

Integrated output of Ion Probe 0.02V/large div.

(b) WITH DIVERTER

Axial Ion Probe 0.5V/large div.

Integrated output of Ion Probe 0.005V/large div.

(c)

Voltage across Plates 1kV/large div.

Diverter current 7kA/large div.

Fig.3 Typical oscillograms

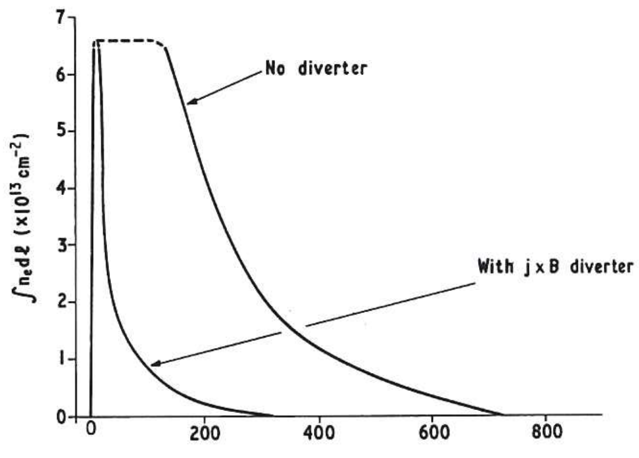


Fig.4 Line density measurements of plasma injected into the guide field of the MTSE II mirror machine.