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# Some Considerations in the Design of a Venetian Blind Direct Converter

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Some Considerations in the Design of a Venetian Blind Direct Converter*

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The structural design of a Venetian Blind direct converter will depend on the choice, for example, of: 1) Expander field, 2) Selective leakage, 3) Number of collector stages, 4) Method of cooling and 5) The general configuration and orientation. This note is intended to outline the major compromises that will result from the variation of parameters to fit a particular design. The relationships given are for a two-stage unit, but it is straightforward to extend them to multiple-stage units.

1) Power Density

The negative grid must be kept cool enough to prevent the significant emission of thermionic electrons. Fig. 1 shows the beam power density, $P_b$ at which the radiatively cooled tungsten grid wires emit one electron for each intercepted ion. In that case the efficiency is reduced to about

$$\eta \approx \eta_0 [1 - 1.7 (1-T)]$$

where T is the transmission factor for the grid and $\eta_0$ is the efficiency without this effect.

Because thermionic emission is so sensitive to temperature, ribbon wires can be better than round ones even though they have a greater area for emission. Fig. 1 assumes perfect alignment of the ribbons with the beam. The divergence of the beam makes this impossible.

*Work performed under the auspices of the U.S. Energy Research and Development Administration.

2) Magnetic Field B at the Collector:

The magnetic field at the direct converter must be weak enough that the energy sorting and collection of ions is not affected. Ion trajectories and velocity components are altered by less than 10% if $\tilde{\alpha} \leq 4d$, where d is shown in Fig. 2 and $\tilde{\alpha} = Mv/eB$ is the gyro radius that an ion would have if all of its initial velocity were directed perpendicular to the field. For 200 keV $D^+$ this condition becomes

$$B(T) \leq .023/d(m)$$

3) Magnetic Field Expansion Ratio, R:

The residual perpendicular velocity and the gyro motion produce a spread in incident angle $\alpha_o$ (see Fig. 2) equal to $\Delta\alpha_o = \pm 1/\sqrt{R}$. When averaged over this range of angle, the efficiency $\eta$ is reduced by the approximate factor:

$$\eta = \eta_o \left(1 - \frac{7}{R}\right) ,$$

where $\eta_o$ is the efficiency without this effect.

4) Field Line Curvature:

If the magnetic field lines in the expander are curved, the magnetic moment of the ions may not be conserved and the perpendicular energy may not be reduced simply by 1/R. The result is an additional angular spread of up to $\Delta\alpha_o \approx \pm 0.3\ (p/r)$, where $p = 2\pi Mv/eB = 2\pi\tilde{\alpha}$ is the ion pitch length and r is the radius of curvature of the field lines. (See Ref. 3). The efficiency $\eta$ will be reduced by a factor given approximately by

$$\eta = \eta_o\ [1 - .6\ p^2/r^2].$$

Example: For 200 keV $D^+$, $p(m) = .574/B(T)$ and $\eta$ is decreased by .6% for $r(m) = 5.74/B(T)$.

5) Space Charge

The electric field due to space charge must be kept small enough that it does not prevent ions from reaching the proper electrodes. For a given electrode spacing d and voltage difference V, this sets the upper limit on ion current density. Here, we want to operate at the maximum power density (condition 1. above), so that the current density is specified. Space charge, then, determines the maximum spacings d for a given energy distribution (and hence voltages):

$$d^2_{max} \propto \overline{W}^{5/2}$$

A computer calculation with an approximation to the expected energy distribution shows that for $D^+$ ions with $\overline{W}$ = 200 keV and 25 W/cm$^2$ $d_1 \leq 1.9$ m and $d_2 \leq 1.7$ m. To allow a factor of 2 for peak current density, we must reduce these d's by $\sqrt{2}$.

Note: The maximum d given in Table III of Ref. 1 are wrong and should be reduced by $\sqrt{10}$ to be correct.

6) Ribbon thickness

The ratio $\delta/h$ (see Fig. 2) should be kept small to reduce the fraction of energetic ions that are intercepted on the low voltage electrode, and the ratio h/d must be kept less than about 1/4 to prevent the severe distortion of the electric field at the edges of the ribbons. Since d is limited by space charge, $\delta$ can be increased only at the expense of a reduction in efficiency. The reduction is approximately given by:

$$\eta = \eta_0 \, (1 - \delta/3h).$$

7) Interception of ions on structure

Any part of the beam power that is intercepted by a ground-potential structure (including the grounded grid) effectively bypasses the direct converter and goes directly to the bottoming thermal cycle. If a fraction, f, of the incident power is intercepted the direct converter efficiency is reduced to

$$\eta = \eta_o (1 - f)$$

8) Vacuum Requirements

The gas pressure in the region of the direct converter must be kept below about $10^{-5}$ torr for voltage holding. At $p = 10^{-5}$ torr, only 1% of the ions will undergo charge exchange before reaching the collectors if the injection energy is 200 keV for $D^+$. This increases to 2% at 150 keV. See Fig. 3.

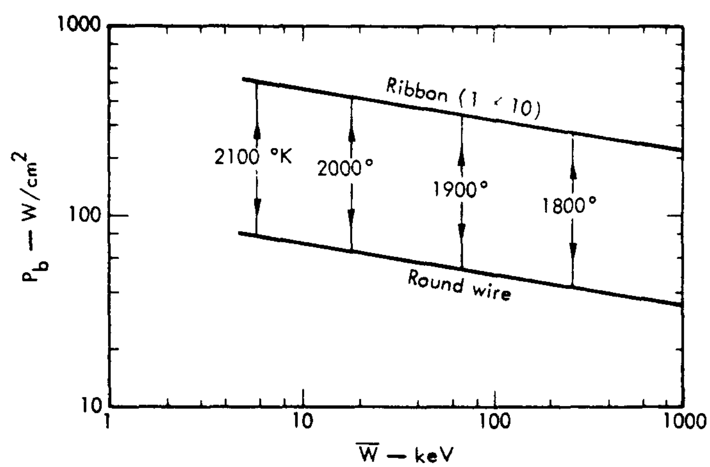


Fig. 1

Beam power density limit set by thermionic emission at the negative grid. The curves show where the emission current is equal to the intercepted ion current.

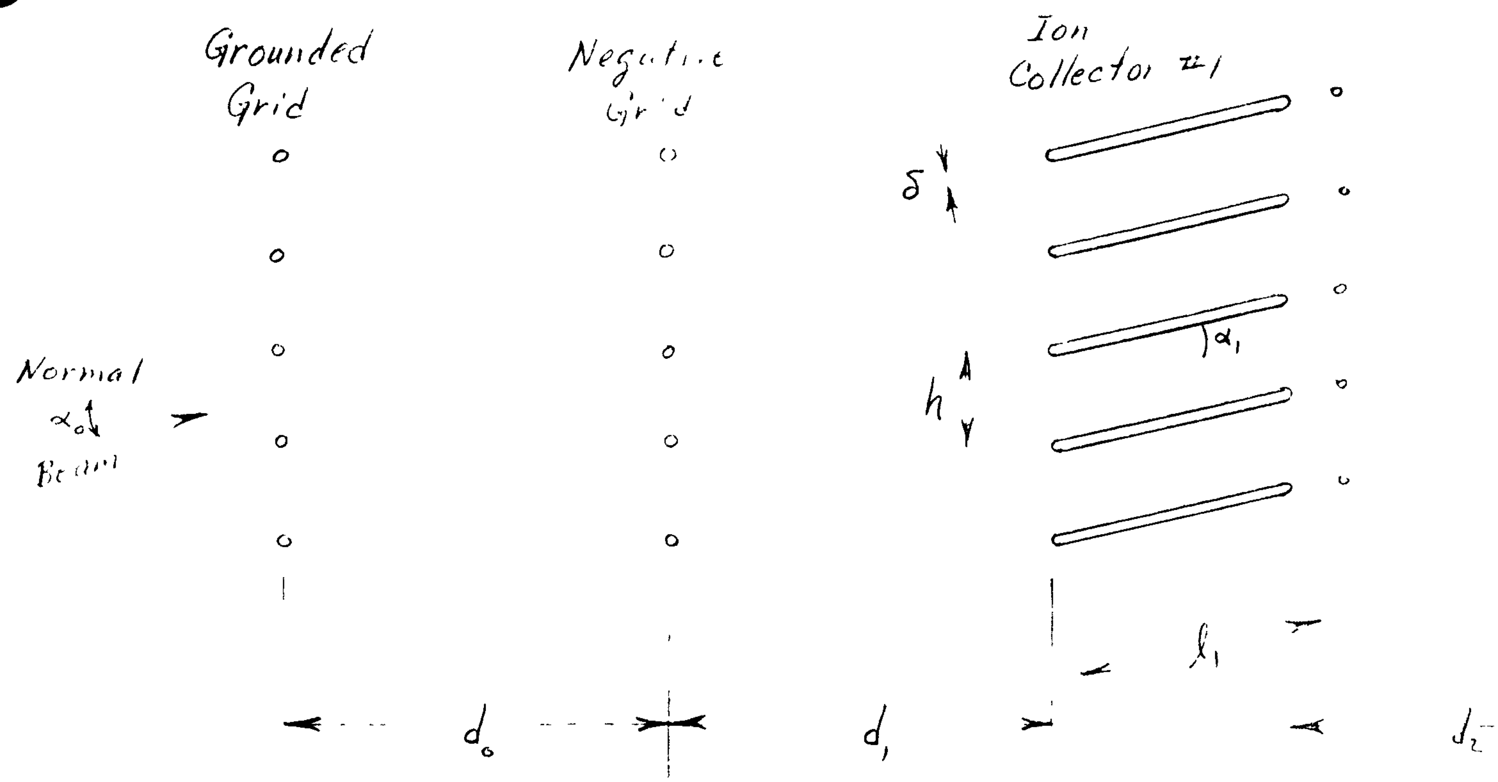


Fig. 2

Showing the basic dimensions in a Venetian Blind direct converter

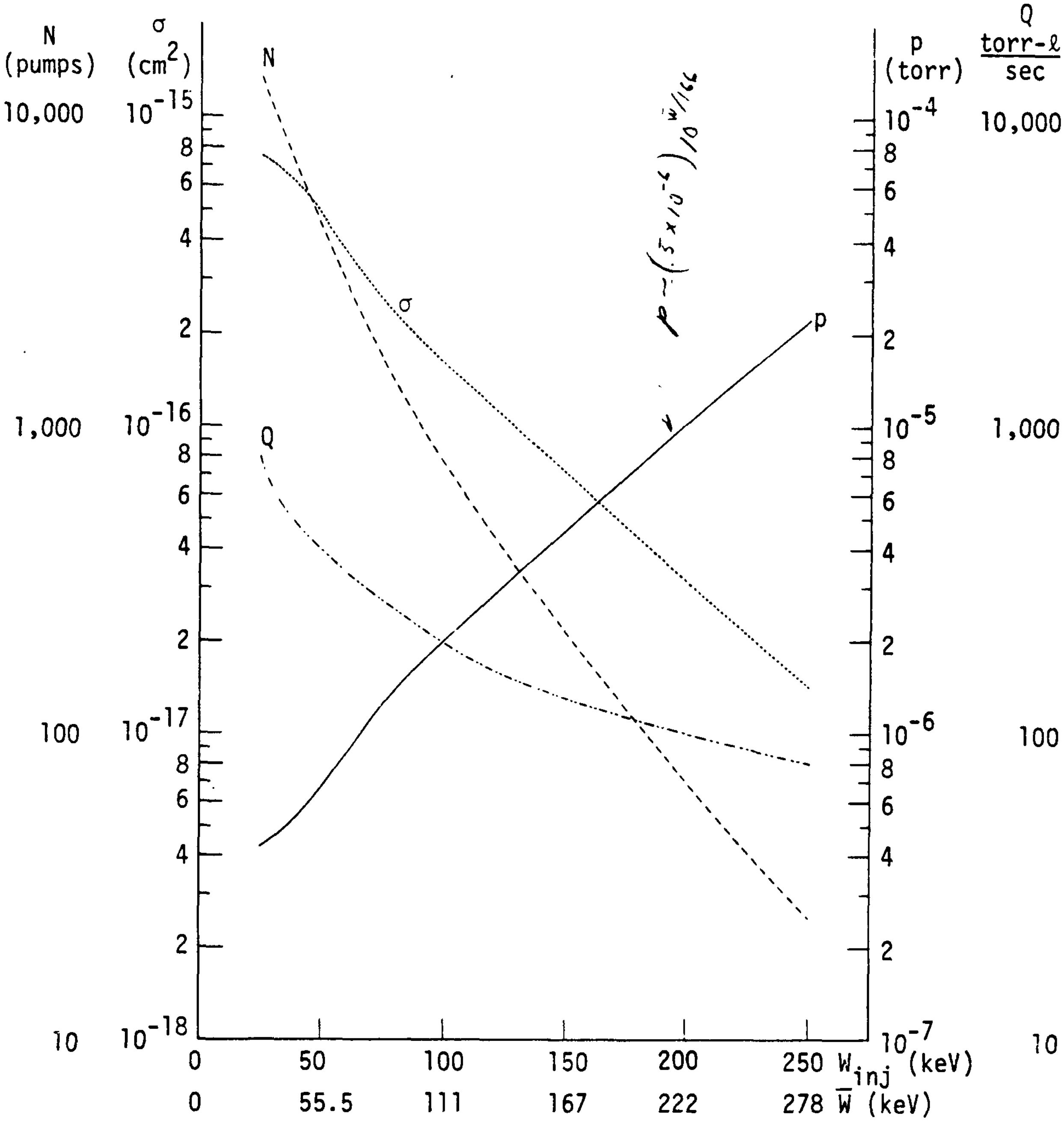


Fig. 3

Plots of the parameters that determine the vacuum pumping requirements: Q* is the gas throughput due to the ion beam, σ is the cross-section for charge exchange of $D^+$ with $D_2$, P is the pressure at which 3%† of the ions undergo charge exchange, and $N^*$ is the number of $1.4 \times 10^5$ ℓ/sec pumps required. * per 250 NW unit. † Path length L = 80 m

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