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THE DITE NEUTRAL INJECTION SYSTEM

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A B S T R A C T

The basic philosophy behind the design of the DITE neutral injection system is outlined, and the system briefly described. Two injection lines of this type, each capable of delivering up to 140 kW of fast neutrals, will be fitted initially.

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Introduction One of the main aims of the DITE tokamak experiment at Culham is to make a detailed study of the physics of plasma heating by the injection of powerful beams of fast neutral hydrogen atoms. In order to do this it is desirable to have available neutral atom beams capable of supplying power at a rate comparable with or at least a substantial fraction of the ohmic heating power.

The injection lines described in this paper are capable of supplying neutral beams of up to 140 kW per line.

Injection Design Constraints The design evolved from the consideration of a number of constraints and experience gained on CLEO tokamak. The main points considered were:

1. Reduction of gas density in the entry tube. The overall neutralization efficiency is reduced by partial reionization and subsequent deflection of the ions produced onto the walls [1]. The problem is aggravated by gas evolved if the original charged fraction is also dumped in this region. This problem is essentially eliminated by utilizing a magnetic deflector which guides the charged fraction directly into a Ti getter pump.

2. Reduction of the slow gas load to the torus. This is desirable from the viewpoint of tokamak operation.

The use of large Ti getter pumps and by injecting through the main torus pumping system alleviates both this and the reionization problems.

3. Reduction of the stray magnetic field in the region of the ion source. CLEO experience indicated that the ion source performance was degraded by stray magnetic fields of $\sim$ 30 gauss.

The increase in length due to the torus pumps and the magnetic deflector places the source in a region of low magnetic field intensity.

The Vacuum System The design of the vacuum system is such that we achieve good neutralization efficiency and a minimum gas load to the DITE torus. A diagram of the complete system is shown in figure 1.

With the CLEO source operating at 10 A we expect the slow gas load to be ~ 1.2 torr-litre/sec. There is additional gas produced by interception of the divergent beam and the deflected charged fraction. This is estimated to be 0.6 torr-litre/sec. The total flow F = 1.8 torr litre/sec.

In order to reduce the reionization of the neutral beam to an acceptable level, ie < 10% the gas target formed by residual gas between the deflector and the entrance port must be $< 10^{15}$ mol/cm^2, ie 2×10^{-2} torr-cm. As this section is ~ 1.5 m long the average pressure, P_o, must be $< 1.3 \times 10^{-4}$ torr. Hence the minimum pumping speed required is 1.6×10^4 lt/sec.

The Ti getter pumps in the beam dump section have an area of ~ 7000 cm^2 and their speed is ~ 20×10^3 lt/sec assuming a sticking coefficient of ~ 0.06.

In addition the DITE torus pumps have a pumping speed ≈ 10×10^3 lt/sec. Hence beam loss due to reionization should be only a few percent.

The Ion Source The ion source is basically the same as that used on CLEO tokamak. It is described in detail in ref [2] and a diagram of the source is shown in figure 2.

Our experience at Culham using a capacitor bank for the high voltage supply and a pulse repetition rate ~ 1 pulse per minute, is that we are able to obtain optimum running conditions more easily with the CLEO type ring anode source illustrated, than with the duopigatron type source currently in use at various other laboratories [3,4].

The Injection Energy In assessing the optimum injection energy it is necessary to consider the following factors:

1. The characteristics of the ion source. The current-voltage relation is limited at its upper end by breakdown, and at the lower end by by the maximum current density the plasma source can supply.

2. The neutralization efficiency.

3. Trapping of the beam in the plasma.

4. Transfer of energy from the beam to the plasma.

The optimum energy indicated by our analysis is in a broad band from 20-28 keV.

Geometry The geometry of the line is such that only that part of the beam falling in a half angle of 1.2^{o} will enter the machine. In the case of the CLEO type source this is ~ 70% of the beam power. As the neutralization efficiency is also ~ 70% we have an overall efficiency of ~ 50%. Hence the required 140 kW should be obtained with the source operating at ~ 28 kV and 10 A.

Performance A complete line has been tested and shown to deliver the specified power of up to 140 kW for pulse lengths up to ~ 40 ms.

The pumping speed of the Ti getter pumps was found to be approximately that calculated and no problems were encountered from dumping the deflected charged fraction of the beam onto the titanium surface.

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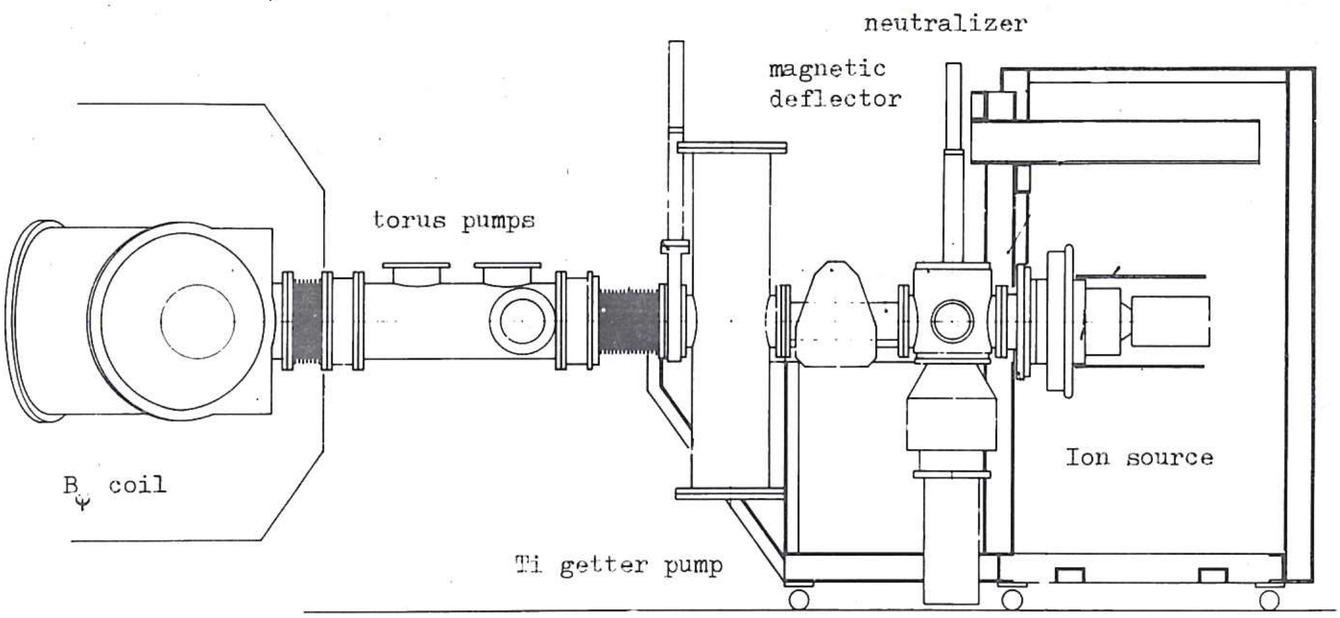

Fig.1 DITE Beam Line

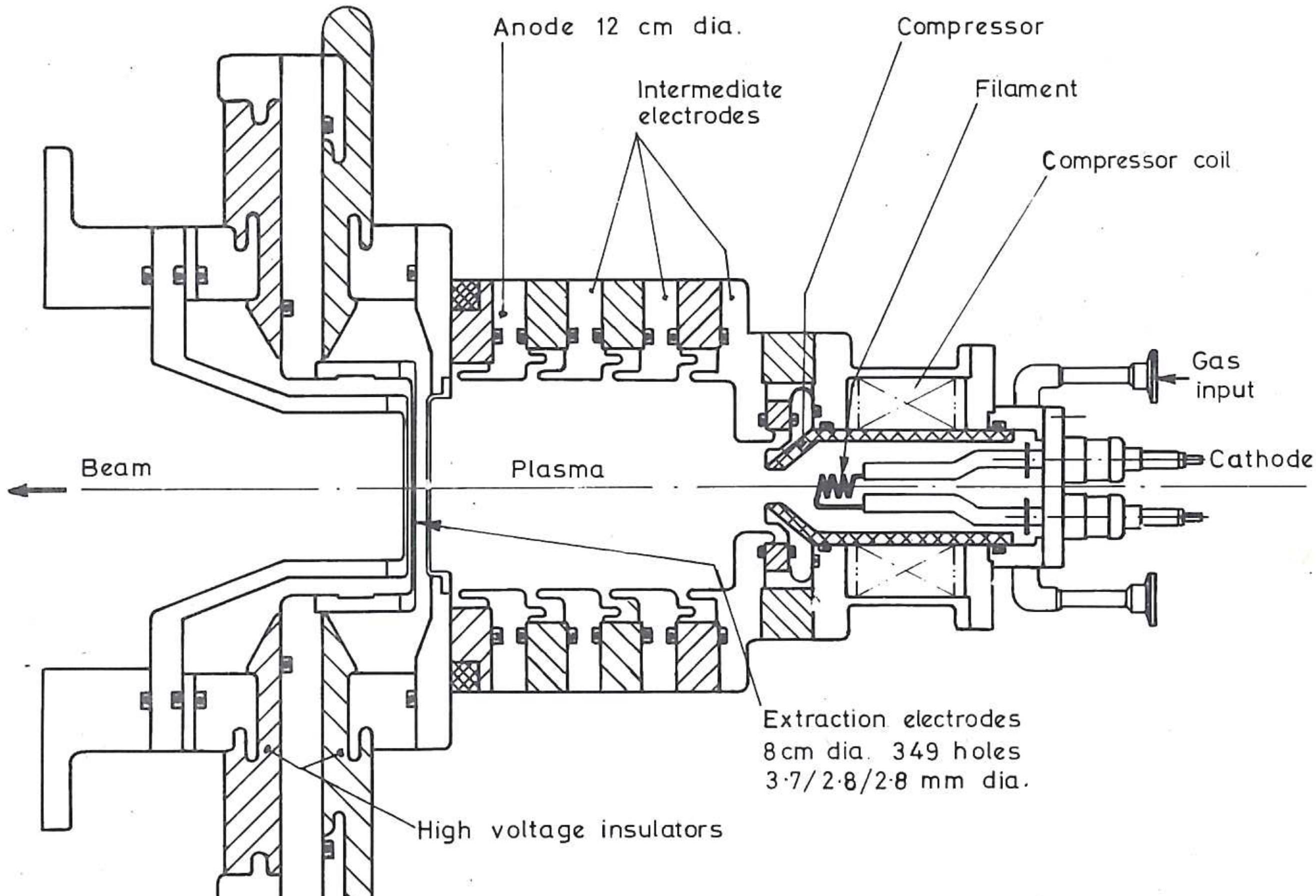

Fig.2 Ion Source