Title

MECHANICAL DESIGN AND CONSTRUCTION OF A 200 mA, 100 keV, DC, NEGATIVE ION ACCELERATOR

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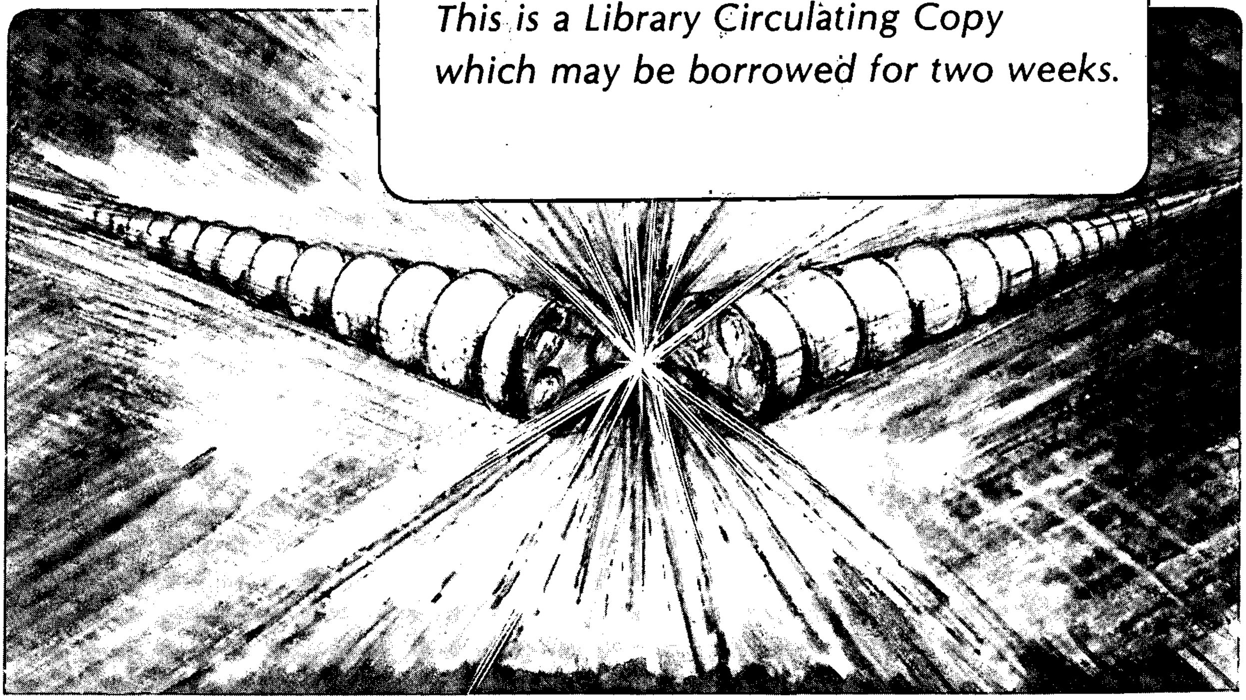

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MECHANICAL DESIGN AND CONSTRUCTION OF A 200 mA, 100 keV, DC, NEGATIVE ION ACCELERATOR*

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Abstract

A volume production source and a 100 keV, dc, accelerator together with an additional, modular, 100 keV, electro static focused accelerator provide a starting point for a high energy H^-/D^- beamline (200 keV to 800 keV), intended for fusion energy applications [1]. The 100 keV accelerator tests started in June 1987. The mechanical design and construction of the accelerator is described.

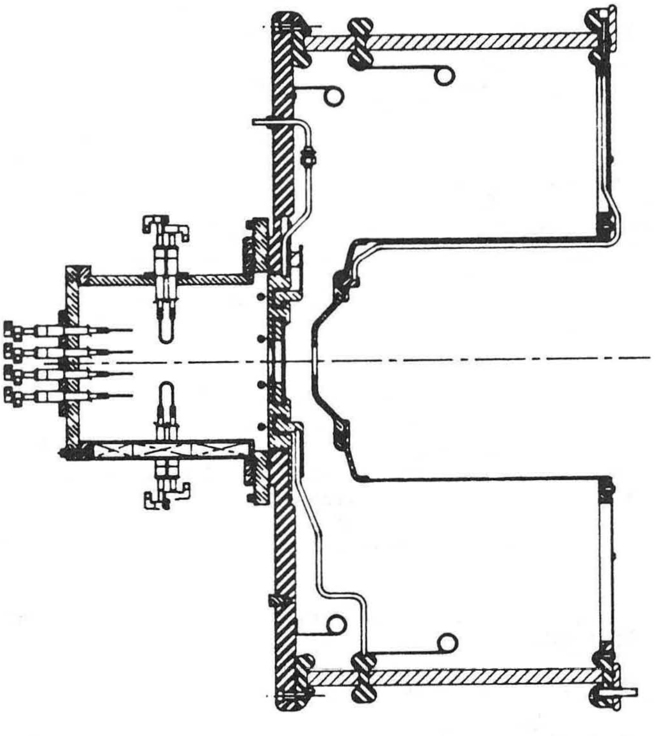

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Fig. 1 Cross section of assembled source and accelerator.

Discussion

The accelerator, shown in Fig. 1 and 2, is a single hole design having a 29 mm diameter source electrode apperature. All the electrodes are water cooled to allow steady state operation. Brazed construction is used for the copper electrodes to accommodate the cooling water passages. Fig. 3 shows the cooling water passages in the no. 1 electrode before the cover was brazed on. The accelerator also incorporates an electron trap. The electron trap removes electrons from the beam by means of magnets, Fig. 4, which sweep them into the no. 2 electrode [2]. The accelerator was designed to keep the electron energy low (2 keV) so the heat load on the electron trap is at a reasonable level. Even with the relatively low electron energy the design heat flux for this electrode is 2 kW/cm^2. To handle this heat load high velocity water flow near the heated surface is required. Fig. 5 shows the water passage arrangement for the no. 2 electrode.

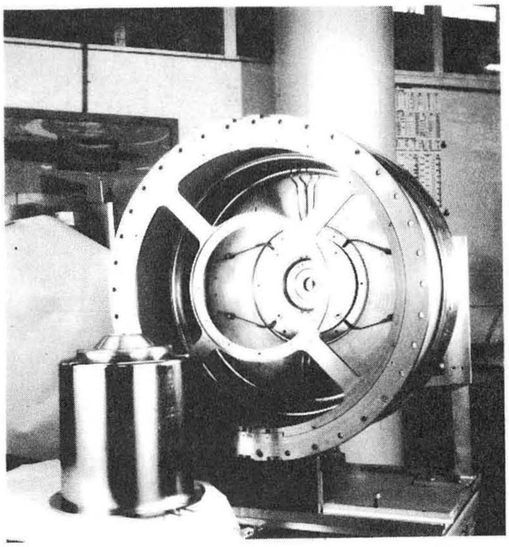

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Fig. 2 Assembled accelerator with no. 3 electrode removed.

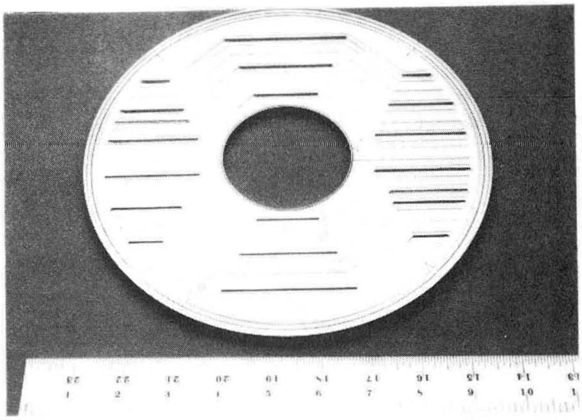

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Fig. 3 Electrode no. 1 cooling water passages.

As shown in Fig. 1 electrodes no. 1, 2, and 2b are mounted on the accelerator back plate. The back plate thickness is 2.54 cm. The measured deflection of the back plate under vacuum load was 0.040 cm compared to 0.066 cm calculated for a simply supported plate. The deflection is well within the specified value for this large apperature accelerator. The insulator is cast epoxy, Shell Epon 826 (75%), furane D40 (15%), Dow Corning 736 (10%), by

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weight. It has an 81.3 cm I.D. and a wall thickness of 1.90 cm. The glue joints between the insulator and the stainless steel flanges are made using Emerson-Cumings 45 adhesive.

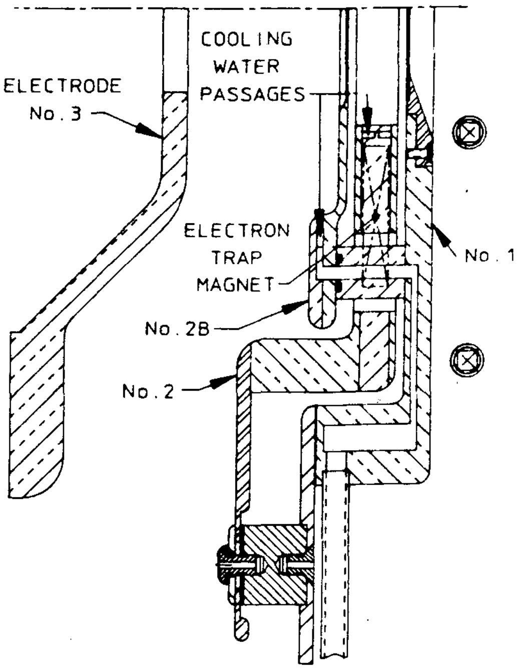

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Fig. 4 Detail of electrodes.

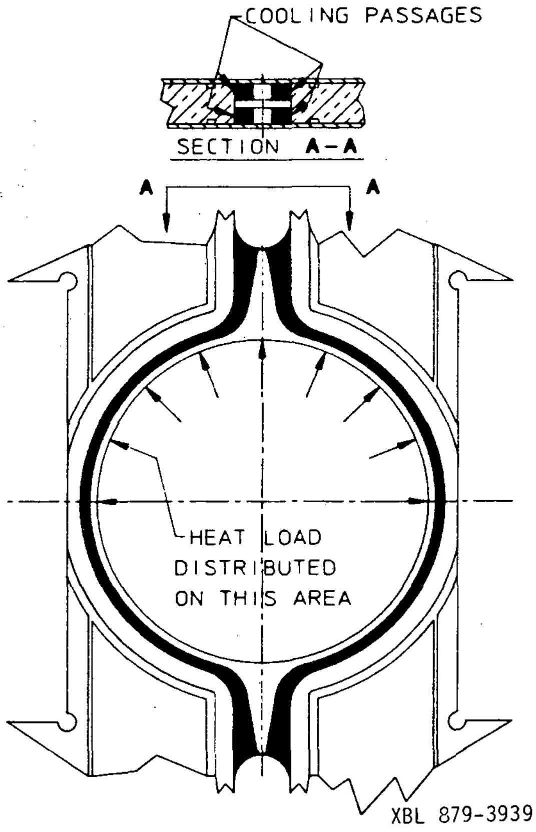

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Fig. 5 Cooling water passages in no. 2 electrode.

Heat Transfer Calculations

For the no. 1 electrode a design heat flux of 30 W/cm^2 was used. For the no. 2 electrode were the design heat flux was 2 kW/cm^2 the correlations for boiling heat transfer from [3] were used. These correlations were used to design high heat flux heat absorbtion panels for the Neutral Beam Engineering Test Facility. The panels performed as designed for the life of the test stand. The correlations are summarized below:

Forced convection non-boiling heat flux - Qfc kW/cm^2

$$Qfc = 0.001h[(tw-ts) + (ts-tb)] \qquad (1)$$

Incipient boiling - Qib kW/cm^2

$$Qib = 4.93e{-6} \times [(0.145P)^{1.156}] \times [1.8(tw-ts)]^{(0.334\ P)} \qquad (2)$$

Fully developed boiling - Qb kW/cm^2

$$tw-ts = 44.44 \times (Qb^{0.25}) / (e^{P/6200}) \qquad (3)$$

Critical heat flux - Qcrit kW/cm^2

$$Qcrit = 7.2e{-3} \times (V^{0.5}) \times (ts-tb) \qquad (4)$$

Where:
h = 0.023 x (k/d) x (Re$^{0.8}$) x (Pr$^{0.4}$) w/cm^2 C
Re = Reynolds no.
Pr = Prandtl no.
k = thermal conductivity of liquid at avg bulk temperature, w/cm C
d = hydraulic diameter of passage, cm
tw = wall temperature, C
ts = saturation temperature at local pressure, C
tb = bulk liquid temperature, C
P = local pressure, kPa abs
V = local water velocity, m/s
ts-tb = subcooling, C

In the transition region between incipient boiling and fully developed boiling - Qt kW/cm^2

$$Qt = Qfc + Qb - Qib$$

where Qib = Qb evaluated at the (tw-ts) found from a simultaneous solution of equation 1 and 2.

A plot of the boiling heat transfer curve is shown in Fig. 6, for the design conditions. The boiling curve was used in a finite element code where an iterative solution is required to find the temperature distribution. The temperature distribution calculated by the finite element code TACO2D is shown in Fig. 7. From the calculated maximum wall temperature, t_{wm}, and the boiling curve the maximum water side heat flux, Qw, is determined. This heat flux is compared to the critical heat flux to determine the margin of safety. From Fig. 6 it can be seen that the margin of safety is Qcrit/Qw = 1.28. Only edge cooling was used for the no. 3 electrode since the estimated heat load was low.

Gas Pressure Calculations

To minimize stripping the H$^-$ beam the gas pressure along the beam has to be as low as possible. The annulus between the no. 3 electrode hat and the insulator provides a large pumping area. The no. 3 electrode support consists of four spokes resulting in high transparency. The pressure distribution along the beam center line, calculated using an axisymmetric monte carlo computer code, is shown in Fig. 8. For this pressure distribution the beam loss in the accelerator is 21.5%. The calculated gas flow of 99 sccm compares to a measured value of 90 sccm.

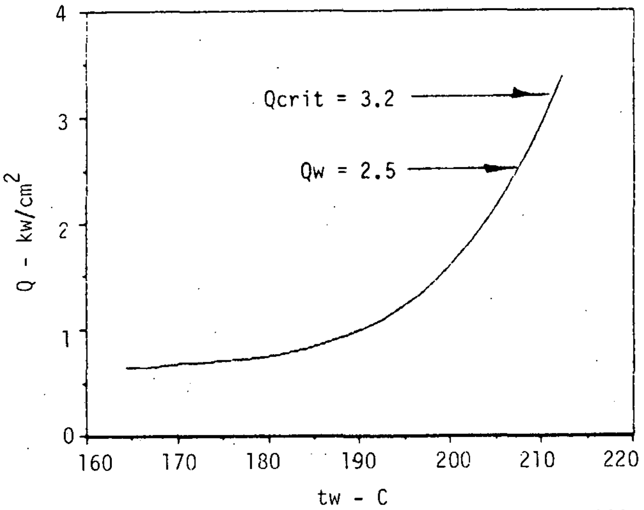

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Fig. 6 Boiling heat transfer curve, V = 11 m/s t_b = 30°C, P = 690 kPa abs (100 psia).

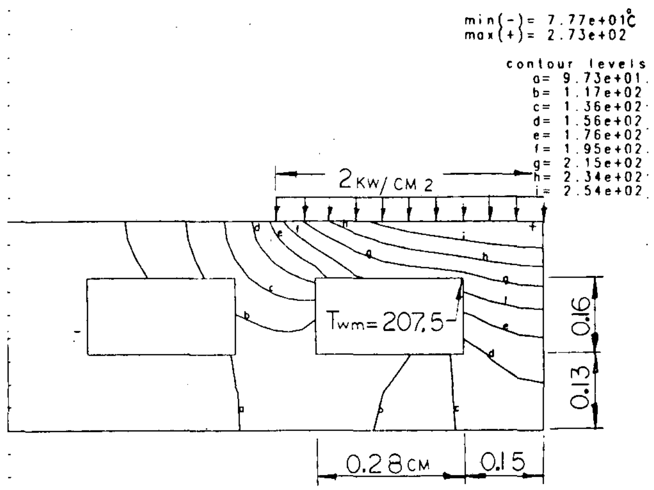

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Fig. 7 Electron trap temperature distribution.

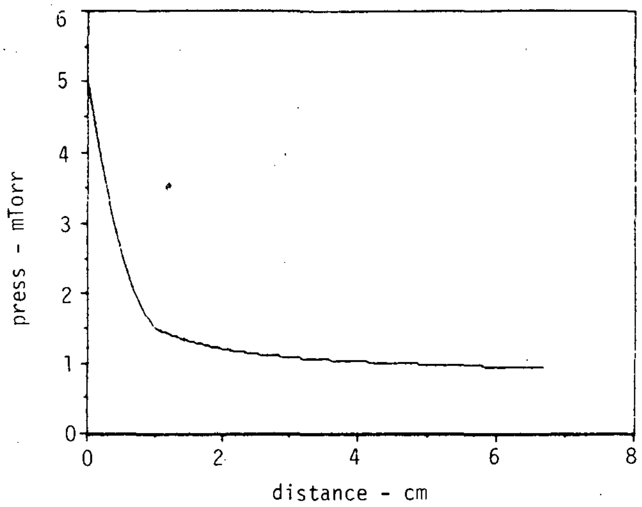

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Fig. 8 Calculated gas pressure along the axis of the accelerator for a pressure of 5 mTorr in the source.

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[3] W. A. Rinehart, et al., "A Heat Absorption Panel for Neutral and Ion Beam Dumps," ASME Paper 82-HT-31.

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