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IMPROVED HYPERSONIC LAMINAR WAKE CALCULATIONS INCLUDING RATE CHEMISTRY

GASL Report TR-249

by
Martin H. SteigerESTI PROCESSED

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IMPROVED HYPERSONIC
LAMINAR WAKE
CALCULATIONS INCLUDING
RATE CHEMISTRY

TECHNICAL REPORT NO. 249

By Martin H. Steiger

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TECHNICAL REPORT NO. 249

IMPROVED HYPERSONIC LAMINAR WAKE CALCULATIONS

INCLUDING RATE CHEMISTRY

By Martin H. Steiger

I INTRODUCTION

This report is concerned with the prediction of the properties of a laminar, axisymmetric, hypersonic wake which may not be in thermodynamic equilibrium. The flow is treated as a continuum, by a boundary layer approximation, utilizing integral method techniques according to the approach developed in Reference 1.

In Reference 1 Bloom and Steiger considered both laminar and turbulent wakes. Their integral-method approach involves satisfaction of the conservation equations on the average over a normal section, and satisfaction of the differential equations exactly along the central axis. Reasonable profiles in terms of a transformed normal coordinate and $(i + 4)$ undetermined parameters were assumed, where i denotes the number of components of the mixture considered. These parameters are utilized to express the axial variation of the physical quantities of interest.

The $(i + 4)$ parameters were u_o , H_o , δ_m , a_{O_0} , a_{N_0} , $a_{NO_0^+}$ and the equations utilized in their solution were the momentum integral, momentum boundary condition, energy integral or energy boundary condition, and conservation of species i boundary conditions. The development of the solution was straight-forward, but due to the limitations of a small digital computer used for the computations several approximations in the calculation procedure were made which may have caused some error.

The purpose of this report is to refine the aforementioned work in preparation for large-computer calculation. In particular the present analysis includes:

(a) An improved rate chemistry and representative thermodynamics.

The air chemistry includes rate processes which involve seven species, i.e., O_2 , O , N_2 , N , NO , NO^+ and e^- . The pertinent mass action laws and the development of the chemical kinetics and the thermodynamics are to be found in Reference 4.

(b) An additional parameter is introduced (H_{nn_O}) which couples the energy integral equation and boundary condition. This permits a simple evaluation of the effect of an initial defect in the stagnation enthalpy and/or Prandtl - Lewis numbers different from unity on the flow field.

(c) The system of equations is programmed on the IBM 7090 digital computer. This enables such advantages as automatic interval change, utilization of a Runge-Kutta scheme in the forward integration, test for maximum truncation error, evaluation of the temperature (which is given in terms of a transcendental algebraic expression) to any desirable accuracy and calculation of profiles in the physical plane at any predetermined axial stations.

References 1 and 2 give a detailed discussion of the problems associated with wakes behind blunt bodies traveling at hypersonic speeds and a compilation of the more recent developments and references. Of particular interest at the present time are wakes with so-called "turbulent cores" and three-dimensional effects. The former is discussed in References 1 and 2 and expanded in References 3 and 5, while the latter is considered in Reference 6.

The collaboration of Dr. Martin H. Bloom during the course of this work is acknowledged with thanks. Also, thanks are extended to Gertrude Weilerstein who programmed the analysis.

II ANALYSIS

In the following system of equations for mixtures of perfect gases it is assumed that the binary diffusion coefficients of several species are approximately the same*, so that each diffusion velocity V_i is given by Fick's law $a_i V_i = -D \text{ grad } a_i$. Therefore, a single Lewis number ($Le = \rho D C_p / k$) appears, wherein the fluid properties are those of the mixture. Likewise a single Prandtl number ($Pr = \mu C_p / k$) of the mixture is defined. Both parameters subsequently are assumed constant along the axis.

The equations that govern the flow in an axially-symmetric laminar wake are:

Overall Mass Conservation

$$(\rho u r)_x + (\rho v r)_r = 0 \quad (1)$$

Momentum

$$(\rho u^2 r)_x + (\rho u v r)_r = (\mu r u_r)_r \quad (2a)$$

$$P_r = 0 \quad (2b)$$

Energy

$$\begin{aligned} (\rho u r H)_x + (\rho v r H)_r &= \left[\frac{\mu}{\sigma} r H_r \right]_r + \left[\frac{\mu}{\sigma} (\sigma-1) r u u_r \right]_r + \\ &+ \left[\frac{\mu}{\sigma} (Le-1) r \sum_i h_i a_i r \right]_r \end{aligned} \quad (3)$$

* For an elaboration of this point see Reference 1, Appendix A.

Mass Conservation of Species i (i = O₂, N₂, O, N, NO, NO⁺ and e⁻):

$$(\rho u r a_i)_x + (\rho v r a_i)_r = \left[\frac{\mu Le}{\sigma} r a_{ir} \right]_r + \rho r W_i \quad (4)$$

where notation not defined in the text is defined at the end of the report.

The following lists the boundary conditions (those used in exact solutions are enclosed in curved brackets) and auxiliary conditions employed in the integral method. The latter consist of the conservation equations evaluated along the axis, and of outer edge conditions, which, in this instance, express the neglect of radial gradients at the outer edge.

The boundary conditions are:

$$\text{at } r = 0 : \left\{ v = 0, u_r = 0, H_r = 0, a_{ir} = 0 \right\} \quad (5)$$

$$\rho u u_x = 2(\mu u_r)_r \quad (6)$$

$$\begin{aligned} \rho u H_x &= 2 \left[\frac{\mu}{\sigma} H_r \right]_r + 2 \left[\frac{\mu}{\sigma} (\sigma - 1) u u_r \right]_r + \\ &+ 2 \left[\frac{\mu}{\sigma} (Le - 1) \sum_i h_i a_{ir} \right]_r \end{aligned} \quad (7)$$

$$\rho u a_{ix} = 2 \left[\frac{\mu Le}{\sigma} a_{ir} \right]_r + \rho W_i \quad (8)$$

$$u = u_o(x), H = H_o(x), H_{rr} = H_{rr_o}(x), a_i = a_{io}(x) \quad (9)$$

$$\text{as } r \rightarrow \delta \quad u = u_e, H = H_e, a_i = a_{ie} \quad (10)$$

{where u_e, a_{ie} and H_e are constant}

$$u_r = u_{rr} = 0, H_r = H_{rr} = 0, a_{ir} = a_{irr} = 0 \quad (11)$$

Integral equations are derived from Equations (1-4) assuming that integrated transport terms, that is, terms like $r u_r$, are negligible at the outer edge limit. The integral equations are;

Momentum

$$\frac{d}{dx} \left[\int_0^\delta \bar{\rho} \bar{u} (1 - \bar{u}) r dr \right] = 0 \quad \text{or}$$

$$\theta = \theta_c \quad \text{where } \theta = \int_0^\delta \bar{\rho} \bar{u} (1 - \bar{u}) r dr \quad (12)$$

Energy

$$\frac{d}{dx} \left[\int_0^\delta \bar{\rho} \bar{u} (1 - \bar{H}) r dr \right] = 0 \quad \text{or}$$

$$\theta_E = \theta_{E_c} \quad \text{where } \theta_E = \int_0^\delta \bar{\rho} \bar{u} (1 - \bar{H}) r dr \quad (13)$$

Species Concentration

$$\frac{d}{dx} \left[\int_0^\delta \bar{\rho} \bar{u} (a_{ie} - a_i) r dr \right] = - \frac{1}{u_e} \int_0^\delta \bar{\rho} W_i r dr \quad (14)$$

The following transformation are now introduced into the integral equations (12 - 14) and boundary conditions (6-8)

$$mdm = \bar{\rho} r dr, \quad m = \delta_m n \quad (15a)$$

$$\delta^2 / 2 = \int_0^{\delta_m} \frac{mdm}{\bar{\rho}} = \delta_m^2 \int_0^{n=1} \frac{ndn}{\bar{\rho}} \quad (15b)$$

The working forms of the governing equations and boundary conditions are:

$$\delta_m^2 \int_0^1 \bar{u}(1 - \bar{u}) n dn = \theta_c \quad (16)$$

$$u_o u_{ox} = \frac{2\mu_o}{\rho_e \delta_m^2} u_{nn_o} \quad (17)$$

$$\delta_m^2 \int_0^1 \bar{u}(1 - \bar{H}) n dn = \theta_{E_c} \quad (18)$$

$$u_o \frac{dH_o}{dx} = \frac{2\mu_o}{\rho_e \delta_m^2} \left[\frac{H_{nn_o}}{\sigma_o} + \frac{(\sigma_o - 1)}{\sigma_o} u_o u_{nn_o} + \frac{(Le_o - 1)}{\sigma_o} \sum_i h_{i_o} a_{inn_o} \right] \quad (19)$$

$$\frac{d}{dx} \left[\delta_m^2 \int_0^1 u(a_{ie} - a_i) n dn \right] = - \delta_m^2 \int_0^1 w_i n dn \quad (20)$$

$$u_o \frac{d a_{io}}{dx} = \frac{2\mu_o}{\rho_e \delta_m^2} \left(\frac{Le_o}{\sigma_o} \right) a_{inn_o} + w_{i_o} \quad (21)$$

and

$$\text{at } n = 0; \quad u = u_o(x), \quad u_n = 0, \quad H_n = 0 \quad (22a)$$

$$a_{in} = 0 \quad H_{nn} = H_{nn_o}(x)$$

$$n = 1; \quad u = u_e, \quad H = H_e, \quad a_i = a_{ie} \quad (22b)$$

$$u_n = u_{nn} = H_n = H_{nn} = a_{in} = a_{inn} = 0$$

A compromise between simplicity and accuracy influences the choice of specific procedures for solutions by the integral method. Here the profiles are depicted by polynomials in n with undetermined parameters (u_o , H_o , H_{nn_o} and a_{i_o}) to express streamwise variation. Another undetermined parameter, the wake thickness

(δ_m) is included implicitly. The equations that will be used to solve for these $(i + 4)$ undetermined parameters will be Equations (16 - 19) and (21). Clearly, additional parameters can be included and additional differential or integral conditions (for example, Equation (20)) satisfied at will; however, the more usual approach, underlying simplicity, will be followed here. The profile selection restricts the initial profile to the specified form. In particular cases more accurate curve-fits of the initial conditions in terms of n can be employed. Within reasonable limits these will not have a substantial influence on the overall results. The peak variations represented by u_o , H_o and a_{i_o} are believed to be the most influential parameters.

The assumed profiles, which satisfy the appropriate boundary conditions are:

$$\frac{u - u_o}{u_e - u_o} = \frac{a_i - a_{i_o}}{a_{i_e} - a_{i_o}} = 6n^2 - 8n^3 + 3n^4 \quad (23a)$$

and

$$\begin{aligned} H = H_o + (H_e - H_o) & (10n^3 - 15n^4 + 6n^5) + \\ & + \frac{H_{nno}}{2} (n^2 - 3n^3 + 3n^4 - n^5) \end{aligned} \quad (23b)$$

III CALCULATIONS

By utilizing the assumed profiles (23a-b) the governing equations (16-19) and (21) are reduced to a form that only involves the $(i + 5)$ undetermined parameters and variables that depend explicitly on the thermodynamic state. To complete the system, these equations are supplemented by the thermodynamics and chemical kinetics developed in Reference 4.

This system has been programmed on the IBM 7090 digital computer by Gertrude Weilerstein*. The programming techniques in the present case are analogous to those described in Reference 4. Also, the present program incorporates a procedure by which both the normal and axial distribution of the pertinent variables are typed out at predetermined values of the axial coordinate. The calculation procedure is described below.

The input data are, in general, the conditions at the edge of the viscous layer (i.e., u_e , T_e , ρ_e , P_e , H_e and a_{ie}), the initial data at the axis necessary for the forward integration (i.e., θ_c , u_{oc} , H_{oc} , a_{ioc} and H_{nnoc}), the Lewis and Prandtl number (Le_o , σ_o), the initial value of the streamwise coordinate, etc.

At the initial station, say $x = x_c$, sufficient information is known to calculate the following:

(A) Profiles (for $0 \leq n \leq 1$ at intervals of $\Delta n = 0.1$):

$$u = u_o + (u_e - u_o)(6n^2 - 8n^3 + 3n^4) \quad (24a)$$

* A summary of the data preparation for the 7090 digital program has been prepared by Gertrude Weilerstein of GASL

$$H = H_o + (H_e - H_o)(10n^3 - 15n^4 + 6n^5) + \frac{H_{nn}n_o}{2} (n^2 - 3n^3 + 3n^4 - n^5) \quad (24b)$$

$$a_i = a_{i_0} + (a_{ie} - a_{i_0})(6n^2 - 8n^3 + 3n^4)$$

$$i = O_2, N_2, O, N, NO, NO^+, e^- \quad (24c)$$

$$h = H - \frac{u^2}{2} \quad (24d)$$

and for the corresponding values of n , the temperature (T) is calculated from .

$$\begin{aligned} h &= RT \left[\sum_J \left(\frac{a_J}{M_J} \right) \left(\Lambda_J + \frac{7}{2} \right) + \frac{5}{2} \sum_k \frac{a_k}{M_k} \right] + a_o \left(\frac{D_{O_2}}{2m_o} \right) + \\ &+ a_N \left(\frac{D_{N_2}}{2m_n} \right) + \frac{a_{NO}}{m_{NO}} \left(\frac{D_{N_2} + D_{O_2}}{2} - D_{NO} \right) + \\ &+ \frac{a_{NO^+}}{m_{NO^+}} \left(I_{NO} + \frac{D_{N_2} + D_{O_2}}{2} - D_{NO} \right) \end{aligned}$$

where

$$\Lambda_J = \frac{\frac{V}{T_j} / T}{\left(e^{\frac{V}{T_J}} / T - 1 \right)} \quad (24e)$$

and

$$J = O_2, N_2, NO, NO^+ ; k = O, N, e^-$$

the density by:

$$\frac{\rho_e}{\rho} = \frac{T}{T_e} \frac{\sum_i \frac{a_i}{M_i}}{\sum_i \frac{a_{ie}}{M_{ie}}} ; i = O_2, N_2, O, N, NO, NO^+, e^- \quad (24f)$$

the physical thickness by:

$$r = \left[\frac{210 \theta_c u_e^2}{(u_e - u_o)(10u_e + 11u_o)} \right]^{1/2} \left[2 \int_0^n \frac{\rho_e}{\rho} n dn \right]^{1/2} \quad (24g)$$

and the particle concentration of electrons by:

$$N_{e^-} = \frac{a_e \eta \rho}{M_{e^-}} \quad (24h)$$

Therefore, profiles of the thermodynamic state and all pertinent variables are calculated as functions of both the transformed (n) and physical (r) normal coordinates. This procedure is repeated at predetermined values of the axial coordinate (s).

The calculation of the coefficient of viscosity at the axis (μ_o) completes the necessary information for a forward integration. It is given by

$$\mu_o = 5.48 \times \frac{T_o^{3/2}}{1.8 [T_o + 199]} \times 10^{-8} \quad (25)$$

The axial solution is then obtained from the following system (here we define $s = x/L$ where L is a characteristic length and equals unity for an isobaric flow field, therefore $L = 1$ in this analysis)

$$\frac{du_o}{ds} = \frac{L \mu_o}{\rho_e u_e^2 \theta_c} - \frac{4}{35 u_o} (u_e - u_o)^2 (10u_e + 11u_o) \quad (26)$$

$$\begin{aligned} \frac{dH_o}{ds} = & \frac{4}{35} \left[\frac{L \mu_o}{\rho_e \theta_c u_e^2} \right] \left[\frac{u_e - u_o}{u_o} (10u_e + 11u_o) \right] \left[\frac{H_{nno}}{120} \right] + \\ & + \frac{(\sigma_o - 1)}{\sigma_o} u_o (u_e - u_o) + \frac{(Le_o - 1)}{\sigma_o} \sum_i h_{io} (a_{ie} - a_{io}) \end{aligned} \quad (27a)$$

where

$$\sum_i h_{i_0} (a_{i_e} - a_{i_0}) = \sum_i h_{i_0} a_{i_e} - h_o \quad (27b)$$

and assuming that the external flow only consists of the undissociated components of air, it follows that

$$\sum_i h_{i_0} a_{i_e} = h_{O_2o} a_{O_2e} + h_{N_2o} a_{N_2e} \quad (27c)$$

where

$$h_{O_2o} = RT_o \frac{a_{O_2o}}{M_{O_2}} \left(\frac{7}{2} + \Lambda_{O_2o} \right)$$

and

$$h_{N_2o} = RT_o \frac{a_{N_2o}}{M_{N_2}} \left(\frac{7}{2} + \Lambda_{N_2o} \right)$$

$$H_{nn_o} = \frac{4(H_e - H_o)(349 u_e + 311 u_o)}{43 u_e + 23 u_o} - K \left[\frac{4(u_e - u_o)(10 u_e + 11 u_o)}{43 u_e + 23 u_o} \right] \quad (28a)$$

where

$$K = \frac{4(H_e - H_{oc})(349 u_e + 311 u_{oc}) - H_{nn_{oc}}(43 u_e + 23 u_{oc})}{4(u_e - u_{oc})(10 u_e + 11 u_{oc})} \quad (28b)$$

Obviously, Equations (27) and (28) permit an estimate as to the effect that initial defects in stagnation enthalpy and/or Lewis-Prandtl number has on the flow field. For a flow which is initially isoenergetic, that is, $H_e = H_{oc}$ and $H_{nn_o} = 0$, it follows that $K = 0$. If it is further assumed that the Prandtl and Lewis numbers are unity then Equations (27) and (28) state that the flow remains isoenergetic (i.e., $H = H_{oc} = H_e = \text{constant throughout } s \geq s_c$). Clearly, under these conditions the governing partial differential equation yields the same results.

$$u_o \frac{da_{i_o}}{ds} = \frac{L\mu_o}{\rho_e u_e^2 \theta_c} \frac{4}{35} \frac{Le_o}{\sigma_o} (u_e - u_o)(10u_e + 11u_o)(a_{i_e} - a_{i_o}) + \frac{M_i}{\rho} \left(\sum_l \dot{w}_l \right)_{i_o} \quad (29)$$

where $i = O_2, N_2, O, N, NO, NO^+, e^-$.

The term $\frac{M_i}{\rho} \left(\sum_l \dot{w}_l \right)_{i_o}$ in Equation (29) is the net rate of production of i^{th} species ($1/\text{sec}$) - with contribution from l mass action laws - and depends on the thermochemistry of air. In Reference 4 the principles of chemical kinetics are applied to the following reactions:



$\frac{M_i}{\rho} \left(\sum_l \dot{w}_l \right)_{i_o}$ Equations (9a - k) of Reference 4 are identical to the expression for $i = O_2, N_2, O, N, NO, NO^+, e^-$ and therefore will not be reproduced here.

Example Calculation

Calculations have been made of the laminar wake properties for one trajectory point of a blunt body, i.e., $u_{\infty} = 18,900 \text{ ft/sec}$ at 150,000 ft. This corresponds to Case 1 of Reference 1. The initial data is shown in Table 1 and the axial distribution of the pertinent variables in Figure 1a-d. Several typical type-outs, including profiles, are given in Tables (2a-f). The computation time on the 7090 digital computer was approximately five minutes.

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14

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SYMBOLS

c_p	specific heat, constant pressure
D_i	dissociation energy per mole, (see Reference 4)
D_{ij}	binary diffusion coefficient
e^-	refer to electron species
h	static enthalpy
H	stagnation enthalpy
H_{nn_0}	curvature of the stagnation enthalpy profile at $n = 0$
I_j	ionization energy per mole (see Reference 4)
k	thermal conductivity
K	defined by Equation (28)
L	characteristic length, this report $L = 1$ ft.
Le	Lewis number $Le = \frac{\rho D_{ij} c_p}{k}$
m	transformed normal coordinate Equation (15a, b)
M_i	molecular weight, mass/mole
n	transformed normal coordinate, Equation (15 a, b)
N	refers to atomic nitrogen
N_2	refers to molecular nitrogen
N_e^-	refers to particle concentration of electrons, electrons/cc
O	refers to atomic oxygen
O_2	refers to molecular oxygen
NO	refers to nitric oxide
NO^+	refers to ionized nitric oxide
r	normal coordinate
R	gas constant per mole

Symbols (Continued)

s	transformed streamwise coordinate $s = x/L$
T	temperature, $^{\circ}\text{K}$
T_i^V	characteristic vibrational temperature
u, v	streamwise and normal velocity component
u_{∞}	free stream flight velocity
$\frac{M_i}{\rho} \left(\sum_i w_i \right)_i$	net rate of production of species i
x	streamwise coordinate
X	catalyst
a_i	mass fraction of species i
δ	physical viscous layer thickness
δ_m	transformed viscous layer thickness
θ	momentum thickness $\theta = \int_0^{\delta} \bar{\rho} \bar{u} (1 - \bar{H}) r dr$
θ_E	energy thickness $\theta_E = \int_0^{\delta} \bar{\rho} \bar{u} (1 - \bar{H}) r dr$
θ_i	i^{th} species thickness $\theta_i = \int_0^{\delta} \bar{\rho} \bar{u} (a_{Le} - a_i) r dr$
μ	coefficient of viscosity
ρ	density
Λ	see Equation (24c)
Σ	summation
η	Avagadro's number
σ	Prandtl number $\sigma = \frac{\mu c_p}{k}$

c	conditions at initial station
e	conditions at edge of viscous layer, constant
e^-	refers to electron species
N	refers to atomic nitrogen
N_2	refers to molecular nitrogen
NO	refers to nitric oxide
NO^+	refers to ionized nitric oxide
O	refers to atomic oxygen
O_2	refers to molecular oxygen
i, J, k	indices, ($i = O_2, N_2, O, N, NO, NO, e^-$)
o	values evaluated along axis
x, y, n	denotes partial differentiation with respect to indicated variable
∞	undisturbed flight conditions

Superscripts

- denotes nondimensional quantities with respect to condition at the edge of the viscous layer, $\bar{u} = \frac{u}{u_e}$,
 $\bar{H} = \frac{H}{H_e}$, etc.

TABLE IA. Flight Conditions

(1)	Velocity	18,900 ft/sec
(2)	Pressure	2.94 #/sq. ft
(3)	Density	3.39×10^{-6} slug/ft ³
(4)	Temperature	280 °K

B. Initial Conditions

(1) Mass Fractions

$$\begin{array}{ll}
 a_O = .232 & a_{NO} = 0 \\
 a_{O_2} = 0 & a_{NO^+} = 5.63 \times 10^{-4} \\
 a_N = .133 & a_e = 1.029 \times 10^{-8} \\
 a_{N_2} = .635 &
 \end{array}$$

$$(2) \text{ Velocity} \quad 13,078.8 \text{ ft/sec}$$

$$(3) \theta_c \quad .0065 \text{ ft}^2$$

$$(4) H_{nn_O} \quad 0$$

$$(5) \text{ Stagnation enthalpy } 1.81646 \times 10^8 \text{ ft}^2/\text{sec}^2$$

C. Miscellaneous

$$(1) \text{ Crocco Integral } H = \text{constant throughout}$$

$$(2) Le_O = \sigma_O = 1$$

TABLE 2 - COMPUTATION
PARAMETERS FOR CONDITIONS AT EDGE OF VISCOUS LAYER

PRESSURE= 2.9400000E 00 LB/FT SQ DENSITY= 3.3900000E-06SLUG/CU FT TEMPERATURE= 2.8000000E 02DEGREES KELVIN
VELOCITY= 1.8900000E 04 FT/SEC TOTAL ENTHALPY= 1.8164608E 08 FT SQ/SEC SQ
ALPHA(01) = 0.
ALPHA(0N0) = 0.
ALPHA(02) = 2.3200000E-01
ALPHA(N0+) = 0.
ALPHA(N2) = 7.6799999E-01

PARAMETERS FOR INITIAL CONDITIONS AT S=0

L=1.0 H(0N0)= 0.
THETA(C)= 6.4999999E-03 L(0)= 1.0000000E 00 P(0)= 1.0000000E 02
VELOCITY= 1.3078800E 04 FT/SEC TOTAL ENTHALPY= 1.8164608E 08 FT SQ/SEC SQ
ALPHA(01) = 2.3200000E-01 ALPHA(02) = 0.
ALPHA(0N0) = 0.
ALPHA(02) = 5.6299999E-04 ALPHA(N0+) = 1.3300000E-01
ALPHA(N2) = 6.3500000E-01
ALPHA(E) = 1.0290553E-08

PARAMETERS FOR INITIAL CONDITIONS AT START OF INTEGRATION

INITIAL VALUE OF S = 0.
LIMITING VALUE OF S = 1.0000000E 03
VELOCITY= 1.3078800E 04 FT/SEC
TOTAL ENTHALPY= 1.8164608E 08 FT SQ/SEC SQ
ALPHA(01) = 2.3200000E-01 ALPHA(02) = 0.
ALPHA(0N0) = 0.
ALPHA(02) = 5.6299999E-04 ALPHA(N0+) = 1.3300000E-01
ALPHA(N2) = 6.3500000E-01
ALPHA(E) = 1.0290553E-08

DIMENSIONS OF OUTPUT

TOTAL ENTHALPY----FT SQ/SEC SQ
DENSITY-----SLUG/CU FT
PHYSICAL THICKNESS-----FT
VELOCITY-----FT/SEC
TEMPERATURE-----DEGREES KELVIN
STATIC ENTHALPY---FT SQ/SEC SQ
PARTICLES OF ELECTRONS.PART/SEC

TABLE 2a

STEP	1	S= 0.	H(NN0)= 0.	MU= 6.5113116E-07
N	PHY THICKNESS	TOTAL ENTHALPY	VELOCITY	STATIC ENTHALPY
0.	0.	1.8164608E 08	1.3078800E 04	9.6118577E 07
0.1	9.6612742E-02	1.8164608E 08	1.3383249E 04	9.2090408E 07
C-2	1.9631582E-01	1.8164608E 08	1.4131273E 04	8.1799644E 07
0-3	2.9693844E-01	1.8164608E 08	1.5106324E 04	6.7545570E 07
0-4	3.9242253E-01	1.8164608E 08	1.6133765E 04	5.1496885E 07
C-5	4.7672841E-01	1.8164608E 08	1.7080875E 04	3.5767940E 07
C-6	5.4622893E-01	1.8164608E 08	1.7856640E 04	2.2212704E 07
0-7	6.0066962E-01	1.8164608E 08	1.8412765E 04	1.213116E 07
C-8	6.4319152E-01	1.8164608E 08	1.8741663E 04	6.021140E 06
C-9	6.7921233E-01	1.8164608E 08	1.8878462E 04	3.4479240E 06
1-C	7.1399304E-01	1.8164608E 08	1.8900000E 04	3.0410800E 06
N	ALPHA101	ALPHA(021	ALPHA(N1)	ALPHA(N2)
0-	2.3200000E-01	0.	1.3390000E-01	6.3500000E-01
0-1	2.1986640E-01	1.2133600E-02	1.2604410E-01	5.4195589E-01
C-2	1.9005440E-01	4.1945598E-02	1.0895360E-01	6.5904639E-01
C-3	1.5119440E-01	8.0805597E-02	8.6676099E-02	6.8132389E-01
0-4	1.1024640E-01	1.2175359E-01	6.3201602E-02	7.0479839E-01
0-5	7.2500001E-02	1.5950000E-01	4.1562501E-02	7.2643749E-01
C-6	4.1574405E-02	1.9042559E-01	2.3833604E-02	7.4416639E-01
0-7	1.9418400E-02	2.1258160E-01	1.1132100E-02	7.5686789E-01
0-8	6.3104014E-03	2.2568960E-01	3.6176015E-03	7.6438239E-01
C-9	8.5839256E-04	2.3114161E-01	4.9209595E-04	7.6750790E-01
1-C	0.	2.3200000E-01	0.	7.6799999E-01
				0.
				ALPHA(1E1)
				5.6299999E-04
				5.355506E-04
				4.6120959E-04
				3.6690710E-04
				2.6753761E-04
				1.7593750E-04
				1.088961E-04
				1.6440673E-09
				1-C290553E-03
				9.7523563E-09
				8.4300238E-09
				6.7063533E-09
				4.8900709E-09
				3.2157978E-09
				0.

TABLE 2b

STEP 2 S = 2.0473996E 01 H(NN0) = 0.

MU = 7.4170520E-07

N	PHY THICKNESS	TOTAL ENTHALPY	VELOCITY	STATIC ENTHALPY	DENSITY	TEMPERATURE	PART CF ELEC
0.	0.	1.3164608E 08	1.3251400E 04	9.3846281E 07	8.0043803E-07	8.6852022E 02	4.41C3252E 09
C-1	1.0571165E-01	1.8164608E 08	1.3546822E 04	8.9867891E 07	7.8221983E-07	9.2129542E 02	4.-C845343E 09
0.2	2.1262335E-01	1.8164608E 08	1.4272667E 04	7.9791571E 07	7.64806222E-07	9.-74C7277E 02	3.4521070E 09
0.3	3.1803192E-01	1.8164608E 08	1.52118807E 04	6.5840033E 07	7.-9281506E-07	9.-8289996E 02	2.-8468364F 09
0.4	4.1633257E-01	1.8164608E 08	1.6215785E 04	5.0170237E 07	8.-9398060E-07	9.-1609211E 02	2.-34C7C91E 09
0.5	5.02123390E-01	1.8164608E 08	1.7134812E 04	3.-4845186E 07	1.-1013615E-06	7.-8024892E 02	1.-8963639E 09
C-6	5.7227497E-01	1.8164608E 08	1.-7887770E 04	2.-1659914E 07	1.-4696850E-06	6.-0931412E 02	1.-4511264E 09
C-7	6.-2684433E-01	1.8164608E 08	1.-8427212E 04	1.-1865008E 07	2.-0568462E-06	4.-4890969E 02	7.-4857172E 08
C-8	6.-6917431E-01	1.8164608E 08	1.-8746358E 04	5.-9331140E 06	2.-7847810E-06	3.-3777817E 02	4.-1735252E 08
C-9	7.-0424335E-01	1.8164608E 08	1.-8879100E 04	3.-4358660E 06	3.-2919193E-06	2.-8798586E 02	6.-711C411E 07
1.C	7.-3924563E-01	1.8164608E 08	1.-8900000E 04	3.-0410800E 06	3.-3905055E-06	2.-7995825E 02	0.
A	ALPHA(0)	ALPHA(1021)	ALPHA(N1)	ALPHA(N2)	ALPHA(N0)	ALPHA(N0+)	ALPHA(441E1)
C-1	2.-3059329E-01	1.-6343220E-03	1.-2258456E-01	6.-4561470E-01	1.-188896E-04	5.-3211800E-07	9.-7263634E-12
C-2	2.-1853327E-01	1.-3682446E-02	1.-1617339E-01	6.-5201545E-01	1.-1267107E-04	5.-0428823E-C7	9.-2152431E-12
C-3	1.-889C203E-01	4.-3284435E-02	1.-0042128E-01	6.-6774195E-01	9.-7393835E-05	4.-3591107E-07	7.-9683294E-12
C-4	1.-5027765E-01	8.-1870683E-02	7.-9888361E-02	6.-8824149E-01	7.-747934E-05	3.-4678131E-C7	6.-3390621L-12
C-5	1.-0957794E-01	1.-2253022E-01	5.-8252188E-02	7.-09E4249E-01	5.-6496035E-05	2.-528649E-07	4.-62222532F-12
C-6	7.-2060408E-02	1.-6001072E-01	3.-8307678E-02	7.-2975459E-01	3.-7152800E-05	1.-6628688E-07	3.-C395752E-12
C-7	4.-1322324E-02	1.-9071846E-01	2.-1967158E-02	7.-4606854E-01	2.-1304904E-05	9.-5355560E-08	1.-7435722E-12
C-8	1.-9300658E-02	2.-1271839E-01	1.-0260328E-02	7.-5775634E-01	9.-9510052E-06	4.-4538275E-08	8.-1414632E-13
C-9	8.-5318834E-04	2.-2573405E-01	3.-3343015E-03	7.-6467112E-01	3.-2337812E-06	1.-4473613E-08	2.-6457352E-13
1.C	0.-	4.-53555875E-04	7.-6754717E-01	4.-3988529E-07	1.-9688B215E-09	3.-5989441E-14	0.
A	2.-3200000E-01	0.-	7.-6799999E-01	0.-	0.	0.	0.

TABLE 2c

STEP	N	PHY THICKNESS	TOTAL ENTHALPY	VELOCITY	STATIC ENTHALPY	DENSITY	TEMPERATURE	PART OF ELEC	
								S= 8.1913937E 01	H(MNO)= 0.
0.	0.	1.8164608E 08	1.3794843E 04	8.-6497234E 07	5.-8050182E-07	1.-2574427E 03	1.-2049521E 09		
C-1	1.-2733121E-01	1.8164608E 08	1.4061842E 04	8.-2778373E 07	5.-8607040E-07	1.-2607253E 03	1.-1529873E 09		
0.2	2.-5202411E-01	1.8164608E 08	1.-4717855E 04	7.-3338448E 07	6.-1127029E-07	1.-2461929E 03	1.-639416CE 09		
0.3	3.-7000211E-01	1.8164608E 08	1.-5572969E 04	6.-0387399E 07	6.-7397569E-07	1.-1778050E 03	9.-1171295E 06		
0.4	4.-7632023E-01	1.8164608E 08	1.-6474029E 04	4.-5949264E 07	7.-9709466E-07	1.-0420835E 03	7.-8623539E 08		
0.5	5.-6683789E-01	1.8164608E 08	1.-7304638E 04	3.-1920830E 07	1.-0164723E-06	8.-5368679E 02	6.-5934359E 08		
0.6	6.-3953657E-01	1.8164608E 08	1.-7985155E 04	1.-9913172E 07	1.-3918656E-06	6.-4713013E 02	5.-1772735E 08		
0.7	6.-9525163E-C1	1.8164608E 08	1.-8472698E 04	1.-1025790E 07	1.-9910687E-06	4.-6503752E 02	3.-4592177E 08		
0.8	7.-3786731E-01	1.8164608E 08	1.-8761140E 04	5.-6558999E 06	2.-7475808E-06	3.-4266796E 02	1.-5512641E 06		
0.9	7.-7340034E-01	1.8164608E 08	1.-8881111E 04	3.-3979040E 06	3.-2850019E-06	2.-8862884E 02	2.-5229023E 07		
1.0	8.-0759324E-01	1.8164608E 08	1.-8900000E 04	3.-0410800E 06	3.-3905055E-06	2.-7995825E 02	0.-		
N	ALPHA(10)	ALPHA(1021)	ALPHA(N)	ALPHA(N2)	ALPHA(N0)	ALPHA(N0)	ALPHA(N0+)	ALPHA(1)	ALPHA(1)
0.	2.3116609E-01	9.-8246590E-04	8.-8854264E-02	6.-7927578E-01	2.-1494215E-04	2.-0043641E-07	3.-6643805E-12		
0.1	2.-1907610E-01	1.-30646682E-02	8.-4207186E-02	6.-8391605E-01	2.-0370067E-04	1.-8995359E-07	3.-4727334E-12		
0.2	1.-8937126E-01	4.-2750434E-02	7.-2789413E-02	6.-9531711E-01	1.-7608061E-04	1.-6419751E-07	3.-0C186255E-12		
0.3	1.-5065094E-01	8.-1445869E-02	5.-7906324E-02	7.-1017842E-01	1.-4007780E-04	1.-3062441E-07	2.-3880753E-12		
0.4	1.-0985013E-01	1.-2222046E-01	4.-2223548E-02	7.-2583824E-01	1.-0214051E-04	9.-5247387E-08	1.-7413137E-12		
0.5	7.-2239404E-02	1.-5980701E-01	2.-7766958E-02	7.-4027367E-01	6.-7169423E-05	6.-2636331E-08	1.-1451170E-12		
0.6	4.-1424969E-02	1.-9060165E-01	1.-5922687E-02	7.-521062E-01	3.-8517639E-05	3.-5918210E-08	6.-5665709E-13		
0.7	1.-9348601E-02	2.-1266383E-01	7.-4371015E-03	7.-6057378E-01	1.-7990656E-05	1.-6777527E-08	3.-0670855E-13		
0.8	6.-2877200E-03	2.-2571632E-01	2.-4168370E-03	7.-6558669E-01	5.-8464283E-06	5.-4518718E-09	9.-9671193E-14		
0.9	8.-5530802E-04	2.-3114524E-01	3.-2875780E-04	7.-6767172E-01	7.-9528036E-07	7.-4160944E-10	1.-3553111E-14		
1.0	0.-	2.-3200000E-01	0.-	7.-6799999E-01	0.-	0.-	0.-		

TABLE 2d

STEP	10	S= 1.8431376E-02	H(MNO)= 0.	MU= 1.1144444E-06
N	PHY THICKNESS	TOTAL ENTHALPY	VELOCITY	STATIC ENTHALPY
0.	0.	1.8164608E 08	1.4611056E 04	7.4904596E 07
C. 1	1.5378478E-01	1.8164608E 08	1.4835368E 04	7.1602008E-07
0-2	3.0122093E-01	1.8164608E 08	1.5386497E 04	6-3273931E 07
0-3	4.3657628E-01	1.8164608E 08	1.6104895E 04	5-1962253E 07
0-4	5.5515978E-01	1.8164608E 08	1.6861894E 04	3-9484350E 07
0-5	6.5387564E-01	1.8164608E 08	1.7559705E 04	2-7474460E 07
0-6	7.3181024E-C1	1.8164608E 08	1.8131421E 04	1-7271864E 07
0-7	7.9069844E-01	1.8164608E 08	1.8541015E 04	9-7614559E 06
0-8	8.35166336E-01	1.8164608E 08	1.8783340E 04	5-2391400E 06
0-9	8-7189728E-01	1.8164608E 08	1.8884131E 04	3-3408820E 06
1-0	9.0716773E-01	1.8164608E 08	1.8900000E 04	3-0410800E 06
				3-3905055E-06
				2-7995825E 02
PART OF ELEC				
TEMPERATURE				
1-6763062E 03				
1-6448236E 03				
1-6596832E-07				
1-5509107E 03				
1-5314825E 08				
1-8968879E 03				
4-3917533E 08				
3-7960043E 08				
3-0505372E 08				
2-0784456E CB				
2-4759939E 07				
1-5561040E 07				
0.				0.
ALPHA(E)				
1-23838B3E-07				
1-1736206E-07				
1-0144877E-07				
8-0705769E-08				
1-4755792E-12				
1-0759472E-12				
7-0756225E-13				
4-0574454E-13				
1-8951342E-13				
6-1586234E-14				
8-3776675E-15				
0.				0.
ALPHA(N0+)				
5-6154516E-04				
5-3217635E-04				
4-6001779E-04				
3-6595898E-04				
2-6684627E-04				
1-5484945E-01				
1-7548287E-04				
1-0062488E-04				
7-60021922E-08				
1-03653130E-08				
3-3684184E-09				
4-5820059E-10				
0.				0.
ALPHA(N0)				
7-2591827E-01				
7-2811914E-01				
7-3352664E-01				
7-4057533E-01				
7-4800276E-01				
7-5287609E-01				
7-6084789E-01				
7-6447775E-01				
7-6685537E-01				
7-6784430E-01				
2-3200000E-01				
7-6799999E-01				

TABLE 2c

STEP 16 S= 3.0719336E 02 HINNO= 0.

MU= 1.2160996E-06

STEP	PHY THICKNESS	TOTAL ENTHALPY	VELOCITY	STATIC ENTHALPY	DENSITY	TEMPERATURE	PART OF ELEC
C.	1.8164608E 08	1.5362315E 04	6-3645711E 07	4-0543029E-07	1-9391573E 03	4-2289822E 03	
0.1	1-7604986E-01	1-8164608E 08	1-5547336E 04	6-0786245E 07	4-2111437E-07	1-8838548E 03	4-1628484E 03
C.2	3-4327505E-C1	1-8164608E 08	1-6001929E 04	5-3615217E 07	4-6738331E-07	1-7360179E 03	3-9937677E 03
0.3	4-9467807E-01	1-8164608E 08	1-6594491E 04	4-3957516E 07	5-5134612E-07	1-5166699E 03	3-7479320E 03
0.4	6-2549970E-01	1-8164608E 08	1-7218892E 04	3-3400958E 07	6-9125438E-07	1-2499979E 03	3-4263689E 03
0.5	7-3316627E-01	1-8164608E 08	1-7794473E 04	2-3324440E 07	9-229406E-07	9-6654751E 02	3-0C63470E 03
C.6	8-1744391E-01	1-8164608E 08	1-8266046E 04	1-4821852E 07	1-3068309E-06	7-0311714E 02	2-4427394E 03
C.7	8-8073323E-01	1-8164608E 08	1-8603896E 04	8-5936120E 06	1-9213184E-06	4-8560847E 02	1-6774301E 03
0.8	9-2832366E-01	1-8164608E 08	1-8803775E 04	4-8551060E 06	2-7091375E-06	3-4840496E 02	7-6863432E 07
C.9	9-6755468E-01	1-8164608E 08	1-8886911E 04	3-2883840E 06	3-2779288E-06	2-8935113E 02	1-25500815E 02
1.0	1-0052327E 00	1-8164608E 08	1-8900000E 04	3-0410800E 06	3-3905055E-06	2-7995825E 02	0-
N	ALPHA(0)	ALPHA(102)	ALPHA(101)	ALPHA(102)	ALPHA(101)	ALPHA(100)	ALPHA(100)
C.0	2-2486548E-01	5-8058574E-03	4-1700652E-03	7-6266677E-01	2-83586668E-03	1-0071510E-07	1-5-14250E-12
C.1	2-1310501E-01	1-7635811E-02	3-9519708E-03	7-6294569E-01	2-6856556E-03	9-5447701E-08	1-7451135E-12
C.2	1-8420980E-01	4-6701757E-02	3-4161174E-03	7-6363102E-01	2-3215037E-03	8-2505810E-08	1-5084954E-12
C.3	1-4654483E-01	8-4589274E-02	2-7176315E-03	7-6452433E-01	1-8468311E-03	6-5636032E-08	1-2003567E-12
C.4	1-6685608E-01	1-2451254E-01	1-9816151E-03	7-6546585E-01	1-3466536E-03	4-7859818E-08	8-7504522E-13
C.5	7-0270466E-02	1-6131433E-01	1-3031454E-03	7-6633336E-01	8-8558341E-04	3-1473470E-08	5-7544534E-13
C.6	4-0295901E-02	1-9146600E-01	7-4727580E-04	7-6704428E-01	5-0782901E-04	1-8048149E-08	3-2995342E-13
C.7	1-8821239E-02	2-1306755E-01	3-4903444E-04	7-675360E-01	2-3719465E-04	8-4298540E-09	1-5412727E-13
0.8	6-1163436E-03	2-2584751E-01	1-1342583E-04	7-6785493E-01	7-7081203E-05	2-7394522E-09	5-0086779E-14
0.9	8-3199515E-04	2-3116308E-01	1-5429105E-05	7-6798026E-01	1-0485237E-05	3-7264325E-10	6-8132349E-15
1.0	0-	2-3200000E-01	0-	7-6799999E-01	0-	0-	0-

TABLE 2f

STEP	$S = 6.1439093E-02$	$H(NNO) = 0.$	$\mu_u = 1.0947830E-06$	PHY THICKNESS	TOTAL ENTHALPY	VELOCITY	STATIC ENTHALPY	DENSITY	TEMPERATURE	PART OF ELEC
C.	1.8164608E-08	1.6404286E-04	4.7095776E-07	5.0877311E-07	1.6278890E-03	2.9079275E-08				
C. 1	1.8164608E-08	1.6534812E-04	4.4946076E-07	5.2912482E-07	1.5757790E-03	2.86660809E-08				
C. 2	1.8164608E-08	1.6855511E-04	3.9591952E-07	5.8831028E-07	1.4410096E-03	2.7545827E-08				
0.2	1.8164608E-08	1.7273543E-04	3.2458434E-07	6.9334045E-07	1.2500339E-03	2.5825795E-08				
0.3	1.8164608E-08	1.7714037E-04	2.4752534E-07	8.6370949E-07	1.0276518E-03	2.3458680E-08				
0.4	1.8164608E-08	1.8120089E-04	1.7477262E-07	1.1352774E-06	7.9959759E-02	2.0277353E-08				
0.5	1.8164608E-08	1.8452768E-04	1.1393760E-07	1.5619529E-06	5.9220018E-02	1.5997920E-08				
0.6	1.8164608E-08	1.8691109E-04	6.9673100E-06	2.1787233E-06	4.3040605E-02	1.0422862E-08				
0.7	1.8164608E-08	1.8832116E-04	4.3217760E-06	2.8681371E-06	3.2963689E-02	4.4589071E-07				
0.8	1.8164608E-08	1.8890766E-04	3.2155640E-06	3.3083314E-06	2.8675704E-02	6.9962873E-06				
0.9	1.8164608E-08	1.8900000E-04	3.0410800E-06	3.3905055E-06	2.795825E-02	0.				
1.0	1.8164608E-08	1.8900000E-04	3.0410800E-06	3.3905055E-06	2.795825E-02	0.				
				ALPHA(N)	ALPHA(N2)	ALPHA(N0)	ALPHA(N0+1)	ALPHA(E)		
				0.84461441E-08	7.6653276E-01	3.3843791E-03	5.5181972E-08	1.090051E-12		
				8.0044106E-08	7.6660950E-01	3.2073761E-03	5.229555E-08	9.5623511E-13		
				9.8107184E-02	6.9190813E-06	2.7724834E-03	4.5205072E-08	8.2657783E-13		
				1.2548395E-01	5.5043522E-08	7.6704380E-01	2.2055999E-03	6.5756931E-13		
				1.5433170E-01	4.0136079E-08	7.6730276E-01	1.6082570E-03	2.6222474E-08		
				1.6092394E-01	2.6394201E-08	7.6754148E-01	1.0576185E-03	1.7244367E-08		
				2.0271094E-01	1.5135493E-08	7.6773707E-01	6.0648084E-04	9.8886107E-09		
				2.1631979E-01	7.0694224E-09	7.6787719E-01	2.8327253E-04	4.6187311E-09		
				2.2755434E-01	2.2973525E-09	7.6796008E-01	9.2055153E-05	1.5009500E-09		
				2.3139526E-01	3.1250469E-10	7.6799456E-01	1.2522098E-05	2.0417179E-10		
				2.3200600E-01	0.	7.6799999E-01	0.	0.		

TABLE 2g

STEP 50 S= 1.0004340E 03 H(NN0)= 0.

N	PHY THICKNESS	TOTAL ENTHALPY	VELOCITY	STATIC ENTHALPY	DENSITY	TEMPERATURE	PART OF ELEC
0-	0.	1.8164608E 08	1.-7013829E 04	3.-6910886E 07	6.-2227910E-07	1.-3739893E 03	2.-0113701E 08
0- 1	1.8978921E-01	1.-8164608E 08	1.-7112476E 04	3.-5227666E 07	6.-4679759E-07	1.-3288013E 03	1.-9812809E 08
0- 2	3.-7010485E-01	1.-8164608E 08	1.-7354849E 04	3.-1050692E 07	7.-1753719E-07	1.-2133525E 03	1.-8999455E 08
0- 3	5.-3384699E-01	1.-8164608E 08	1.-7670782E 04	2.-5517804E 07	8.-4127729E-07	1.-0527031E 03	1.-7721222E 08
0- 4	6.-7666391E-01	1.-8164608E 08	1.-8003692E 04	1.-9579624E 07	1.-0377572E-06	8.-6916211E 02	1.-5939657E 08
0- 5	7.-9659712E-01	1.-8164608E 08	1.-8310571E 04	1.-4007566E 07	1.-3405909E-06	6.-8448075E 02	1.-3541074E 08
0- 6	8.-9418443E-01	1.-8164608E 08	1.-8561998E 04	9.-3721960E 06	1.-7896973E-06	5.-2010101E 02	1.-0365316E 08
0- 7	9.-7267853E-01	1.-8164608E 08	1.-8742127E 04	6.-0124100E 06	2.-3831448E-06	3.-9465803E 02	6.-4473709E 07
0- 8	1.-0378338E 00	1.-8164608E 08	1.-8848696E 04	4.-0094100E 06	2.-9790674E-06	3.-1767127E 02	2.-6191254E 07
0- 9	1.-0966629E 00	1.-8164608E 08	1.-8895021E 04	3.-1729600E 06	3.-3278624E-06	2.-8511192E 02	3.-9793796E 06
1- 0	1.-1551583E 00	1.-8164608E 08	1.-8900000E 04	3.-0410800E 06	3.-3905055E-06	2.-7995825E 02	C.
N	ALPHA(0)	ALPHA(02)	ALPHA(N)	ALPHA(N2)	ALPHA(N0)	ALPHA(N0*)	ALPHA(E)
0-	1.-2201345E-01	1.-0872027E-01	5.-0316869E-09	7.-6689145E-01	2.-5572038E-03	3.-1202443E-08	5.-7061234E-13
0- 1	1.-1563215E-01	1.-1516780E-01	4.-7685297E-09	7.-6694942E-01	2.-4234620E-03	2.-957055E-08	5.-40765931E-13
0- 2	9.-9953420E-02	1.-3100925E-01	4.-1219579E-09	7.-6709187E-01	2.-0948613E-03	2.-9561041E-08	4.-6744562E-13
0- 3	7.-9516168E-02	1.-5165860E-01	3.-2791504E-09	7.-6727755E-01	1.-6665297E-03	2.-0334632E-08	3.-7186806E-13
0- 4	5.-7980795E-02	1.-7341747E-01	2.-3910578E-09	7.-6747321E-01	1.-2151833E-03	1.-4827402E-08	2.-7115502E-13
0- 5	3.-8129205E-02	1.-9347508E-01	1.-5724022E-09	7.-6765357E-01	7.-9912621E-04	9.-7507639E-09	1.-7831636E-13
0- 6	2.-1864814E-02	2.-0990827E-01	9.-0167844E-10	7.-6780134E-01	4.-5825098E-04	5.-5914786E-09	1.-C225375E-13
0- 7	1.-0212526E-02	2.-2168148E-01	4.-2115217E-10	7.-6790721E-01	2.-1403775E-04	2.-6116444E-09	4.-7760251E-14
0- 8	3.-3187670E-03	2.-2864679E-01	1.-3686197E-10	7.-6796983E-01	6.-9555972E-05	8.-4870688E-10	1.-5520666E-14
0- 9	4.-5144651E-04	2.-3154387E-01	1.-8617108E-11	7.-6799589E-01	9.-4615679E-06	1.-1544809E-10	2.-1112466E-15
1- 0	0.	2.-3200000E-01	0.	7.-6799999E-01	0.	0.	0.

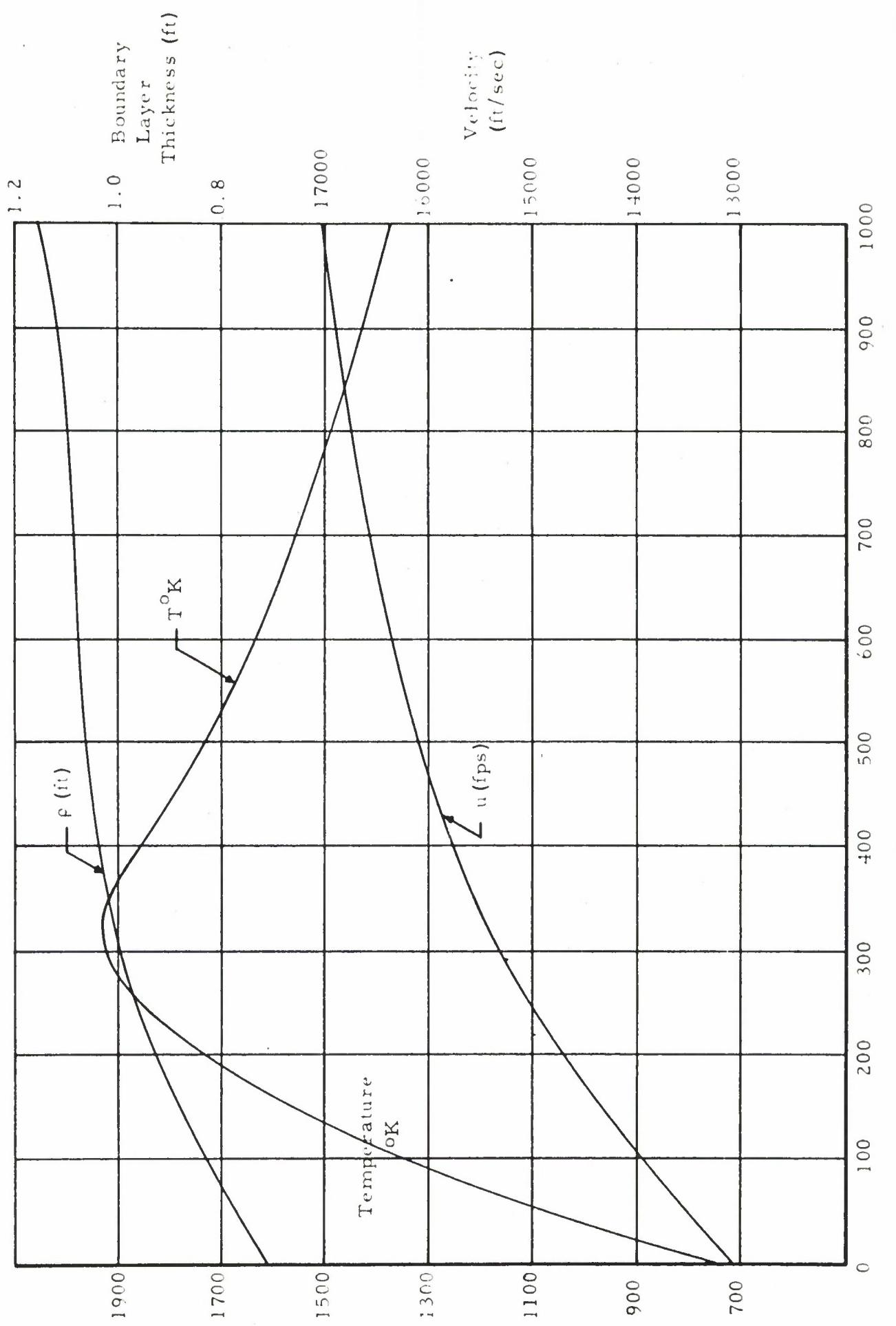
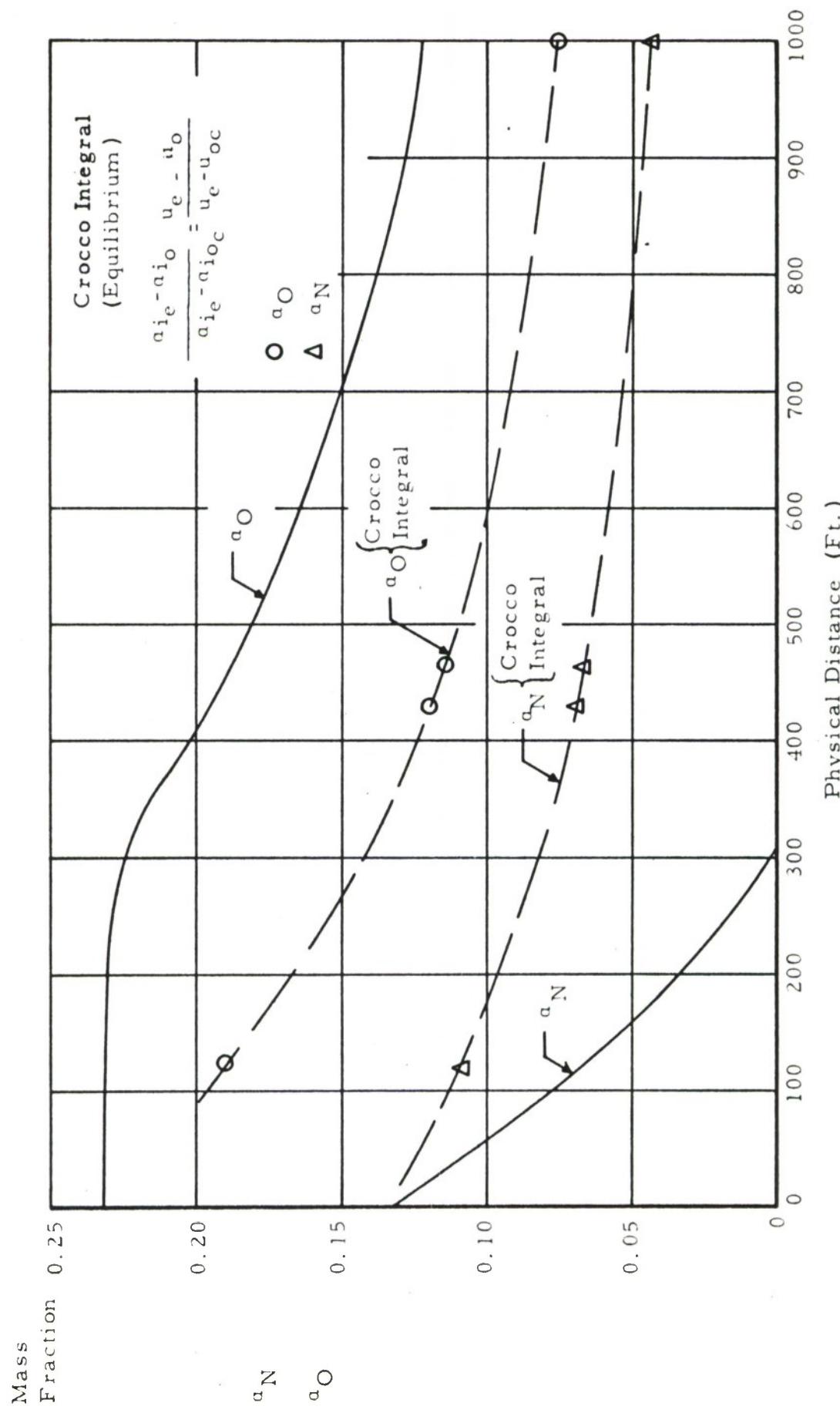


Figure 1a. Distribution of Temperature, Velocity and Physical Boundary Layer Thickness Along the Axis.



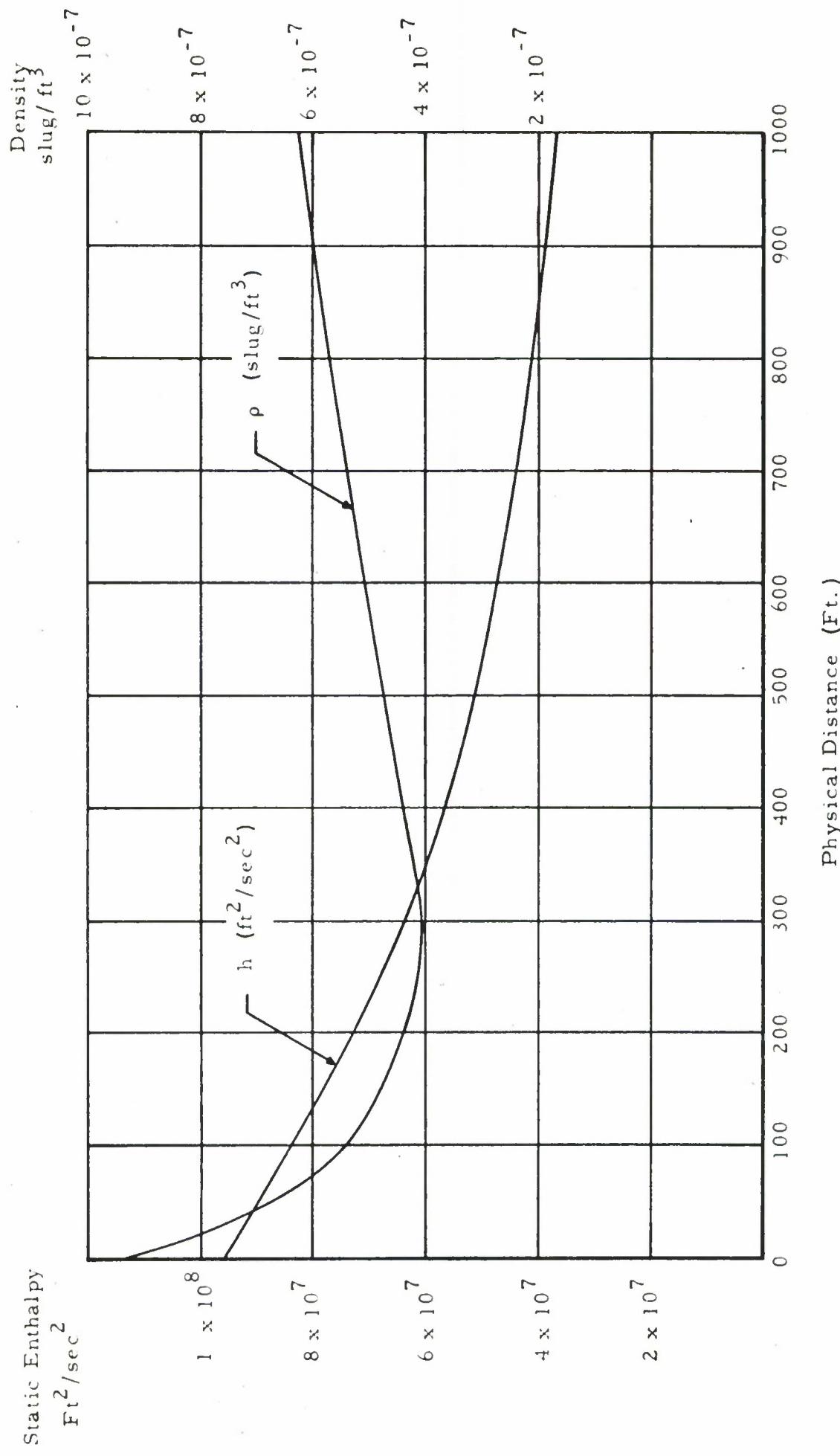


Figure 1 c. Distribution of Enthalpy and Density Along the Axis

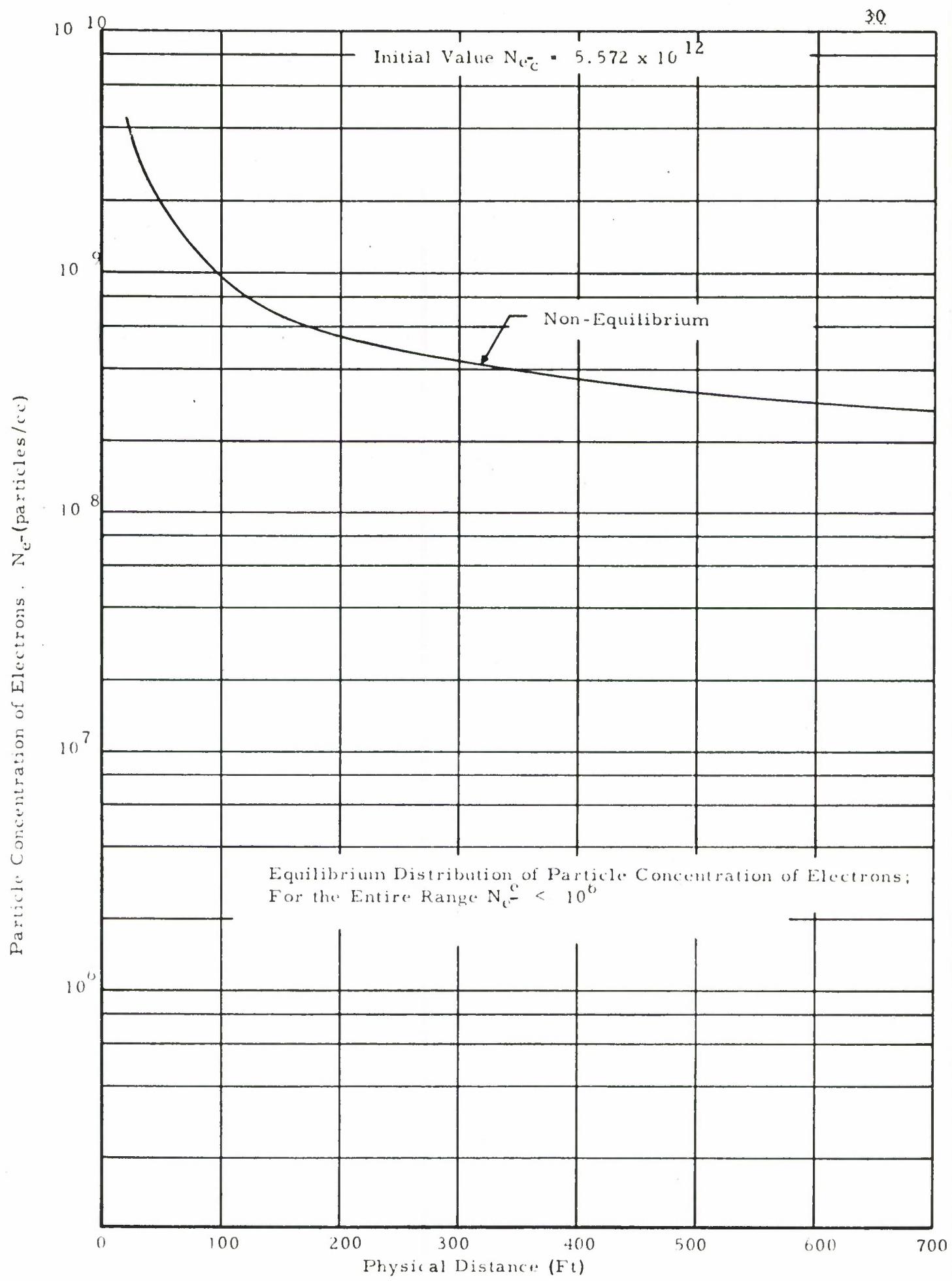


Figure 1d. Particle Concentration of Electrons Along the Axis