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PAIRS OF EMITTER AND COLLECTOR SHEATHS FOR CESIUM THERMIONIC DIODES

by James F. Morris

Lewis Research Center
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SUMMARY

Coupled theoretic sheaths given in this report approximate thermionic diodes. The sheaths result from particle emissions of electrodes affected by sheath fields and of cesium plasmas ionized by thermal electrons. By matching their net current densities, the analysis pairs collisionless emitter and collector sheaths to simulate diodes. Midway between the electrodes in both space and temperatures lie the plasmas at 1700° to 2000° K with 10^{12} and 10^{13} electrons per cubic centimeter. The emitters and collectors differ by 400° to 800° K. For these conditions, the computed outputs for the converters range from 0.01 to 1 watt per square centimeter. Although such powers fall below desired performance levels, they provide low-current checks for thermionic-diode experiments.

Sheath properties for the present systems and for electrodes in plasmas with raised electron temperatures agree with equilibrium results. But the theory applies only for equilibria, near-equilibria, and relatively low net transports. Overall sheath characteristics correlate with electrode and plasma conditions. One helpful parameter is a hybrid, the emission Debye length, $\lambda_{DE} \approx 6.9\,(T_E/N_{eP})^{1/2}$. This variable correlates data for these sheaths better than the plasma Debye length. Effective sheath widths for the present study lie between 1.7 and 2.6 emission Debye lengths.

The independent variables for the present graphic correlations of sheath properties involve only electrode and plasma parameters. Because one states these conditions at the outset, the graphs allow immediate estimates of sheath characteristics - without the complex iterative calculations.

INTRODUCTION

This study estimates several potential profiles that might develop in a cesium thermionic diode. The theoretic results detail pairs of collisionless emitter and collector sheaths (ref. 1) but leave the plasma losses to other analyses (refs. 2 to 4). In the model, the sheath separates a thermally ionized plasma (ref. 5) from an emitting electrode (refs. 6 to 9). Sheath fields alter the emission barriers (refs. 10 and 11) or effective work functions of the electrodes. This field phenomenon requires a special virtual electrode (ref. 1) that allows both positive and negative particles to undergo the same absolute potential drop through the sheath. For usual thermionic-diode work, the accelerated particle from the electrode changes less in absolute potential energy than the retarded particle. If both charges undergo the same absolute potential change in the old sheath model, net currents occur in calculations for equilibria; of course, such occurrences violate the second law of thermodynamics. Because of its self-consistent sheath drops, the present theory allows no net currents in isothermal systems. But when the electrode temperature rises above that of the plasma, net negative charge flows from the electrode; then it is an emitter. If the electrode temperature falls below that of the plasma, the electrode is a collector.

By setting the plasma temperatures between those of the electrodes in a system and by matching the entering and leaving current densities, the present calculation method yields pairs of emitter and collector sheaths. Although the analysis ignores energy transfer from emitter to collector, placing the plasma temperatures midway between those of the emitter and collector reduces the differences in heat transfer. As previously stated, the theory applies only for relatively small net transports. Thus, with electrode and plasma temperatures and electron concentration specified, this method yields work functions and sheath data for well coupled emitters and collectors.

Such detailed internal data for diodes are needed. Analyses of outputs alone fail to reveal mechanisms for transport and ionization in thermionic converters (ref. 2). Theory and experiment must probe the interior of the diode to provide design criteria. Identities of controlling processes emerge when interelectrode measurements compare with theoretic conditions, like those presented in this report. These processes limit diode currents and voltages in the plasma and at the electrodes. Reducing these output restrictions depends on knowing and using the internal functions of the thermionic converter.

One example of this approach involves the "isothermal-diode theory" (ref. 12). That model provides equilibrium data to compare with diode operations and diagnostics like the emission spectroscopy of the plasma gap (ref. 13). After an isothermal check and calibration of the diode and sensors, results for power production have firm bases and more meaning. In addition, internal measurements track the changes of mechanisms as the diode departs from equilibrium. But the sheath model used in the isothermal-diode theory merely adds simple space-charge curves (ref. 14) for ions and electrons. The present sheath model applies more accurately to diode equilibria. And the near-equilibrium and small-transport interpretations (ref. 1) allow this theory to approximate some heterothermal diode systems.

Examples given in this report combine emitter and collector sheaths with like current densities to form diodes. The electrodes bracket cesium plasmas with several sets of conditions presented in table I.

TABLE I. - SHEATH PARAMETERS

Cesium plasma		Electrodes	
Electron concentration, cm^{-3}	Temperature, ^{o}K	Emitter temperature, ^{o}K	Collector temperature, ^{o}K
10^{13}	2000	2400	1600
10^{13}	2000	2200	1800
10^{12}	1800	2000	1600
10^{12}	1700	2000	1400

Sheath calculations for work functions from 1.5 to 5.0 volts provided bases for interpolations to pair emitters and collectors. These graded solutions also yielded properties to compare with the general correlations of reference 1. Thus, overall sheath characteristics for the systems of table I appear with data for equilibria (ref. 1) and for electrodes in plasmas with elevated electron temperatures (ref. 1). After this check of the results, interpolations revealed possible combinations of electrodes for thermionic converters. Work functions, net current densities, sheath drops and widths, and potential, distance diagrams indicate theoretic conditions in the selected cesium diodes.

In addition to this report and the theoretic background given in reference 1, the FORTRAN statement of the computing method for this sheath model is presented in reference 15.

THEORY

Reference 1 gives details of the model for emission sheaths, but to complete the description of potential profiles in cesium diodes, this report presents the theory also. However, in this description the equations appear in simple unexpanded forms.

Assumptions

Sheaths for emitting electrodes submit readily to analyses based on existing theories as the result of three assumptions: First, confining the study to plane sheaths greatly simplifies calculations. Second, using equations for equilibrium phenomena allows concise mathematical statements of emission (refs. 6 to 9) and plasma (ref. 5) processes. In the present model, the contact ionization probability accounts for ion generation at the electrodes (ref. 9). The contact ions and the electrons escape the electrode surfaces by thermal emission (refs. 6 to 9) into the sheath. Near the electrodes, though, sheath fields alter the emission barriers (refs. 10 and 11). The resulting effective work functions yield emitted current densities different from those for emissions with no external fields. Across the sheath from the electrode, plasma atoms ionize by colliding with thermal electrons (ref. 5). But the third assumption, ruling out collisions in the sheath, removes great complications. Without collisions, all charge transport involves only acceleration or retardation in the sheath fields. Of course, the atoms move back and forth between the electrode and plasma unaffected by the sheaths.

With the component theories identified by the names of their authors, the description of the sheath model is clear and brief: This study analyzes plane collisionless electron and positive-ion sheaths between Saha plasmas and Schottky versions of Richardson-Dushman, Saha-Langmuir electrodes. Although the contributing theories derived from restrictive models, experiments reveal that they perform well in many nonequilibrium situations (refs. 2, 11, and 16). These findings encourage the use of the present sheath model for electrode, plasma systems near equilibrium or with relatively small net transport (ref. 1). This might be termed the fourth assumption.

Parameters

A sheath solution usually begins with a listing of the controllable or independent variables. In a simple system, these parameters describe the plasma and the electrode, not the sheath.

Plasma:

- Electron and ion concentrations (equal)
- Electron, ion, and atom temperatures
- Ionization potential
- Vapor pressure of plasma chemical
- Minimum mean free path

The last two properties enter computed tests to prevent continuous removal of the plasma chemical by condensation on electrodes and to assure essentially collisionless sheaths.

Electrode:

- Temperature
- Work function

In some systems, the work function depends strongly on the arrival rate of the plasma chemical at the solid surface and the electrode temperature as well as its composition. In this report, the work function serves as a parameter, but it might be specified in accordance with plasma, sheath, and electrode properties.

Saha-Langmuir Null Point

With the independent variables and assumptions given, simple calculations predict an isothermal electrode, plasma system with no sheath and, of course, no net current. In this state, each particle flux from the electrode equals the random current density of that particle in the plasma. The plasma results from ionization by thermal electrons (ref. 5):

$$N_{eP} = \frac{N_{aP}}{N_{iP}} \left(\frac{2\pi m_e \kappa T_{eP}}{h^2}\right)^{3/2} \exp\left(-\frac{eI}{\kappa T_{eP}}\right) \tag{1}$$

(The symbols are defined in appendix A.) The plasma indicated in equation (1) equilibrates with the emitting electrode at the Saha-Langmuir null point to produce a state described by equations (2a) to (7a).

ELECTRODE | PLASMA

Electrons

$$\text{(2a)} \quad j_{eOE} = \frac{4\pi m_e (\kappa T_E)^2}{h^3} \exp\left(-\frac{e\varphi'}{\kappa T_E}\right) = j_{eIP} = j_{eIE} = \frac{N_{eP} e}{2}\left(\frac{2\kappa T_{eP}}{\pi m_e}\right)^{1/2} = j_{eOP} \quad \text{(5a)}$$

Ions

$$\text{(3a)} \quad j_{iOE} = \frac{j_{iIE} + j_{aIE}}{2 \exp\left[\frac{e(I - \varphi')}{\kappa T_E}\right] + 1} = j_{iIP} = j_{iIE} = \frac{N_{iP} e}{2}\left(\frac{2\kappa T_{iP}}{\pi m_i}\right)^{1/2} = j_{iOP} \quad \text{(6a)}$$

Atoms

$$\text{(4a)} \quad j_{aOE} = \frac{j_{iIE} + j_{aIE}}{1 + \frac{1}{2} \exp\left[-\frac{e(I - \varphi')}{\kappa T_E}\right]} = j_{aIP} = j_{aIE} = \frac{N_{aP} e}{2}\left(\frac{2\kappa T_{aP}}{\pi m_a}\right)^{1/2} = j_{aOP} \quad \text{(7a)}$$

Equation (2a) comes from references 6 to 8, equations (3a) and (4a) derive from reference 9, and equations (5a) to (7a) depend on reference 5.

The Saha-Langmuir null point defines the plasma electron potential as that at the top of the electrode emission barrier. In this report, particle potential means motive (refs. 1 and 17). Thus, as figure 1 shows in a motive diagram, the electron potential in the plasma stands above that in metal by a voltage equal to the work function.

When the work function falls below that of the Saha-Langmuir null point, excessive electrons escape the solid, and an electron sheath separates the electrode from the plasma. If the work function climbs above that of the Saha-Langmuir null point, the metal emits too many ions, and a positive-ion sheath intervenes. In either event, though, the sheath arises to prevent net current in the isothermal system. This balance maintains because the sheath accelerates one emitted charge and retards the other. Of course, this process reverses for particles entering the sheath from the plasma.

A sheath imposes an electrostatic field on the electrode; the field changes the emission barrier (ref. 10). Figure 2 superposes an external field on the image potential in the usual manner. By this mechanism, the emission barrier or effective work function decreases for the particle accelerated from the electrode.

At the Saha-Langmuir null point, though, the effective and normal work functions and the plasma potential are all the same voltage above the electrode Fermi level:

$$\varphi = \varphi' = \varphi_o = \varphi_{oo} = \frac{\kappa T}{e}\left(\frac{3}{2} \ln T - \ln N_{eP} + \frac{3}{2} \ln \frac{2\pi m_e \kappa}{h^2} + \ln 2\right) \tag{8}$$

Of course, changing any of the independent variables in equations (2) to (7) destroys the Saha-Langmuir null point, and immediately, the relation of the electrode to the plasma grows complicated. To simplify the problems and eliminate errors, this analysis uses an effective electrode introduced in reference 1.

Virtual Schottky Electrode

The virtual Schottky electrode (ref. 1) is a theoretic construct that replaces the overall functions of the electrode surface in the present sheath model. Because the potentials and dynamics of the electrode surface evade definition, such substitutions of gross effects for detailed local mechanisms are necessary as well as convenient. For example, the traditional thermionic emitter (ref. 12) looses one charge at the normal work function and the other at an effective work function lowered by the sheath field. Of course, these two potential levels occur neither on the electrode surface nor at the same place in space. But both work functions act as properties of the solid surface in the model. Furthermore, the traditional thermionic emitter uses the image potential only to determine the maximum of the emission barrier. The theory cuts off the image potential short of the sheath and plasma (ref. 12). Although the old effective emitter served well, it poses two problems in sheath calculations: The absolute overall voltages through the sheath differ for opposite charges, and net current results in an isothermal system. These difficulties created the need for the virtual Schottky electrode.

With a virtual Schottky electrode, both charges undergo the same absolute sheath drop, no net charge flows at equilibrium, and the electrode emits all particles under the influence of one effective work function. As figure 3 shows, this effective work function is the usual work function altered by the Schottky depression $(e|E_E|)^{1/2}$. The Schottky depression lowers the work function in the positive-ion sheath and raises the work function in the electron sheath. This effect increases electron emission in a positive-ion sheath and ion emission in an electron sheath. Conversely, the effective work function decreases ion emission in a positive-ion sheath and electron emission in an electron sheath at the virtual Schottky electrode. The latter property departs from tradition. But the amount of retarded charge from the virtual Schottky electrode that escapes through the sheath into the plasma is the same as for the traditional thermionic emitter. This result stems from the new overall sheath drop, which equals the traditional sheath drop minus the Schottky depression.

Thus, the overall emissions of electrons and ions from the virtual Schottky electrode are identical with those from the traditional thermionic emitter. Also coincident with tradition, the image potential does not extend into the sheath and plasma with the virtual Schottky electrode. To repeat, however, the new model gives one absolute sheath drop, no net current in isothermal systems, and one effective work function for electron, ion, and atom emissions.

The virtual Schottky electrode handles particle escape from the electrode effectively, but what of the particles leaving the plasma? Initially, the new overall sheath drop may appear troublesome, but using the old sheath drop for both charges from the plasma produces net currents for equilibria. Although the old drop accelerates the right amount of one charge to the electrode it returns too many of the retarded particles back to the plasma. Correcting this error requires two work functions and two sheath drops. The virtual Schottky electrode, though, uses one effective work function and one overall sheath drop to yield no isothermal flow of net charge.

The new sheath drop may also seem too small for the accelerated plasma particle. However, the new and the old models deliver identical accelerated current densities to the electrode. Furthermore, the new sheath drop is correct for the retarded flow from the plasma, and according to earlier arguments, the new theory handles all emissions well. Thus, the virtual Schottky electrode provides a sheath model that treats all charge flows correctly and conveniently.

Sheath Current Densities

The fully expanded equations for sheath current densities appear in reference 1. Some of those expressions look a bit alien, but they all came from the equations (2a) to (7a), with additions of effective work functions and exponential cutoffs by sheath barriers.

As figure 3 indicates, φ' in equations (2a) to (7a) is $\varphi - (eE_E)^{1/2}$ for positive-ion sheaths and $\varphi + (-eE_E)^{1/2}$ for electron sheaths. Equations (2a) to (7a) also change for intervening sheaths:

Positive-ion sheath (ΔV_S is positive):

(2b) $$j_{eOE} = j_{eIP} \neq j_{eIE} = j_{eOP} \exp\left(-\frac{e\,\Delta V_S}{\kappa T_{eP}}\right)$$ (5b)

(3b) $$j_{iOE} \exp\left(-\frac{e\,\Delta V_S}{\kappa T_E}\right) = j_{iIP} \neq j_{iIE} = j_{iOP}$$ (6b)

(4b) $$j_{aOE} = j_{aIP} = j_{aIE} = j_{aOP}$$ (7b)

Electron sheath (ΔV_S is negative):

(2c) $$j_{eOE} \exp\left(\frac{e\,\Delta V_S}{\kappa T_E}\right) = j_{eIP} \neq j_{eIE} = j_{eOP}$$ (5c)

(3c) $$j_{iOE} = j_{iIP} \neq j_{iIE} = j_{iOP} \exp\left(\frac{e\,\Delta V_S}{\kappa T_{iP}}\right)$$ (6c)

(4c) $$j_{aOE} = j_{aIP} = j_{aIE} = j_{aOP}$$ (7c)

With appropriate substitutions from this paragraph, equations (2a) to (7a) become those of reference 1.

The net negative current densities into the plasma also result from the equations of the preceding paragraph:

Positive-ion sheath (ΔV_S is positive):

$$J = j_{eOE} + j_{iOP} - j_{iOE} \exp\left(-\frac{e\,\Delta V_S}{\kappa T_E}\right) - j_{eOP} \exp\left(-\frac{e\,\Delta V_S}{\kappa T_{eP}}\right) \tag{9}$$

Electron sheath (ΔV_S is negative):

$$J = j_{eOE} \exp\left(\frac{e\,\Delta V_S}{\kappa T_E}\right) + j_{iOP} \exp\left(\frac{e\,\Delta V_S}{\kappa T_{iP}}\right) - j_{iOE} - j_{eOP} \tag{10}$$

Of course, these current densities prevail through the respective sheaths. But the expressions for current densities within the sheaths are more complicated. Because such equations serve only for computing charge densities in the sheaths, they appear only implicitly in the next section.

Sheath Charge Densities

If the separate charge-flow terms at ΔV within the sheath are divided by their average velocities, the resulting sum is the charge density at ΔV. Thus, the charge density relations evolve from equations (9) and (10):

Positive-ion sheath (ΔV is positive):

The first term j_{eOE} in equation (9) represents the flow of electrons from the electrode accelerated through $\Delta V_S - \Delta V$ to produce an average velocity

$$\langle v \rangle_{\Delta V} = \frac{\left(\frac{2\kappa T_E}{\pi m_e}\right)^{1/2} \exp\left[-\frac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]}{1 - \operatorname{erf}\left[\frac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]^{1/2}} \tag{11}$$

and a negative charge density

$$\rho_1 = \frac{j_{eOE}\left\{1 - \operatorname{erf}\left[\frac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]^{1/2}\right\}}{\left(\frac{2\kappa T_E}{\pi m_e}\right)^{1/2} \exp\left[-\frac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]} \tag{12}$$

The second term j_{iOP} in equation (9) gives the flow of ions from the plasma accelerated through ΔV. By analogy with equations (11) and (12), the net negative charge density becomes

$$-\rho_2 = -\frac{j_{iOP}\left[1 - \operatorname{erf}\left(\frac{e\,\Delta V}{\kappa T_{iP}}\right)^{1/2}\right]}{\left(\frac{2\kappa T_{iP}}{\pi m_i}\right)^{1/2} \exp\left(-\frac{e\,\Delta V}{\kappa T_{iP}}\right)} \tag{13}$$

The third term $j_{iOE} \exp(-e\,\Delta V_S/\kappa T_E)$ in equation (9) results from the flow of electrode ions through the retarding field of the sheath. At ΔV, this retardation amounts to $\Delta V_S - \Delta V$. Thus, a cutoff flow $j_{iOE} \exp\left[-e(\Delta V_S - \Delta V)/\kappa T_E\right]$ passes ΔV climbing the sheath barrier with an average velocity $(2\kappa T_E/\pi m_i)^{1/2}$. This part contributes a negative charge density:

$$-\rho_{3a} = -\frac{j_{iOE} \exp\left[-\dfrac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]}{\left(\dfrac{2\kappa T_E}{\pi m_i}\right)^{1/2}} \tag{14}$$

But another flow

$$j_{iOE}\left\{\exp\left[-\frac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right] - \exp\left(-\frac{e\,\Delta V_S}{\kappa T_E}\right)\right\}$$

cut off at $\Delta V_S - \Delta V$ and reflected by potentials up to ΔV_S, returns past ΔV. This stream travels at an average velocity of

$$\frac{\left(\dfrac{2\kappa T_E}{\pi m_i}\right)^{1/2}\left[1 - \exp\left(-\dfrac{e\,\Delta V}{\kappa T_E}\right)\right]}{\operatorname{erf}\left(\dfrac{e\,\Delta V}{\kappa T_E}\right)^{1/2}}$$

and also effects the negative charge density

$$-\rho_{3b} = -\frac{j_{iOE} \operatorname{erf}\left(\dfrac{e\,\Delta V}{\kappa T_E}\right)^{1/2}}{\left(\dfrac{2\kappa T_E}{\pi m_i}\right)^{1/2} \exp\left[\dfrac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]} \tag{15}$$

The overall influence of j_{iOE} on the negative charge density at ΔV is the sum of equations (14) and (15):

$$-\rho_3 = -\frac{j_{iOE}\left[1 + \operatorname{erf}\left(\frac{e\,\Delta V}{\kappa T_E}\right)^{1/2}\right]}{\left(\frac{2\kappa T_E}{\pi m_i}\right)^{1/2} \exp\left[\frac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]} \tag{16}$$

The fourth term $j_{eOP} \exp\left(-e\,\Delta V_S/\kappa T_{eP}\right)$ in equation (9) indicates the retarding effect of the positive-ion sheath on plasma electrons. By inspection of equation (16), the effect of this retarded electron stream on the negative charge density at ΔV is

$$\rho_4 = \frac{j_{eOP}\left\{1 + \operatorname{erf}\left[\frac{e(\Delta V_S - \Delta V)}{\kappa T_{eP}}\right]^{1/2}\right\}}{\left(\frac{2\kappa T_{eP}}{\pi m_e}\right)^{1/2} \exp\left(\frac{e\,\Delta V}{\kappa T_{eP}}\right)} \tag{17}$$

Adding equations (12), (13), (16), and (17) yields the net negative charge density at ΔV:

$$\rho_{\Delta V} = \frac{j_{eOE}\left\{1 - \operatorname{erf}\left[\frac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]^{1/2}\right\}}{\left(\frac{2\kappa T_E}{\pi m_e}\right)^{1/2} \exp\left[-\frac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]} - \frac{j_{iOP}\left[1 - \operatorname{erf}\left(\frac{e\,\Delta V}{\kappa T_{iP}}\right)^{1/2}\right]}{\left(\frac{2\kappa T_{iP}}{\pi m_i}\right)^{1/2} \exp\left(-\frac{e\,\Delta V}{\kappa T_{iP}}\right)}$$

$$- \frac{j_{iOE}\left[1 + \operatorname{erf}\left(\frac{e\,\Delta V}{\kappa T_E}\right)^{1/2}\right]}{\left(\frac{2\kappa T_E}{\pi m_i}\right)^{1/2} \exp\left[\frac{e(\Delta V_S - \Delta V)}{\kappa TE}\right]} + \frac{j_{eOP}\left\{1 + \operatorname{erf}\left[\frac{e(\Delta V_S - \Delta V)}{\kappa T_{eP}}\right]^{1/2}\right\}}{\left(\frac{2\kappa T_{eP}}{\pi m_e}\right)^{1/2} \exp\left(\frac{e\,\Delta V}{\kappa T_{eP}}\right)} \tag{18}$$

When ΔV equals zero, the third term of equation (18) approximates half of the positive charge density in plasma. This simple relation allows an initial estimate of ΔV_S.

Electron sheath (ΔV is negative):

Using figure 3, one can analogize the expression for net negative charge density in an electron sheath from equation (18):

$$\rho_{\Delta V} = \frac{j_{eOE}\left[1 + \mathrm{erf}\left(-\frac{e\,\Delta V}{\kappa T_E}\right)^{1/2}\right]}{\left(\frac{2\kappa T_E}{\pi m_e}\right)^{1/2} \exp\left[-\frac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]} - \frac{j_{iOP}\left\{1 + \mathrm{erf}\left[-\frac{e(\Delta V_S - \Delta V)}{\kappa T_{iP}}\right]^{1/2}\right\}}{\left(\frac{2\kappa T_{iP}}{\pi m_i}\right)^{1/2} \exp\left(-\frac{e\,\Delta V}{\kappa T_{iP}}\right)}$$

$$- \frac{j_{iOE}\left\{1 - \mathrm{erf}\left[-\frac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]^{1/2}\right\}}{\left(\frac{2\kappa T_E}{\pi m_i}\right)^{1/2} \exp\left[\frac{e(\Delta V_S - \Delta V)}{\kappa T_E}\right]} + \frac{j_{eOP}\left[1 - \mathrm{erf}\left(-\frac{e\,\Delta V}{\kappa T_{eP}}\right)^{1/2}\right]}{\left(\frac{2\kappa T_{eP}}{\pi m_e}\right)^{1/2} \exp\left(\frac{e\,\Delta V}{\kappa T_{eP}}\right)} \tag{19}$$

Here, at zero ΔV, the first term approximates half of the electron charge density in the plasma and allows an estimate of ΔV_S.

Sheath Structures

With the net charge densities given by equations (18) and (19), simple expressions yield electrostatic fields and corresponding distances for assigned ΔV's through the sheaths

$$E_{\Delta V} = \pm\left(-8\pi \int_0^{\pm\Delta V} \rho_{\Delta V}\, dV\right)^{1/2} \tag{20}$$

$$x_{\Delta V} = \int_{\Delta V}^{\Delta V_S} \frac{dV}{E_{\Delta V}} \tag{21}$$

where $x = 0$ at $\Delta V = \Delta V_S$ and $x = x_P = x_S$ at $\Delta V = 0$. Although equations (20) and (21) appear simple, their evaluations require numeric integrations. These results are sums of the areas of trapezoids based on 20 equal increments of ΔV from zero to ΔV_S. Equation (20) poses no problem; for the machine, neither does equation (21). But at $\Delta V = 0$, E is zero, and equation (21) lacks definition. The machine, however, merely uses half of the E at $\Delta V/20$ as the average for the first increment and computes a finite x_S. This distance is an effective sheath width, which includes most of the sheath structure. The value of the effective sheath width derives from the extent that it represents a fully developed sheath. As reference 1 shows, for near-equilibria and small net transport, the positive and negative charges of the sheath almost balance at x_S. Thus, the effective sheath width contains practically all the sheath functions within a few emission Debye lengths (ref. 1).

Computing Method

The iterative sheath solution follows an almost classic numeric method:

(1) Run screening tests to select noncondensing plasmas that produce essentially collisionless sheaths. These tests require effective plasma pressures lower than the vapor pressure of the plasma chemical at the electrode temperature and minimum mean free paths longer than the Debye length. Reference 1 discusses this screening for cesium.

(2) Solve for current densities deleting effects of sheath fields (eqs. (2a) to (7a)).

(3) Estimate the overall sheath potential drop ΔV_S (see section Sheath Charge Densities).

(4) Divide ΔV_S into 20 increments and compute charge densities for increasing potentials through the sheath.

(5) Integrate the charge density function over ΔV to obtain the sheath field (eq. (20)).

(6) Use the sheath potential drop and field at the virtual Schottky electrode to calculate new emissions.

(7) Repeat the cycle until no boundary current density changes by more than 0.1 percent of the smallest boundary current density.

(8) Integrate the negative reciprocal of sheath field over voltage to determine sheath distances (eq. (21)).

(9) Compute and record incremental and overall sheath results for the final iteration. The details of these equations, computing methods, FORTRAN statements, and machine outputs appear in reference 15.

DISCUSSION OF RESULTS

This report aims primarily at approximating some possible internal potential structures for cesium diodes. But on the way to that goal, the results also allow correlations of overall sheath characteristics. These generalizations make up figures 4 to 8. Motive diagrams and equations in the previous section amplify the meanings of the parameters and properties of the sheaths. Because all but the ordinates of figures 4 to 8 come directly from the assigned parameters (ref. 1), the reader can estimate sheath conditions with these plots rather than with the complicated iterative solutions.

In figures 4 to 8, the data correlate well because of the selection of the variables: Reference 1 and the previous section define the effective sheath width x_S. The emission Debye length λ_{DE} arose because emission energy rather than plasma electron temperature dominates charge separation in these sheaths (ref. 1). For this reason, the sheath properties depend on emitter temperature T_E and plasma electron concentration N_{eP}. The hybrid emission Debye length is a function of these basic variables

$$\lambda_{DE} \approx 6.9\,(T_E/N_{eP})^{1/2} \tag{22}$$

This emission Debye length correlates the sheath data better than the ordinary Debye length. The ratio of the effective sheath width x_S to the emission Debye length λ_{DE} is the dimensionless sheath width of figure 4.

In figures 4 to 8, the abscissas are a dimensionless variable termed the Richardson-Dushman sheath drop or R-D drop. This R-D drop results from dividing the work function minus the plasma potential by the voltage equivalent of the emitter temperature. The ordinate of figure 5 is the actual sheath drop divided by the dimensional R-D drop $(\varphi - \varphi_0)$. The dimensionless electrode field of figure 6 is the product of the actual electrode field and the emission Debye length divided by the dimensional R-D drop. And finally, figures 7 and 8 present the majority charge density at the electrode and the current density for these sheaths.

In reference 1, two conditions restrict the applicability of the sheath model: Net current densities remain below 6 percent of the random particle fluxes in the plasmas. And minority charge densities at the effective sheath edge approximate their values in the neutral plasmas to within 1 percent. In the present report, however, wider regions of sheath similarities result from using less demanding limits: Net current densities range up to 11 percent of the random plasma circulations. And minority charge densities at the sheath, plasma interface approach their plasma values to within 2 percent.

This shift constitutes no change in the interpretation of the restrictions of the theory - the smaller the net transport and the sheath-edge charge discrepancy, the better. The expansion of the bounds merely extends the results to systems of higher diode-power production, hence greater interest. In most of these extrapolations, however, the sheaths yet resemble equilibrium and near-equilibrium versions from reference 1, as figures 4 to 8 reveal.

Effective sheath widths for separated electrode and plasma temperatures are shown in figure 4 to be close to the equilibrium correlation at high R-D drops. While the results for electrode temperatures lower than those of the plasmas behave like those of reference 1, the curve for electrode temperatures higher than those of the plasmas breaks upward as R-D drops decrease. This departure occurs because the net electron current grows exponentially with electrode temperature. Thus, the minority charge strongly influences the structure of these positive-ion sheaths at low overall potential drops. When the electron current imbalance comes from raising the plasma temperature, though, the outcome approximates that for increasing the electron temperature only at the same electron concentration (refs. 1 and 5).

In figure 5, the present overall sheath drops appear quite similar to those for equilibria. The emitter fields of figure 6 duplicate the equilibrium trends and extend them into straight semilogarithmic lines. These asymptotic exponentials are approximately three times the R-D drop. As figure 7 illustrates, the majority-charge density at the emitter again depends only on the plasma electron number and the R-D drop. And the net current densities given in figure 8 look much like those of reference 1.

In general, sheaths between an electrode and a cesium plasma with either an elevated or a reduced temperature compare with those for equilibria and for systems with only the electron temperatures increased (ref. 1). Because changing plasma and plasma-electron temperatures produces similar effects, decreasing the plasma-electron temperature should also yield results like those of figures 4 to 8 and of reference 1.

Returning from generalization to the specific goal, figure 9 presents matched pairs of electrode sheaths in cesium plasmas. These coupled sheaths pass net negative current densities, which match within 2 percent, from the emitter to the collector. Complete tabulations of detailed and overall results attend each sheath; definitions of symbols appear in appendix B. In addition to the points for the graphic potential distributions, these tables give data for profiles of charged-particle number densities and of electric fields in thermionic diodes.

Although figure 9 shows no changes in potential across the plasmas, separating the zero potential levels of corresponding emitter and collector sheaths by a suitable amount approximates the plasma drop (refs. 2 to 4). For these relatively small net current densities, the necessary plasma fields are low compared with those at the electrodes. Such gradual gradients in the plasmas comply with the assumptions of the sheath model.

Because reference 1 dwells on the limitations of the theory, this work mentions them only in passing. But one problem requires emphasis: In practice the plasma, sheath, and electrode determine the work function; it is not an assignable parameter.

Thus, though the systems given here might be approximated by special selections, they serve as examples, not recommended diodes. Yet the demonstrated generalizations of sheath effects make the specific results practical as well as heuristic. To reveal properties for particular electrode materials, however, calculations must include variations of work functions with cesium arrival rates.

Lacking this refinement and its computational complication, the present studies still yield emission barriers not far removed from reality. The work functions vary for emitters from 3.8 to 4.9 volts and for collectors from 3.5 to 4.1 with ion sheaths and from 2.0 to 2.2 with electron sheaths. In the cesium plasmas with 10^{13} electrons per cubic centimeter, the net current densities range from 0.094 to 1.2 amperes per square centimeter through effective sheath widths from 1.9 to 2.3 microns. At 10^{12} electrons per cubic centimeter, 0.010 to 0.095 amperes per square centimeter pass through 5.8- to 6.9-micron sheaths.

Such widths take up little of the typical 250-micron gap between electrodes in a thermionic converter. But the fields and potential changes of the sheaths strongly influence diode performances. Overall sheath drops in this work range from 0.83 to 1.8 volts for emitters and from 0.35 to 0.82 in absolute values for collectors. And if small plasma losses occur, these cesium cells produce approximately 0.01 to 1 watt per square centimeter.

Although interesting diodes usually generate more than 10 watts per square centimeter, the lower levels given here represent a part of the spectrum of productive energy conversion. Furthermore, the conditions depart considerably from those for the isothermal diode (refs. 1 and 12). The data, therefore, extend the theoretic region available for comparison with experiment and prediction of performance in thermionics. In addition, the generalizations of overall characteristics for the sheath model of reference 1 should add to the mechanistic understanding of plasma energy converters.

CONCLUDING REMARKS

These low-current approximations of cesium diodes dramatize sheath effects. Although the interelectrode space is small enough to be a mechanical problem, the effective emitter and collector sheaths take up little of the diode gap. Yet the sheath drops are similar to diode output voltages. Little sheath widths and large potential changes mean big fields at the electrodes. These fields depress emission barriers for particles accelerated from the electrodes and swell current densities. Because diode emitters often develop positive-ion sheaths, their fields produce electron emissions greater than basic work functions indicate. And because ion sheaths increase the cesium delivery to the electrode, the basic work functions run lower than those indicated by cesium arrival rates based on plasma circulation. The lower work functions also yield more electron emission. Thus, positive-ion sheaths contribute to greater diode currents with two characteristics: intense fields and high cesium arrival at the emitter.

Although transport within the sheath affects diode outputs directly, these sheath effects on electron emission appear more important. Many research programs now seek emitters with low work functions at high temperatures to boost emission. This problem is difficult, particularly because low work functions often mean high vapor pressures and added impurities. In the face of this need and its cost, the idea of improving emission with a strong positive-ion sheath looks promising. The ion sheath uses the electrodes and the plasma that are the basic diode to increase fields and cesium concentrations at the emitter. When both these sheath properties lower the effective work function of the emitter, electron emission and diode power grow rapidly.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, July 21, 1967,
120-33-02-01-22.

APPENDIX A

SYMBOLS

E	electric field
e	electronic unit charge
h	Planck's constant
I	ionization potential
J	overall net current
j	current density or net particle current density
m	particle mass
N	particle number density
T	temperature
V	potential
ΔV	potential relative to plasma potential
v	velocity
x	distance from emitter
κ	Boltzmann constant
μ	Fermi level
λ_{DE}	emission Debye length, $6.9(T_E/N_{eP})^{1/2}$
φ	work function
φ'	effective work function for virtual Schottky emitter
φ_o	work function (plasma potential) that precludes an ion sheath (used for plasma potentials for both ion and electron sheaths where they appear on the same figure)
φ_{oo}	work function (plasma potential) that precludes an electron sheath

Subscripts:

a	atom
e	electron
E	emitter
i	ion
IE	into emitter
IP	into plasma
O	overall (from work function to plasma potential)
OE	out of emitter
OP	out of plasma
P	plasma
S	across sheath
ΔV	at ΔV

APPENDIX B

NOMENCLATURE FOR IBM OUTPUT

FORTRAN symbol	Algebraic symbol	Description	Units
I	I	ionization potential for plasma atoms	V
TE	T_E	emitter temperature	^oK
PHI	φ	work function	V
NEP	$N_{eP} = N_{iP}$	plasma electron number density	cm^{-3}
TEP	T_{eP}	plasma electron temperature	^oK
TIP	$T_{iP} = T_{aP}$ for these solutions	plasma ion temperature	^oK
LAMBDA	$\lambda_{DT_{eP}} \approx 6.9\left(\frac{T_{eP}}{N_{eP}}\right)^{1/2}$	plasma Debye length	cm
PV	p_{vp}	vapor pressure of plasma element at T_E	torr $\left(\frac{N/m^2}{1.333\times10^2}\right)$
LAMBDA(TE)	$\lambda_{DT_E} \approx 6.9\left(\frac{T_E}{N_{eP}}\right)^{1/2}$	emission Debye length	cm
DV	ΔV	sheath potential measured from plasma electron potential	V
ND(DV)	$N_{e\,\Delta V} - N_{i\,\Delta V}$	net number density of charged particles at ΔV	cm^{-3}
NE(DV)	$N_{e\,\Delta V}$	electron number density at ΔV	cm^{-3}
NI(DV)	$N_{i\,\Delta V}$	ion number density at ΔV	cm^{-3}
E(DV)	$E_{\Delta V}$	electron electrostatic field at ΔV	V/cm
X(DV)	$X_{\Delta V}$	distance from emitter to ΔV	cm
JEE	j_{eE}	emitted electron current density	A/cm^2
JEP	j_{eP}	plasma electron random current density	A/cm^2
JIP	j_{iP}	plasma ion random current density	A/cm^2

FORTRAN symbol	Algebraic symbol	Description	Units
JAP	j_{aP}	plasma atom equivalent random current density	A/cm^2
J	J	net current density through sheath	A/cm^2
PP	p_P	plasma pressure	torr $\left(\frac{N/m^2}{1.333\times 10^2}\right)$
JIE	j_{iE}	emitted ion current density	A/cm^2
JAE	j_{aP}	emitted equivalent atom current density	A/cm^2
JA	j_a	net equivalent atom current density	A/cm^2
JI	j_i	net ion current density	A/cm^2
JE	j_e	net electron current density	A/cm^2
JA/JAP	j_a/j_{aP}	-------------------------------	-----------
JE/JEP	j_e/j_{eP}	-------------------------------	-----------
JI/JIP	j_i/j_{iP}	-------------------------------	-----------
DVS	ΔV_S	overall sheath voltage drop	V
XDVS	$X_{\Delta V_S} = X_P = X_S$	effective sheath thickness	cm
NAP	N_{aP}	plasma atom number density	cm^{-3}
XD/LAM	X_S/λ_D	-------------------------------	-----------
SC	$(eE_E)^{1/2}$	Schottky depression of work function	V
PHZ	φ_o	plasma potential (work function for no sheath)	V
EDVS	$E_{\Delta V_S} = E_E$	electrostatic field at emitter	V/cm
DVSRD	$\Delta V_0 = (\varphi - \varphi_o)$	Richardson-Dushman overall sheath voltage drop	V
DVS/RD	$\frac{\Delta V_S}{\Delta V_0} = \frac{\Delta V_S}{\varphi - \varphi_o}$	-------------------------------	-----------
ELM/RD	$E_E\lambda_D/(\varphi - \varphi_o)$	-------------------------------	-----------

FORTRAN	Algebraic symbol	Description	Units
PHZZ	φ_{oo} ($\varphi_{oo} = \varphi_o$ for equilibrium and electron sheaths)	plasma potential at equilibrium (work function for no sheath and no net current)	----------
DRD/KT	$e\lvert\varphi - \varphi_o\rvert/\kappa T_e$	----------------------------------	----------
NTP	-------------	total particle number density in plasma	cm^{-3}
NCE	-------------	total charge number density at emitter	cm^{-3}
NTE	-------------	total particle number density at emitter	cm^{-3}
RD/KTE	$e\lvert\varphi - \varphi_o\rvert/\kappa T_E$	----------------------------------	----------
X/LMTE	x_S/λ_{DE}	----------------------------------	----------
ELT/RD	$E_E\lambda_{DE}/(\varphi - \varphi_o)$	----------------------------------	----------
NEPA	--------------	plasma electron number density from sheath calculations	cm^{-3}
NIPA	--------------	plasma ion number density from sheath calculations	cm^{-3}

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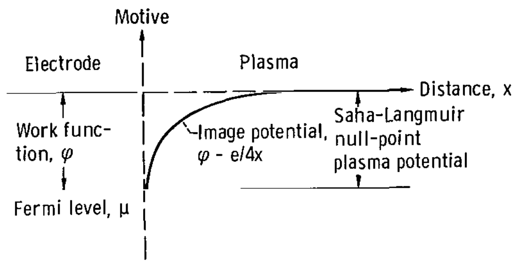


Figure 1. - Motive diagram of a Saha-Langmuir null point $\Delta T = 0$, $\Delta V_S = 0$, $J = 0$.

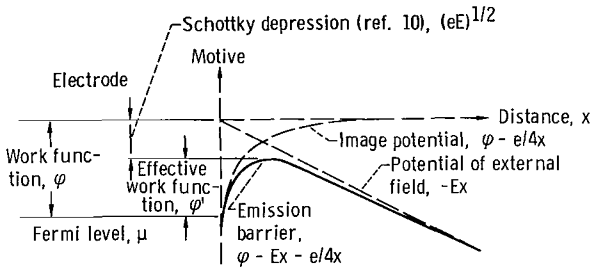
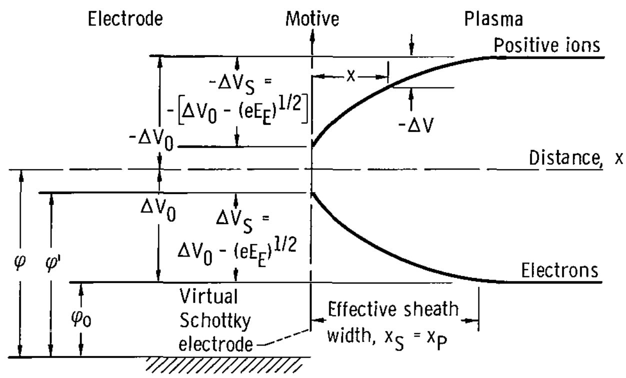
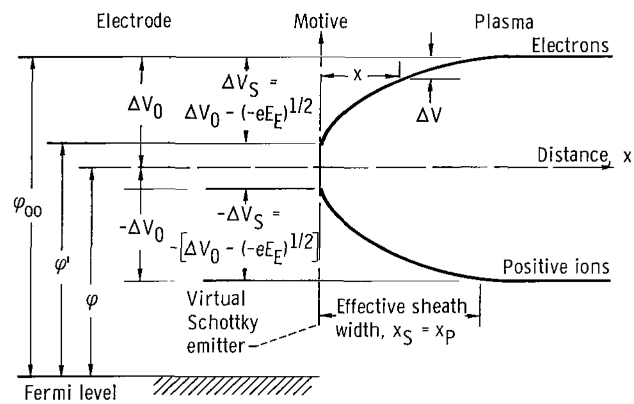


Figure 2. - Motive diagram for effect of external field on electrode (ref. 10).



(a) Positive-ion sheath. For electrons, E and ΔV are positive; effective work function, $\varphi' = \varphi - (-eE_E)^{1/2}$.



(b) Electron sheath. For electrons, E and ΔV are negative; effective work function, $\varphi' = \varphi + (-eE_E)^{1/2}$.

Figure 3. - Plane sheaths between virtual Schottky electrodes and near-equilibrium plasmas.

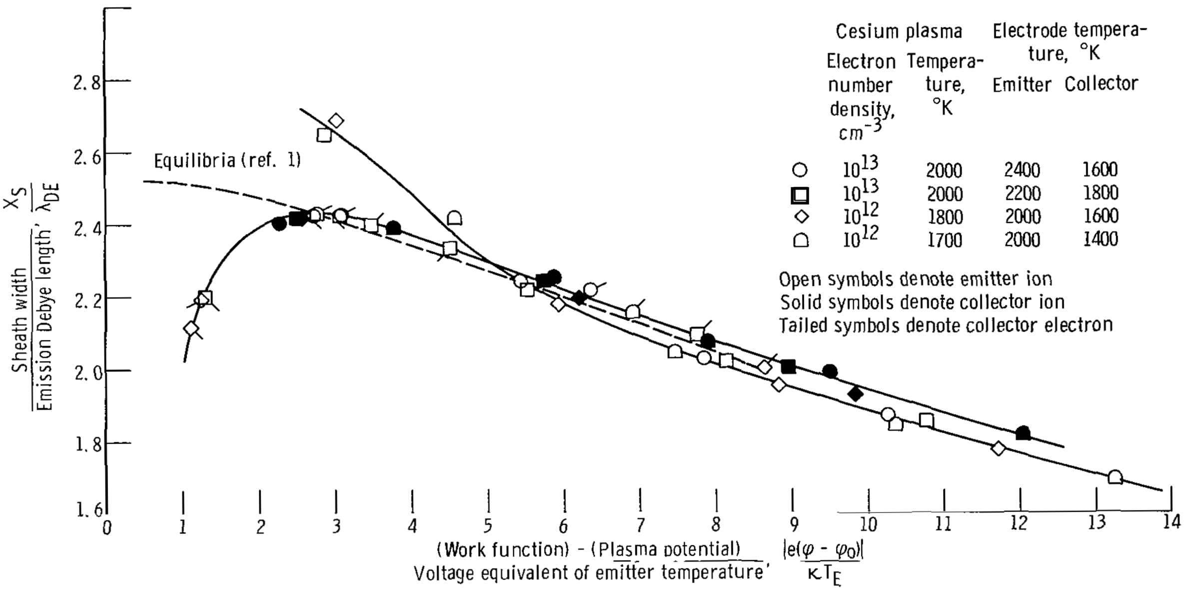


Figure 4. - Effective sheath widths for emitters and collectors in cesium plasmas.

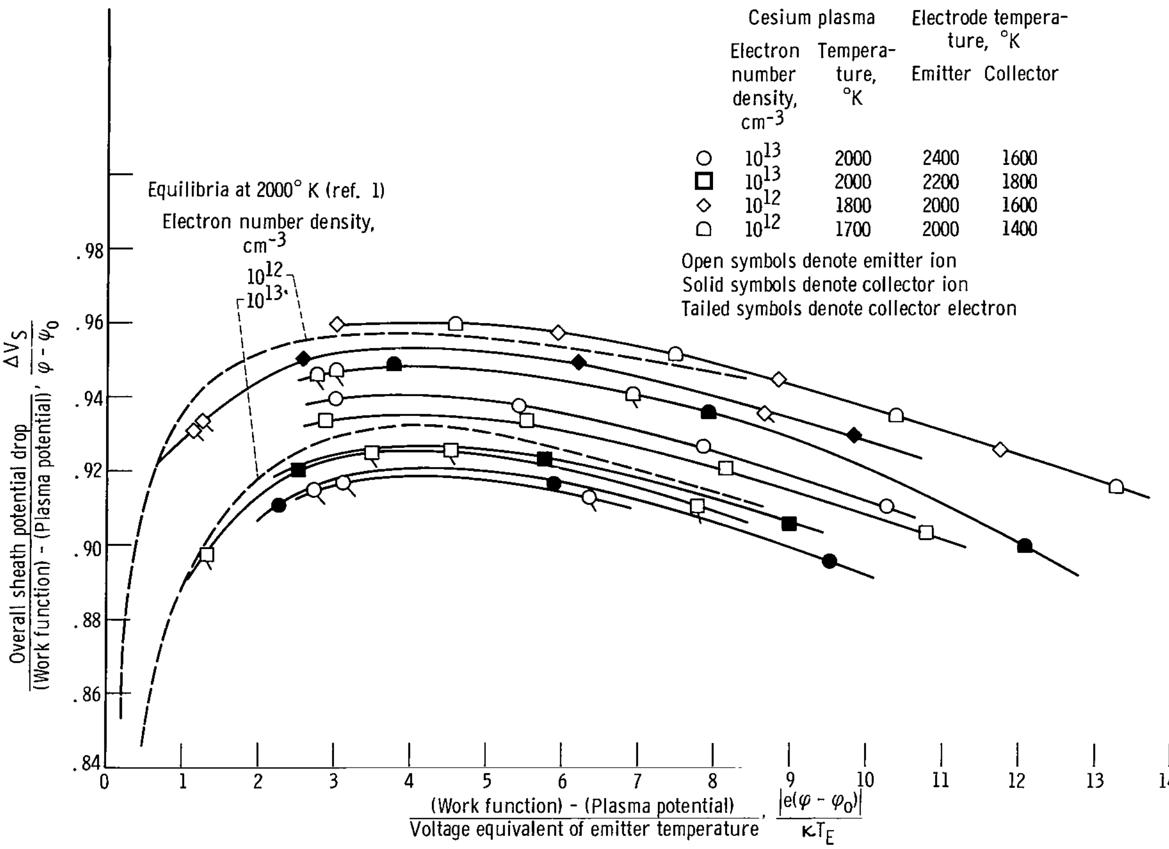


Figure 5. - Overall sheath potential drops for emitters and collectors in cesium plasmas.

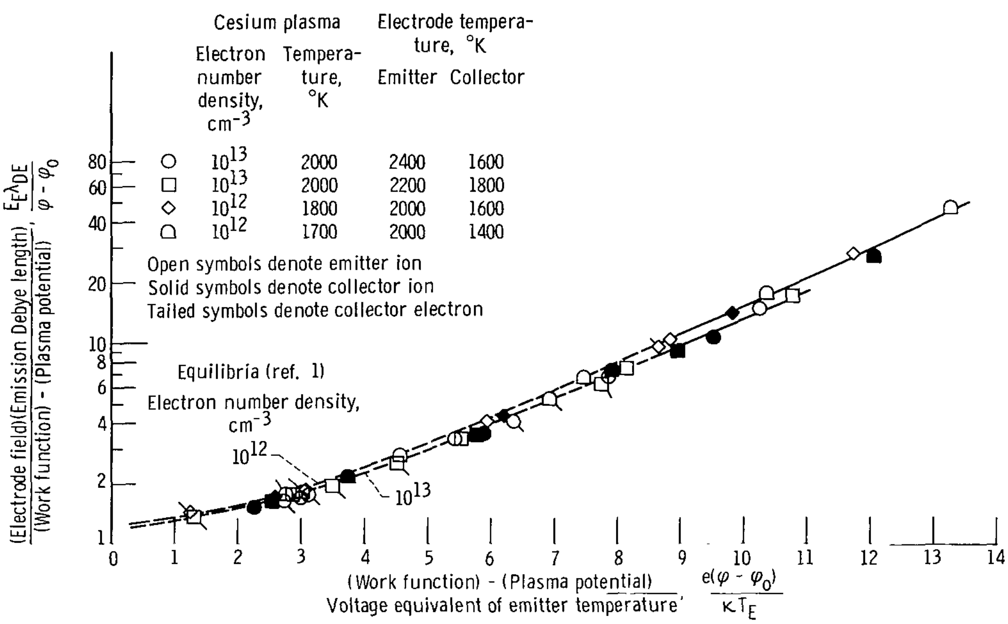


Figure 6. - Sheath fields at emitters and collectors in cesium plasmas.

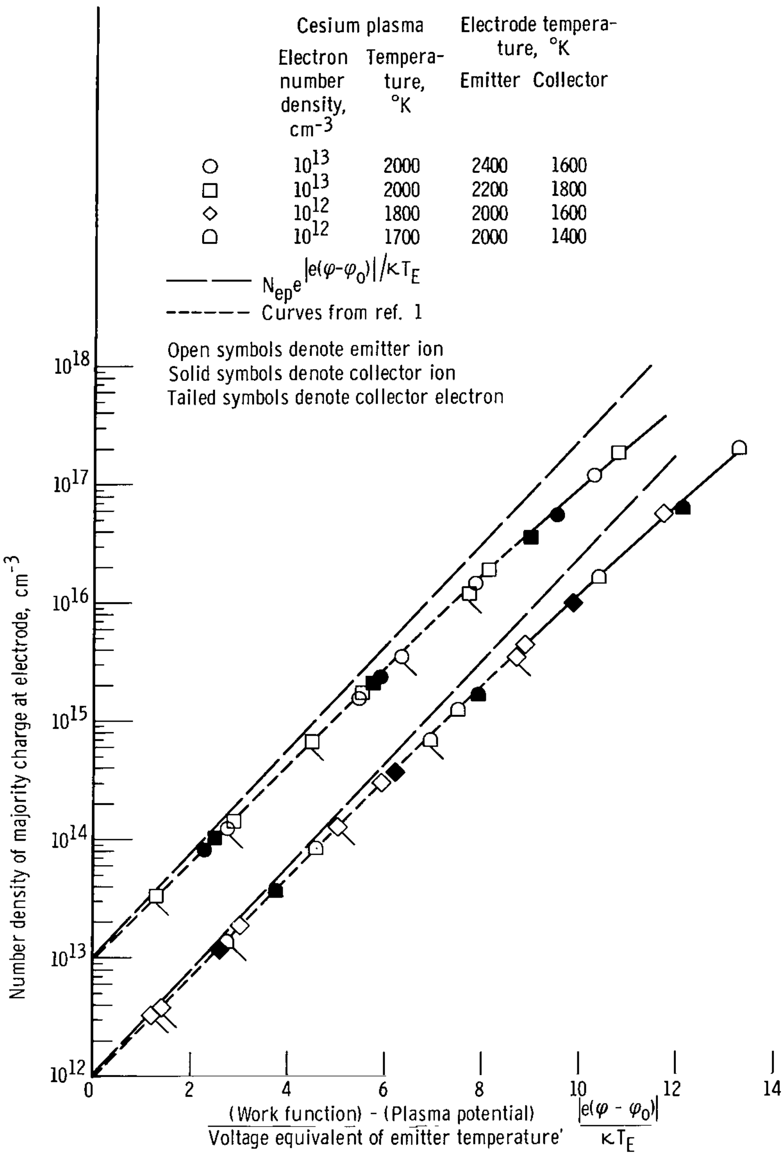


Figure 7. - Charge concentrations at emitters and collectors in cesium plasmas. At $|e(\varphi - \varphi_0)/\kappa T_E| = 0$, $N_{eE} = N_{ep} = N_{iE} = N_{ip}$.

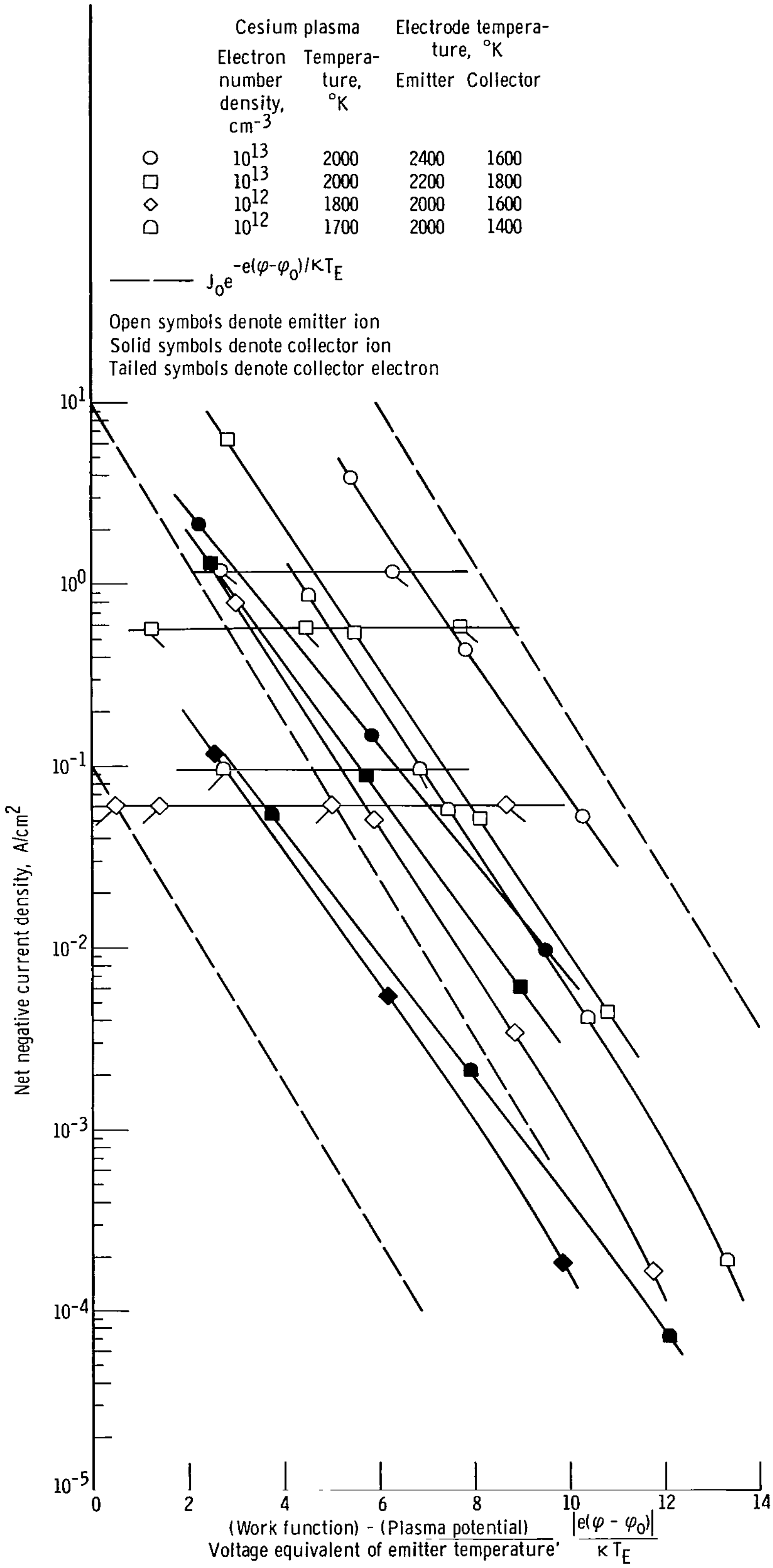
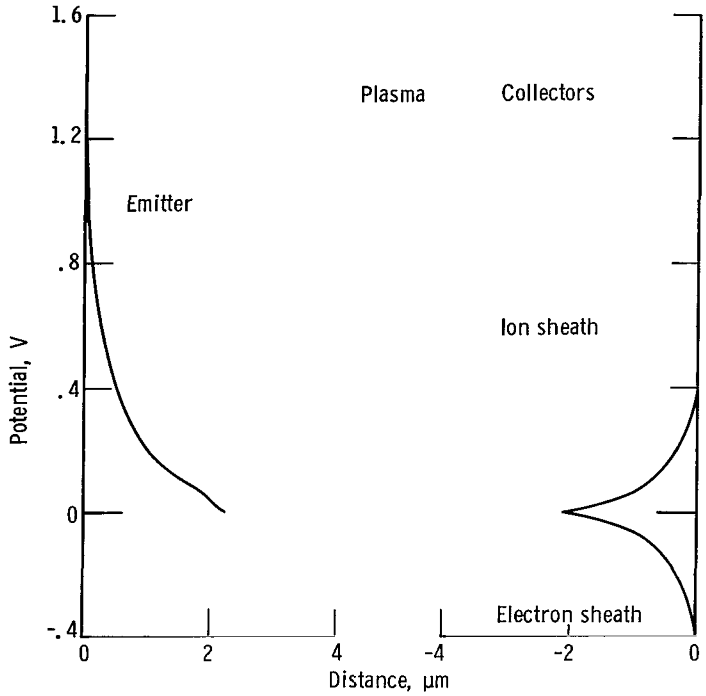


Figure 8. - Charge transport through emitter and collector sheaths in cesium plasmas.



I = 3.893 TE = 2400. PHI = 4.272 NEP = 1.00E 13 TEP = 2.00E 03 TIP = 2000.0 LAMBDA = 9.7556E-05

PV = 1.598737E 05 LAMBDA(TE) = 1.0087E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.009999E 13	-1.000000E 13	-0.	2.256271E-04
0.06507	-6.618598E 12	6.957478E 12	-1.357608E 13	8.833566E 02	1.887951E-04
0.13014	-1.383268E 13	4.804104E 12	-1.863678E 13	1.766472E 03	1.337507E-04
0.19521	-2.224785E 13	3.328880E 12	-2.557673E 13	2.728608E 03	1.036144E-04
0.26029	-3.276504E 13	2.318626E 12	-3.508366E 13	3.732453E 03	8.297349E-05
0.32536	-4.647790E 13	1.627215E 12	-4.810511E 13	4.824291E 03	6.751232E-05
0.39043	-6.478569E 13	1.154493E 12	-6.594018E 13	6.032539E 03	5.537477E-05
0.45550	-8.953691E 13	8.318211E 11	-9.036874E 13	7.368223E 03	4.557765E-05
0.52057	-1.232167E 14	6.121721E 11	-1.238289E 14	8.925752E 03	3.752875E-05
0.58564	-1.691971E 14	4.633422E 11	-1.696605E 14	1.068382E 04	3.083825E-05
0.65072	-2.320749E 14	3.632996E 11	-2.324382E 14	1.270642E 04	2.523234E-05
0.71579	-3.181314E 14	2.970021E 11	-3.184284E 14	1.504398E 04	2.050905E-05
0.78086	-4.359604E 14	2.542226E 11	-4.362146E 14	1.775464E 04	1.651381E-05
0.84593	-5.973263E 14	2.280736E 11	-5.975543E 14	2.090573E 04	1.312498E-05
0.91100	-8.183387E 14	2.140208E 11	-8.185528E 14	2.457547E 04	1.024476E-05
0.97607	-1.121061E 15	2.092568E 11	-1.121270E 15	2.885489E 04	7.793276E-06
1.04115	-1.535712E 15	2.123831E 11	-1.535925E 15	3.385015E 04	5.704540E-06
1.10622	-2.103684E 15	2.234675E 11	-2.103908E 15	3.968513E 04	3.923520E-06
1.17129	-2.881672E 15	2.449507E 11	-2.881917E 15	4.650455E 04	2.404045E-06
1.23636	-3.947328E 15	2.862793E 11	-3.947614E 15	5.447750E 04	1.107186E-06
1.30143	-5.406900E 15	4.805255E 11	-5.407381E 15	6.380158E 04	0.

JEE =	1.165749E 00	JEP =	1.112723E 01	JIP =	2.260730E-02	JAP =	6.764868E 00
J =	1.157747E 00	PP =	6.238296E-01	JIE =	1.339161E 01	JAE =	6.762711E 00
JA =	-2.157748E-03	JI =	-2.157762E-03	JE =	1.159904E 00	JA/JAP =	-3.189637E-04
JE/JEP =	1.042402E-01	JI/JIP =	-9.544538E-02	DVS =	1.30143	XDVS =	2.256271E-04
NAP =	2.992338E 15	XD/LAM =	2.312799E 00	SC =	9.588501E-02	PHZ =	2.87621
EDVS =	6.380158E 04	DVSRD =	1.395792E 00			DVS/RD =	9.323972E-01
ELM/RD =	4.459273E 00	PHZZ =	3.692223E 00			DRD/KT =	8.099059E 00
NTP =	3.012338E 15	NCE =	5.407861E 15	NTE =	8.400199E 15	RD/KTE =	6.749216E 00
X/LMTE =	2.111287E 00	ELT/RD =	4.884889E 00	NEPA=	1.009999E 13		

(a-1) Current density, 1.16 amperes per square centimeter.

(a) Emitter at 2400° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Some sheath structures for cesium thermionic diodes.

I = 3.893 TE = 1600. PHI = 3.612 NEP = 1.00E 13 TEP = 2.00E 03 TIP = 2000.0 LAMBDA = 9.7556E-05

PV = 3.009556E 04 LAMBDA(TE) = 8.7257E-05

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.833136E 12	-1.000000E 13	-0.	2.116130E-04
0.01949	-2.883488E 12	8.760454E 12	-1.164394E 13	3.191117E 02	1.810722E-04
0.03898	-5.609068E 12	7.801921E 12	-1.341099E 13	6.338395E 02	1.351554E-04
0.05848	-8.487627E 12	6.945281E 12	-1.543291E 13	9.484653E 02	1.095040E-04
0.07797	-1.157709E 13	6.179583E 12	-1.775667E 13	1.268142E 03	9.154333E-05
0.09746	-1.493582E 13	5.495039E 12	-2.043086E 13	1.595151E 03	7.774842E-05
0.11695	-1.862700E 13	4.882894E 12	-2.350990E 13	1.931269E 03	6.659232E-05
0.13644	-2.272058E 13	4.335320E 12	-2.705590E 13	2.278161E 03	5.726797E-05
0.15593	-2.729482E 13	3.845305E 12	-3.114012E 13	2.637488E 03	4.929484E-05
0.17543	-3.243795E 13	3.406567E 12	-3.584451E 13	3.010954E 03	4.236287E-05
0.19492	-3.824991E 13	3.013463E 12	-4.126337E 13	3.400328E 03	3.625988E-05
0.21441	-4.484436E 13	2.660917E 12	-4.750528E 13	3.807461E 03	3.083402E-05
0.23390	-5.235093E 13	2.344335E 12	-5.469527E 13	4.234297E 03	2.597267E-05
0.25339	-6.091781E 13	2.059534E 12	-6.297735E 13	4.682887E 03	2.158984E-05
0.27289	-7.071473E 13	1.802650E 12	-7.251738E 13	5.155398E 03	1.761823E-05
0.29238	-8.193638E 13	1.570029E 12	-8.350641E 13	5.654122E 03	1.400412E-05
0.31187	-9.480644E 13	1.358048E 12	-9.616449E 13	6.181495E 03	1.070381E-05
0.33136	-1.095823E 14	1.162768E 12	-1.107451E 14	6.740104E 03	7.681227E-06
0.35085	-1.265611E 14	9.790209E 11	-1.275401E 14	7.332705E 03	4.906167E-06
0.37034	-1.460890E 14	7.968113E 11	-1.468858E 14	7.962247E 03	2.353050E-06
0.38984	-1.686481E 14	5.215330E 11	-1.691697E 14	8.632064E 03	0.

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J = -1.154740E 00	PP = 6.238296E-01	JIE = 3.418007E-01	JAE = 6.767255E 00
JA = 2.386689E-03	JI = 2.386708E-03	JE = -1.157127E 00	JA/JAP = 3.528064E-04
JE/JEP = -1.039906E-01	JI/JIP = 1.055725E-01	DVS = 0.38984	XDVS = 2.116130E-04
NAP = 2.992338E 15	XD/LAM = 2.169147E 00	SC = 3.526893E-02	PHZ = 3.18710
EDVS = 8.632064E 03	DVSRD = 4.249049E-01		DVS/RD = 9.174681E-01
ELM/RD = 1.981875E 00	PHZZ = 2.377628E 00		DRD/KT = 2.465504E 00
NTP = 3.012338E 15	NCE = 1.696912E 14	NTE = 3.162030E 15	RD/KTE = 3.081680E 00
X/LMTE = 2.425180E 00	ELT/RD = 1.772642E 00	NEPA= 9.833136E 12	

I = 3.893 TE = 1600. PHI = 1.954 NEP = 1.00E 13 TEP = 2000.0 TIP = 2000.0 LAMBDA = 9.7556E-05

PV = 3.009556E 04 LAMBDA(TE) = 8.7257E-05

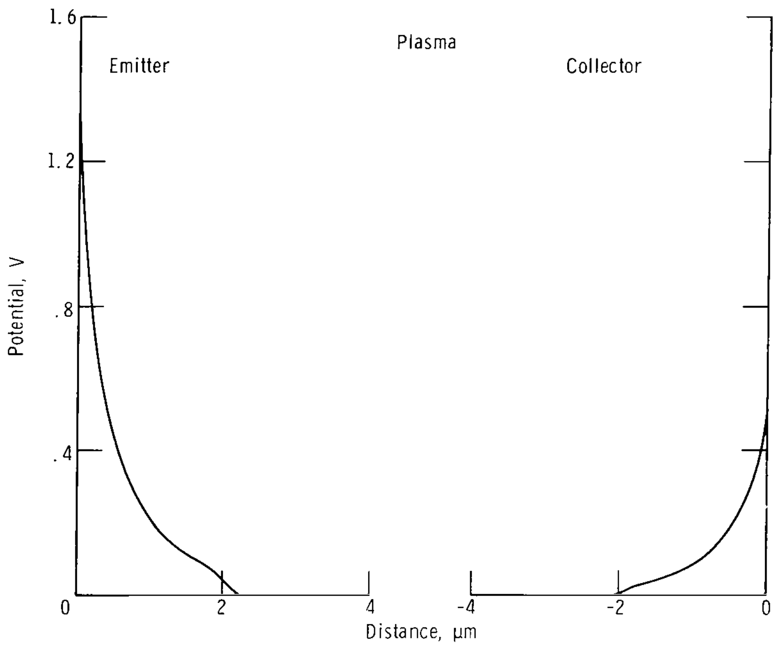
DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.000000E 13	-9.831554E 12	0.	2.116272E-04
-0.01942	2.875574E 12	1.163802E 13	-8.762450E 12	-3.181042E 02	1.810990E-04
-0.03884	5.590805E 12	1.339753E 13	-7.806721E 12	-6.317585E 02	1.351993E-04
-0.05827	8.457499E 12	1.540974E 13	-6.952238E 12	-9.452371E 02	1.095539E-04
-0.07769	1.153299E 13	1.772114E 13	-6.188154E 12	-1.263697E 03	9.159548E-05
-0.09711	1.487498E 13	2.037975E 13	-5.504770E 12	-1.589408E 03	7.780088E-05
-0.11653	1.854588E 13	2.343929E 13	-4.893411E 12	-1.924132E 03	6.664395E-05
-0.13596	2.261474E 13	2.696105E 13	-4.346311E 12	-2.269517E 03	5.731799E-05
-0.15538	2.715879E 13	3.101531E 13	-3.856516E 12	-2.627208E 03	4.934268E-05
-0.17480	3.226502E 13	3.568281E 13	-3.417791E 12	-2.958887E 03	4.240806E-05
-0.19422	3.803193E 13	4.105647E 13	-3.024532E 12	-3.386302E 03	3.630205E-05
-0.21364	4.457148E 13	4.724318E 13	-2.671696E 12	-3.791283E 03	3.087284E-05
-0.23307	5.201128E 13	5.436600E 13	-2.354717E 12	-4.215748E 03	2.600787E-05
-0.25249	6.049713E 13	6.256657E 13	-2.069433E 12	-4.661723E 03	2.162117E-05
-0.27191	7.019595E 13	7.200794E 13	-1.811998E 12	-5.131345E 03	1.764550E-05
-0.29133	8.129907E 13	8.287784E 13	-1.578772E 12	-5.626877E 03	1.402714E-05
-0.31076	9.402624E 13	9.539237E 13	-1.366139E 12	-6.150721E 03	1.072243E-05
-0.33018	1.086302E 14	1.098003E 14	-1.170161E 12	-6.705429E 03	7.695326E-06
-0.34960	1.254025E 14	1.263882E 14	-9.856597E 11	-7.293716E 03	4.915641E-06
-0.36902	1.446830E 14	1.454856E 14	-8.025926E 11	-7.918491E 03	2.357818E-06
-0.38845	1.669463E 14	1.674723E 14	-5.259754E 11	-8.583042E 03	0.

JEE = 1.665437E 02	JEP = 1.112723E 01	JIP = 2.260730E-02	JAP = 6.764868E 00
J = -1.172362E 00	PP = 6.238296E-01	JIE = 3.407139E-06	JAE = 6.767238E 00
JA = 2.370059E-03	JI = 2.369997E-03	JE = -1.174732E 00	JA/JAP = 3.503482E-04
JE/JEP = -1.055728E-01	JI/JIP = 1.048333E-01	DVS = -0.38845	XDVS = 2.116272E-04
NAP = 2.992338E 15	XDLAM = 2.169292E 00	SC = 3.516864E-02	PHZ = 2.37763
EDVS = -8.583042E 03	DVSRD = -4.236283E-01		DVS/RD = 9.169484E-01
ELM/RD = 1.976558E 00	PHZZ = 2.377628E 00		DRD/KT = 2.458096E 00
NTP = 3.012338E 15	NCE = 1.679983E 14	NTE = 3.160337E 15	RD/KTE = -3.072620E 00
X/LMTE = 2.425343E 00	ELT/RD = 1.767887E 00	NIPA= -9.831554E 12	

(a-1) Concluded. Current density, 1.16 amperes per square centimeter.

(a) Continued. Emitter at 2400° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Continued.



(a-2) Current density, 0.565 ampere per square centimeter.

(a) Continued. Emitter at 2400° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Continued.

I = 3.893   TE = 2400.   PHI = 4.437   NEP = 1.00E 13   TEP = 2.00E 03   TIP = 2000.0   LAMBDA = 9.7556E-05

PV = 1.598737E 05   LAMBDA(TE) = 1.0687E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.004679E 13	-1.000000E 13	-0.	2.189288E-04
0.07244	-7.455330E 12	6.616218E 12	-1.407155E 13	9.891803E 02	1.823133E-04
0.14488	-1.565911E 13	4.363347E 12	-2.002246E 13	2.003033E 03	1.276157E-04
0.21732	-2.559239E 13	2.884072E 12	-2.847646E 13	3.070213E 03	9.773652E-05
0.28975	-3.856352E 13	1.912963E 12	-4.047649E 13	4.224497E 03	7.736591E-05
0.36219	-5.623272E 13	1.275686E 12	-5.750840E 13	5.503449E 03	6.221110E-05
0.43463	-8.082475E 13	8.577383E 11	-8.168248E 13	6.948101E 03	5.041708E-05
0.50707	-1.154106E 14	5.839232E 11	-1.159945E 14	8.604132E 03	4.099473E-05
0.57951	-1.642920E 14	4.048611E 11	-1.646969E 14	1.052334E 04	3.334341E-05
0.65195	-2.335377E 14	2.881353E 11	-2.338258E 14	1.276535E 04	2.706430E-05
0.72439	-3.317369E 14	2.124762E 11	-3.319494E 14	1.539947E 04	2.187502E-05
0.79682	-4.710655E 14	1.639443E 11	-4.712295E 14	1.850697E 04	1.756598E-05
0.86926	-6.687958E 14	1.334271E 11	-6.689293E 14	2.218354E 04	1.397621E-05
0.94170	-9.494380E 14	1.150020E 11	-9.495530E 14	2.654233E 04	1.097892E-05
1.01414	-1.347778E 15	1.048744E 11	-1.347883E 15	3.171741E 04	8.472398E-06
1.08658	-1.913191E 15	1.007058E 11	-1.913292E 15	3.786795E 04	6.374001E-06
1.15902	-2.715759E 15	1.012288E 11	-2.715860E 15	4.518307E 04	4.615929E-06
1.23145	-3.854959E 15	1.061356E 11	-3.855065E 15	5.388772E 04	3.142193E-06
1.30389	-5.471992E 15	1.164482E 11	-5.472108E 15	6.424956E 04	1.906345E-06
1.37633	-7.767282E 15	1.368157E 11	-7.767419E 15	7.658720E 04	8.697043E-07
1.44877	-1.102526E 16	2.354694E 11	-1.102550E 16	9.127997E 04	0.

JEE	= 5.717384E-01	JEP	= 1.112723E 01	JIP	= 2.260730E-02	JAP	= 6.764868E 00
J	= 5.670946E-01	PP	= 6.238296E-01	JIE	= 2.730491E 01	JAE	= 6.762711E 00
JA	= -2.157748E-03	JI	= -2.157763E-03	JE	= 5.692524E-01	JA/JAP	= -3.189637E-04
JE/JEP	= 5.115851E-02	JI/JIP	= -9.544541E-02	DVS	= 1.44877	XDVS	= 2.189288E-04
NAP	= 2.992338E 15	XD/LAM	= 2.244138E 00	SC	= 1.146893E-01	PHZ	= 2.87621
EDVS	= 9.127997E 04	DVSRD	= 1.560792E 00			DVS/RD	= 9.282278E-01
ELM/RD	= 5.705370E 00	PHZZ	= 3.692223E 00			DRD/KT	= 9.056468E 00
NTP	= 3.012338E 15	NCE	= 1.102573E 16	NTE	= 1.401807E 16	RD/KTE	= 7.547057E 00
X/LMTE	= 2.048608E 00	ELT/RD	= 6.249920E 00	NEPA	= 1.004679E 13		

I = 3.893   TE = 1600.   PHI = 3.745   NEP = 1.00E 13   TEP = 2.00E 03   TIP = 2000.0   LAMBDA = 9.7556E-05

PV = 3.009956E 04   LAMBDA(TE) = 8.7257E-05

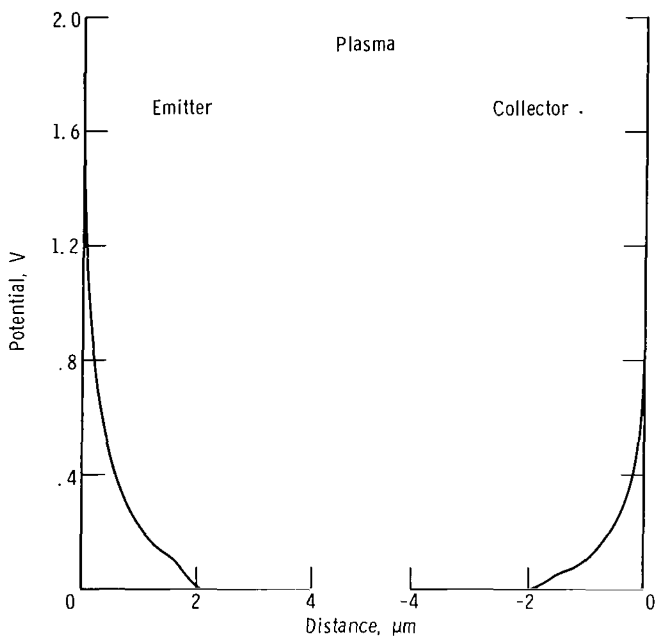
DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.926792E 12	-1.000000E 13	-0.	2.080876E-04
0.02567	-3.637556E 12	8.541629E 12	-1.217918E 13	4.112792E 02	1.768856E-04
0.05133	-7.311376E 12	7.347814E 12	-1.465919E 13	8.235829E 02	1.301019E-04
0.07700	-1.131420E 13	6.318844E 12	-1.763305E 13	1.242739E 03	1.041942E-04
0.10266	-1.577680E 13	5.431880E 12	-2.121068E 13	1.674591E 03	8.620479E-05
0.12833	-2.085119E 13	4.667238E 12	-2.551843E 13	2.123109E 03	7.249727E-05
0.15399	-2.669891E 13	4.007952E 12	-3.070686E 13	2.592051E 03	6.150215E-05
0.17966	-3.351735E 13	3.439397E 12	-3.695675E 13	3.085264E 03	5.239198E-05
0.20532	-4.153661E 13	2.948960E 12	-4.448557E 13	3.606793E 03	4.467468E-05
0.23099	-5.102940E 13	2.525762E 12	-5.355517E 13	4.160935E 03	3.803265E-05
0.25665	-6.232047E 13	2.160412E 12	-6.448088E 13	4.752292E 03	3.224822E-05
0.28232	-7.579774E 13	1.844797E 12	-7.764254E 13	5.385809E 03	2.716520E-05
0.30799	-9.192576E 13	1.571896E 12	-9.349765E 13	6.066818E 03	2.266728E-05
0.33365	-1.112617E 14	1.335610E 12	-1.125973E 14	6.801083E 03	1.866518E-05
0.35932	-1.344748E 14	1.130618E 12	-1.356054E 14	7.594852E 03	1.508865E-05
0.38498	-1.623695E 14	9.522214E 11	-1.633217E 14	8.454903E 03	1.188120E-05
0.41065	-1.959132E 14	7.961722E 11	-1.967093E 14	9.388607E 03	8.996576E-06
0.43631	-2.362704E 14	6.584230E 11	-2.369289E 14	1.040359E 04	6.396293E-06
0.46198	-2.848435E 14	5.345740E 11	-2.853780E 14	1.150980E 04	4.047910E-06
0.48764	-3.433229E 14	4.178581E 11	-3.437407E 14	1.271558E 04	1.923758E-06
0.51331	-4.137905E 14	2.548268E 11	-4.140453E 14	1.403184E 04	0.

JEE	= 6.779675E-04	JEP	= 1.112723E 01	JIP	= 2.260730E-02	JAP	= 6.764868E 00
J	= -5.629839E-01	PP	= 6.238296E-01	JIE	= 8.369708E-01	JAE	= 6.767255E 00
JA	= 2.386689E-03	JI	= 2.386713E-03	JE	= -5.653706E-01	JA/JAP	= 3.528064E-04
JE/JEP	= -5.080965E-02	JI/JIP	= 1.055727E-01	DVS	= 0.51331	XDVS	= 2.080876E-04
NAP	= 2.992338E 15	XD/LAM	= 2.133010E 00	SC	= 4.496683E-02	PHZ	= 3.18710
EDVS	= 1.403184E 04	DVSRD	= 5.579050E-01			DVS/RD	= 9.200664E-01
ELM/RD	= 2.453622E 00	PHZZ	= 2.377628E 00			DRD/KT	= 3.237234E 00
NTP	= 3.012338E 15	NCE	= 4.143001E 14	NTE	= 3.406638E 15	RD/KTE	= 4.046543E 00
X/LMTE	= 2.384777E 00	ELT/RD	= 2.194586E 00	NEPA	= 9.926792E 12		

(a-2) Concluded. Current density, 0.565 ampere per square centimeter.

(a) Continued. Emitter at 2400° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Continued.



(a-3) Current density, 0.0951 ampere per square centimeter.

(a) Continued. Emitter at 2400° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Continued.

I = 3.893 TE = 2400. PHI = 4.859 NEP = 1.00E 13 TEP = 2.00E 03 TIP = 2000.0 LAMBDA = 9.7556E-05

PV = 1.598737E 05 LAMBDA(TE) = 1.0687E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.000721E 13	-1.000000E 13	-0.	2.042425E-04
0.09074	-9.468681E 12	5.914065E 12	-1.538275E 13	1.247655E 03	1.678794E-04
0.18147	-2.042758E 13	3.496455E 12	-2.392403E 13	2.543927E 03	1.136823E-04
0.27221	-3.510543E 13	2.068539E 12	-3.717397E 13	3.949829E 03	8.436198E-05
0.36295	-5.649429E 13	1.225211E 12	-5.771950E 13	5.537153E 03	6.468228E-05
0.45369	-8.885063E 13	7.271904E 11	-8.957783E 13	7.386112E 03	5.034638E-05
0.54442	-1.385465E 14	4.331423E 11	-1.389797E 14	9.588460E 03	3.947238E-05
0.63516	-2.153280E 14	2.595869E 11	-2.155876E 14	1.225215E 04	3.103790E-05
0.72590	-3.342291E 14	1.572177E 11	-3.343863E 14	1.550684E 04	2.440928E-05
0.81663	-5.185164E 14	9.691411E 10	-5.186133E 14	1.951032E 04	1.915821E-05
0.90737	-8.042432E 14	6.147986E 10	-8.043047E 14	2.445636E 04	1.497776E-05
0.99811	-1.247303E 15	4.076324E 10	-1.247344E 15	3.058408E 04	1.163928E-05
1.08885	-1.934365E 15	2.877600E 10	-1.934394E 15	3.818965E 04	8.967894E-06
1.17958	-2.999826E 15	2.199264E 10	-2.999848E 15	4.764060E 04	6.827606E-06
1.27032	-4.652100E 15	1.834837E 10	-4.652119E 15	5.939358E 04	5.111437E-06
1.36106	-7.214391E 15	1.665199E 10	-7.214408E 15	7.401648E 04	3.734624E-06
1.45179	-1.118791E 16	1.624944E 10	-1.118792E 16	9.221585E 04	2.629693E-06
1.54253	-1.734991E 16	1.685130E 10	-1.734993E 16	1.148710E 05	1.742761E-06
1.63327	-2.690575E 16	1.851304E 10	-2.690577E 16	1.430767E 05	1.030719E-06
1.72401	-4.172464E 16	2.200478E 10	-4.172467E 16	1.781958E 05	4.590293E-07
1.81474	-6.470531E 16	4.009592E 10	-6.470535E 16	2.219251E 05	0.

JEE = 9.742226E-02	JEP = 1.112723E 01	JIP = 2.260730E-02	JAP = 6.764868E 00
J = 9.496715E-02	PP = 6.238296E-01	JIE = 1.602433E 02	JAE = 6.762711E 00
JA = -2.157748E-03	JI = -2.157763E-03	JE = 9.712492E-02	JA/JAP = -3.189637E-04
JE/JEP = 8.728582E-03	JI/JIP = -9.544543E-02	DVS = 1.81474	XDVS = 2.042425E-04
NAP = 2.992338E 15	XD/LAM = 2.093596E 00	SC = 1.788291E-01	PHZ = 2.87621
EDVS = 2.219251E 05	DVSRD = 1.982792E 00		DVS/RD = 9.152465E-01
ELM/RD = 1.091899E 01	PHZZ = 3.692223E 00		DRD/KT = 1.150512E 01
NTP = 3.012338E 15	NCE = 6.470539E 16	NTE = 6.769773E 16	RD/KTE = 9.587597E 00
X/LMTE = 1.911183E 00	ELT/RD = 1.196116E 01	NEPA= 1.000721E 13	

I = 3.893 TE = 1600. PHI = 4.080 NEP = 1.00E 13 TEP = 2.00E 03 TIP = 2000.0 LAMBDA = 9.7556E-05

PV = 3.009556E 04 LAMBDA(TE) = 8.7257E-05

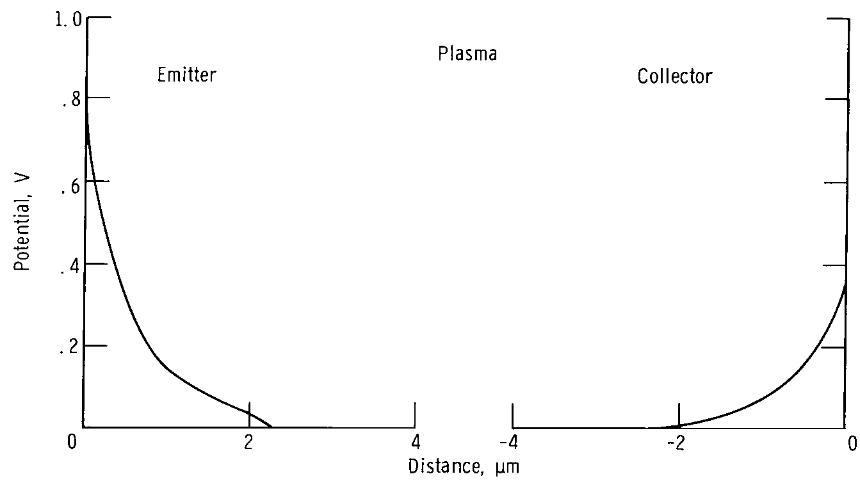
DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.989565E 12	-1.000000E 13	-0.	1.925366E-04
0.04080	-5.706830E 12	7.881213E 12	-1.359804E 13	6.495216E 02	1.611276E-04
0.08160	-1.201011E 13	6.217263E 12	-1.822738E 13	1.315905E 03	1.142153E-04
0.12240	-1.954813E 13	4.904023E 12	-2.445215E 13	2.016074E 03	8.859300E-05
0.16321	-2.895037E 13	3.867553E 12	-3.281792E 13	2.765829E 03	7.109789E-05
0.20401	-4.101512E 13	3.049500E 12	-4.406462E 13	3.580785E 03	5.802456E-05
0.24481	-5.678154E 13	2.403809E 12	-5.918535E 13	4.477907E 03	4.777138E-05
0.28561	-7.762047E 13	1.894135E 12	-7.951461E 13	5.476070E 03	3.949005E-05
0.32641	-1.053545E 14	1.491792E 12	-1.068463E 14	6.596498E 03	3.267192E-05
0.36721	-1.424178E 14	1.174138E 12	-1.435919E 14	7.863230E 03	2.698479E-05
0.40802	-1.920703E 14	9.233016E 11	-1.929936E 14	9.303627E 03	2.219755E-05
0.44882	-2.586846E 14	7.251739E 11	-2.594097E 14	1.094895E 04	1.814151E-05
0.48962	-3.481314E 14	5.686139E 11	-3.487700E 14	1.283509E 04	1.468879E-05
0.53042	-4.682969E 14	4.448195E 11	-4.687417E 14	1.503100E 04	1.173955E-05
0.57122	-6.297785E 14	3.468299E 11	-6.301254E 14	1.750053E 04	9.214058E-06
0.61202	-8.468194E 14	2.691278E 11	-8.470885E 14	2.038201E 04	7.047412E-06
0.65283	-1.138565E 15	2.073176E 11	-1.138772E 15	2.371067E 04	5.186084E-06
0.69363	-1.530751E 15	1.578487E 11	-1.530908E 15	2.755949E 04	3.585435E-06
0.73443	-2.057975E 15	1.177275E 11	-2.058093E 15	3.201285E 04	2.207922E-06
0.77523	-2.766750E 15	8.396413E 10	-2.766833E 15	3.716841E 04	1.021781E-06
0.81603	-3.719612E 15	4.394938E 10	-3.719656E 15	4.313927E 04	0.

JEE = 7.544589E-05	JEP = 1.112723E 01	JIP = 2.260730E-02	JAP = 6.764868E 00
J = -9.526046E-02	PP = 6.238296E-01	JIE = 7.521140E 00	JAE = 6.767255E 00
JA = 2.386689E-03	JI = 2.386709E-03	JE = -9.764717E-02	JA/JAP = 3.528064E-04
JE/JEP = -8.775517E-03	JI/JIP = 1.055725E-01	DVS = 0.81603	XDVS = 1.925366E-04
NAP = 2.992338E 15	XD/LAM = 1.973604E 00	SC = 7.884449E-02	PHZ = 3.18710
EDVS = 4.313927E 04	DVSRD = 8.929049E-01		DVS/RD = 9.139079E-01
ELM/RD = 4.712254E 00	PHZZ = 2.377628E 00		DRD/KT = 5.181066E 00
NTP = 3.012338E 15	NCE = 3.719700E 15	NTE = 6.712039E 15	RD/KTE = 6.476333E 00
X/LMTE = 2.206556E 00	ELT/RD = 4.215662E 00	NEPA= 9.989565E 12	

(a-3) Concluded. Current density, 0.0951 ampere per square centimeter.

(a) Concluded. Emitter at 2400° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Continued.



(b-1) Current density, 1.17 amperes per square centimeter.

(b) Emitter at 2200° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1800° K.

Figure 9. - Continued.

I = 3.893   TE = 2200.   PHI = 3.840   NEP = 1.00E 13   TEP = 2.00E 03   TIP = 2000.0   LAMBDA = 9.7556E-05

PV = 1.188282E 05   LAMBDA(TE) = 1.0232E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.012256E 13	-1.000000E 13	-0.	2.348875E-04
0.04150	-4.401610E 12	7.985257E 12	-1.238687E 13	5.752824E 02	1.988192E-04
0.08300	-9.121887E 12	6.306092E 12	-1.542798E 13	1.160930E 03	1.448779E-04
0.12450	-1.423150E 13	4.987090E 12	-1.921859E 13	1.761721E 03	1.152269E-04
0.16600	-1.998704E 13	3.951251E 12	-2.393830E 13	2.382540E 03	9.474000E-05
0.20749	-2.667529E 13	3.138061E 12	-2.981335E 13	3.030670E 03	7.918457E-05
0.24899	-3.462608E 13	2.499974E 12	-3.712605E 13	3.714042E 03	6.675134E-05
0.29049	-4.422842E 13	1.999635E 12	-4.622806E 13	4.441064E 03	5.649242E-05
0.33199	-5.594943E 13	1.607705E 12	-5.755714E 13	5.220657E 03	4.784576E-05
0.37349	-7.035711E 13	1.301155E 12	-7.165826E 13	6.062346E 03	4.044861E-05
0.41499	-8.814787E 13	1.061921E 12	-8.920979E 13	6.976372E 03	3.405169E-05
0.45649	-1.101802E 14	8.758588E 11	-1.110561E 14	7.973815E 03	2.847526E-05
0.49799	-1.375162E 14	7.319264E 11	-1.382481E 14	9.066731E 03	2.358454E-05
0.53949	-1.714726E 14	6.215517E 11	-1.720941E 14	1.026830E 04	1.927530E-05
0.58098	-2.136843E 14	5.381622E 11	-2.142224E 14	1.159298E 04	1.546475E-05
0.62248	-2.661829E 14	4.768569E 11	-2.666598E 14	1.305671E 04	1.208575E-05
0.66398	-3.314948E 14	4.342484E 11	-3.319291E 14	1.467706E 04	9.082840E-06
0.70548	-4.127618E 14	4.085828E 11	-4.131704E 14	1.647348E 04	6.409544E-06
0.74698	-5.138917E 14	4.006076E 11	-5.142923E 14	1.846751E 04	4.026417E-06
0.78848	-6.397421E 14	4.178285E 11	-6.401600E 14	2.068306E 04	1.899649E-06
0.82998	-7.962514E 14	5.775976E 11	-7.968290E 14	2.314647E 04	0.

JEE = 1.254258E 00	JEP = 1.112723E 01	JIP = 2.260730E-02	JAP = 6.764868E 00
J = 1.163027E 00	PP = 6.238296E-01	JIE = 1.889456E 00	JAE = 6.763765E 00
JA = -1.103461E-03	JI = -1.103441E-03	JE = 1.164131E 00	JA/JAP = -1.631164E-04
JE/JEP = 1.046200E-01	JI/JIP = -4.880905E-02	DVS = 0.82998	XDVS = 2.348875E-04
NAP = 2.992338E 15	XD/LAM = 2.407723E 00	SC = 5.775337E-02	PHZ = 2.95266
EDVS = 2.314647E 04	DVSRD = 8.873363E-01		DVS/RD = 9.353580E-01
ELM/RD = 2.544777E 00	PHZZ = 3.359795E 00		DRD/KT = 5.148754E 00
NTP = 3.012338E 15	NCE = 7.974066E 14	NTE = 3.789745E 15	RD/KTE = 4.680685E 00
X/LMTE = 2.295674E 00	ELT/RD = 2.668985E 00	NEPA= 1.012256E 13	

I = 3.893   TE = 1800.   PHI = 3.518   NEP = 1.00E 13   TEP = 2.00E 03   TIP = 2000.0   LAMBDA = 9.7556E-05

PV = 5.299324E 04   LAMBDA(TE) = 9.2550E-05

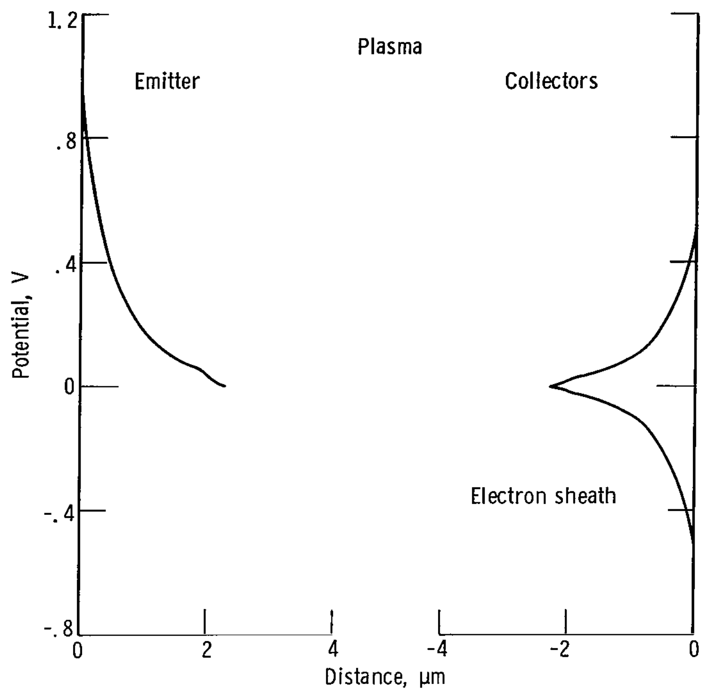
DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.828457E 12	-1.000000E 13	-0.	2.238946E-04
0.01888	-2.565220E 12	8.787326E 12	-1.135255E 13	2.962457E 02	1.920246E-04
0.03777	-4.969854E 12	7.853677E 12	-1.282353E 13	5.878368E 02	1.440933E-04
0.05665	-7.462415E 12	7.016308E 12	-1.447872E 13	8.780012E 02	1.172788E-04
0.07553	-1.008056E 13	6.265173E 12	-1.634573E 13	1.170926E 03	9.846240E-05
0.09441	-1.286197E 13	5.591260E 12	-1.845323E 13	1.468325E 03	8.396921E-05
0.11330	-1.584646E 13	4.986479E 12	-2.083294E 13	1.771484E 03	7.220954E-05
0.13218	-1.907680E 13	4.443568E 12	-2.352037E 13	2.081575E 03	6.234422E-05
0.15106	-2.259955E 13	3.956002E 12	-2.655555E 13	2.399748E 03	5.387421E-05
0.16994	-2.646568E 13	3.517910E 12	-2.998359E 13	2.727162E 03	4.647792E-05
0.18883	-3.073141E 13	3.124000E 12	-3.385541E 13	3.065003E 03	3.993556E-05
0.20771	-3.545902E 13	2.769488E 12	-3.822851E 13	3.414492E 03	3.409010E-05
0.22659	-4.071778E 13	2.450032E 12	-4.316781E 13	3.776893E 03	2.882524E-05
0.24548	-4.658498E 13	2.161656E 12	-4.874664E 13	4.153521E 03	2.405237E-05
0.26436	-5.314712E 13	1.900672E 12	-5.504779E 13	4.545743E 03	1.970230E-05
0.28324	-6.050122E 13	1.663567E 12	-6.216479E 13	4.954990E 03	1.571991E-05
0.30212	-6.875643E 13	1.446841E 12	-7.020327E 13	5.382760E 03	1.206048E-05
0.32101	-7.803586E 13	1.246650E 12	-7.928251E 13	5.830624E 03	8.687206E-06
0.33989	-8.847936E 13	1.057906E 12	-8.953727E 13	6.300239E 03	5.569360E-06
0.35877	-1.002490E 14	8.706907E 11	-1.011197E 14	6.793364E 03	2.680994E-06
0.37765	-1.136107E 14	5.910647E 11	-1.142018E 14	7.312071E 03	0.

JEE = 6.759118E-02	JEP = 1.112723E 01	JIP = 2.260730E-02	JAP = 6.764868E 00
J = -1.174909E 00	PP = 6.238296E-01	JIE = 2.447925E-01	JAE = 6.766029E 00
JA = 1.160145E-03	JI = 1.160125E-03	JE = -1.176069E 00	JA/JAP = 1.714955E-04
JE/JEP = -1.056929E-01	JI/JIP = 5.131638E-02	DVS = 0.37765	XDVS = 2.238946E-04
NAP = 2.992338E 15	XD/LAM = 2.295041E 00	SC = 3.246050E-02	PHZ = 3.10802
EDVS = 7.312071E 03	DVSRD = 4.099805E-01		DVS/RD = 9.211533E-01
ELM/RD = 1.739925E 00	PHZZ = 2.702235E 00		DRD/KT = 2.378905E 00
NTP = 3.012338E 15	NCE = 1.147928E 14	NTE = 3.107131E 15	RD/KTE = 2.643228E 00
X/LMTE = 2.419185E 00	ELT/RD = 1.650638E 00	NEPA= 9.828457E 12	

(b-1) Concluded. Current density, 1.17 amperes per square centimeter.

(b) Continued. Emitter at 2200° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1800° K.

Figure 9. - Continued.



I = 3.893   TE = 2200.   PHI = 3.988   NEP = 1.00E 13   TEP = 2.00E 03   TIP = 2000.0   LAMBDA = 9.7556E-05

PV = 1.188282E 05   LAMBDA(TE) = 1.0232E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.005616E 13	-1.000000E 13	-0.	2.276368E-04
0.04833	-5.230219E 12	7.611963E 12	-1.284218E 13	6.767474E 02	1.919291E-04
0.09666	-1.081944E 13	5.765875E 12	-1.658531E 13	1.365058E 03	1.385188E-04
0.14499	-1.704872E 13	4.371667E 12	-2.142039E 13	2.074530E 03	1.091677E-04
0.19332	-2.434177E 13	3.318872E 12	-2.766064E 13	2.815680E 03	8.893687E-05
0.24165	-3.318902E 13	2.524044E 12	-3.571306E 13	3.600801E 03	7.364350E-05
0.28998	-4.417937E 13	1.924148E 12	-4.610352E 13	4.443037E 03	6.149360E-05
0.33831	-5.603921E 13	1.471577E 12	-5.951079E 13	5.356435E 03	5.154331E-05
0.38664	-7.568049E 13	1.130374E 12	-7.681086E 13	6.356150E 03	4.323005E-05
0.43497	-9.826077E 13	8.733944E 11	-9.913416E 13	7.458679E 03	3.618834E-05
0.48330	-1.272592E 14	6.801490E 11	-1.279394E 14	8.682147E 03	3.016516E-05
0.53163	-1.645735E 14	5.351880E 11	-1.651087E 14	1.004660E 04	2.497655E-05
0.57996	-2.126442E 14	4.268787E 11	-2.130711E 14	1.157434E 04	2.048343E-05
0.62829	-2.746142E 14	3.464889E 11	-2.749607E 14	1.329032E 04	1.657737E-05
0.67662	-3.545343E 14	2.875079E 11	-3.548218E 14	1.522249E 04	1.317166E-05
0.72495	-4.576278E 14	2.451550E 11	-4.578730E 14	1.740235E 04	1.019559E-05
0.77328	-5.906324E 14	2.160607E 11	-5.908484E 14	1.986537E 04	7.590539E-06
0.82161	-7.622396E 14	1.981528E 11	-7.624378E 14	2.265167E 04	5.307284E-06
0.86994	-9.836629E 14	1.909735E 11	-9.838539E 14	2.580657E 04	3.304080E-06
0.91827	-1.269368E 15	1.977849E 11	-1.269566E 15	2.938140E 04	1.545226E-06
0.96660	-1.637964E 15	2.797103E 11	-1.638244E 15	3.343425E 04	0.

JEE = 6.100813E-01	JEP = 1.112723E 01	JIP = 2.260730E-02	JAP = 6.764868E 00
J = 5.681875E-01	PP = 6.238296E-01	JIE = 3.884507E 00	JAE = 6.763765E 00
JA = -1.103461E-03	JI = -1.103440E-03	JE = 5.692909E-01	JA/JAP = -1.631164E-04
JE/JEP = 5.116197E-02	JI/JIP = -4.880902E-02	DVS = 0.96660	XDVS = 2.276368E-04
NAP = 2.992338E 15	XD/LAM = 2.333400E 00	SC = 6.941140E-02	PHZ = 2.95266
EDVS = 3.343425E 04	DVSRD = 1.035336E 00		DVS/RD = 9.336139E-01
ELM/RD = 3.150384E 00	PHZZ = 3.359795E 00		DRD/KT = 6.007521E 00
NTP = 3.012338E 15	NCE = 1.638524E 15	NTE = 4.630862E 15	RD/KTE = 5.461383E 00
X/LMTE = 2.224810E 00	ELT/RD = 3.304150E 00	NEPA= 1.005616E 13	

(b-2) Current density, 0.568 ampere per square centimeter.

(b) Continued. Emitter at 2200° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1800° K.

Figure 9. - Continued.

I = 3.893   TE = 1800.   PHI = 3.653   NEP = 1.00E 13   TEP = 2.00E 03   TIP = 2000.0   LAMBDA = 9.7556E-05

PV = 5.299324E 04   LAMBDA(TE) = 9.2550E-05

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.926178E 12	-1.000000E 13	-0.	2.217119E-04
0.02522	-3.263862E 12	8.563446E 12	-1.182731E 13	3.861644E 02	1.890610E-04
0.05043	-6.526109E 12	7.385902E 12	-1.391201E 13	7.722810E 02	1.400835E-04
0.07565	-9.990107E 12	6.368313E 12	-1.635842E 13	1.162338E 03	1.129094E-04
0.10087	-1.374558E 13	5.488874E 12	-1.923445E 13	1.560666E 03	9.398240E-05
0.12609	-1.788850E 13	4.728746E 12	-2.261725E 13	1.965981E 03	7.950270E-05
0.15130	-2.252519E 13	4.071648E 12	-2.659684E 13	2.393176E 03	6.783373E-05
0.17652	-2.777535E 13	3.503507E 12	-3.127886E 13	2.832927E 03	5.811441E-05
0.20174	-3.377530E 13	3.012156E 12	-3.678746E 13	3.292062E 03	4.983365E-05
0.22696	-4.068158E 13	2.587072E 12	-4.326865E 13	3.773531E 03	4.266230E-05
0.25217	-4.867503E 13	2.219150E 12	-5.089418E 13	4.280439E 03	3.637533E-05
0.27739	-5.796561E 13	1.900500E 12	-5.986611E 13	4.816064E 03	3.081165E-05
0.30261	-6.879788E 13	1.624276E 12	-7.042216E 13	5.383882E 03	2.585169E-05
0.32782	-8.145746E 13	1.384517E 12	-8.284198E 13	5.987589E 03	2.140397E-05
0.35304	-9.627862E 13	1.176006E 12	-9.745463E 13	6.631125E 03	1.739675E-05
0.37826	-1.136531E 14	9.941249E 11	-1.146472E 14	7.318703E 03	1.377252E-05
0.40348	-1.340406E 14	8.346861E 11	-1.348752E 14	8.054832E 03	1.048437E-05
0.42869	-1.579809E 14	6.936886E 11	-1.586746E 14	8.844349E 03	7.493410E-06
0.45391	-1.861089E 14	5.667734E 11	-1.866757E 14	9.692454E 03	4.766925E-06
0.47913	-2.191731E 14	4.472309E 11	-2.196204E 14	1.060475E 04	2.277096E-06
0.50435	-2.580992E 14	2.821973E 11	-2.583814E 14	1.158735E 04	0.

JEE = 2.986471E-02	JEP = 1.112723E 01	JIP = 2.260730E-02	JAP = 6.764868E 00
J = -5.652454E-01	PP = 6.238296E-01	JIE = 5.540256E-01	JAE = 6.766029E 00
JA = 1.160145E-03	JI = 1.160124E-03	JE = -5.664056E-01	JA/JAP = 1.714555E-04
JE/JEP = -5.090267E-02	JI/JIP = 5.131637E-02	DVS = 0.50435	XDVS = 2.217119E-04
NAP = 2.992338E 15	XD/LAM = 2.272667E 00	SC = 4.086271E-02	PHZ = 3.10802
EDVS = 1.158735E 04	DVSRD = 5.449805E-01		DVS/RD = 9.254376E-01
ELM/RD = 2.074228E 00	PHZZ = 2.702235E 00		DRD/KT = 3.162240E 00
NTP = 3.012338E 15	NCE = 2.586636E 14	NTE = 3.251002E 15	RD/KTE = 3.513601E 00
X/LMTE = 2.395601E 00	ELT/RD = 1.967786E 00	NEPA= 9.926178E 12	

I = 3.893   TE = 1800.   PHI = 2.163   NEP = 1.00E 13   TEP = 2000.0   TIP = 2000.0   LAMBDA = 9.7556E-05

PV = 5.299324E 04   LAMBDA(TE) = 9.2550E-05

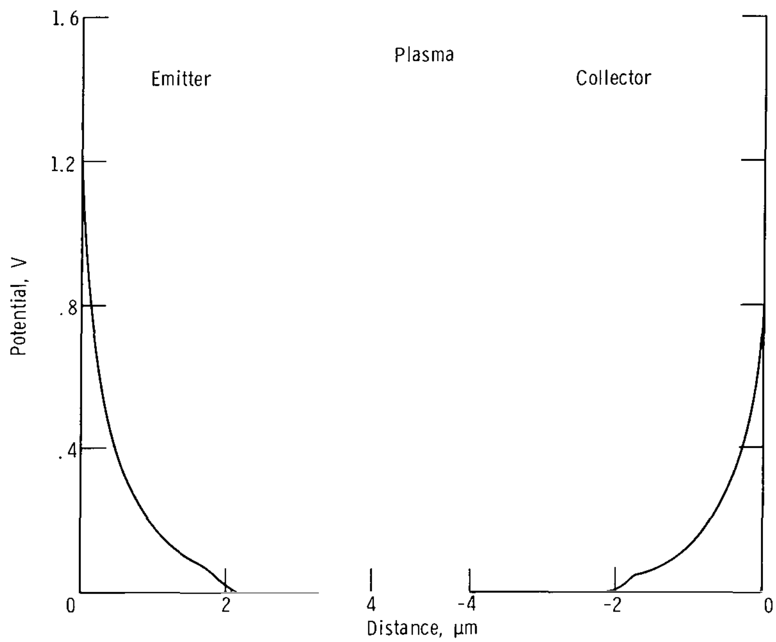
DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.000000E 13	-9.923419E 12	0.	2.218905E-04
-0.02494	3.231311E 12	1.180597E 13	-8.574659E 12	-3.820980E 02	1.892580E-04
-0.04988	6.454815E 12	1.386210E 13	-7.407285E 12	-7.639652E 02	1.403041E-04
-0.07481	9.873700E 12	1.627053E 13	-6.396834E 12	-1.149525E 03	1.131360E-04
-0.09975	1.357464E 13	1.909677E 13	-5.522135E 12	-1.543004E 03	9.420812E-05
-0.12469	1.765012E 13	2.241499E 13	-4.764864E 12	-1.947223E 03	7.972383E-05
-0.14963	2.220239E 13	2.631155E 13	-4.109159E 12	-2.364808E 03	6.804777E-05
-0.17456	2.734633E 13	3.088762E 13	-3.541288E 12	-2.798402E 03	5.831940E-05
-0.19950	3.321250E 13	3.626186E 13	-3.049359E 12	-3.250732E 03	5.002799E-05
-0.22444	3.995051E 13	4.257358E 13	-2.623069E 12	-3.724641E 03	4.284463E-05
-0.24938	4.773285E 13	4.998634E 13	-2.253487E 12	-4.223116E 03	3.654444E-05
-0.27431	5.675936E 13	5.869223E 13	-1.932862E 12	-4.749308E 03	3.096652E-05
-0.29925	6.726234E 13	6.891680E 13	-1.654456E 12	-5.306557E 03	2.599141E-05
-0.32419	7.951257E 13	8.092497E 13	-1.412390E 12	-5.898408E 03	2.152778E-05
-0.34913	9.382632E 13	9.502783E 13	-1.201509E 12	-6.528637E 03	1.750397E-05
-0.37407	1.105735E 14	1.115908E 14	-1.017234E 12	-7.201279E 03	1.386263E-05
-0.39900	1.301874E 14	1.310429E 14	-8.554056E 11	-7.920644E 03	1.055694E-05
-0.42394	1.531760E 14	1.538880E 14	-7.120260E 11	-8.691357E 03	7.548093E-06
-0.44888	1.801355E 14	1.807182E 14	-5.827100E 11	-9.518380E 03	4.803494E-06
-0.47382	2.117676E 14	2.122283E 14	-4.606377E 11	-1.040705E 04	2.295408E-06
-0.49875	2.489432E 14	2.492347E 14	-2.915563E 11	-1.136322E 04	0.

JEE = 2.630338E 02	JEP = 1.112723E 01	JIP = 2.260730E-02	JAP = 6.764868E 00
J = -5.658240E-01	PP = 6.238296E-01	JIE = 6.290403E-05	JAE = 6.766057E 00
JA = 1.188517E-03	JI = 1.188495E-03	JE = -5.710125E-01	JA/JAP = 1.756895E-04
JE/JEP = -5.131669E-02	JI/JIP = 5.257128E-02	DVS = -0.49875	XDVS = 2.218905E-04
NAP = 2.992338E 15	XDLAM = 2.274498E 00	SC = 4.046558E-02	PHZ = 2.70224
EDVS = -1.136322E 04	DVSRD = -5.392351E-01		DVS/RD = 9.249283E-01
ELM/RD = 2.055780E 00	PHZZ = 2.702235E 00		DRD/KT = 3.128903E 00
NTP = 3.012338E 15	NCE = 2.495263E 14	NTE = 3.241865E 15	RD/KTE = -3.476559E 00
X/LMTE = 2.397531E 00	ELT/RD = 1.950284E 00	NIPA= -9.923419E 12	

(b-2) Concluded. Current density, 0.568 ampere per square centimeter.

(b) Continued. Emitter at 2200° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1800° K.

Figure 9. - Continued.



(b-3) Current density, 0.0945 ampere per square centimeter.

(b) Continued. Emitter at 2200° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1800° K.

Figure 9. - Continued.

I = 3.893 TE = 2200. PHI = 4.367 NEP = 1.00E 13 TEP = 2.00E 03 TIP = 2000.0 LAMBDA = 9.7556E-05

PV = 1.188282E 05 LAMBDA(TE) = 1.0232E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.000823E 13	-1.000000E 13	-0.	2.117406E-04
0.06539	-7.204253E 12	6.850891E 12	-1.405514E 13	9.238766E 02	1.763506E-04
0.13078	-1.517836E 13	4.690565E 12	-1.986893E 13	1.872272E 03	1.234973E-04
0.19618	-2.486858E 13	3.212448E 12	-2.808143E 13	2.872307E 03	9.465088E-05
0.26157	-3.747579E 13	2.201137E 12	-3.967692E 13	3.954321E 03	7.499928E-05
0.32696	-5.453878E 13	1.509246E 12	-5.604802E 13	5.151542E 03	6.038403E-05
0.39235	-7.812570E 13	1.035926E 12	-7.916163E 13	6.500481E 03	4.900742E-05
0.45774	-1.110828E 14	7.121744E 11	-1.117950E 14	8.041975E 03	3.991197E-05
0.52314	-1.573786E 14	4.907780E 11	-1.578694E 14	9.822435E 03	3.251761E-05
0.58853	-2.225819E 14	3.394345E 11	-2.229214E 14	1.189526E 04	2.644025E-05
0.65392	-3.145319E 14	2.360446E 11	-3.147680E 14	1.432249E 04	2.140875E-05
0.71931	-4.442807E 14	1.654925E 11	-4.444462E 14	1.717663E 04	1.722239E-05
0.78470	-6.274218E 14	1.174422E 11	-6.275392E 14	2.054288E 04	1.372728E-05
0.85010	-8.859642E 14	8.483207E 10	-8.860490E 14	2.452170E 04	1.080234E-05
0.91549	-1.250978E 15	6.284621E 10	-1.251040E 15	2.923174E 04	8.350484E-06
0.98088	-1.766326E 15	4.821535E 10	-1.766374E 15	3.481350E 04	6.292801E-06
1.04627	-2.493938E 15	3.874793E 10	-2.493977E 15	4.143343E 04	4.564508E-06
1.11166	-3.521251E 15	3.303345E 10	-3.521284E 15	4.928893E 04	3.112036E-06
1.17706	-4.971717E 15	3.031538E 10	-4.971747E 15	5.861426E 04	1.890867E-06
1.24245	-7.019635E 15	3.075723E 10	-7.019666E 15	6.968749E 04	8.638726E-07
1.30784	-9.911092E 15	4.571059E 10	-9.911138E 15	8.283883E 04	0.

JEE = 1.008447E-01	JEP = 1.112723E 01	JIP = 2.260730E-02	JAP = 6.764868E 00
J = 9.410946E-02	PP = 6.238296E-01	JIE = 2.350014E 01	JAE = 6.763765E 00
JA = -1.103461E-03	JI = -1.103441E-03	JE = 9.521290E-02	JA/JAP = -1.631164E-04
JE/JEP = 8.556749E-03	JI/JIP = -4.880904E-02	DVS = 1.30784	XDVS = 2.117406E-04
NAP = 2.992338E 15	XD/LAM = 2.170455E 00	SC = 1.092577E-01	PHZ = 2.95266
EDVS = 8.283883E 04	DVSRD = 1.414336E 00		DVS/RD = 9.247019E-01
ELM/RD = 5.713925E 00	PHZZ = 3.359795E 00		DRD/KT = 8.206663E 00
NTP = 3.012338E 15	NCE = 9.911184E 15	NTE = 1.290352E 16	RD/KTE = 7.460603E 00
X/LMTE = 2.069449E 00	ELT/RD = 5.992815E 00	NEPA= 1.000823E 13	

I = 3.893 TE = 1800. PHI = 3.987 NEP = 1.00E 13 TEP = 2.00E 03 TIP = 2000.0 LAMBDA = 9.7556E-05

PV = 5.299324E 04 LAMBDA(TE) = 9.2550E-05

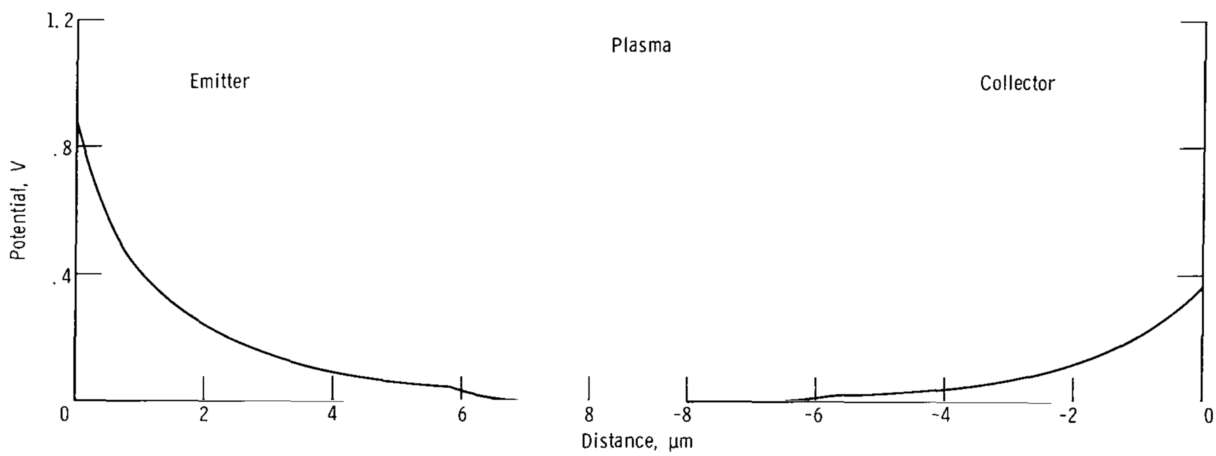
DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.989709E 12	-1.000000E 13	-0.	2.078054E-04
0.04058	-5.166846E 12	7.891344E 12	-1.305819E 13	6.163767E 02	1.748841E-04
0.08117	-1.071509E 13	6.233181E 12	-1.694827E 13	1.244076E 03	1.256521E-04
0.12175	-1.707307E 13	4.922855E 12	-2.199592E 13	1.894993E 03	9.863310E-05
0.16234	-2.466435E 13	3.887378E 12	-2.855173E 13	2.580692E 03	8.006198E-05
0.20292	-3.359889E 13	3.069076E 12	-3.706797E 13	3.312627E 03	6.607340E-05
0.24350	-4.570905E 13	2.422374E 12	-4.813142E 13	4.102982E 03	5.500214E-05
0.28409	-6.059282E 13	1.911258E 12	-6.250407E 13	4.964965E 03	4.596948E-05
0.32467	-7.966942E 13	1.507269E 12	-8.117569E 13	5.913065E 03	3.845077E-05
0.36525	-1.042441E 14	1.187915E 12	-1.054320E 14	6.963297E 03	3.210494E-05
0.40584	-1.360078E 14	9.354208E 11	-1.369433E 14	8.133469E 03	2.669596E-05
0.44642	-1.771435E 14	7.357362E 11	-1.778792E 14	9.443488E 03	2.205234E-05
0.48701	-2.304807E 14	5.777521E 11	-2.310585E 14	1.091569E 04	1.804460E-05
0.52759	-2.996900E 14	4.526808E 11	-3.001427E 14	1.257521E 04	1.457200E-05
0.56817	-3.895351E 14	3.535643E 11	-3.898887E 14	1.445043E 04	1.155412E-05
0.60876	-5.062009E 14	2.748812E 11	-5.064758E 14	1.657343E 04	8.925517E-06
0.64934	-6.577193E 14	2.122279E 11	-6.579315E 14	1.898058E 04	6.632072E-06
0.68992	-8.545220E 14	1.620451E 11	-8.546840E 14	2.171308E 04	4.628439E-06
0.73051	-1.110159E 15	1.213325E 11	-1.110280E 15	2.481777E 04	2.876257E-06
0.77109	-1.442232E 15	8.710556E 10	-1.442320E 15	2.834784E 04	1.342807E-06
0.81168	-1.873616E 15	4.698618E 10	-1.873663E 15	3.236380E 04	0.

JEE = 4.117551E-03	JEP = 1.112723E 01	JIP = 2.260730E-02	JAP = 6.764868E 00
J = -9.494723E-02	PP = 6.238296E-01	JIE = 4.018363E 00	JAE = 6.766029E 00
JA = 1.160145E-03	JI = 1.160128E-03	JE = -9.610736E-02	JA/JAP = 1.714955E-04
JE/JEP = -8.637134E-03	JI/JIP = 5.131654E-02	DVS = 0.81168	XDVS = 2.078054E-04
NAP = 2.992339E 15	XD/LAM = 2.130117E 00	SC = 6.829121E-02	PHZ = 3.10802
EDVS = 3.236380E 04	DVSRD = 8.799805E-01		DVS/RD = 9.234283E-01
ELM/RD = 3.591977E 00	PHZZ = 2.702235E 00		DRD/KT = 5.100270E 00
NTP = 3.012338E 15	NCE = 1.873710E 15	NTE = 4.866049E 15	RD/KTE = 5.666967E 00
X/LMTE = 2.245340E 00	ELT/RD = 3.407649E 00	NEPA= 9.989709E 12	

(b-3) Concluded. Current density, 0.0945 ampere per square centimeter.

(b) Concluded. Emitter at 2200° K, plasma at 2000° K with 10^{13} electrons per cubic centimeter, and collector at 1800° K.

Figure 9. - Continued.



(c-1) Current density, 0.0939 ampere per square centimeter.

(c) Emitter at 2000° K, plasma at 1800° K with 10^{12} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Continued.

I = 3.893 TE = 2000. PHI = 3.883 NEP = 1.00E 12 TEP = 1.80E 03 TIP = 1800.0 LAMBDA = 2

PV = 8.283912E 04 LAMBDA(TE) = 3.0850E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.009769E 12	-1.000000E 12	-0.	6.887280E-04
0.04347	-5.145627E 11	7.655534E 11	-1.280116E 12	2.013225E 02	5.807565E-04
0.08695	-1.067829E 12	5.811007E 11	-1.648930E 12	4.064130E 02	4.192997E-04
0.13042	-1.682312E 12	4.418087E 11	-2.124120E 12	6.178939E 02	3.306351E-04
0.17390	-2.359139E 12	3.366452E 11	-2.735784E 12	8.386166E 02	2.695355E-04
0.21737	-3.265687E 12	2.572758E 11	-3.522963E 12	1.072139E 03	2.233408E-04
0.26085	-4.338571E 12	1.974044E 11	-4.535976E 12	1.322269E 03	1.866273E-04
0.30432	-5.687330E 12	1.522757E 11	-5.839605E 12	1.593161E 03	1.565443E-04
0.34779	-7.398934E 12	1.182985E 11	-7.517232E 12	1.889162E 03	1.313941E-04
0.39127	-9.583404E 12	9.276245E 10	-9.676166E 12	2.215081E 03	1.100747E-04
0.43474	-1.238089E 13	7.362291E 10	-1.245451E 13	2.576170E 03	9.182368E-05
0.47822	-1.597065E 13	5.933998E 10	-1.602999E 13	2.978226E 03	7.608725E-05
0.52169	-2.058257E 13	4.875682E 10	-2.063133E 13	3.427686E 03	6.244695E-05
0.56516	-2.651187E 13	4.100915E 10	-2.655288E 13	3.931734E 03	5.057670E-05
0.60864	-3.413800E 13	3.545873E 10	-3.417345E 13	4.498418E 03	4.021592E-05
0.65211	-4.394890E 13	3.164730E 10	-4.398055E 13	5.136775E 03	3.115209E-05
0.69559	-5.657227E 13	2.927045E 10	-5.660154E 13	5.856982E 03	2.320912E-05
0.73906	-7.281563E 13	2.818008E 10	-7.284381E 13	6.670516E 03	1.623912E-05
0.78254	-9.371797E 13	2.845592E 10	-9.374643E 13	7.590335E 03	1.011666E-05
0.82601	-1.206158E 14	3.078202E 10	-1.206466E 14	8.631089E 03	4.734422E-06
0.86948	-1.552193E 14	4.578762E 10	-1.552651E 14	9.809306E 03	0.

JEE = 9.785058E-02	JEP = 1.055622E 00	JIP = 2.144716E-03	JAP = 9.248073E-01
J = 9.385337E-02	PP = 8.074131E-02	JIE = 3.510241E-01	JAE = 9.246913E-01
JA = -1.160130E-04	JI = -1.160136E-04	JE = 9.396938E-02	JA/JAP = -1.254456E-04
JE/JEP = 8.901806E-02	JI/JIP = -5.409274E-02	DVS = 0.86948	XDVS = 6.887280E-04
NAP = 4.312026E 14	XD/LAM = 2.353278E 00	SC = 3.759708E-02	PHZ = 2.97604
EDVS = 9.809306E 03	DVSRD = 9.069565E-01		DVS/RD = 9.586834E-01
ELM/RD = 3.165384E 00	PHZZ = 3.426548E 00		DRD/KT = 5.847333E 00
NTP = 4.332026E 14	NCE = 1.553109E 14	NTE = 5.865135E 14	RD/KTE = 5.262600E 00
X/LMTE = 2.232515E 00	ELT/RD = 3.336607E 00	NEPA= 1.009769E 12	

I = 3.893 TE = 1600. PHI = 3.534 NEP = 1.00E 12 TEP = 1.80E 03 TIP = 1800.0 LAMBDA = 2.9267E-04

PV = 3.009956E 04 LAMBDA(TE) = 2.7593E-04

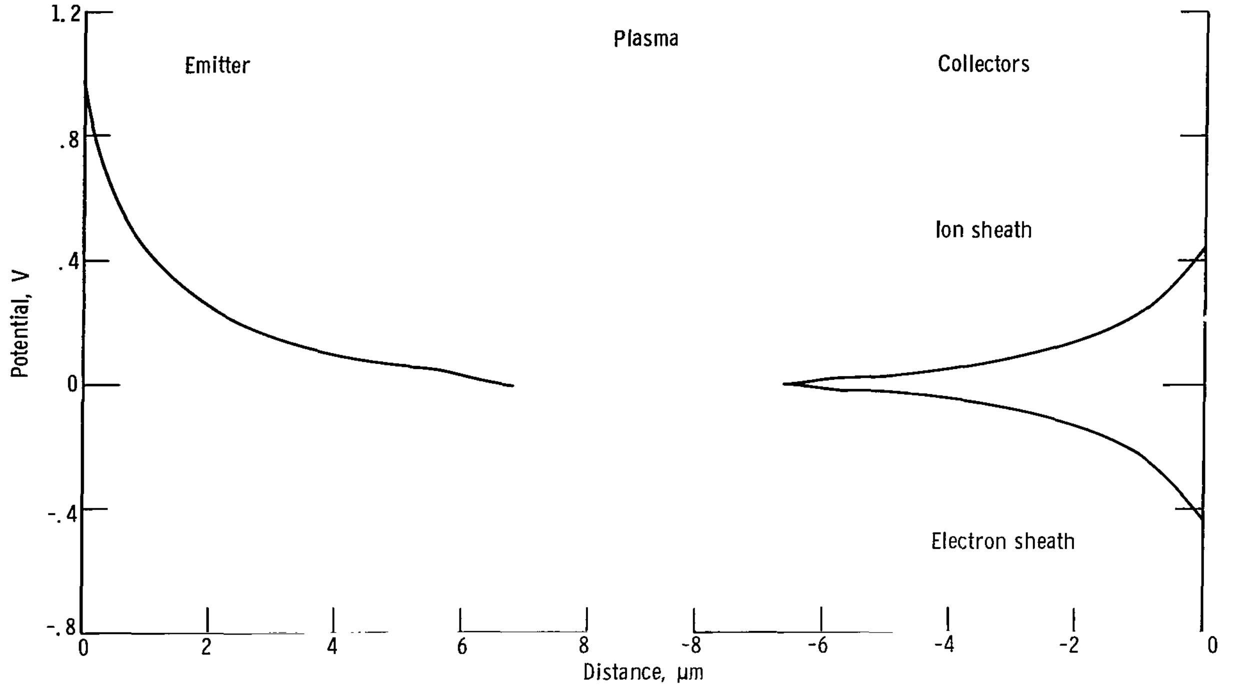
DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.860199E 11	-1.000000E 12	-0.	6.671946E-04
0.01855	-2.775633E 11	8.730431E 11	-1.150606E 12	9.657509E 01	5.711752E-04
0.03709	-5.435150E 11	7.727492E 11	-1.316264E 12	1.921375E 02	4.268932E-04
0.05564	-8.213658E 11	6.837047E 11	-1.505070E 12	2.877149E 02	3.464005E-04
0.07418	-1.116153E 12	6.046370E 11	-1.720790E 12	3.845580E 02	2.900568E-04
0.09273	-1.433026E 12	5.344161E 11	-1.967442E 12	4.832629E 02	2.467547E-04
0.11128	-1.777505E 12	4.720384E 11	-2.249543E 12	5.843150E 02	2.116963E-04
0.12982	-2.155617E 12	4.166125E 11	-2.572230E 12	6.881757E 02	1.823514E-04
0.14837	-2.574018E 12	3.673455E 11	-2.941364E 12	7.953063E 02	1.572168E-04
0.16692	-3.040112E 12	3.235322E 11	-3.363644E 12	9.061785E 02	1.353239E-04
0.18546	-3.562185E 12	2.845441E 11	-3.846729E 12	1.021279E 03	1.160109E-04
0.20401	-4.149558E 12	2.498201E 11	-4.399378E 12	1.141115E 03	9.880471E-05
0.22255	-4.812753E 12	2.188573E 11	-5.031611E 12	1.266214E 03	8.335492E-05
0.24110	-5.563684E 12	1.912022E 11	-5.754886E 12	1.397129E 03	6.939423E-05
0.25965	-6.415873E 12	1.664412E 11	-6.582315E 12	1.534441E 03	5.671370E-05
0.27819	-7.384703E 12	1.441898E 11	-7.528893E 12	1.678761E 03	4.514665E-05
0.29674	-8.487703E 12	1.240749E 11	-8.611778E 12	1.830734E 03	3.455768E-05
0.31528	-9.744890E 12	1.057042E 11	-9.850594E 12	1.991041E 03	2.483508E-05
0.33383	-1.117921E 13	8.858484E 10	-1.126779E 13	2.160403E 03	1.588539E-05
0.35238	-1.281725E 13	7.180855E 10	-1.288906E 13	2.339589E 03	7.629562E-06
0.37092	-1.469672E 13	4.705756E 10	-1.474378E 13	2.529468E 03	0.

JEE = 2.602679E-03	JEP = 1.055622E 00	JIP = 2.144716E-03	JAP = 9.248073E-01
J = -9.386405E-02	PP = 8.074131E-02	JIE = 2.979853E-02	JAE = 9.249300E-01
JA = 1.226589E-04	JI = 1.226581E-04	JE = -9.398671E-02	JA/JAP = 1.326319E-04
JE/JEP = -8.903448E-02	JI/JIP = 5.719082E-02	DVS = 0.37092	XDVS = 6.671946E-04
NAP = 4.312026E 14	XD/LAM = 2.279701E 00	SC = 1.909192E-02	PHZ = 3.14402
EDVS = 2.529468E 03	DVSRD = 3.899834E-01		DVS/RD = 9.511250E-01
ELM/RD = 1.898268E 00	PHZZ = 2.655090E 00		DRD/KT = 2.514303E 00
NTP = 4.332026E 14	NCE = 1.479084E 13	NTE = 4.459934E 14	RD/KTE = 2.828590E 00
X/LMTE = 2.417988E 00	ELT/RD = 1.789704E 00	NEPA= 9.860199E 11	

(c-1) Concluded. Current density, 0.0939 ampere per square centimeter.

(c) Continued. Emitter at 2000° K, plasma at 1800° K with 10^{12} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Continued.



I = 3.893 TE = 2000. PHI = 3.965 NEP = 1.00E 12 TEP = 1.80E 03 TIP = 1800.0 LAMBDA = 2.9267E-04

PV = 8.283912E 04 LAMBDA(TE) = 3.0850E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.006017E 12	-1.000000E 12	-0.	6.754719E-04
0.04735	-5.662340E 11	7.430727E 11	-1.309307E 12	2.204018E 02	5.680545E-04
0.09470	-1.175754E 12	5.493491E 11	-1.725103E 12	4.449958E 02	4.074344E-04
0.14205	-1.866264E 12	4.066392E 11	-2.272903E 12	6.774914E 02	3.192866E-04
0.18940	-2.692492E 12	3.015268E 11	-2.994018E 12	9.220022E 02	2.586637E-04
0.23675	-3.719015E 12	2.241258E 11	-3.943141E 12	1.183270E 03	2.129778E-04
0.28410	-5.025177E 12	1.671518E 11	-5.192328E 12	1.466386E 03	1.768246E-04
0.33145	-6.711210E 12	1.252378E 11	-6.836447E 12	1.776836E 03	1.473552E-04
0.37880	-8.905941E 12	9.443016E 10	-9.000372E 12	2.120598E 03	1.228667E-04
0.42615	-1.177665E 13	7.181713E 10	-1.184846E 13	2.504253E 03	1.022485E-04
0.47350	-1.554180E 13	5.525527E 10	-1.559706E 13	2.935119E 03	8.472849E-05
0.52085	-2.048773E 13	4.316823E 10	-2.053090E 13	3.421385E 03	6.974269E-05
0.56820	-2.699035E 13	3.439879E 10	-2.702475E 13	3.972279E 03	5.686293E-05
0.61555	-3.554380E 13	2.810063E 10	-3.557190E 13	4.598236E 03	4.575418E-05
0.66290	-4.679794E 13	2.365988E 10	-4.682160E 13	5.311105E 03	3.614783E-05
0.71025	-6.160775E 13	2.063998E 10	-6.162839E 13	6.124370E 03	2.782450E-05
0.75760	-8.109827E 13	1.874690E 10	-8.111702E 13	7.053410E 03	2.060227E-05
0.80495	-1.067501E 14	1.781814E 10	-1.067679E 14	8.115787E 03	1.432859E-05
0.85230	-1.405116E 14	1.786073E 10	-1.405295E 14	9.331584E 03	8.874362E-06
0.89965	-1.849471E 14	1.929275E 10	-1.849664E 14	1.072378E 04	4.129579E-06
0.94700	-2.434249E 14	2.915727E 10	-2.434541E 14	1.231865E 04	0.

JEE	= 6.240591E-02	JEP	= 1.055622E 00	JIP	= 2.144716E-03	JAP	= 9.248073E-01
J	= 5.993526E-02	PP	= 8.074131E-02	JIE	= 5.503952E-01	JAE	= 9.246913E-01
JA	= -1.160130E-04	JI	= -1.160135E-04	JE	= 6.005127E-02	JA/JAP	= -1.254456E-04
JE/JEP	= 5.688712E-02	JI/JIP	= -5.409268E-02	DVS	= 0.94700	XDVS	= 6.754719E-04
NAP	= 4.312026E 14	XD/LAM	= 2.307984E 00	SC	= 4.213244E-02	PHZ	= 2.976C4
EDVS	= 1.231865E 04	DVSRD	= 9.889565E-01			DVS/RD	= 9.575744E-01
ELM/RD	= 3.645529E 00	PHZZ	= 3.426548E 00			DRD/KT	= 6.376004E 00
NTP	= 4.332026E 14	NCE	= 2.434832E 14	NTE	= 6.746858E 14	RD/KTE	= 5.738404E 00
X/LMTE	= 2.189546E 00	ELT/RD	= 3.842725E 00	NEPA	= 1.006017E 12		

(c-2) Current density, 0.0601 ampere per square centimeter.

(c) Continued. Emitter at 2000° K, plasma at 1800° K with 10^{12} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Continued.

I = 3.893 TE = 1600. PHI = 3.606 NEP = 1.00E 12 TEP = 1.80E 03 TIP = 1800.0 LAMBDA = 2.9267E-04

PV = 3.009556E 04 LAMBDA(TE) = 2.7593E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.916152E 11	-1.000000E 12	-0.	6.623008E-04
0.02200	-3.207324E 11	8.591840E 11	-1.179916E 12	1.130777E 02	5.650060E-04
0.04401	-6.395217E 11	7.442338E 11	-1.383756E 12	2.259840E 02	4.190270E-04
0.06601	-9.777071E 11	6.444499E 11	-1.622157E 12	3.399153E 02	3.379762E-04
0.08801	-1.343730E 12	5.578229E 11	-1.901553E 12	4.561655E 02	2.814918E-04
0.11002	-1.746574E 12	4.826089E 11	-2.229183E 12	5.755788E 02	2.382594E-04
0.13202	-2.196161E 12	4.172939E 11	-2.613455E 12	6.989599E 02	2.034035E-04
0.15403	-2.703638E 12	3.605634E 11	-3.064201E 12	8.269305E 02	1.743576E-04
0.17603	-3.281666E 12	3.112756E 11	-3.592942E 12	9.604316E 02	1.495980E-04
0.19803	-3.944743E 12	2.684384E 11	-4.213181E 12	1.100237E 03	1.281433E-04
0.22004	-4.709568E 12	2.311891E 11	-4.940757E 12	1.247213E 03	1.093226E-04
0.24204	-5.595470E 12	1.987766E 11	-5.794247E 12	1.402273E 03	9.265575E-05
0.26404	-6.624894E 12	1.705458E 11	-6.795440E 12	1.566383E 03	7.778627E-05
0.28605	-7.823971E 12	1.459231E 11	-7.969894E 12	1.740570E 03	6.444170E-05
0.30805	-9.223187E 12	1.244031E 11	-9.347590E 12	1.925928E 03	5.240836E-05
0.33006	-1.085816E 13	1.055351E 11	-1.096370E 13	2.123624E 03	4.151516E-05
0.35206	-1.277056E 13	8.890589E 10	-1.285947E 13	2.334505E 03	3.162255E-05
0.37406	-1.500918E 13	7.411456E 10	-1.508330E 13	2.561107E 03	2.261489E-05
0.39607	-1.763123E 13	6.071304E 10	-1.769195E 13	2.803665E 03	1.439505E-05
0.41807	-2.070402E 13	4.798613E 10	-2.075200E 13	3.064121E 03	6.880407E-06
0.44007	-2.431148E 13	3.009824E 10	-2.434158E 13	3.344168E 03	0.

JEE =	1.576137E-03	JEP =	1.055622E 00	JIP =	2.144716E-03	JAP =	9.248073E-01
J =	-6.014636E-02	PP =	8.074131E-02	JIE =	4.920639E-02	JAE =	9.249300E-01
JA =	1.226569E-04	JI =	1.226581E-04	JE =	-6.026902E-02	JA/JAP =	1.326319E-04
JE/JEP =	-5.709340E-02	JI/JIP =	5.719083E-02	DVS =	0.44007	XDVS =	6.623008E-04
NAP =	4.312026E 14	XD/LAM =	2.262980E 00	SC =	2.195225E-02	PHZ =	3.14402
EDVS =	3.344168E 03	DVSRD =	4.619834E-01			DVS/RD =	9.525769E-01
ELM/RD =	2.118538E 00	PHZZ =	2.695090E 00			DRD/KT =	2.578501E 00
NTP =	4.332026E 14	NCE =	2.437168E 13	NTE =	4.555743E 14	RD/KTE =	3.350614E 00
X/LMTE =	2.400253E 00	ELT/RD =	1.997377E 00	NEPA=	9.916152E 11		

I = 3.893 TE = 1600. PHI = 2.240 NEP = 1.00E 12 TEP = 1800.0 TIP = 1800.0 LAMBDA = 2.9267E-04

PV = 3.009556E 04 LAMBDA(TE) = 2.7593E-04

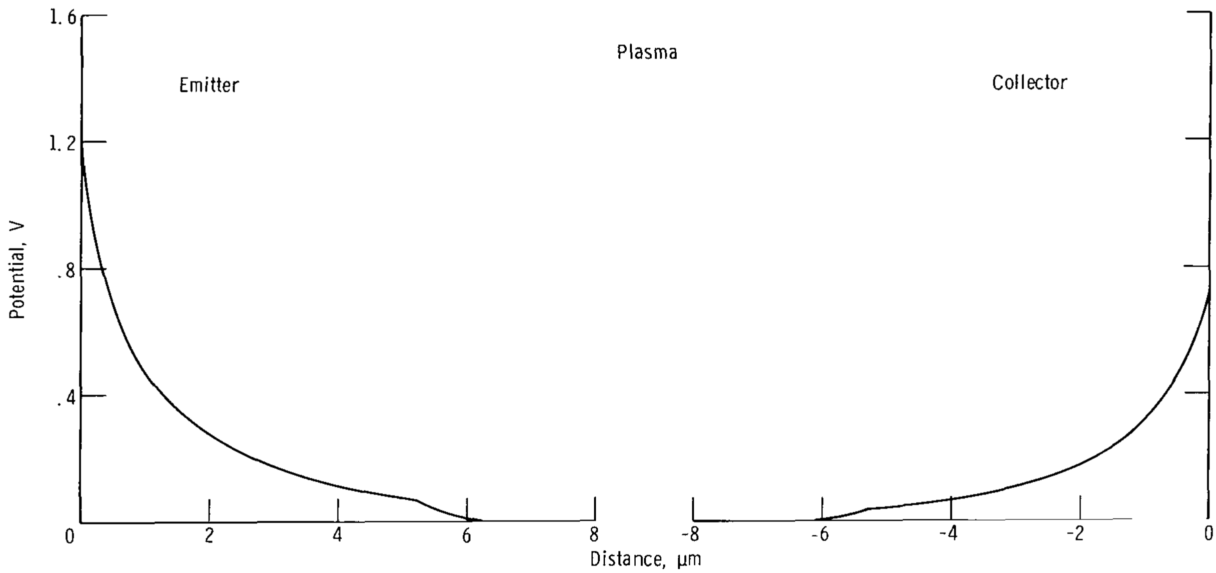
DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.000000E 12	-9.911988E 11	0.	6.629512E-04
-0.02167	3.164751E 11	1.177085E 12	-8.606103E 11	-1.114780E 02	5.657426E-04
-0.04335	6.301436E 11	1.377160E 12	-7.470163E 11	-2.227087E 02	4.198756E-04
-0.06502	9.623858E 11	1.610583E 12	-6.481975E 11	-3.348650E 02	3.388561E-04
-0.08669	1.321259E 12	1.883483E 12	-5.622236E 11	-4.492312E 02	2.823723E-04
-0.10837	1.715308E 12	2.202724E 12	-4.874156E 11	-5.666115E 02	2.391244E-04
-0.13004	2.153945E 12	2.576258E 12	-4.223127E 11	-6.877400E 02	2.042422E-04
-0.15171	2.647714E 12	3.013357E 12	-3.656438E 11	-8.133497E 02	1.751619E-04
-0.17339	3.206558E 12	3.524861E 12	-3.163023E 11	-9.441937E 02	1.503614E-04
-0.19506	3.850118E 12	4.123443E 12	-2.733246E 11	-1.081056E 03	1.288601E-04
-0.21673	4.588061E 12	4.823932E 12	-2.358710E 11	-1.224758E 03	1.099881E-04
-0.23841	5.440471E 12	5.643680E 12	-2.032087E 11	-1.376166E 03	9.326558E-05
-0.26008	6.428292E 12	6.602989E 12	-1.746968E 11	-1.536195E 03	7.833687E-05
-0.28175	7.575845E 12	7.725618E 12	-1.497729E 11	-1.705816E 03	6.492993E-05
-0.30343	8.911427E 12	9.039367E 12	-1.279398E 11	-1.886062E 03	5.283154E-05
-0.32510	1.046802E 13	1.057677E 13	-1.087524E 11	-2.078033E 03	4.187106E-05
-0.34677	1.228410E 13	1.237591E 13	-9.180133E 10	-2.282904E 03	3.190936E-05
-0.36845	1.440463E 13	1.448132E 13	-7.668609E 10	-2.501932E 03	2.283120E-05
-0.39012	1.688220E 13	1.694515E 13	-6.295484E 10	-2.736464E 03	1.453982E-05
-0.41179	1.977854E 13	1.982841E 13	-4.987641E 10	-2.987947E 03	6.952963E-06
-0.43347	2.317110E 13	2.320250E 13	-3.140443E 10	-3.257971E 03	0.

JEE =	2.308551E 01	JEP =	1.055622E 00	JIP =	2.144716E-03	JAP =	9.248073E-01
J =	-6.024420E-02	PP =	8.074131E-02	JIE =	3.359529E-06	JAE =	9.249350E-01
JA =	1.277626E-04	JI =	1.277621E-04	JE =	-6.037197E-02	JA/JAP =	1.381505E-04
JE/JEP =	-5.719092E-02	JI/JIP =	5.957062E-02	DVS =	-0.43347	XDVS =	6.629512E-04
NAP =	4.312026E 14	XDLAM =	2.265203E 00	SC =	2.166749E-02	PHZ =	2.69509
EDVS =	-3.257971E 03	DVSRD =	-4.550903E-01			DVS/RD =	9.524813E-01
ELM/RD =	2.095193E 00	PHZZ =	2.695090E 00			DRD/KT =	2.934060E 00
NTP =	4.332026E 14	NCE =	2.323391E 13	NTE =	4.544365E 14	RD/KTE =	-3.300618E 00
X/LMTE =	2.402610E 00	ELT/RD =	1.975367E 00	NIPA=	-9.911988E 11		

(c-2) Concluded. Current density, 0.0601 ampere per square centimeter.

(c) Continued. Emitter at 2000° K, plasma at 1800° K with 10^{12} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Continued.



(c-3) Current density, 0.00994 ampere per square centimeter.

(c) Continued. Emitter at 2000° K, plasma at 1800° K with 10^{12} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Continued.

I = 3.893 TE = 2000. PHI = 4.297 NEP = 1.00E 12 TEP = 1.80E 03 TIP = 1800.0 LAMBDA = 2.9267E-04

PV = 8.283912E 04 LAMBDA(TE) = 3.0850E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.000893E 12	-1.000000E 12	-0.	6.283255E-04
0.06278	-7.642846E 11	6.680647E 11	-1.432349E 12	2.948401E 02	5.218654E-04
0.12555	-1.618728E 12	4.460263E 11	-2.064755E 12	5.983123E 02	3.629432E-04
0.18833	-2.677579E 12	2.979024E 11	-2.975481E 12	9.201331E 02	2.763678E-04
0.25111	-4.087337E 12	1.990912E 11	-4.286428E 12	1.271257E 03	2.175635E-04
0.31389	-6.040205E 12	1.331801E 11	-6.173385E 12	1.663735E 03	1.740060E-04
0.37666	-8.800243E 12	8.921944E 10	-8.889463E 12	2.110921E 03	1.402700E-04
0.43944	-1.273912E 13	5.990426E 10	-1.279902E 13	2.627908E 03	1.134559E-04
0.50222	-1.838619E 13	4.036142E 10	-1.842655E 13	3.232048E 03	9.179985E-05
0.56500	-2.649969E 13	2.734008E 10	-2.652703E 13	3.943540E 03	7.412862E-05
0.62777	-3.816855E 13	1.867186E 10	-3.818722E 13	4.786121E 03	5.961082E-05
0.69055	-5.495855E 13	1.291075E 10	-5.497146E 13	5.787862E 03	4.762936E-05
0.75333	-7.912246E 13	9.092841E 09	-7.913155E 13	6.982112E 03	3.771058E-05
0.81611	-1.139023E 14	6.576280E 09	-1.139089E 14	8.408613E 03	2.948208E-05
0.87888	-1.639642E 14	4.934679E 09	-1.639692E 14	1.011482E 04	2.264592E-05
0.94166	-2.360248E 14	3.886532E 09	-2.360287E 14	1.215750E 04	1.696085E-05
1.00444	-3.397519E 14	3.249204E 09	-3.397552E 14	1.460460E 04	1.222977E-05
1.06722	-4.890618E 14	2.910989E 09	-4.890647E 14	1.753752E 04	8.290743E-06
1.12999	-7.039862E 14	2.821106E 09	-7.039891E 14	2.105383E 04	5.010064E-06
1.19277	-1.013360E 15	3.023216E 09	-1.013363E 15	2.527047E 04	2.277084E-06
1.25555	-1.458688E 15	4.829145E 09	-1.458693E 15	3.032772E 04	0.

JEE	= 1.041565E-02	JEP	= 1.055622E 00	JIP	= 2.144716E-03	JAP	= 9.248073E-01
J	= 9.977531E-03	PP	= 8.074131E-02	JIE	= 3.297723E 00	JAE	= 9.246913E-01
JA	= -1.160279E-04	JI	= -1.160138E-04	JE	= 1.009355E-02	JA/JAP	= -1.254617E-04
JE/JEP	= 9.561708E-03	JI/JIP	= -5.409285E-02	DVS	= 1.25555	XDVS	= 6.283255E-04
NAP	= 4.312026E 14	XD/LAM	= 2.146892E 00	SC	= 6.610813E-02	PHZ	= 2.976C4
EDVS	= 3.032772E 04	DVSRD	= 1.320956E 00			DVS/RD	= 9.504844E-01
ELM/RD	= 6.719327E 00	PHZZ	= 3.426548E 00			DRD/KT	= 8.516476E 00
NTP	= 4.332026E 14	NCE	= 1.458698E 15	NTE	= 1.889901E 15	RD/KTE	= 7.664828E 00
X/LMTE	= 2.036720E 00	ELT/RD	= 7.082793E 00	NEPA	= 1.000893E 12		

I = 3.893 TE = 1600. PHI = 3.900 NEP = 1.00E 12 TEP = 1.80E 03 TIP = 1800.0 LAMBDA = 2.9267E-04

PV = 3.009956E 04 LAMBDA(TE) = 2.7593E-04

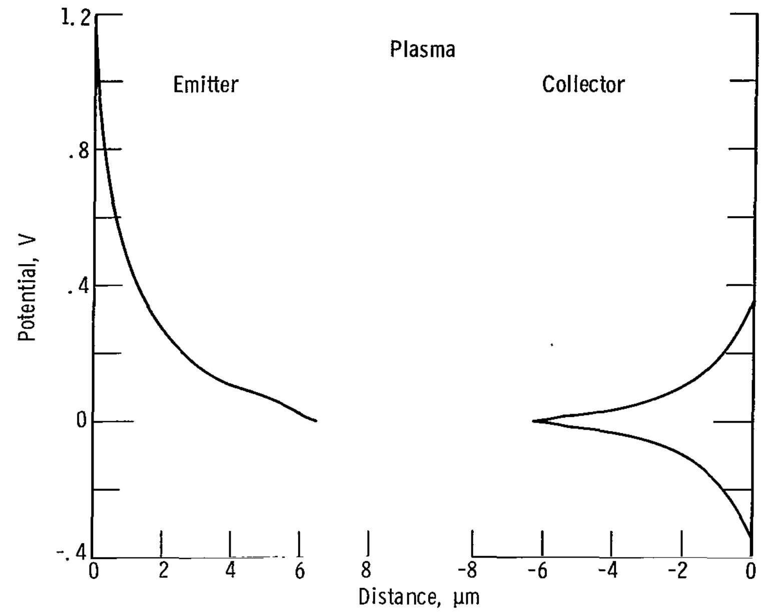
DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.988602E 11	-1.000000E 12	-0.	6.205916E-04
0.03595	-5.135105E 11	7.919449E 11	-1.305455E 12	1.828930E 02	5.223030E-04
0.07191	-1.064864E 12	6.278313E 11	-1.692695E 12	3.691402E 02	3.753166E-04
0.10786	-1.696982E 12	4.976637E 11	-2.194646E 12	5.622899E 02	2.946491E-04
0.14381	-2.451556E 12	3.944183E 11	-2.845974E 12	7.657701E 02	2.392045E-04
0.17976	-3.378797E 12	3.125243E 11	-3.691322E 12	9.829498E 02	1.974416E-04
0.21572	-4.540980E 12	2.475635E 11	-4.788544E 12	1.217408E 03	1.643874E-04
0.25167	-6.016671E 12	1.960313E 11	-6.212702E 12	1.473025E 03	1.374177E-04
0.28762	-7.906058E 12	1.551484E 11	-8.061207E 12	1.754059E 03	1.149657E-04
0.32357	-1.033777E 13	1.227099E 11	-1.046048E 13	2.065216E 03	9.601294E-05
0.35953	-1.347766E 13	9.696666E 10	-1.357462E 13	2.411730E 03	7.985494E-05
0.39548	-1.754007E 13	7.653118E 10	-1.761660E 13	2.799451E 03	6.597988E-05
0.43143	-2.280254E 13	6.030214E 10	-2.286284E 13	3.234938E 03	5.400160E-05
0.46738	-2.962472E 13	4.740509E 10	-2.967213E 13	3.725575E 03	4.361958E-05
0.50334	-3.847298E 13	3.714493E 10	-3.851012E 13	4.279692E 03	3.459412E-05
0.53929	-4.995227E 13	2.896782E 10	-4.998123E 13	4.906704E 03	2.673013E-05
0.57524	-6.484750E 13	2.243007E 10	-6.486993E 13	5.617273E 03	1.986633E-05
0.61119	-8.417723E 13	1.717104E 10	-8.419440E 13	6.423485E 03	1.386763E-05
0.64715	-1.092633E 14	1.288417E 10	-1.092762E 14	7.339059E 03	8.619703E-06
0.68310	-1.418213E 14	9.259140E 09	-1.418305E 14	8.379577E 03	4.025060E-06
0.71905	-1.840787E 14	4.956113E 09	-1.840837E 14	9.562755E 03	0.

JEE	= 2.083629E-04	JEP	= 1.055622E 00	JIP	= 2.144716E-03	JAP	= 9.248073E-01
J	= -9.906002E-03	PP	= 8.074131E-02	JIE	= 3.722160E-01	JAE	= 9.249300E-01
JA	= 1.226589E-04	JI	= 1.226581E-04	JE	= -1.002866E-02	JA/JAP	= 1.326319E-04
JE/JEP	= -9.500242E-03	JI/JIP	= 5.719083E-02	DVS	= 0.71905	XDVS	= 6.205916E-04
NAP	= 4.312026E 14	XD/LAM	= 2.120466E 00	SC	= 3.712159E-02	PHZ	= 3.144C2
EDVS	= 9.562755E 03	DVSRD	= 7.559834E-01			DVS/RD	= 9.511477E-01
ELM/RD	= 3.702076E 00	PHZZ	= 2.695090E 00			DRD/KT	= 4.873979E 00
NTP	= 4.332026E 14	NCE	= 1.840886E 14	NTE	= 6.152912E 14	RD/KTE	= 5.483227E 00
X/LMTE	= 2.249094E 00	ELT/RD	= 3.490351E 00	NEPA	= 9.988602E 11		

(c-3) Concluded. Current density, 0.00994 ampere per square centimeter.

(c) Concluded. Emitter at 2000° K, plasma at 1800° K with 10^{12} electrons per cubic centimeter, and collector at 1600° K.

Figure 9. - Continued.



I = 3.893 TE = 2000. PHI = 3.906 NEP = 1.00E 12 TEP = 1.70E 03 TIP = 1700.0 LAMBDA = 2.8442E-04

PV = 8.283912E 04 LAMBDA(TE) = 3.0850E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.008739E 12	-1.000000E 12	-0.	6.441116E-04
0.05695	-6.938156E 11	6.868530E 11	-1.380669E 12	2.675522E 02	5.376924E-04
0.11389	-1.456478E 12	4.687214E 11	-1.925200E 12	5.417011E 02	3.787115E-04
0.17084	-2.362692E 12	3.209329E 11	-2.683625E 12	8.291452E 02	2.918101E-04
0.22778	-3.518224E 12	2.208383E 11	-3.739062E 12	1.137648E 03	2.324426E-04
0.28473	-5.054578E 12	1.530851E 11	-5.207663E 12	1.476055E 03	1.881252E-04
0.34167	-7.143899E 12	1.072667E 11	-7.251166E 12	1.853999E 03	1.534780E-04
0.39862	-1.001834E 13	7.633033E 10	-1.009467E 13	2.282109E 03	1.256441E-04
0.45556	-1.399594E 13	5.549719E 10	-1.405144E 13	2.772307E 03	1.028972E-04
0.51251	-1.951585E 13	4.153068E 10	-1.955738E 13	3.338152E 03	8.409734E-05
0.56945	-2.718685E 13	3.224072E 10	-2.721909E 13	3.995221E 03	6.844118E-05
0.62640	-3.785456E 13	2.614808E 10	-3.788071E 13	4.761556E 03	5.533479E-05
0.68334	-5.269461E 13	2.225766E 10	-5.271687E 13	5.658162E 03	4.432294E-05
0.74029	-7.334225E 13	1.990599E 10	-7.336215E 13	6.709591E 03	3.504723E-05
0.79724	-1.020725E 14	1.866021E 10	-1.020912E 14	7.944619E 03	2.721976E-05
0.85418	-1.420510E 14	1.825412E 10	-1.420693E 14	9.397039E 03	2.060590E-05
0.91113	-1.976825E 14	1.855483E 10	-1.977011E 14	1.110659E 04	1.501235E-05
0.96807	-2.750963E 14	1.956524E 10	-2.751159E 14	1.312002E 04	1.027860E-05
1.02502	-3.828216E 14	2.150447E 10	-3.828431E 14	1.549243E 04	6.270595E-06
1.08196	-5.327266E 14	2.522713E 10	-5.327518E 14	1.828871E 04	2.875917E-06
1.13891	-7.413156E 14	4.286911E 10	-7.413585E 14	2.158531E 04	0.

JEE = 9.498955E-02	JEP = 1.025880E 00	JIP = 2.084290E-03	JAP = 4.286189E 00
J = 9.438200E-02	PP = 3.623402E-01	JIE = 1.676028E 00	JAE = 4.286013E 00
JA = -1.764297E-04	JI = -1.764407E-04	JE = 9.455844E-02	JA/JAP = -4.116238E-05
JE/JEP = 9.217303E-02	JI/JIP = -8.465268E-02	DVS = 1.13891	XDVS = 6.441116E-04
NAP = 2.056427E 15	XD/LAM = 2.264636E 00	SC = 5.577174E-02	PHZ = 2.71173
EDVS = 2.158531E 04	DVSRD = 1.194266E 00		DVS/RD = 9.536466E-01
ELM/RD = 5.140673E 00	PHZZ = 3.426548E 00		CRD/KT = 8.152599E 00
NTP = 2.058427E 15	NCE = 7.414014E 14	NTE = 2.797828E 15	RC/KTE = 6.929709E 00
X/LMTE = 2.087891E 00	ELT/RD = 5.575843E 00	NEPA= 1.008739E 12	

(d-1) Current density, 0.0945 ampere per square centimeter.

(d) Emitter at 2000° K, plasma at 1700° K with 10^{12} electrons per cubic centimeter, and collector at 1400° K.

Figure 9. - Continued.

I = 3.893 TE = 1400. PHI = 3.413 NEP = 1.00E 12 TEP = 1.70E 03 TIP = 1700.0 LAMBDA = 2.8442E-04

PV = 1.441017E 04 LAMBDA(TE) = 2.5811E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.854893E 11	-1.000000E 12	-0.	6.249127E-04
0.01745	-2.936673E 11	8.729265E 11	-1.166594E 12	9.634515E 01	5.343749E-04
0.03489	-5.749712E 11	7.729504E 11	-1.347922E 12	1.916736E 02	3.983282E-04
0.05234	-8.721470E 11	6.841435E 11	-1.556291E 12	2.871934E 02	3.224463E-04
0.06978	-1.191386E 12	6.052469E 11	-1.796633E 12	3.843244E 02	2.693768E-04
0.08723	-1.539020E 12	5.351421E 11	-2.074162E 12	4.837451E 02	2.286482E-04
0.10467	-1.921934E 12	4.728352E 11	-2.394769E 12	5.860076E 02	1.957310E-04
0.12212	-2.347769E 12	4.174428E 11	-2.765211E 12	6.916386E 02	1.682339E-04
0.13957	-2.825093E 12	3.681789E 11	-3.193272E 12	8.011682E 02	1.447343E-04
0.15701	-3.363590E 12	3.243440E 11	-3.687934E 12	9.151424E 02	1.243149E-04
0.17446	-3.974256E 12	2.853142E 11	-4.259570E 12	1.034130E 03	1.063482E-04
0.19190	-4.669632E 12	2.505319E 11	-4.920164E 12	1.158725E 03	9.038518E-05
0.20935	-5.464064E 12	2.194972E 11	-5.683561E 12	1.289556E 03	7.609295E-05
0.22679	-6.374000E 12	1.917586E 11	-6.565759E 12	1.427284E 03	6.321719E-05
0.24424	-7.418339E 12	1.669038E 11	-7.585243E 12	1.572608E 03	5.155891E-05
0.26169	-8.618826E 12	1.445484E 11	-8.763374E 12	1.726269E 03	4.095914E-05
0.27913	-1.000052E 13	1.243184E 11	-1.012484E 13	1.889057E 03	3.128855E-05
0.29658	-1.159234E 13	1.058180E 11	-1.169816E 13	2.061609E 03	2.244029E-05
0.31402	-1.342776E 13	8.854596E 10	-1.351630E 13	2.245418E 03	1.432486E-05
0.33147	-1.554579E 13	7.156864E 10	-1.561736E 13	2.440843E 03	6.866408E-06
0.34892	-1.799906E 13	4.628674E 10	-1.804534E 13	2.649154E 03	0.

JEE	=	1.428525E-04	JEP	=	1.025880E 00	JIP	=	2.084290E-03	JAP	=	4.286189E 00
J	=	-9.443445E-02	PP	=	3.623402E-01	JIE	=	3.411028E-02	JAE	=	4.286382E 00
JA	=	1.927614E-04	JI	=	1.928268E-04	JE	=	-9.462728E-02	JA/JAP	=	4.497268E-05
JE/JEP	=	-9.224013E-02	JI/JIP	=	9.251441E-02	DVS	=	0.34892	XDVS	=	6.249127E-04
NAP	=	2.056427E 15	XD/LAM	=	2.197134E 00	SC	=	1.953838E-02	PHZ	=	3.04459
EDVS	=	2.649154E 03	DVSRD	=	3.684109E-01				DVS/RC	=	9.470811E-01
ELM/RD	=	2.045208E 00	PHZZ	=	2.334041E 00				DRD/KT	=	2.514539E 00
NTP	=	2.056427E 15	NCE	=	1.809163E 13	NTE	=	2.074518E 15	RD/KTE	=	3.053855E 00
X/LMTE	=	2.421124E 00	ELT/RD	=	1.855996E 00	NEPA	=	9.854893E 11			

I = 3.893 TE = 1400. PHI = 1.965 NEP = 1.00E 12 TEP = 1700.0 TIP = 1700.0 LAMBDA = 2.8442E-04

PV = 1.441017E 04 LAMBDA(TE) = 2.5811E-04

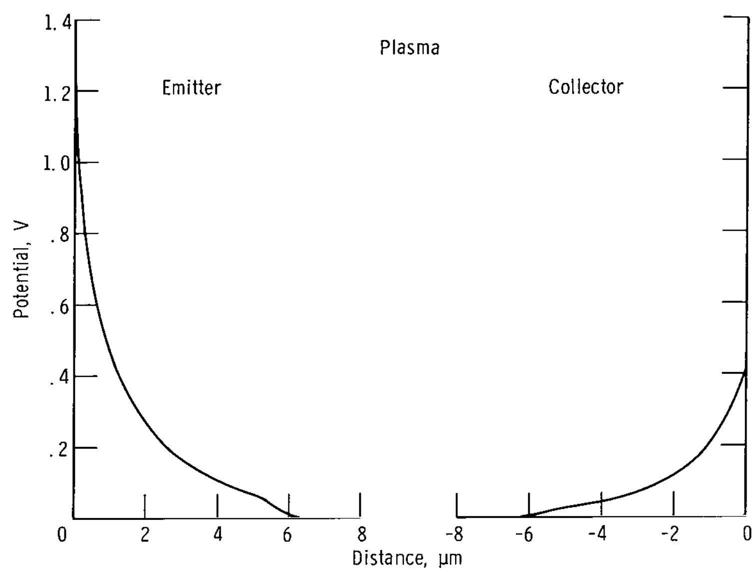
DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.000000E 12	-9.855585E 11	0.	6.248806E-04
-0.01748	2.940720E 11	1.166886E 12	-8.728144E 11	-9.649473E 01	5.343271E-04
-0.03495	5.758933E 11	1.348591E 12	-7.726981E 11	-1.919819E 02	3.982592E-04
-0.05243	8.736631E 11	1.557448E 12	-6.837853E 11	-2.876708E 02	3.223700E-04
-0.06990	1.193604E 12	1.798415E 12	-6.048111E 11	-3.849813E 02	2.692981E-04
-0.08738	1.542084E 12	2.076736E 12	-5.346520E 11	-4.845936E 02	2.285696E-04
-0.10486	1.926029E 12	2.398338E 12	-4.723099E 11	-5.870623E 02	1.956540E-04
-0.12233	2.353126E 12	2.770024E 12	-4.168980E 11	-6.929166E 02	1.681594E-04
-0.13981	2.832002E 12	3.199629E 12	-3.676272E 11	-8.026897E 02	1.446632E-04
-0.15728	3.372404E 12	3.696199E 12	-3.237955E 11	-9.169304E 02	1.242479E-04
-0.17476	3.985408E 12	4.270184E 12	-2.847768E 11	-1.036211E 03	1.062857E-04
-0.19223	4.683646E 12	4.933659E 12	-2.500121E 11	-1.161130E 03	9.032775E-05
-0.20971	5.481575E 12	5.700575E 12	-2.189998E 11	-1.292317E 03	7.604093E-05
-0.22719	6.395774E 12	6.587062E 12	-1.912874E 11	-1.430440E 03	6.317093E-05
-0.24466	7.445256E 12	7.611758E 12	-1.664618E 11	-1.576201E 03	5.151869E-05
-0.26214	8.652072E 12	8.796209E 12	-1.441377E 11	-1.730347E 03	4.092521E-05
-0.27961	1.004138E 13	1.016532E 13	-1.239409E 11	-1.893672E 03	3.126112E-05
-0.29709	1.164239E 13	1.174787E 13	-1.054754E 11	-2.067020E 03	2.241953E-05
-0.31457	1.348859E 13	1.357713E 13	-8.824058E 10	-2.251290E 03	1.431093E-05
-0.33204	1.562026E 13	1.569157E 13	-7.130492E 10	-2.447446E 03	6.859402E-06
-0.34952	1.808953E 13	1.813563E 13	-4.609492E 10	-2.656567E 03	0.

JEE	=	1.687301E 01	JEP	=	1.025880E 00	JIP	=	2.084290E-03	JAP	=	4.286189E 00
J	=	-9.471753E-02	PP	=	3.623402E-01	JIE	=	2.887888E-07	JAE	=	4.286381E 00
JA	=	1.914501E-04	JI	=	1.914663E-04	JE	=	-9.490900E-02	JA/JAP	=	4.466674E-05
JE/JEP	=	-9.251474E-02	JI/JIP	=	9.186164E-02	DVS	=	-0.34952	XDVS	=	6.248806E-04
NAP	=	2.056427E 15	XD/LAM	=	2.197021E 00	SC	=	1.956570E-02	PHZ	=	2.33404
EDVS	=	-2.656567E 03	DVSRD	=	-3.690406E-01				DVS/RC	=	9.470978E-01
ELM/RD	=	2.047431E 00	PHZZ	=	2.334041E 00				DRD/KT	=	2.519238E 00
NTP	=	2.056427E 15	NCE	=	1.818172E 13	NTE	=	2.074608E 15	RD/KTE	=	-3.059074E 00
X/LMTE	=	2.421000E 00	ELT/RD	=	1.858014E 00	NIPA	=	-9.855585E 11			

(d-1) Concluded. Current density, 0.0945 ampere per square centimeter.

(d) Continued. Emitter at 2000° K, plasma at 1700° K with 10^{12} electrons per cubic centimeter, and collector at 1400° K.

Figure 9. - Continued.



(d-2) Current density, 0.0603 ampere per square centimeter.

(d) Continued. Emitter at 2000° K, plasma at 1700° K with 10^{12} electrons per cubic centimeter, and collector at 1400° K.

Figure 9. - Continued.

I = 3.893 TE = 2000. PHI = 3.989 NEP = 1.00E 12 TEP = 1.70E 03 TIP = 1700.0 LAMBDA = 2.8442E-04

PV = 8.283912E 04 LAMBDA(TE) = 3.0850E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.005445E 12	-1.000000E 12	-0.	6.321153E-04
0.06077	-7.458719E 11	6.659945E 11	-1.411866E 12	2.865828E 02	5.260823E-04
0.12155	-1.571336E 12	4.418651E 11	-2.013201E 12	5.807606E 02	3.677260E-04
0.18232	-2.575519E 12	2.939011E 11	-2.869420E 12	8.910122E 02	2.812986E-04
0.24310	-3.891425E 12	1.962434E 11	-4.087669E 12	1.227189E 03	2.224327E-04
0.30387	-5.689071E 12	1.318151E 11	-5.820886E 12	1.600289E 03	1.786824E-04
0.36465	-8.197442E 12	8.933887E 10	-8.286781E 12	2.022375E 03	1.446683E-04
0.42542	-1.173378E 13	6.136829E 10	-1.179515E 13	2.506925E 03	1.175214E-04
0.48620	-1.674378E 13	4.298705E 10	-1.678677E 13	3.069268E 03	9.549959E-05
0.54697	-2.385786E 13	3.095035E 10	-2.388882E 13	3.727083E 03	7.744601E-05
0.60775	-3.397052E 13	2.311787E 10	-3.399364E 13	4.500974E 03	6.254166E-05
0.66852	-4.835281E 13	1.807971E 10	-4.837089E 13	5.415125E 03	5.017886E-05
0.72929	-6.881215E 13	1.490976E 10	-6.882706E 13	6.498068E 03	3.989097E-05
0.79007	-9.791948E 13	1.300373E 10	-9.793248E 13	7.783579E 03	3.131060E-05
0.85084	-1.393323E 14	1.197361E 10	-1.393442E 14	9.311737E 03	2.414326E-05
0.91162	-1.982542E 14	1.158107E 10	-1.982658E 14	1.113018E 04	1.814977E-05
0.97239	-2.820889E 14	1.169996E 10	-2.821006E 14	1.329559E 04	1.313409E-05
1.03317	-4.013704E 14	1.230809E 10	-4.013827E 14	1.587545E 04	8.934476E-06
1.09394	-5.710864E 14	1.353353E 10	-5.710999E 14	1.895018E 04	5.416841E-06
1.15472	-8.125616E 14	1.592531E 10	-8.125775E 14	2.261562E 04	2.469671E-06
1.21549	-1.156130E 15	2.747631E 10	-1.156157E 15	2.698599E 04	0.

JEE = 6.091001E-02	JEP = 1.025880E 00	JIP = 2.084290E-03	JAP = 4.286189E 00
J = 6.047798E-02	PP = 3.623402E-01	JIE = 2.613776E 00	JAE = 4.286013E 00
JA = -1.764297E-04	JI = -1.764407E-04	JE = 6.065442E-02	JA/JAP = -4.116238E-05
JE/JEP = 5.912430E-02	JI/JIP = -8.465268E-02	DVS = 1.21549	XDVS = 6.321153E-04
NAP = 2.056427E 15	XD/LAM = 2.222458E 00	SC = 6.235972E-02	PHZ = 2.71173
EDVS = 2.698599E 04	DVSRD = 1.277266E 00		DVS/RD = 9.516345E-01
ELM/RD = 6.009242E 00	PHZZ = 3.426548E 00		DRD/KT = 8.719194E 00
NTP = 2.058427E 15	NCE = 1.156185E 15	NTE = 3.212612E 15	RD/KTE = 7.411315E 00
X/LMTE = 2.049005E 00	ELT/RD = 6.517937E 00	NEPA= 1.005445E 12	

I = 3.893 TE = 1400. PHI = 3.482 NEP = 1.00E 12 TEP = 1.70E 03 TIP = 1700.0 LAMBDA = 2.8442E-04

PV = 1.441017E 04 LAMBDA(TE) = 2.5811E-04

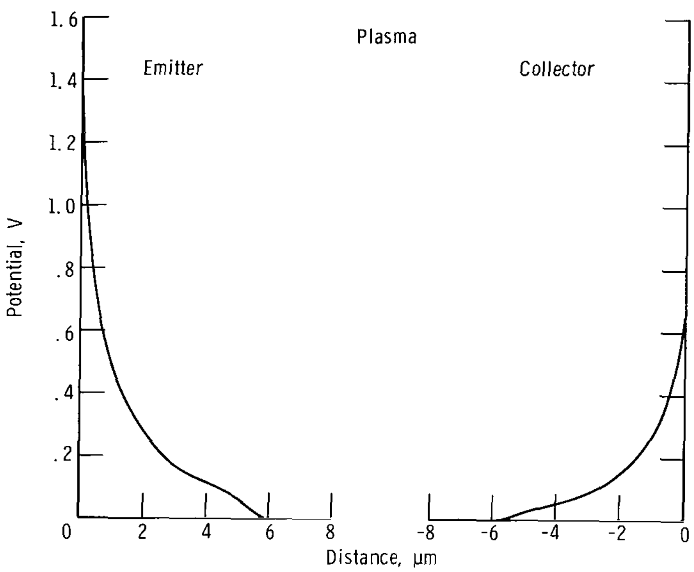
DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.913494E 11	-1.000000E 12	-0.	6.189336E-04
0.02074	-3.398462E 11	8.591597E 11	-1.199006E 12	1.130053E 02	5.271698E-04
0.04148	-6.787724E 11	7.443854E 11	-1.423158E 12	2.259341E 02	3.895084E-04
0.06222	-1.043452E 12	6.447246E 11	-1.688177E 12	3.402369E 02	3.131327E-04
0.08296	-1.444307E 12	5.581786E 11	-2.002486E 12	4.574300E 02	2.599848E-04
0.10370	-1.892562E 12	4.830122E 11	-2.375574E 12	5.784719E 02	2.193889E-04
0.12444	-2.400852E 12	4.177185E 11	-2.818571E 12	7.042448E 02	1.867380E-04
0.14518	-2.983651E 12	3.609886E 11	-3.344640E 12	8.356380E 02	1.596039E-04
0.16592	-3.657706E 12	3.116854E 11	-3.969391E 12	9.735755E 02	1.365432E-04
0.18666	-4.442530E 12	2.688206E 11	-4.711351E 12	1.119029E 03	1.166251E-04
0.20740	-5.360978E 12	2.315343E 11	-5.592513E 12	1.273031E 03	9.921259E-05
0.22814	-6.439915E 12	1.990777E 11	-6.638993E 12	1.436678E 03	8.384894E-05
0.24888	-7.711008E 12	1.707974E 11	-7.881805E 12	1.611143E 03	7.019473E-05
0.26961	-9.211656E 12	1.461208E 11	-9.357777E 12	1.797686E 03	5.799002E-05
0.29035	-1.098610E 13	1.245433E 11	-1.111064E 13	1.997657E 03	4.703061E-05
0.31109	-1.308673E 13	1.056138E 11	-1.319235E 13	2.212511E 03	3.715273E-05
0.33183	-1.557565E 13	8.891854E 10	-1.566457E 13	2.443815E 03	2.822256E-05
0.35257	-1.852650E 13	7.405437E 10	-1.860056E 13	2.693264E 03	2.012901E-05
0.37331	-2.202674E 13	6.056796E 10	-2.208731E 13	2.962687E 03	1.277860E-05
0.39405	-2.618040E 13	4.772894E 10	-2.622813E 13	3.254069E 03	6.091752E-06
0.41479	-3.111620E 13	2.951788E 10	-3.114571E 13	3.569589E 03	0.

JEE = 8.274303E-05	JEP = 1.025880E 00	JIP = 2.084290E-03	JAP = 4.286189E 00
J = -6.017024E-02	PP = 3.623402E-01	JIE = 5.889001E-02	JAE = 4.286382E 00
JA = 1.927614E-04	JI = 1.928273E-04	JE = -6.036307E-02	JA/JAP = 4.497268E-05
JE/JEP = -5.884030E-02	JI/JIP = 9.251464E-02	DVS = 0.41479	XDVS = 6.189336E-04
NAP = 2.056427E 15	XD/LAM = 2.176112E 00	SC = 2.268005E-02	PHZ = 3.04459
EDVS = 3.569589E 03	DVSRD = 4.374110E-01		DVS/RD = 9.482894E-01
ELM/RD = 2.321086E 00	PHZZ = 2.334041E 00		DRD/KT = 2.985964E 00
NTP = 2.058427E 15	NCE = 3.117523E 13	NTE = 2.087602E 15	RD/KTE = 3.625814E 00
X/LMTE = 2.397959E 00	ELT/RD = 2.106351E 00	NEPA= 9.913494E 11	

(d-2) Concluded. Current density, 0.0603 ampere per square centimeter.

(d) Continued. Emitter at 2000° K, plasma at 1700° K with 10^{12} electrons per cubic centimeter, and collector at 1400° K.

Figure 9. - Continued.



(d-3) Current density, 0.0101 ampere per square centimeter.

(d) Continued. Emitter at 2000° K, plasma at 1700° K with 10^{12} electrons per cubic centimeter, and collector at 1400° K.

Figure 9. - Continued.

I = 3.893   TE = 2000.   PHI = 4.329   NEP = 1.00E 12   TEP = 1.70E 03   TIP = 1700.0   LAMBDA = 2.8442E-04

PV = 8.283912E 04   LAMBDA(TE) = 3.0850E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	1.000831E 12	-1.000000E 12	-0.	5.892593E-04
0.07611	-9.484383E 11	5.956415E 11	-1.544080E 12	3.616358E 02	4.840334E-04
0.15222	-2.052919E 12	3.546478E 11	-2.407567E 12	7.380044E 02	3.272443E-04
0.22832	-3.539552E 12	2.113172E 11	-3.750869E 12	1.147090E 03	2.425068E-04
0.30443	-5.713734E 12	1.260766E 11	-5.839811E 12	1.609901E 03	1.856951E-04
0.38054	-9.012904E 12	7.538837E 10	-9.088292E 12	2.149997E 03	1.443583E-04
0.45665	-1.409485E 13	4.525288E 10	-1.414011E 13	2.794440E 03	1.130411E-04
0.53275	-2.196917E 13	2.734337E 10	-2.199651E 13	3.575176E 03	8.877943E-05
0.60886	-3.419797E 13	1.670750E 10	-3.421468E 13	4.530668E 03	6.973634E-05
0.68497	-5.320595E 13	1.039999E 10	-5.321635E 13	5.707835E 03	5.467022E-05
0.76108	-8.276119E 13	6.669537E 09	-8.276786E 13	7.164380E 03	4.269173E-05
0.83719	-1.287222E 14	4.475115E 09	-1.287266E 14	8.971649E 03	3.313863E-05
0.91329	-2.001991E 14	3.198456E 09	-2.002023E 14	1.121813E 04	2.550489E-05
0.98940	-3.113597E 14	2.473152E 09	-3.113621E 14	1.401382E 04	1.939727E-05
1.06551	-4.842374E 14	2.083294E 09	-4.842395E 14	1.749556E 04	1.450676E-05
1.14162	-7.530990E 14	1.903723E 09	-7.531009E 14	2.183381E 04	1.058882E-05
1.21772	-1.171236E 15	1.865707E 09	-1.171238E 15	2.724053E 04	7.449002E-06
1.29383	-1.821529E 15	1.939533E 09	-1.821531E 15	3.398162E 04	4.932233E-06
1.36994	-2.832875E 15	2.133651E 09	-2.832877E 15	4.238587E 04	2.914610E-06
1.44605	-4.405735E 15	2.538280E 09	-4.405737E 15	5.286505E 04	1.296990E-06
1.52215	-6.851868E 15	4.633651E 09	-6.851873E 15	6.593229E 04	0.

JEE = 1.027777E-02	JEP = 1.025880E 00	JIP = 2.084290E-03	JAP = 4.286189E 00
J = 1.006982E-02	PP = 3.623402E-01	JIE = 1.549025E 01	JAE = 4.286013E 00
JA = -1.764297E-04	JI = -1.764404E-04	JE = 1.024626E-02	JA/JAP = -4.116238E-05
JE/JEP = 9.987780E-03	JI/JIP = -8.465254E-02	DVS = 1.52215	XDVS = 5.892593E-04
NAP = 2.056427E 15	XD/LAM = 2.071780E 00	SC = 9.747294E-02	PHZ = 2.71173
EDVS = 6.593229E 04	DVSRD = 1.617266E 00		DVS/RD = 9.411501E-01
ELM/RD = 1.159523E 01	PHZZ = 3.426548E 00		CRD/KT = 1.104019E 01
NTP = 2.058427E 15	NCE = 6.851878E 15	NTE = 8.908304E 15	RC/KTE = 9.384160E 00
X/LMTE = 1.910087E 00	ELT/RD = 1.257679E 01	NEPA= 1.000831E 12	

I = 3.893   TE = 1400.   PHI = 3.758   NEP = 1.00E 12   TEP = 1.70E 03   TIP = 1700.0   LAMBDA = 2.8442E-04

PV = 1.441017E 04   LAMBDA(TE) = 2.5811E-04

DV	ND(DV)	NE(DV)	NI(DV)	E(DV)	X(DV)
0.	0.	9.987947E 11	-1.000000E 12	-0.	5.756700E-04
0.03371	-5.416813E 11	7.931922E 11	-1.334873E 12	1.818971E 02	4.830003E-04
0.06743	-1.132250E 12	6.298494E 11	-1.762100E 12	3.678754E 02	3.445100E-04
0.10114	-1.825904E 12	5.000779E 11	-2.325982E 12	5.621565E 02	2.687041E-04
0.13485	-2.674427E 12	3.969757E 11	-3.071403E 12	7.687038E 02	2.167907E-04
0.16856	-3.742061E 12	3.150593E 11	-4.057121E 12	9.513791E 02	1.778595E-04
0.20228	-5.110720E 12	2.499725E 11	-5.360692E 12	1.234330E 03	1.472004E-04
0.23599	-6.886375E 12	1.982544E 11	-7.084629E 12	1.502121E 03	1.223224E-04
0.26970	-9.207316E 12	1.571554E 11	-9.364472E 12	1.799831E 03	1.017352E-04
0.30341	-1.225496E 13	1.244906E 11	-1.237945E 13	2.133151E 03	8.446766E-05
0.33713	-1.626805E 13	9.852430E 10	-1.636658E 13	2.508496E 03	6.984588E-05
0.37084	-2.156140E 13	7.787677E 10	-2.163928E 13	2.933125E 03	5.737931E-05
0.40455	-2.855057E 13	6.145130E 10	-2.861202E 13	3.415277E 03	4.669686E-05
0.43826	-3.778453E 13	4.837553E 10	-3.783290E 13	3.964334E 03	3.750931E-05
0.47198	-4.998878E 13	3.795480E 10	-5.002674E 13	4.590996E 03	2.958572E-05
0.50569	-6.612239E 13	2.963457E 10	-6.615203E 13	5.307490E 03	2.273818E-05
0.53940	-8.745331E 13	2.296963E 10	-8.747628E 13	6.127809E 03	1.681144E-05
0.57312	-1.156581E 14	1.759710E 10	-1.156757E 14	7.067979E 03	1.167577E-05
0.60683	-1.529536E 14	1.320705E 10	-1.529668E 14	8.146377E 03	7.221715E-06
0.64054	-2.022714E 14	9.482527E 09	-2.022809E 14	9.384084E 03	3.356268E-06
0.67425	-2.674892E 14	5.019802E 09	-2.674943E 14	1.080530E 04	0.

JEE = 9.631111E-06	JEP = 1.025880E 00	JIP = 2.084290E-03	JAP = 4.286189E 00
J = -1.008112E-02	PP = 3.623402E-01	JIE = 5.059372E-01	JAE = 4.286382E 00
JA = 1.927614E-04	JI = 1.928273E-04	JE = -1.027395E-02	JA/JAP = 4.497268E-05
JE/JEP = -1.001477E-02	JI/JIP = 9.251465E-02	DVS = 0.67425	XDVS = 5.756700E-04
NAP = 2.056427E 15	XD/LAM = 2.024001E 00	SC = 3.945967E-02	PHZ = 3.04459
EDVS = 1.080530E 04	DVSRD = 7.134109E-01		DVS/RD = 9.451121E-01
ELM/RD = 4.307844E 00	PHZZ = 2.334041E 00		CRD/KT = 4.870065E 00
NTP = 2.058427E 15	NCE = 2.674993E 14	NTE = 2.323926E 15	RC/KTE = 5.513650E 00
X/LMTE = 2.230341E 00	ELT/RD = 3.909305E 00	NEPA= 9.987947E 11	

(d-3) Concluded. Current density, 0.0101 ampere per square centimeter.

(d) Concluded. Emitter at 2000° K, plasma at 1700° K with 10^{12} electrons per cubic centimeter, and collector at 1400° K.

Figure 9. - Concluded.

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