AIP Conference Proceedings

The effects of electron suppression fields on D− production

M. F. Thornton, A. J. T. Holmes, L. M. Lea, and G. O. R. Naylor

Citation: AIP Conf. Proc. **210**, 244 (1990); doi: 10.1063/1.39594
View online: http://dx.doi.org/10.1063/1.39594
View Table of Contents: http://proceedings.aip.org/dbt/dbt.jsp?KEY=APCPCS&Volume=210&Issue=1
Published by the American Institute of Physics.

THE EFFECTS OF ELECTRON SUPPRESSION FIELDS ON D^- PRODUCTION

M.F. Thornton, A.J.T. Holmes, L.M. Lea and G.O.R. Naylor
Culham Laboratory
(Euratom/UKAEA Fusion Association)
Abingdon, Oxon. OX14 3DB, England

ABSTRACT

This paper presents the results of experimental studies on a number of different 'current carrying wire' type first grid electron suppressors: or 'inserts', as they shall be called throughout this paper. Extracted negative ion currents are compared for the different inserts over a range of field strengths. Currents are also compared to those extracted with no suppressor present. An attempt is made to relate the negative ion currents obtained for each insert, with field depth and uniformity. Results are presented on the extraction of negative ions with an insert operating some distance into the source. The insert is also tested with a dipole rather than tent field used to separate the driver and extraction regions of the source.

INTRODUCTION

In extracting negative ions from a volume production source, electrons are also removed. With accelerators in use at Culham Laboratory, electrons are dumped in a trap within the second electrode at a fraction of the beam energy. Using this technique a considerable amount of power is expended accelerating electrons to the trap. This lost power can be reduced by 'suppressing electrons' at the source/accelerator interface, via a magnetic field applied across the extraction aperture. A reduction in the electron current extracted from an ion source using a permanent magnet suppressor has been demonstrated by several groups[1-3]. Electron suppression with an insert of the form described in this paper has also been demonstrated[4-5]. Ideally, an electron suppressor would reduce the electron current to zero while keeping constant, or increasing, the negative ion density extracted. The insert offers a flexible method of approaching this goal.

EXPERIMENTAL DETAILS

The ion source used was a multicusp bucket type, 550 mm x 310 mm x 210 mm deep. A magnetic filter separated the driver and extraction regions. The filter was created by re-orientation of certain of the wall-mounted permanent magnets. Unless stated otherwise, all experiments were carried out with a tent filter. A miniature diagnostic accelerator with a 1.5 mm diameter extraction aperture and total accelerating voltage of 10 kV was used. Electrons extracted from the source were magnetically deflected into a trap within the accelerator, while negative ions were collected on a Faraday cup. For all experiments the source was operated at 400 A arc current and 120 V arc voltage. Deuterium gas was used at a pressure of 12 mTorr.

The "insert" device used to suppress the electron current extracted from the source, is shown in diagramatic form in Figure 1. The dipole magnetic field is imposed transverse to the extraction aperture, on the source side. The field lines intersect the insert wall, which may be biased independently of the beam forming electrode. If the coil pitch and depth are kept similar in size, the insert creates a field of comparable thickness to the coil depth. Thus it is possible to produce a relatively intense, local field in front of an aperture, when compared with that produced by a permanent magnet suppressor.

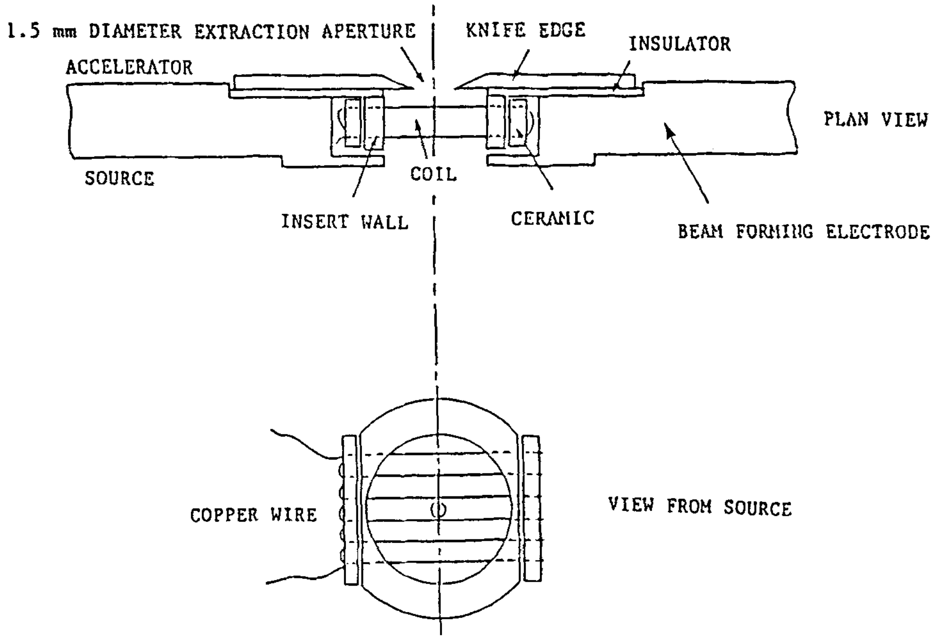

Figure 1 : The electromagnetic insert assembly.

EXPERIMENTAL RESULTS

A number of different insert assemblies have been tested. A summary of the inserts and the magnetic fields they create is given in Table 1. Figure 2 illustrates the various parameters given in Table 1.

	Coil Depth /mm	Coil Pitch /mm	K.E to field max /mm	K.E to 1/e of field max /mm	Variation of B along centre line %
A	4	4	4.0	6.3	20
B	5	5	3.8	6.5	21
C	8	4	6.0	10.0	0
D	5	15	3.8	8.1	240
E	17	17	10.5	19.0	15

Table 1 : A summary of the different inserts and the magnetic fields they produce.

K.E = knife edge

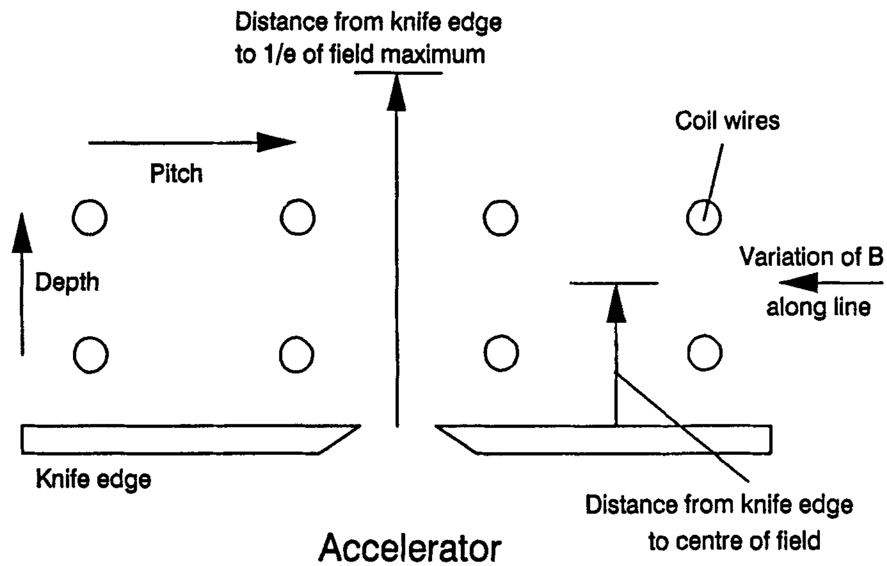

Figure 2 : A cross-section of an insert, indicating those parameters given in table 1.

All the fields given in this table were calculated using a two dimensional electromagnetic analysis package, PE2D[6]. Theoretical predictions were compared with Gauss probe measurements wherever possible and agreement was found to be good (± 15%). The distance from the knife edge, to the point where the magnetic field fell to 1/e times the maximum, was used to gauge the field width. The percentage variation in B from the minimum value, along the centre line of each coil, was used as a measure of field uniformity across the aperture. It can be seen, that inserts A and B (see Table 1) give relatively narrow, uniform fields. Insert C, a broader, uniform field. Insert D, narrow, but highly non-uniform and insert E, a much wider, uniform field.

The extracted negative ion current densities for different inserts at varying field strengths are shown in Figures 3 and 4. The currents are plotted as $J_-/J_-(o)$ where $J_-(o)$ is the negative ion current density obtained under identical source conditions, but with no suppressor present. It is important to distinguish between two factors affecting D^- extraction with an insert. One is the enhancement, or the increase in D^- yield with the insert field on compared to the field off. The other, is the D^- current obtained with no insert field applied. The yields with no insert field lie between 40%-60% of the current extracted with no suppressor. Thus, as in the case of insert C, it is possible for an insert to give poor negative ion yields, while the magnetic field still gives a sizable enhancement. This substantial fall in ion current from the presence of each insert structure can be understood by plasma loss, to the walls of the well and coil wires, in the insert assembly.

Inserts A and B with a short coil pitch and depth, giving narrow and uniform fields, produced easily the best results. The maximum current densities approximately equal the value with no suppressor. Insert A, while giving D^- yields equal to those obtained with no suppressor, reduced the extracted electron current by a factor of 27. On the other hand, insert B has been operated to reduce the electron to ion ratio down below 2:1, the negative ion yield was reduced to 60% of the maximum value. Insert C, with its coil depth and therefore field width increased by approximately 4 mm gives a significantly poorer performance. The field still gives an enhancement of negative ion yields but from a lower initial value. Insert D with its slightly narrower, but non-uniform field gives virtually no enhancement. Insert E with a uniform but much deeper field gives a very small enhancement. Note that when insert A was operated, a small reversed field was required to offset the residual field from the electron trap in the accelerator. This offset was not observed with the other inserts.

The next set of results apply only to insert B (pitch = 5 mm, depth = 5 mm). Figure 5 shows the negative ion densities versus insert field, for the extraction aperture at 45 mm and 90 mm into the source. Here $J_-(o)$ remains the D^- density extracted with no suppressor present, but with the same aperture position in the source as the experiments carried out with the insert[7]. At 45 mm into the source, one begins to see signs of interaction between the tent filter and the insert field. Negative ion densities were somewhat higher with the coil current in one direction compared to the other, although this was not expected, considering the symmetrical nature of the tent filter field. At 90 mm into the source very little or no increase in D^- was observed when the insert field was applied.

Figure 6 shows the extracted D^- current densities versus insert voltage for both tent and dipole filter fields in the source. The D^- yields with no suppressor present ($J_-(o)$) were very similar for the tent and dipole configurations. When the insert field was applied densities measured with the dipole filter were substantially lower than those with the tent filter. With the dipole filter, no improvement was observed in D^- currents when the insert field was reversed. The dipole filter gave a magnetic field strength of approximately 25 gauss in front of the aperture, the tent filter 5 gauss.

DISCUSSION

Table 2 summarizes the results of D^- extraction with the five different inserts. Enhancement has been defined as the peak negative ion density obtained with an insert, divided by the density extracted with no field applied. This number is important in deciding which of the insert fields are effective at increasing D^- densities extracted from the source.

Insert Type	Field Width /mm	Uniform Field	Peak $J_-/J_-(0)$	Enhancement (peak/zero B value)
A	6.3	Yes	1.03	1.81
B	6.5	Yes	1.00	1.64
C	10.0	Yes	0.68	1.58
D	8.1	No	0.69	1.13
E	19.0	Yes	0.54	1.15

Table 2 : A summary of results on the different inserts.

Increasing the field depth leads to a reduction in the maximum enhancement possible. Similarly, if the magnetic field is highly non-uniform across the aperture, then little enhancement occurs. At the moment this comparison of insert performance with field characteristics is very qualitative in nature, although it may be possible to quantify this analysis after testing a greater number of inserts. At present it has not been possible to operate a successful insert, of this type, with a coil pitch as large as 15 mm. Any attempt to increase pitch while keeping the depth small leads to a non-uniform field: increasing the coil depth and pitch together, leads to a broad field. Both cases give low D^- yields. It requires further work to determine the maximum dimensions for coil pitch and depth, while still retaining good D^- currents. No work has been carried out on this apparatus with insert wires in front of the aperture: it is to be expected that this shadowing effect will reduce the extracted D^- current. This may be important in determining the maximum size of aperture that may be used with this type of suppressor.

None of the inserts tested, gave negative ion currents significantly greater than those obtained with no suppressor present, although there is no reason to believe that this is not possible. It appears from the experiments carried out so far, that the best chance of observing a 'real enhancement', lies in making the magnetic field narrower, but keeping it uniform across the aperture: this could be achieved with an array of more closely spaced wires. However, designing an insert with wires closer than the 4 mm by 4 mm coil already tested, presents technical difficulties. For example, it becomes increasingly difficult to prevent the coil wires from touching and shorting out during operation, while one may be restricted to small aperture sizes to prevent wires blocking the aperture.

Moving the insert into the source, one sees an increasing interaction with the tent filter field. At 45 mm, the enhancement for the positive field is 1.49 and negative field is 1.25, this compares with 1.64 for the same insert back at the beam forming electrode. With the increasing interaction we see a fall in negative ion currents. The dipole filter gives a much stronger field in front of the aperture at the beam forming electrode. This interaction likewise leads to lower D^- currents. Thus these two sets of results appear to display essentially the same phenomenon. When the insert was placed in any field stronger than a few tens of gauss very little enhancement took place with the insert field. This interaction is unlikely to be a simple cancelling of the magnetic fields, as the insert fields were much stronger than the source filters. Likewise, any loss due to field cancellation should be removed when the coil current is reversed: this was not observed.

This result may be important if this type of insert is to be used in a smaller source. Here, even the tent filter may adversely affect operation of the insert positioned at the beam forming electrode.

REFERENCES

1. M. Bacal, P. Devynck and F. Hillion. Production and Application of Light Negative Ions. 2nd Euro. Workshop, Ecole Polytechnique, Palaiseau, March 1986, p. 75, Ecole Polytechnique (1986).

2. R. McAdams, A.J.T. Holmes, M.P.S. Nightingale, L.M. Lea, M.D. Hinton, A.F. Newman, and T.S. Green. Production and Neutralisation of Negative Ions and Beams. 4th Symp, Brookhaven, 1986, New York, p. 298. American Institute of Physics (1987).

3. R. McAdams, A.J.T. Holmes, A.F. Newman and R. King. Production and Application of Light Negative Ions. 3rd Euro. Workshop, Amersfoort, February 1988. p. 15, FOM Institute for Atomic and Molecular Physics (1988).

4. L.M. Lea, A.J.T. Holmes, M. Thornton and G.O.R. Naylor. The Suppression of Electrons Extracted from a Negative Ion Source. International Conference on Ion Sources, Berkeley, July 1989. To be published.

5. R. King, R. McAdams, A.F. Newman and A.J.T. Holmes. Physics Test of An Electron Suppressor with Variable Electric and Magnetic Fields. These proceedings.

6. PE2D, Version 8.1, Vector Fields Limited. 24 Bankside, Kidlington, Oxford, OX5 1JE, England.

7. L.M. Lea, A.J.T. Holmes and G.O.R. Naylor. Recent Results from A Large D^- Volume Production Ion Source. 3rd Euro. Workshop, Amersfoort, February 1988, FOM Institude for Atomic and Molecular Physics (1988).

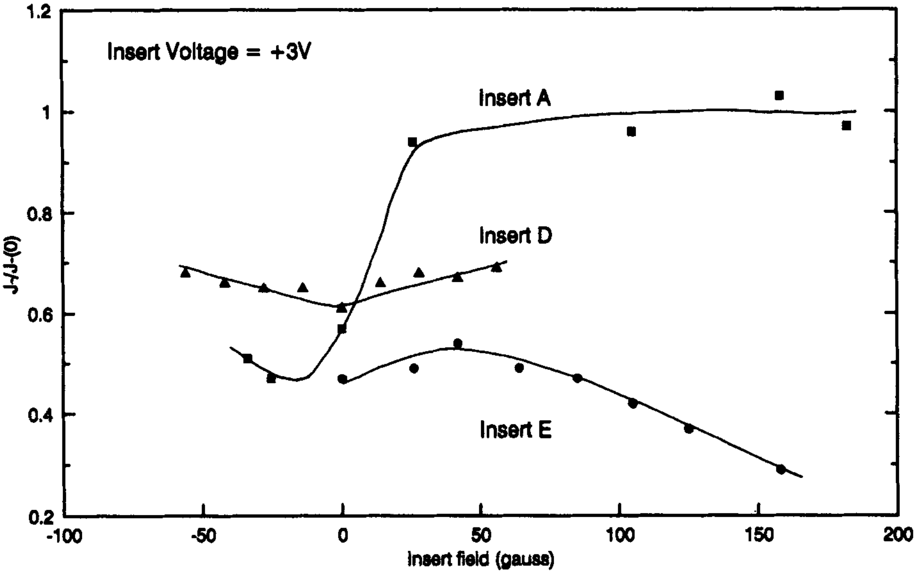

Figure 3 : Negative ion densities with varying magnetic fields, for different inserts.

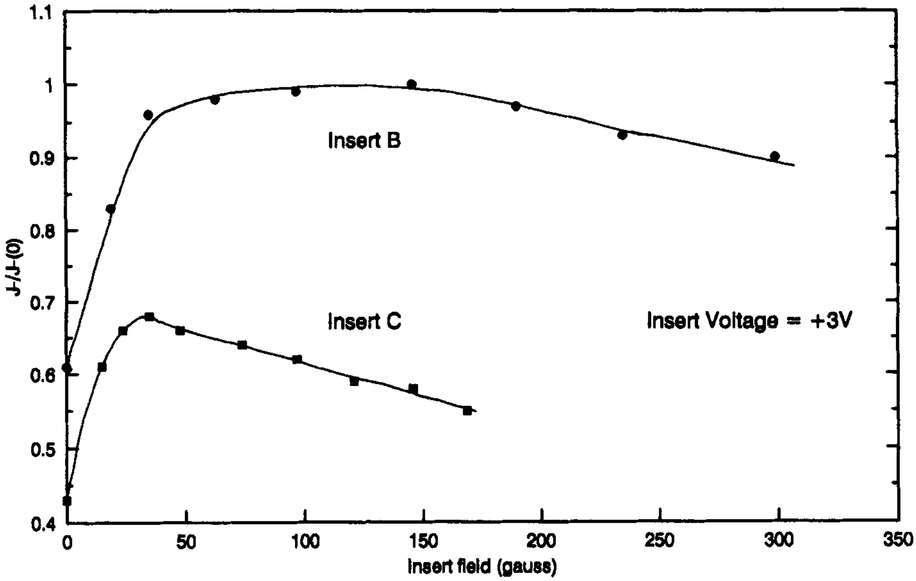

Figure 4 : Negative ion densities with varying magnetic fields, for different inserts.

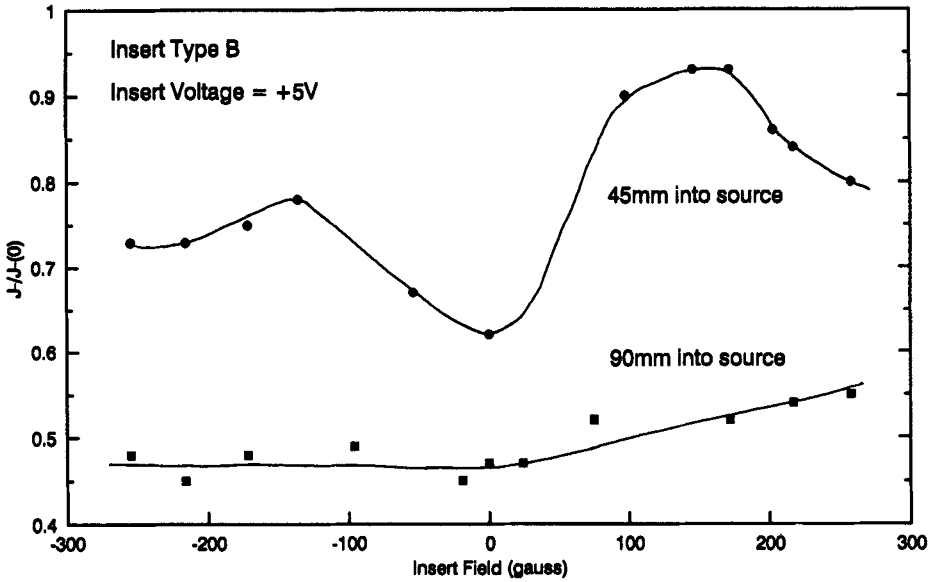

Figure 5 : Negative ion densities with varying insert fields at different positions in the source.

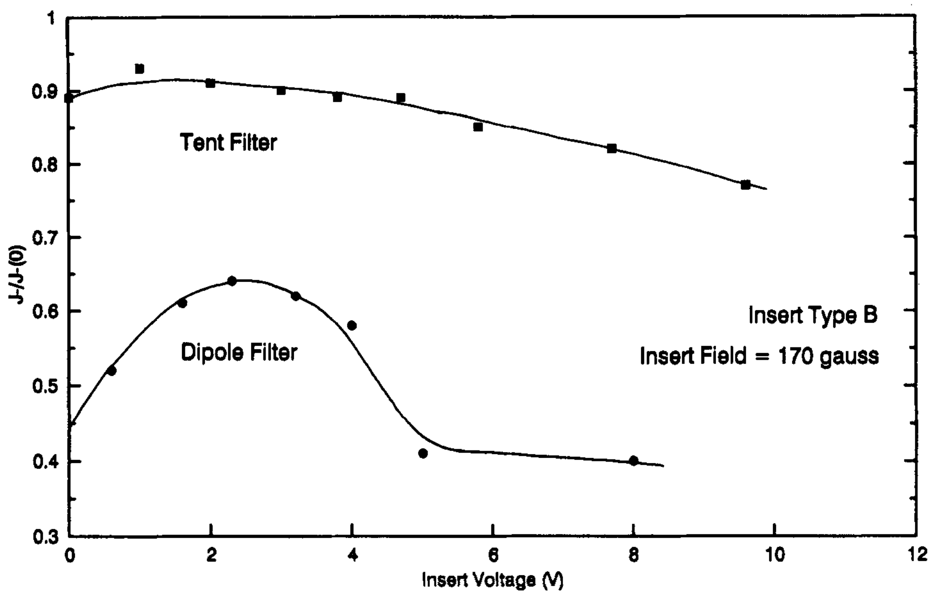

Figure 6 : Negative ion densities with varying insert voltage, for different source filters.

DISCUSSION

Hemsworth: You mentioned what seems to me to be quite important consideration is the shadowing of the aperture by the wires that you expressed to say would limit the dimensions you can use for the aperature. But in a practical system, you are limited to the design of the aperture size by considerations such as beam optics, etc. and if I remember correctly the typical design aperture size is around 30 mm for one MeV accelerators for NET, etc. If you take an aperture that size and use your small pitch filter what is the loss in shadowing of the area and is there a real enhancement as you were defining it?

Thornton: Well, we don't know, we've never tested it on this device. We are limited by our aperture size in this apparatus, so we just don't know what the effect of putting wires in front of an aperture is at the moment.

Holmes: For this reason (shadowing) and plus the engineering problems of building a filter of this type on a large scale, and since its extremely expensive, we decided to move back to the bar magnet type suppressor where we have no shadowing effect. We have actually built a large aperture accelerator operating in D^- with approximately the same pitch as the aperture and that does suppress electrons down to approximately one to one indeed, at high current densities. Though we will design in the field varying ability in the system.

Jongen: When I looked at your first figure showing the beam versus magnet current it seems to be unsymmetrical with current and that was with a tent filter so I was assuming there would be no remaining magnetic field at extraction, could you comment on that.

Thornton: The tent filter gives a field of about 5 Gauss in front of the aperture in the source. But far more important is the straight field from Grid 2, which could be about 15 Gauss, so there you do get nonsymmetry for some of the insets, you don't see it with all the insets but for the one you did.

Jongen: I have a second question. What kind of current density do you have? Would it be possible to use in a dc source?

Thornton: Yes, we used it in a dc source.

Holmes: There's no engineering problem, just money.

Whealton: Have you considering varying simultaneously the bias on the plasma electrode and the tent filter as well, elsewise you might have optimized the other two and leaving you little room for optimization.

Thornton: We haven't tried biasing the beam forming electrode separately, we tried biasing only the insert wall, and the varying the magnetic field, it's possible that things could be improved.

Whealton: I have one other question. Could you tell me the maximum current and current density that you got in the configuration.

Thornton: Well, 400 Amps there that's a positive ion density of about 75 milliamps per centimeters squared, we were getting negative, that is J_0^- of about 18 milliamps per centimeters squared.