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LIMITS ON COLLISIONLESS MODEL OF THERMIONIC CONVERTER

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LIMITS ON COLLISIONLESS MODEL

OF THERMIONIC CONVERTER

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Current-voltage characteristics for gaseous thermionic diodes have been computed[1,2] by using the Langmuir space charge theory modified to include both ions and electrons. The limiting potential distributions defining the model for electron-rich emission are shown in Fig. 1. The region between curves A and B is the space-charge-limited region of the current-voltage characteristic. The limiting monotonic potential distributions (and, hence, the model) exist only for a restricted range of the experimental parameters α and β, defined by

$$\alpha = \frac{N_i^+(o)}{N_e^+(o)} \tag{1}$$

$$\left.\begin{aligned} \beta^2 &= 16\left(\frac{\pi}{2kT}\right)^{3/2} m_e^{1/2}\, eJ_{eo}\, L^2 \qquad \text{(esu)} \\ \beta^2 &= 8.43.10^{11}\ (T/^{o}K)^{-3/2}\ (J_{eo}/\text{amp cm}^{-2})(L/\text{cm})^2 \end{aligned}\right\} \tag{2}$$

where $N_i^+(o)$ and $N_e^+(o)$ are the ion and electron emission charge densities, respectively, k is a constant, T is the emitter temperature, m_e is the electron mass, e is the electronic charge, J_{eo} is the electron emission current density, and L is the electrode separation distance. The ratio β/L is plotted in Fig. 2 against J_{eo} for three temperatures.

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Hansen and Warner[3] have discussed the limits on the range of α for which the potential distributions shown in Fig. 1 can be obtained. They presented the limiting values of α as a function of the dimensionless potential η_a, defined by

$$\eta_a = \frac{eV_a}{kT}$$

where V_a is the difference in surface potentials. The potential η_a, however, is not sufficient for a direct determination of experimental conditions. Hence, the range of α as a function of β was computed by the equation

$$\beta = \int_0^{\eta_a} [F(\eta;\alpha)]^{-1/2}\, d\eta \tag{3}$$

and plotted in Fig. 3 for the case of electron-rich emission ($\alpha \leq 1$). The appropriate functions $F(\eta;\alpha)$ are to be found in ref. 1.

From Fig. 3, the range of the parameters $(\alpha,\beta)_A$ for which the potential distribution A, Fig. 1, may be obtained is given by

$$(\alpha,\beta)_A \leq (\alpha,\beta)_A^*; \tag{4}$$

likewise for potential distribution B, Fig. 1, we must have

$$(\alpha,\beta)_B \leq (\alpha,\beta)_B^*$$

Hence, the shaded area in Fig. 3, $\alpha \leq 1$, represents the range of the experimental parameters α and β for which the model defined by Fig. 1 is valid. It is to be noted that, for given collector temperature and electrode separation as $N_i^+(o)/N_e^+(o) \rightarrow 1$, the allowable electron current density becomes restricted to smaller values; e.g., for

$$\alpha = \frac{N_i^+(o)}{N_e^+(o)} = 0.7$$

we see from Fig. 3 that we must have

$$\beta^2 < 60$$

From Eq. (1), or Fig. 2, with

$$T = 2000^\circ \text{ K}$$

$$L = 10^{-3} \text{ cm}^2 = 10\mu$$

we have

$$J_{eo} < 64 \text{ amp cm}^{-2}$$

The model for ion-rich emission[2] is shown in Fig. 4. The range, $(\hat{\alpha},\hat{\beta})$, of validity of this model can be obtained from the electron-rich results by defining

$$\left.\begin{aligned} \hat{\alpha} &= \alpha^{-1} \\ \hat{\beta}^2 &= \frac{1}{\hat{\alpha}}\,\beta^2 \end{aligned}\right\} \tag{5}$$

These results follow from the symmetry of the equations (cf. ref. 4). The range of validity is shown in the cross hatched region of Fig. 3, $\alpha \geq 1$.

The regions of validity discussed in this note refer only to the models defined in Figs. 1 and 4. This does not preclude the possibility of spatially oscillatory potential distributions as predicted by McIntyre[4] and others within or outside of these regions.

The author expresses his appreciation to Bruce Auer for performing the numerical calculations.

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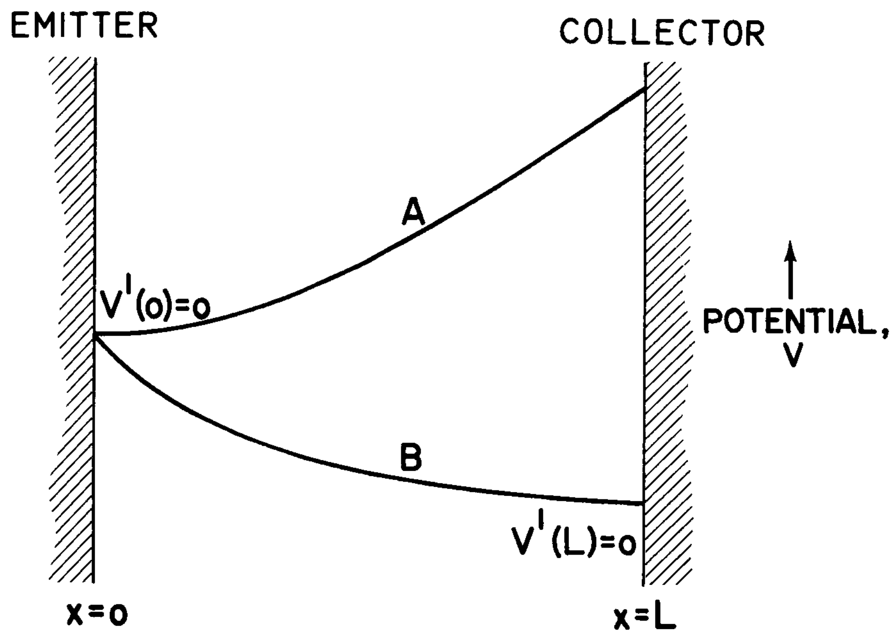

Fig. 1. - Limiting potential distributions for electron-rich emission.

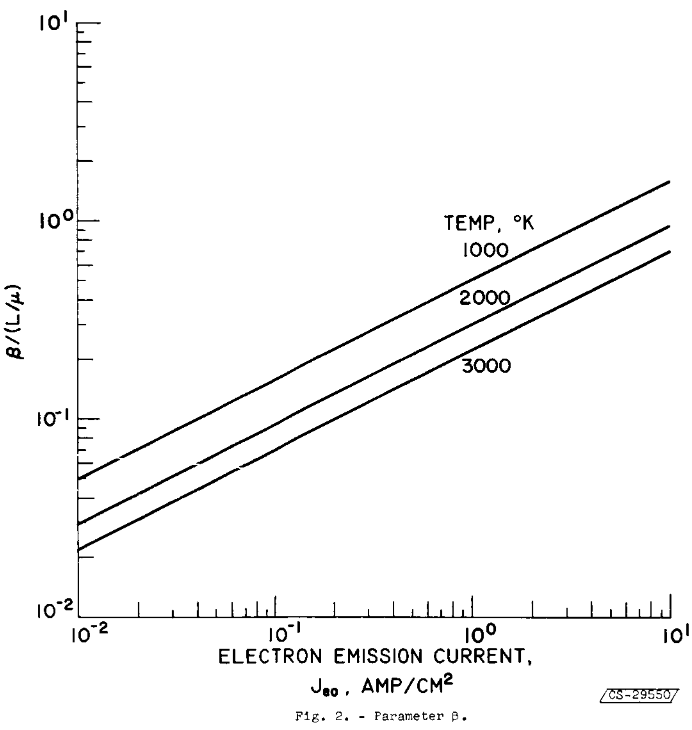

Fig. 2. - Parameter β.

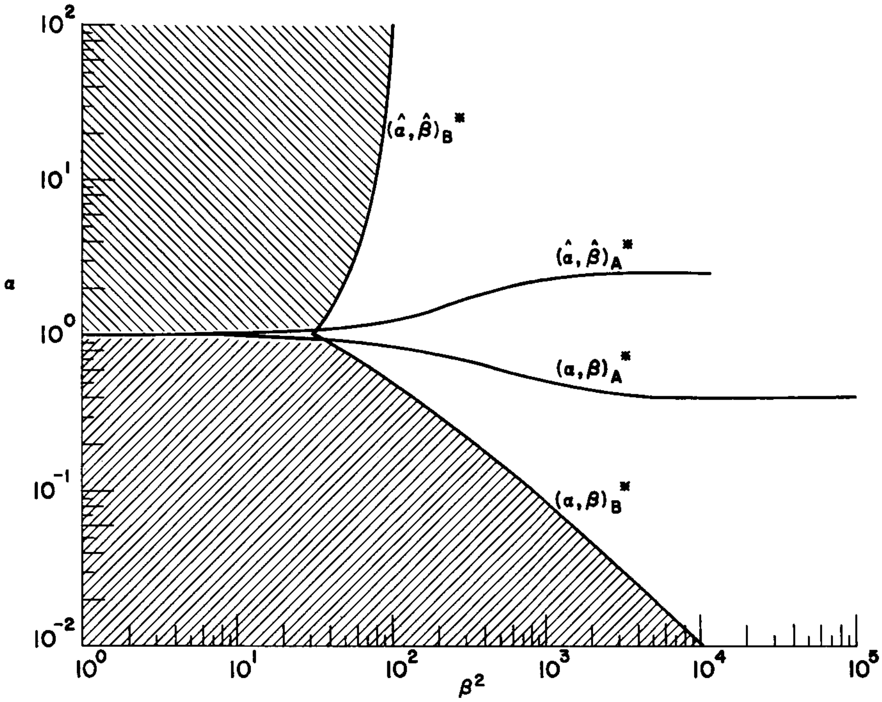

Fig. 3. - Limiting values of α, β.

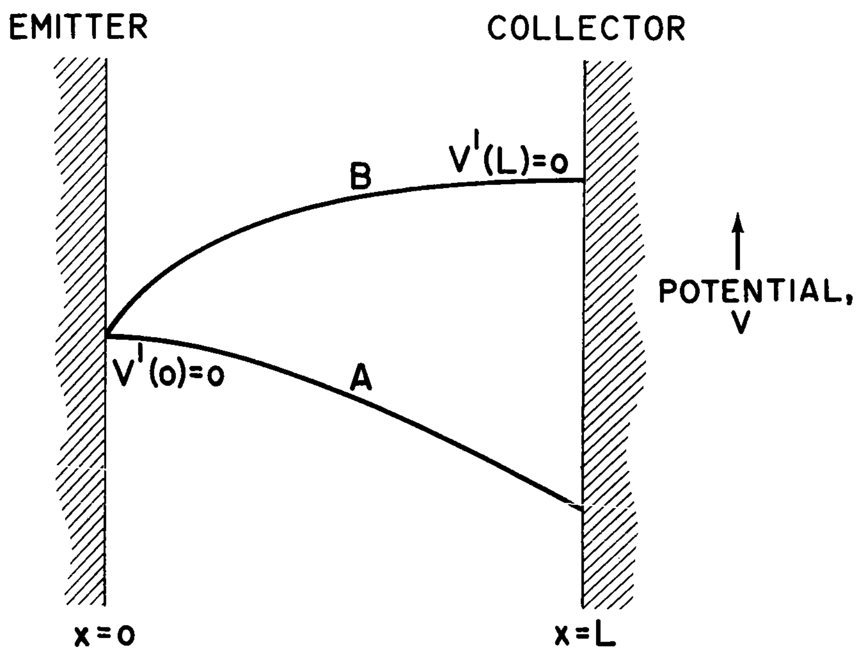

Fig. 4. - Limiting potential distributions for ion-rich emission.

Fig. 1. - Limiting potential distributions for electron-rich emission.

Fig. 2. - Parameter β.

Fig. 3. - Limiting values of α, β.

Fig. 4. - Limiting potential distributions for ion-rich emission.