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by Paul W. Huber

Langley Research Center

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SUMMARY

Real-air hypersonic-flow parameters are presented in tabular and graphical form for flight in the earth's atmosphere as a function of flight velocity and flight altitude. Thermochemical equilibrium-flow properties are given for the inviscid normal shock and stagnation point, and both equilibrium and frozen-flow parameters, including electron concentration, are listed for the far wake of the inviscid stagnation streamline. Plots of electron collision frequency and electrical conductivity in the normal shock and wake plasmas are also included. The tabulations are made for twelve flight altitudes, ranging from 35,900 feet to 322,900 feet and for flight velocities and shock-heated gas temperatures encompassing those encountered in return from planetary missions. Included are discussions of the applicability of the computed parameters to a given problem, and effects due to the uncertainties in the input data for ambient air.

INTRODUCTION

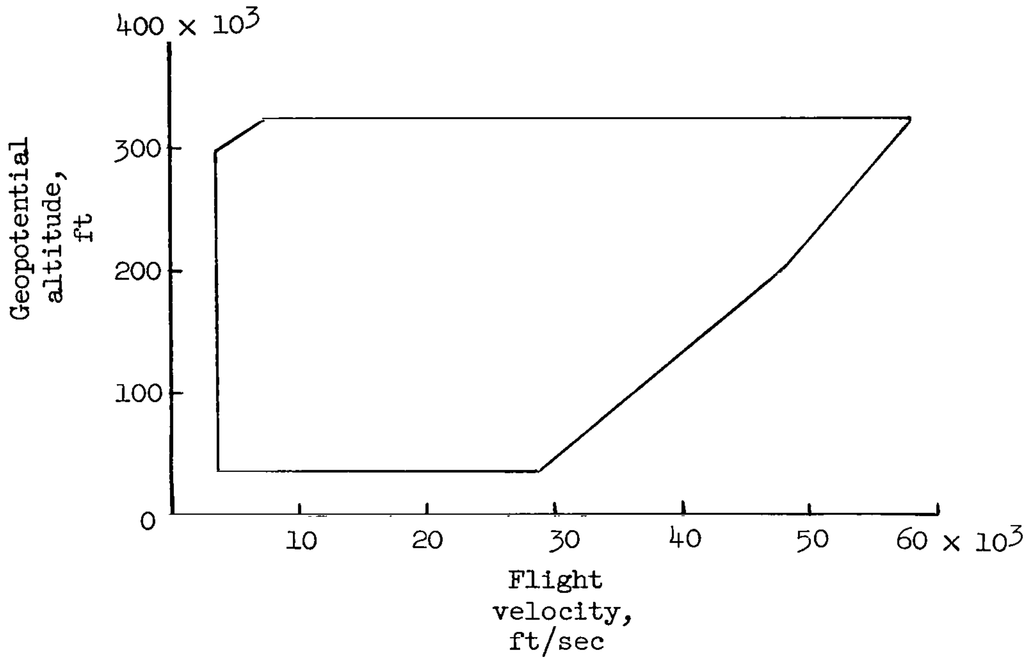
For many problems in hypersonic aerodynamics, radio communications, and radar tracking which are associated with missions involving flight of bodies at high velocity, the complete distribution of flow-field properties about the vehicle and in the wake must be known. The flight of bodies in the earth's atmosphere at speeds greater than approximately 6,000 feet per second (about 1,800° K) entails a regime of thermodynamics in which the composition of the gas in the region of the body is not fixed at the ambient-air value. This so-called real-gas thermodynamic regime, due to compressive and viscous heating of the gas to high temperature, results in much additional complexity to the flow computation since a wide variety of chemical reactions can occur among the heated species of an air mixture and thus can contribute to the nonideal nature of the thermodynamics and determination of the concentration of important species. However, a number of detailed and comprehensive computational programs have been reported in the literature in which the equilibrium thermodynamic properties of high-temperature air are precisely determined and tabulated. (For example, see refs. 1 to 5.) For the most general application to high-temperature air problems, the above-referenced data, as well as most of such data found in the literature, are tabulated in terms of independent values of two gas-state parameters, usually density ρ and temperature T.

In order then to determine the air-flow properties in the region about a hypersonic body, these real-gas thermodynamic data are used, along with the equations of motion and the conservation equations and iterative solutions are obtained from computer programs. Such procedures are complex and time consuming to program for the complete flow about the body and are applicable only to the particular body shape, velocity, and altitude for which the problem was planned. However, certain portions of the flow fields about hypersonic bodies are independent of the body shape for equilibrium flow and may be characterized in terms of only the flight parameters, velocity and altitude. Such regions include the normal-shock flow, the inviscid stagnation-point flow, the inviscid normal-shock-flow streamline in the far wake, and the oblique-shock flow and corresponding far-wake streamline providing the shock angle is known. "Frozen-flow" far wakes also fall in this category. Tabulation of properties of such real-gas flow regions is generally useful and desirable. For direct applicability to problems involving flight in the earth's atmosphere, it is thus desirable that such tabulation be in terms of independent values of the flight parameters (velocity and altitude) rather than the gas-state parameters ρ and T. This approach avoids the inconvenience of the double interpolation required to apply the density-temperature data to given altitude and velocity conditions, since the earth's atmosphere does involve a specific temperature and density combination. The purpose of the present work is to present such tabulations.

Tabulations and charts were presented in reference 6 for the normal-shock flow properties in terms of flight velocity and altitude for a limited number of altitudes and velocity range. Reference 7 presents tabulated normal-shock parameters and gas composition for many altitudes over a velocity range limited to satellite velocity. Charts for normal and oblique shocks are given in reference 8 for a similar velocity range. Because of the increased emphasis on the higher velocity and higher altitude flights of bodies in missions under current consideration (for example, the return at hyperbolic velocity of vehicles from lunar and planetary missions), the work of references 6 to 8 and others no longer has adequate range for application to many of these problems.[1]

[1]Subsequent to completion of the computations and final draft of the text that follows, reference 9 became available and is found to contain, in general, the same type of material as the present work. Comparison of the two reports has been made and the following comments are offered: the parameters common to both agree within the accuracy limitations respectively specified, consideration being given to slight differences in altitudes in many cases. As is the case in reference 7, however, the stagnation-temperature computation in reference 9 is made by use of a very approximate method, which results in errors of over 50 percent in the temperature rise $(T_s - T_2)$ but is within the stated accuracy of 1 percent of T_2. The present work contains many parameters and plots not found in reference 9; on the other hand, reference 9 presents equilibrium composition of the normal shock gas, which is not given herein.

The present work provides tabulated hypersonic-flow properties, including electron concentration, in terms of velocity and altitude for the aforementioned characteristic regions about a body in flight in the earth's atmosphere over a large range of flight conditions shown in the following figure.



The range of flight velocities is such as to encompass those beginning where flow tabulations for $\gamma = 1.40$, such as those of reference 10, cease to be applicable (that is, about 3,500 feet per second) up to values corresponding to reentry from planetary missions. This range is obtained by using thermodynamic input data (ref. 4) over the temperature range of 800° K through $14,000^\circ$ K. The range of flight altitudes selected is such as to include that region of the earth's atmosphere wherein it is believed that significant aerodynamic forces or thermal influences of the atmosphere, with respect to the design requirements of the mission, will be experienced by a body in flight. In view of the nature of the atmospheric property variations (ref. 11), twelve altitudes ranging from 36,000 to 323,000 feet are used.

SYMBOLS

a velocity of sound, ft/sec

$\bar{c}_e$ mean thermal electron velocity, cm/sec

D	dissociation energy per mole
f	signal frequency, per sec
f_p	plasma frequency, $8{,}970\sqrt{N_e}$, sec^{-1} (critical frequency)
g	acceleration due to gravity
H	enthalpy per mole
h	enthalpy per unit mass, $\frac{H}{m}$
J	parameter defined in equation (12)
$K(\ )$	ratio of the real-gas to the ideal-gas value of the bracketed parameter for the given M_1
m	molecular weight per mole
M	Mach number, $\frac{u}{a}$
n_0	Lochschmidt's number
N	specie particle concentration, per cm^3
p	pressure
Q	effective cross-section for momentum exchange with electron, cm^2
Q_c	coulomb (ion) cross-section for momentum exchange with electron, cm^2
$\overline{Q}_n$	average effective neutral cross section for momentum exchange with electron, cm^2
R	gas constant per mole (universal)
s	entropy per unit mass, $\frac{S}{m}$
S	entropy per mole
S^o	entropy at standard pressure per mole
T	temperature, ^oK or ^oR
u	fluid velocity, ft/sec
V	volume per mole

x	specie mole fraction, $\sum_i x_i = 1.0$
Z	compressibility factor, $\frac{m_0}{m}$
α	mole fraction of oxygen photodissociated
γ	specific heat ratio
$\gamma_{T,p}$	parameter defined in equation (12)
γ^*	isentropic exponent (eq. (7))
ρ	mass density, $\frac{m}{V}$
σ	electrical conductivity, sec^{-1} (esu) or mho/cm
ν	electron collision frequency
ω	angular signal frequency, $2\pi f$, radians/sec
ω_p	angular plasma frequency, $2\pi f_p$, radians/sec

Subscripts:

0	standard conditions ($p = 1$ atmosphere, T = ice point)
1	ambient conditions
2	behind normal shock
a	dissociated atoms
dc	direct current ($\omega = 0$)
e	electron
i	species in mixture
OA	oxygen in standard air
s	stagnation behind shock
t	total
w	wake, equilibrium inviscid flow
fw	frozen wake, inviscid flow

METHOD OF COMPUTATION

Normal Shock

The computation of the normal-shock flow properties follows that of reference 6 in which the conservation equations for mass, momentum, and energy are used:

$$\rho_1 u_1 = \rho_2 u_2 \tag{1}$$

$$p_1 + \rho_1 u_1{}^2 = p_2 + \rho_2 u_2{}^2 \tag{2}$$

$$h_t = h_1 + \frac{u_1{}^2}{2} = h_2 + \frac{u_2{}^2}{2} \tag{3}$$

along with the equation of state

$$\frac{p}{\rho} = \frac{ZRT}{m_0} \tag{4}$$

Solution of these equations results in the following relation:

$$\left(\frac{p_2}{p_0} - \frac{p_1}{p_0}\right)\left(\frac{1}{\rho_1/\rho_0} + \frac{1}{\rho_2/\rho_0}\right) = 2\left(\frac{h_2}{\frac{R}{m_0} T_0} - \frac{h_1}{\frac{R}{m_0} T_0}\right) \tag{5}$$

since $Z_0 = 1.0$.

For given input values of $h_1\Big/\frac{R}{m_0} T_0$, p_1/p_0, and ρ_1/ρ_0 (corresponding to ambient-air properties at a given altitude), and for a given value of T_2, equation (5) is iterated until the solutions for $h_2\Big/\frac{R}{m_0} T_0$, ρ_2/ρ_0, and p_2/p_0 are consistent also with the thermodynamic air properties at this temperature. The ambient-air properties as a function of altitude are taken from reference 11 and are listed in table I. The thermodynamic properties for high-temperature air are taken from reference 4, and interpolation of these tables to satisfy equation (5) is accomplished by linear interpolation of the logarithms of ρ_2/ρ_0, p_2/p_0, and $h_2\Big/\frac{R}{m_0} T_0$ at a given temperature.

The flight velocity u_1 is then found by substitution into equations (1) and (2) or (3) the total enthalpy $h_t/\frac{R}{m_0} T_0$ from equation (3), and the flight Mach number M_1 is found by using the values for a_1 listed in table I and taken from reference 11. The velocity u_2 is not tabulated but is readily found from equation (1). The compressibility factor Z_2 and the entropy $s_2/\frac{R}{m_0}$ are found by interpolation of the air tables (ref. 4). The ratios of real-gas to ideal-gas parameters K( ) are found by using ideal-gas values from reference 10 for the same value of flight Mach number M_1.

The velocity of sound behind the normal shock a_2 is found from interpolation of values for a_2 listed in reference 5 as a function of temperature and density. The computation of velocity of sound in reference 5 is made by using the following relations:

$$a^2 = \gamma^* \frac{p}{\rho} = \gamma^* \frac{R}{m_0} TZ \tag{6}$$

$$\gamma^* = \left(\frac{\partial \log p}{\partial \log \rho}\right)_s \tag{7}$$

The isentropic exponent γ^* is found in reference 5 by use of a spline fit method for obtaining slopes (eq. (7)) from the tabulated thermodynamic data. The basic data used were those of reference 4. It is to be particularly noted that the exponent γ^* is not to be confused with the ratio of specific heats γ. These parameters become identical only for the case of a nonreacting gas, such as air below temperatures of about 1,800° K. This exponent γ^* is also different from the "effective" specific-heat ratio for shock density ratio found in references 7 and 12. The isentropic exponent for air may also be found from a plot in reference 13. This parameter was taken from interpolation of the data of reference 5.

The electron concentration $N_{e,2}$ is computed from the following relation:

$$N_{e,2} = x_{e,2} n_0 \frac{p_2/p_0}{T_2/T_0} = x_{e,2} n_0 Z_2 \frac{\rho_2}{\rho_0} \tag{8}$$

where $x_{e,2}$ is the electron mole fraction and is taken from plots of x_e as a function of ρ/ρ_0 and T. These x_e data were taken from reference 3 for the temperature range 3,000° K to 10,000° K, since the more accepted value for NO ionization energy is used in reference 3. For temperatures below 3,000° K, the data of reference 14 were used, and for temperatures above 10,000° K, cross plots of the data of references 1 and 3 were used. It should be noted that T_0 and ρ_0 in reference 3 are slightly different from those used herein.

Stagnation Point

The stagnation-point pressure was computed on the basis of an incompressible total pressure for the normal-shock flow:

$$\frac{p_s}{p_2} = \frac{p_2 + \frac{1}{2}\rho_2 u_2^2}{p_2} \tag{9a}$$

and with a further approximation for $p_1 \ll p_2$:

$$\frac{p_s}{p_2} \approx \frac{\frac{\rho_2}{\rho_1} - \frac{1}{2}}{\frac{\rho_2}{\rho_1} - 1} \tag{9b}$$

Equation (9a) can be expressed in terms of the flight parameters and shock-density ratio in the relation

$$\frac{p_s}{p_1} = 1 + \gamma_1 M_1^2\left(1 - \frac{1}{2}\frac{\rho_1}{\rho_2}\right) \tag{10}$$

These relations were obtained by using also equations (1), (2), (4), and (6). Although equations (9) and (10) are not precisely correct for this compression process, they are numerically convenient, and the results are at least as accurate as can be obtained by reading a Mollier air chart using $h_t \Big/ \frac{R}{m_0} T_0$ and $s_2 \Big/ \frac{R}{m_0}$, the correct method, and more accurate than can be obtained in the case of Newtonian impact pressure from equation (2).

The stagnation-point temperature is again computed from an approximate relation which is numerically convenient and superior to chart reading. This relation

$$\frac{T_s}{T_2} \approx 1 + \frac{J}{2\left(\frac{\rho_2}{\rho_1} - 1\right)} \tag{11}$$

is obtained by using equation (9b) and assuming that the relation

$$J = \frac{\gamma_{T,p} - 1}{\gamma_{T,p}} = \left(\frac{\partial \log_e T}{\partial \log_e p}\right)_s \tag{12}$$

is the constant exponent for the compression from normal shock to stagnation in the following isentropic process:

$$\left.\begin{aligned} & T \propto p^J \\ & \frac{\Delta p}{p} \ll 1.0 \\ & \frac{\Delta T}{T} \ll 1.0 \end{aligned}\right\} \tag{13}$$

The parameters $\gamma_{T,p}$ and J are tabulated in reference 15 for argon-free air and $\gamma_{T,p}$ is plotted herein for illustration.

It should be noted that equation (11) is obtained by using an effective constant value of local specific heat for the process J^{-1}. In reference 7 the computation was made on the assumption that the effective value of specific heat for the process was the nondimensional enthalpy (that is, H/RT). However, this assumption leads to errors in some cases of over 50 percent in the temperature change $\left(T_s - T_2\right)$ for the process, since if only the local specific heat is constant, $\frac{dH}{dT} \neq \frac{H}{T}$ for the case of real air.

Equilibrium Wake

Tabulations are included also for conditions in the far wake of a body for the case of the normal-shock streamline isentropically expanded to ambient pressure, in thermochemical equilibrium and without viscosity. Values of the density ρ_w and temperature T_w were found by plotting the thermodynamic air data of reference 4 in the form p/p_0 as a function of $s\Big/\frac{R}{m_0}$ and reading ρ_w/ρ_0 and T_w at values of the ambient pressure p_1/p_0 and the normal-shock entropy $s_2\Big/\frac{R}{m_0}$, which is the entropy appropriate to this expansion. The values of $x_{e,w}$ for the wake were found from the plots of x_e as a function of ρ/ρ_0, by reading $x_{e,w}$ at values of ρ_w/ρ_0 and T_w (the wake conditions). Values of $N_{e,w}$ were computed from equation (8) rewritten in terms of the wake parameters $x_{e,w}$, p_1/p_0, and T_w/T_0.

Frozen Wake

Computation of an inviscid frozen-wake temperature T_{fw} and electron concentration $N_{e,fw}$ was obtained by the following approximate method: The gas composition was assumed to be frozen at the normal-shock equilibrium value and was then expanded isentropically from normal-shock pressure p_2/p_0 to the far-wake ambient pressure p_1/p_0 by using an effective specific heat for the non-reacting gas mixture (which is, of course, far from an equilibrium composition in the wake) in which the internal energies of the species are assumed to be in equilibrium with the temperature.

The effective specific heat for the process was taken as an average between the initial (shock) and iterated final (wake) values, these temperature-dependent values being computed without regard to reaction energies (since they do not take part in the process) but with the internal energies assumed in equilibrium (coupled) with the translational temperature. The electron concentration $N_{e,fw}$ was then found from equation (8), by use of the wake temperature T_{fw}, pressure p_1/p_0, and the normal-shock electron mole fraction $x_{e,2}$, since the composition was frozen at this value.

RESULTS

The computations were carried out according to the methods previously presented for a range of altitudes from 35,900 to 322,900 geopotential feet. Twelve altitudes were selected and include the six altitudes at the boundaries of the three isothermal layers of the earth's homosphere. The ambient properties as a function of altitude were taken from reference 11, except for enthalpy and entropy which were taken from reference 16 for pressure altitudes up to 294,800 feet, and for enthalpy, entropy, and sound velocity at 322,900 feet which were computed by the methods given in the appendix. These ambient properties are listed in table I and are plotted in figures 1 to 4. Figure 5 is presented to show the comparison of ambient properties from reference 11 (1959 ARDC model atmosphere) with the previous model atmosphere (ref. 17), and with a proposed revision to the model. (See table II and refs. 18 and 19.) A list of constants for use with the tables is given in table III.

The results of the hypersonic-flow-property computations are given in table IV, where the parameters at each selected altitude are tabulated at 33 temperatures for the range from 800° K to 14,000° K. Table IV lists 33 parameters including those for normal-shock, stagnation point, and wake conditions for equilibrium and frozen inviscid flow. The parameters tabulated include, in addition to the thermal properties and sound and flow velocities, the electron concentrations for equilibrium and frozen flows. These latter parameters are useful in plasma computations such as those used for the radio-transmission problem. Some of the more widely used thermodynamic parameters from table IV are plotted in figures 6 to 15 as a function of both velocity and altitude. The electron concentration for the three regions tabulated is plotted in figure 16 as a function of velocity and altitude, with values of plasma frequency f_p also shown. For convenience in rapidly estimating the plasma frequencies encountered during various reentry trajectories, the data from figure 16 are cross-plotted in figure 17 on a velocity-altitude plot showing lines of constant plasma frequency. The parameter $\gamma_{T,p}$ taken from reference 15 is plotted in figure 18 as a function of T and $s\Big/\frac{R}{m_0}$ for use in estimating isentropic flow changes in the real-gas equilibrium shock-heated flow regions. The thermodynamic air data used for these computations included data from reference 16 for the temperature range 800° K through 1,200° K and from references 1, 3, 4, 5, 14, and 15, for the higher temperatures, as discussed previously.

Reliability of Results

Computational accuracy.- For a given set of input values, the accuracy of the parameters computed and tabulated in table IV will be in the range of 0.1 to 0.2 percent, generally. The iteration of equation (5) was not carried further than this accuracy, since the uncertainty in the ambient-air-property input data does not warrant additional precision.

Applicability of results.- All the input data used in the computations, for both the ambient air and the high-temperature air, is with argon included and is therefore consistent and comparable with the data in the general literature for air. The change in the value of the parameters tabulated herein for air from the values in reference 6 on the basis of argon-free air is approximately 0.2 to 0.4 percent for the same model atmosphere.

It can be seen in figures 6(a) and 7(a) that for temperatures of 1,600° K and below (velocities of about 6,000 ft/sec and below) the air composition does not change in the shock-compression process. Consequently, ideal-gas relations (that is, relations for a thermally perfect but calorically imperfect gas) can be used in this range. (See ref. 10.) For temperatures above this range, the so-called real-gas effects become significant, and change of air composition must be taken into account. For temperatures below 800° K (velocities below about 3,500 ft/sec) it can be seen from table IV or from figures 8(a) and 10(a), and also from figure 4 of reference 13 $\left(\gamma^* \text{ as a function of } h\Big/\frac{R}{m_0} T_0\right)$ that ideal-gas relations with constant specific-heat ratio of 1.40 may be used (ref. 10) with only a few percent (<3 percent) error in the results.

The results in table IV are presented in terms of the normal-shock properties; however, the results may be applied also to oblique-shock conditions if the shock angle or the normal component of the flow is specified. (See ref. 6 for procedure; also see refs. 7, 8, 12, and 20.)

Since the computations have been made for only the limiting nonequilibrium conditions - that is, infinite reaction rates (equilibrium) or zero recombination rates (frozen) - the parameters will not be applicable to finite-rate nonequilibrium problems. In many cases, however, these limiting-rate parameters serve to bracket the actual finite-rate problem and thereby provide a means for rapid estimation of the magnitude of the effects of nonequilibrium. At flight altitudes below about 100,000 feet (depending also on body scale) the flow will generally be close to thermochemical equilibrium around typical bodies, and therefore the tabulated data should generally apply for these altitudes. For flight at higher altitudes (up to, say, 200,000 feet) the characteristic reaction lengths for the stagnation streamline of blunt bodies are about equal to the shock standoff distance, so that for this streamline the equilibrium computations should apply near the stagnation point. For other streamlines (oblique shock streamlines), however, neither equilibrium nor frozen-flow computations apply, and thus finite-rate nonequilibrium computations are needed in this altitude range. It is also a good approximation, in the case of the stagnation streamline, to assume a frozen-flow composition (no recombination) in the expansion of this flow about the body and into the wake for these altitudes; and thus the frozen-wake computations should have at least qualitative application in this range. For still higher altitudes, nonequilibrium reactions may extend throughout the flow field, including the stagnation point, and require employment of finite-rate chemical kinetics.

For the altitude range encompassed by the present tabulations, the shock-layer flow around typical bodies is considered to be in the continuum flow regime of fluid mechanics (to a lesser extent dependent on the velocity range) so that the computations of the tabulated parameters are valid in this regard. It must be remembered, however, that for altitudes of the order of 250,000 feet and higher (depending also on scale) the viscous effects in the shock layer become very large - that is, boundary-layer thickness is of the same order as the shock-layer thickness. For this reason, as well as because of the nonequilibrium aspect of the flow, tabulations of inviscid flow properties are not applicable in this range other than to serve as guidelines to more comprehensive computations.

Effects of Ambient-Air-Property Uncertainties

Knowledge of the ambient properties of the earth's atmosphere is being constantly revised, supplemented, and extended as a result of improved measurement techniques and conceptual changes. While these revisions are of a greater magnitude in that part of the atmosphere above the homosphere (above 295,000 feet), the changes have been significant at altitudes even as low as the troposphere (65,000 feet). The ambient-air properties used in the present work were taken from reference 11 (1959 model), which had replaced reference 17 (1956 model) as a model atmosphere, and these properties have already been superseded to a certain extent. (See refs. 18 and 19, table II, and fig. 5 for latest revision.) There have been many other proposed atmospheric models. It is well, then, to consider the magnitude of these changes, the effects of such changes on the hypersonic flow parameters presented, and the other uncertainties involved in application of the results to a particular situation.

Ambient temperature.- The maximum change in ambient temperature in the homosphere from the 1956 to the 1959 model atmosphere is in the mesopause and is about 30° K. (See fig. 5.) The revision is within 15° K of the 1959 model. The latter figure amounts to a change in the ambient enthalpy of about $0.2 \frac{R}{m_0} T_0$, which in comparison with the kinetic energy term in equation (3) for typical velocities is generally only a small fraction of a percent. This small change indicates that for a given flight velocity, the error in normal-shock temperature will be very small due to this ambient temperature change. The error is also small for most of the other parameters including the K( ) parameters, with the exception of those involving ratios of temperatures or those directly dependent upon T_1, for example, T_2/T_1 and M_1. In these parameters the errors could be much higher, that is, as much as 9 percent for the 15° K case, so that correction to these parameters would be necessary, but can be generally avoided by employment of the parameters of lesser dependency. For example, the pressure ratio p_2/p_1 at a given flight velocity is also strongly dependent on an ambient temperature change; however, at a given flight Mach number there is little or no dependency. In order to account for the change in p_2/p_1 due to a change in T_1, therefore, the value of M_1 is correspondingly changed $\left(a_1 \propto T_1^{1/2}\right)$ and the new p_2/p_1 found from the tables as based on the corrected M_1 (or a plot of M_1 as a function of p_2/p_1).

Ambient pressure.- Changes in ambient pressure from the 1956 (ref. 17) to the 1959 (ref. 11) model are found at altitudes above 200,000 feet and at the highest altitudes tabulated herein are of the order of 50 percent of the 1956 values. (The revision lies much closer to the 1959 model.) The physical result of the lower ambient pressure on the shock-heated flow properties is that additional dissociation occurs at the lower pressure level and this results in lower temperatures for a given flight velocity. The effect of this change is not significant below flight velocities of about 30,000 feet per second, but will result in temperatures that are as much as two percent lower for higher flight velocities at the high altitudes where the pressure changes are large. This can be seen from equation (3) along with the high-temperature air properties tables (ref. 4) where the total enthalpy at constant u_1 is unchanged due to p_1 changes but the lower pressure levels result in larger Z's and lower T's in the high-temperature regions. Most of the other parameters are influenced to a somewhat lesser degree by the change, although ρ_2/ρ_1 will be changed by about the same amount. Note, however, that the pressure changes from the 1959 model (ref. 11) to the latest revision (ref. 18) are much smaller than those discussed here, so that the parameters as tabulated herein will be within 1 percent in all cases, and generally better than this.

Ambient composition.- While the composition of the homosphere is constant, the variation of composition above this point (295,000 feet) does not seem to be firmly established. Photodissociation of the ambient O_2 due to U.V. absorption occurs in the thermosphere, and while the ratio of O/N atoms (that is, conservation of total atoms in a reaction process) is believed to remain about constant in the region between 290,000 and 400,000 feet due to diffusion and mixing, the molecular weight is different from standard air and varies with the amount photodissociated. Figure 5 shows that a large change of m_1 occurred from the 1956 to the 1959 model. The later revision (ref. 19) lies somewhere in between these models in this region. Computation of the effects of composition on ambient enthalpy, entropy, and sound velocity is discussed in the appendix.

At the highest altitude tabulated herein (323,000 feet) a little over 1 percent of the ambient oxygen is photodissociated according to the 1959 model atmosphere (see appendix). This produces an increase in the ambient enthalpy of about

$0.5 \frac{R}{m_O} T_O$ over that for a case of no photodissociation. This chemical energy which is stored in the atmosphere results in increased stagnation enthalpy for a given flight velocity and thus increases the temperatures in the shock-heated gas. For the case of 1-percent photodissociated ambient oxygen, the increase is only about 0.1 percent of typical stagnation enthalpies, but could be much higher if compositions are found to be more greatly photodissociated.

It should be pointed out that since the O/N atom ratio is assumed the same as normal air in this altitude region, one can continue to use the tabulated high-temperature air properties, such as reference 4, since these are based on this same ratio. It is necessary to revise only the ambient-air properties of enthalpy, entropy, et cetera (as a result of this photodissociation), which are inputs to the flow computations. (See table I.)

Other factors.- A number of other factors which may affect the reliability of the tabulated parameters as a result of uncertainties in the ambient-air input properties should be considered. For example, high-altitude winds are known to exist in the atmosphere and are not specifiable for a particular time or location. Reported wind velocities do not indicate, however, that significant effects on the tabulated flow parameters are to be expected. Other uncertainties that exist in the ambient-air properties are attributable to seasonal, geographical, temporal, and diurnal variations from the effective average values used in the standard. These factors can in many cases introduce deviations from the standard which are larger than the differences between atmospheric models.

Omission of Collision Frequency and Conductivity From the Tables

In addition to the electron concentration, the electron collision frequency and the electrical conductivity of a plasma - or in the case of reentry flow fields, of a lossy dielectric medium - are of interest in the radio communications problem and to magnetoplasmadynamics work. These parameters were not included in the computations of the tables because of the large uncertainty in the collision cross section for momentum transfer in electron-atom encounters in air species. There is a resulting uncertainty by a factor of roughly 3 in these parameters in the temperature range where the atom fraction is appreciable and the ion fraction not yet significant. There is, in fact, an uncertainty in the electron-molecule interaction data for air in the lower temperature range. For general utility, however, plots of collision frequency and electrical conductivity are presented. These values are based on a simplified plasma model which yields results within a factor of 2 of those using more refined methods, but use of this model is justifiable in view of the uncertainty (of the same magnitude) in the interaction data.

By use of the general relation for collision frequency

$$\nu = \bar{c}_e \sum_i N_i Q_i \tag{14}$$

the following approximations are made. The collision cross sections for electron encounters with all the neutral species are lumped into one effective average value $\overline{Q}_n$. The ions in the mixture are assumed to be singly ionized only (considered applicable up to $T \approx 15{,}000^{\circ}$ K), and electron-electron encounters are neglected. The electrons are assumed to have a Maxwellian velocity distribution at the gas temperature. Equation (14) is then written in terms of mole fraction and by substitution for $\bar{c}_e$ and the various physical constants yields

$$\nu = 4.56 \times 10^{27} \frac{p/p_0}{T^{1/2}}\left[x_e Q_c + (1 - 2x_e)\overline{Q}_n\right] \tag{15}$$

which is herein evaluated by using $\overline{Q}_n$ as a constant having a value 7×10^{-16} square centimeters, and computing Q_c (the coulomb, or ion, cross section) from the impact parameter and the Debye shielding distance in a manner to account also for close encounters similar to that used in reference 21. The results are plotted in figure 19 for the three flow regimes; and in figure 17 lines of constant $\frac{\nu}{\omega_p} = \frac{\nu}{2\pi f_p}$ are plotted by using these results. It is seen from equation (15) that for very small values of x_e $\left(x_e \ll \frac{\overline{Q}_n}{Q_c} \approx 10^{-2}\right)$, equation (15) reduces to

$$\nu = 3.2 \times 10^{12} \frac{p/p_0}{T^{1/2}} \tag{16}$$

when $\overline{Q}_n$ is equal to 7×10^{-16} square centimeters. This relation is useful in the lower temperature range (or in the low x_e-range) where the long-range (coulomb) forces are insignificant.

Based on these collision frequency values, the electrical conductivity has been computed and is plotted in figure 20 for expediency in plasma work. This computation is made from the low-frequency conductivity relation,

$$\sigma = \frac{\omega_p{}^2 \nu}{4\pi\left(\omega^2 + \nu^2\right)} \tag{17}$$

which is then qualified for the case of $\omega = 0 = 2\pi f$ (d-c) for convenience in plotting. If the conversion constant from sec^{-1} (esu) to mho/cm is used, equation (17) then becomes, for the direct-current case plotted:

$$\sigma_{dc} = 2.81 \times 10^{-4} \frac{N_e}{\nu}, \text{ mho/cm} \tag{18}$$

The alternating-current conductivity is then readily obtained by using the σ_{dc} values from the plots and applying the following relation derived from equation (17):

$$\sigma = \sigma_{dc}\left[\frac{1}{1 + \left(\frac{\omega}{\nu}\right)^2}\right] \tag{19}$$

CONCLUDING REMARKS

Real-air hypersonic-flow parameters are presented in tabular and graphical form for flight in the earth's atmosphere as a function of flight velocity and flight altitude. Thermochemical equilibrium flow properties are given for the inviscid normal shock and stagnation point, and both equilibrium and frozen-flow parameters, including electron concentration, are listed for the far wake of the inviscid stagnation streamline. The tabulations are made for twelve flight altitudes ranging from 35,900 feet to 322,900 feet and for flight velocities and shock-heated gas temperatures encompassing those encountered in return from planetary missions. Included are discussions of the applicability of the computed parameters to a given problem, and effects due to the uncertainties in the input data for ambient air.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., November 9, 1962.

APPENDIX

AMBIENT PROPERTIES IN LOWER THERMOSPHERE

Enthalpy

For the case where normal air has been photodissociated (as in the lower thermosphere, ref. 22) the relation

$$Z_1 = \frac{m_O}{m_1} = 1 + \alpha x_{OA} \tag{A1}$$

represents the molecular weight ratio (compressibility factor) in terms of the fraction of oxygen dissociated α. The term αx_{OA} is the fraction of the air molecules dissociated where $x_{OA} = 0.20946$ from table III. It is immediately shown from equation (A1) and table I that at 322,900 feet altitude, α is 0.0115 for $Z_1 = 1.0024$. The mole fraction of dissociated atoms in the mixture (for this case, oxygen atoms only) is given by

$$x_a = \frac{2(Z - 1)}{Z} \tag{A2}$$

and the balance of the species in the mixture $(1 - x_a)$ consists mainly of O_2 and N_2 molecules. The enthalpy of an ideal dissociated gas mixture may be written

$$\frac{h}{\frac{R}{m_O} T_O} = Z \sum_i x_i\left(\frac{H}{RT_O}\right)_i \tag{A3}$$

and that part of the term $\left(\frac{H}{RT_O}\right)_i$ due to the dissociated atoms in the mixture is

$$\left(\frac{H}{RT_O}\right)_a = \left(\frac{H}{RT_O}\right)_{thermal} + \frac{1}{2}\frac{D_O}{RT_O} \tag{A4}$$

where the last term in equation (A4) is the chemical part of the enthalpy. The contribution in equation (A3) due to the chemical term (O atoms only in this case) is, then

$$\frac{1}{2}\frac{D_O}{RT_O} Zx_a = \frac{\alpha x_{OA} D_O}{RT_O} = 45.5\alpha \tag{A5}$$

where $\frac{D_O}{RT_O} = 217$ (5.11 ev) for the oxygen dissociation energy. (See ref. 22.) It is seen from equation (A5) that for $\alpha = 0.0115$ the chemical energy stored in the atmosphere due to photodissociation at 322,900 feet is about $0.52 \frac{R}{m_0} T_0$, based on the 1959 model atmosphere. The enthalpy of the ambient dissociated air was determined and tabulated in table I, by using equation (A3), and the ideal gas species data from reference 16.

Entropy

The entropy for an ideal dissociated gas mixture may be expressed as

$$\frac{s}{R/m_0} = Z \sum_i x_i\left(\frac{S}{R}\right)_i = Z \sum_i x_i\left[\left(\frac{S^o}{R}\right)_i - \log_e\left(\frac{p}{p_0}\right)_i\right] \tag{A6}$$

where

$$\left(\frac{p}{p_0}\right)_i = x_i \frac{p}{p_0} \tag{A7}$$

and S^o/R is the species entropy at standard pressure. Combining and expanding the above relations and noting that $\sum_i x_i = 1.0$ yields:

$$\frac{s}{R/m_0} = Z\left[\sum_i x_i\left(\frac{S^o}{R}\right)_i - \sum_i x_i \log_e x_i - \log_e \frac{p}{p_0}\right] \tag{A8}$$

Using this relation and the ideal gas species properties from reference 16, the entropy for ambient dissociated air at 322,900 feet altitude was computed and tabulated in table I. It should be mentioned that for this case of $\alpha = 0.0115$, the entropy is almost identically the same as undissociated air at this pressure and temperature.

Velocity of Sound

The velocity of sound above the homosphere is not tabulated in reference 11 but may be found from the scale height, which is tabulated therein, if the isentropic exponent γ^* is known. The scale height is expressible as (see ref. 11)

$$\text{Scale height} = \frac{R}{m_0} \frac{TZ}{g} \tag{A9}$$

where the product TZ is the molecular scale temperature. Combining equation (A9) with equation (6) results in the relation

$$a^2 = \gamma^* g \times \text{Scale height} \tag{A10}$$

where g is the acceleration due to gravity at the specified altitude. The value of γ^* for a dissociated mixture is found from equation (7), but for this case of photodissociated ambient air no computations or tabulations are found in the literature. However, an exponent may be assumed on the basis that the small pressure perturbation process for this gas would behave thermally as in a nonreacting gas mixture of this ambient composition (that is, photodissociation considered nonthermal). In effect this is an assumption of frozen-flow composition, and a value of specific-heat ratio γ is computed as for an ideal nonreacting gas mixture.

For the case of $\alpha = 0.0115$ at an altitude of 322,900 feet the value for γ^* is very close to that of normal air, being computed to be 1.404. By use of this value, a_1 is computed from equation (A10) and listed in table I.

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TABLE I.- VARIATION OF AMBIENT-AIR PROPERTIES WITH ALTITUDE

Altitude, ft		T_1, °K	T_1, °R	a_1, ft/sec	p_1/p_0	ρ_1/ρ_0	$\frac{h_1}{\frac{R}{m_0}T_0}$	$\frac{s_1}{\frac{R}{m_0}}$	a_1/a_0	Z_1
Geopotential	Geometric									
0	0	288	519	1,117	1.000	0.9478	3.68	23.77	1.027	1.000
35,900	36,000	217	390	968	.2250	.2832	2.77	24.28	.891	1.000
59,800	60,000	217	390	968	$.7135 \times 10^{-1}$	$.8995 \times 10^{-1}$	2.77	25.43	.891	1.000
82,200	82,500	217	390	968	$.2438 \times 10^{-1}$	$.3071 \times 10^{-1}$	2.77	26.49	.891	1.000
100,000	100,500	233	420	1,005	$.1067 \times 10^{-1}$	$.1250 \times 10^{-1}$	2.98	27.57	.924	1.000
120,300	121,000	252	453	1,043	$.4462 \times 10^{-2}$	$.4841 \times 10^{-2}$	3.22	28.69	.960	1.000
154,800	156,000	283	509	1,106	$.1161 \times 10^{-2}$	$.1122 \times 10^{-2}$	3.61	30.45	1.017	1.000
173,500	175,000	283	509	1,106	$.5826 \times 10^{-3}$	$.5630 \times 10^{-3}$	3.61	31.17	1.017	1.000
200,100	202,000	247	444	1,034	$.2052 \times 10^{-3}$	$.2271 \times 10^{-3}$	3.15	31.73	.951	1.000
230,400	233,000	205	369	942	$.5042 \times 10^{-4}$	$.6713 \times 10^{-4}$	2.62	32.48	.867	1.000
259,700	263,000	166	298	847	$.9631 \times 10^{-5}$	$.1589 \times 10^{-4}$	2.12	33.40	.779	1.000
294,800	299,000	166	298	847	$.1064 \times 10^{-5}$	$.1755 \times 10^{-5}$	2.12	35.60	.779	1.000
322,900	328,000	199	358	930	$.2119 \times 10^{-6}$	$.2903 \times 10^{-6}$	3.05	37.87	.856	1.0024

TABLE II.- REVISIONS TO STANDARD ATMOSPHERE

ACCORDING TO REFERENCE 18

Geopotential altitude, ft	T_1, °K	Change from 1959 model, °K	p_1/p_0	Change from 1959 model, percent	ρ_1/ρ_0	Change from 1959 model, percent
0	288	0	1.000	0	0.948	0
35,900	217	0	.224	-.6	.282	-.6
59,800	217	0	$.716 \times 10^{-1}$	.5	$.905 \times 10^{-1}$	.5
82,200	222	5	$.243 \times 10^{-1}$	-.3	$.300 \times 10^{-1}$	-2.3
100,000	227	-6	$.107 \times 10^{-1}$	.3	$.128 \times 10^{-1}$	2.7
120,300	242	-10	$.434 \times 10^{-2}$	-2.7	$.488 \times 10^{-2}$	.7
154,800	271	-12	$.107 \times 10^{-2}$	-7.5	$.108 \times 10^{-2}$	-4.5
173,500	269	-14	$.518 \times 10^{-3}$	-11	$.526 \times 10^{-3}$	-6.6
200,100	253	6	$.180 \times 10^{-3}$	-12	$.194 \times 10^{-3}$	-14
230,400	216	11	$.461 \times 10^{-4}$	-8.5	$.582 \times 10^{-4}$	-13
259,700	181	15	$.983 \times 10^{-5}$	2.1	$.148 \times 10^{-4}$	-6.9
294,800	181	15	$.125 \times 10^{-5}$	18	$.189 \times 10^{-5}$	7.2

TABLE III.- USEFUL CONSTANTS

a_0 = 1087.4 ft/sec, 331.45 m/sec

g_0 = 32.174 ft/sec^2, 980.67 cm/sec^2

m_0 = 28.966 per mole

$n_0 = 2.686 \times 10^{19}$ per cm^3 (Lochschmidt's number)

p_0 = 2116.2 lb/ft^2, 1.0133×10^6 dynes/cm^2, 1.0133×10^3 mb

R = 49,722 ft-lb/slug-mole $^{\circ}$R, 1.9873 cal/mole $^{\circ}$K

$\frac{R}{m_0}$ = 1716.56 ft-lb/slug $^{\circ}$R

$\frac{R}{m_0}T_0$ = 844,014 ft-lb/slug, 33.86 Btu/lb

T_0 = 491.69 $^{\circ}$R, 273.16 $^{\circ}$K

ρ_0 = 0.002508 slug/ft^3, 1.2931×10^{-3} gm/cm^3

1,000 ft = 0.3048 km, 0.1646 nautical mile

Normal air composition (mole fraction)

N_2	0.78084
O_2	0.20946
Ar	0.00934
CO_2	0.00033
Ne	0.00003

TABLE IV.- NORMAL SHOCK PARAMETERS

(a) For geopotential altitude of 35,900 ft; $T_1 = 217^{\circ}$ K; $a_1 = 968$ ft/sec; $p_1 = 0.2250$ atm

T_2, °K	u_1, ft/sec	M_1	z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log \frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
800	3.697×10^{3}	3.816	1.000	16.95	1.008	3.802	19.17	4.597	1.029	1.298	0.1133	---------	3.687	0.9790	------	-----	371
1,200	4.864	5.021	1.000	29.73	1.017	6.668	33.01	5.375	1.073	1.518	.1812	---------	5.530	.9468	------	-----	498
1,600	5.853	6.042	1.000	43.44	1.024	9.744	47.77	5.890	1.116	1.663	.2210	---------	7.373	.9172	------	-----	621
2,000	6.749	6.959	1.002	58.06	1.030	13.02	63.43	6.290	1.156	1.776	.2499	---------	9.217	.8900	2,041	-----	761
2,200	7.168	7.391	1.001	65.74	1.034	14.75	71.61	6.481	1.179	1.830	.2624	---------	10.14	.8767	------	-----	806
2,400	7.578	7.815	1.001	73.71	1.037	16.53	80.10	6.659	1.200	1.880	.2742	---------	11.06	.8630	2,443	-----	867
2,600	7.988	8.238	1.002	82.19	1.040	18.44	89.10	6.849	1.225	1.934	.2864	---------	11.98	.8476	------	-----	911
2,800	8.402	8.664	1.003	91.25	1.044	20.47	98.68	7.051	1.253	1.991	.2990	---------	12.90	.8304	2,843	-----	960
3,000	8.818	9.094	1.006	100.9	1.047	22.63	108.8	7.257	1.282	2.049	.3116	---------	13.82	.8123	------	-----	1,005
3,200	9.250	9.539	1.009	111.5	1.051	25.00	119.9	7.488	1.316	2.114	.3251	---------	14.75	.7913	3,240	-----	1,048
3,400	9.698	10.00	1.015	123.0	1.055	27.58	132.0	7.730	1.353	2.183	.3390	---------	15.67	.7686	------	-----	1,086
3,600	10.16	10.48	1.023	135.7	1.059	30.43	145.2	7.995	1.393	2.257	.3536	---------	16.59	.7438	3,638	-----	1,118
3,800	10.65	10.98	1.033	149.4	1.063	33.52	159.6	8.260	1.434	2.332	.3678	4.10×10^{-2}	17.51	.7183	------	1,500	1,144
4,000	11.13	11.48	1.044	163.9	1.067	36.75	174.6	8.513	1.473	2.404	.3809	3.79	18.43	.6941	4,038	1,620	1,167
4,200	11.62	11.98	1.057	179.2	1.070	40.19	190.6	8.756	1.510	2.472	.3931	3.49	19.35	.6706	------	1,760	1,185
4,400	12.05	12.43	1.072	194.7	1.073	43.68	205.2	8.962	1.542	2.530	.4032	3.27	20.28	.6496	4,240	1,880	1,200
4,600	12.57	12.96	1.086	210.5	1.075	47.21	223.3	9.141	1.569	2.581	.4118	2.98	21.20	.6311	------	2,030	1,215
4,800	13.02	13.42	1.101	226.2	1.077	50.75	239.7	9.293	1.592	2.624	.4190	2.82	22.12	.6148	4,844	2,140	1,230
5,000	13.44	13.86	1.114	241.6	1.078	54.18	255.8	9.407	1.608	2.656	.4242	2.69	23.04	.6015	5,046	2,250	1,242
5,500	14.41	14.86	1.145	278.2	1.080	62.40	294.2	9.589	1.634	2.707	.4326	2.40	25.35	.5773	5,553	2,520	1,277
6,000	15.31	15.79	1.170	314.2	1.081	70.47	332.0	9.707	1.650	2.741	.4379	2.19	27.65	.5596	6,056	2,720	1,318
6,500	16.22	16.72	1.196	353.0	1.082	79.18	372.8	9.854	1.672	2.782	.4444	2.04	29.95	.5414	6,556	2,880	1,350
7,000	17.24	17.78	1.226	400.1	1.085	89.74	421.8	10.12	1.713	2.857	.4559	1.91	32.26	.5168	7,053	3,040	1,361
7,500	18.40	18.98	1.263	457.4	1.089	102.6	480.3	10.48	1.770	2.958	.4710	1.78	34.55	.4869	7,550	3,195	1,348
8,000	19.70	20.32	1.310	526.2	1.093	118.0	552.6	10.89	1.837	3.076	.4880	1.59	36.87	.4539	8,048	3,360	1,309
8,500	21.13	21.79	1.367	607.5	1.097	136.3	636.6	11.34	1.911	3.203	.5056	1.43	39.17	.4199	8,547	3,580	1,247
9,000	22.65	23.36	1.435	700.5	1.100	157.1	732.8	11.77	1.979	3.323	.5216	1.30	41.47	.3874	9,047	3,910	1,165
9,500	24.21	24.97	1.505	802.4	1.103	180.0	838.0	12.18	2.046	3.439	.5364	1.135	43.78	.3584	9,548	4,470	1,083
10,000	25.76	26.56	1.581	910.3	1.106	204.2	949.6	12.50	2.098	3.529	.5476	1.00	46.08	.3335	10,050	4,930	999
11,000	28.60	29.50	1.726	1,125	1.108	252.3	1,172	12.85	2.154	3.629	.5598	8.51×10^{-3}	50.69	.2980	11,059	5,500	870

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2 / \frac{R}{m_0}T_0$	$h_t / \frac{R}{m_0}T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm^3	$N_{e,w}$, per cm^3	$N_{e,fw}$, per cm^3	γ_2^*
800	1.890	0.9737	1.683	0.4410	1.002	10.49	10.84	26.12	1.846	---------	---------	--------	--------	--------	-----
1,200	2.276	.9417	2.027	.4105	.9896	16.32	16.73	27.17	2.893	---------	---------	--------	--------	--------	-----
1,600	2.605	.9185	2.320	.3939	.9757	22.50	22.99	28.01	3.729	1.5×10^{-17}	---------	6.7×10^{2}	--------	4.0×10^{1}	-----
2,000	2.897	.9000	2.580	.3819	.9605	29.05	29.64	28.67	4.393	7.2×10^{-14}	---------	3.4×10^{6}	--------	1.6×10^{5}	1.277
2,200	3.032	.8918	2.700	.3761	.9514	32.49	33.08	29.00	4.722	1.4×10^{-12}	---------	6.9×10^{7}	--------	2.9×10^{6}	1.266
2,400	3.147	.8793	2.802	.3729	.9474	36.04	36.65	29.31	5.032	1.8×10^{-11}	---------	9.1×10^{8}	--------	3.4×10^{7}	1.255
2,600	3.264	.8681	2.907	.3684	.9398	39.77	40.42	29.63	5.352	1.5×10^{-10}	---------	7.8×10^{9}	--------	2.7×10^{8}	1.244
2,800	3.375	.8562	3.005	.3640	.9314	43.73	44.41	29.90	5.622	9.8×10^{-10}	---------	5.3×10^{10}	--------	1.7×10^{9}	1.231
3,000	3.481	.8437	3.100	.3600	.9240	47.95	48.65	30.20	5.922	5.4×10^{-9}	---------	3.0×10^{11}	--------	8.8×10^{9}	1.219
3,200	3.586	.8309	3.193	.3553	.9143	52.54	53.25	30.53	6.252	1.8×10^{-8}	---------	1.0×10^{12}	--------	2.8×10^{10}	1.209
3,400	3.699	.8191	3.294	.3498	.9025	57.53	58.26	30.85	6.572	5.7×10^{-8}	---------	3.4	--------	8.6	1.201
3,600	3.809	.8065	3.392	.3442	.8899	62.97	63.74	31.16	6.882	1.4×10^{-7}	---------	8.7	--------	2.1	1.196
3,800	3.930	.7960	3.500	.3382	.8762	68.98	69.66	31.53	7.252	3.4	4.1×10^{-17}	2.2×10^{13}	4.5×10^{1}	4.9×10^{11}	1.194
4,000	4.054	.7867	3.610	.3326	.8634	75.10	75.86	31.83	7.552	7.0	1.1×10^{-15}	4.7	1.1×10^{3}	9.9	1.195
4,200	4.180	.7781	3.722	.3274	.8511	81.65	82.45	32.17	7.892	1.4×10^{-6}	2.2×10^{-14}	9.8	2.1×10^{4}	1.9×10^{12}	1.198
4,400	4.321	.7765	3.848	.3209	.8352	88.40	88.44	32.50	8.222	2.6	2.6×10^{-13}	1.9×10^{14}	2.3×10^{5}	3.6	1.203
4,600	4.458	.7693	3.970	.3180	.8286	95.22	95.94	32.86	8.582	4.5	3.3×10^{-12}	3.4	2.7×10^{6}	6.1	1.209
4,800	4.599	.7669	4.095	.3141	.8192	102.0	102.8	33.13	8.852	7.2	1.4×10^{-11}	5.6	1.1×10^{7}	9.6	1.216
5,000	4.741	.7659	4.222	.3108	.8115	108.6	109.4	33.41	9.132	1.15×10^{-5}	7.0×10^{-11}	9.1	5.1×10^{7}	1.5×10^{13}	1.226
5,500	5.053	.7627	4.500	.3068	.8023	124.3	125.4	34.09	9.812	3.05	1.3×10^{-9}	2.5×10^{15}	8.4×10^{8}	3.9	1.232
6,000	5.323	.7574	4.740	.3055	.8002	140.0	141.1	34.67	10.39	6.9	7.7×10^{-9}	5.9×10^{15}	4.7×10^{9}	8.6	1.226
6,500	5.561	.7476	4.952	.3052	.8002	156.9	158.0	35.29	11.01	1.3×10^{-4}	2.7×10^{-8}	1.2×10^{16}	1.5×10^{10}	1.6×10^{14}	1.209
7,000	5.809	.7352	5.173	.3026	.7940	176.9	178.2	35.94	11.66	2.4	6.9×10^{-8}	2.3	3.7	2.9	1.193
7,500	6.072	.7208	5.407	.2984	.7838	201.1	202.6	36.72	12.44	3.8	1.8×10^{-7}	3.8	9.3	4.6	1.183
8,000	6.367	.7065	5.670	.2929	.7702	230.2	231.9	37.51	13.23	5.9	4.4×10^{-7}	6.4	2.2×10^{11}	7.4	1.177
8,500	6.704	.6941	5.970	.2865	.7539	264.6	266.3	38.47	14.19	8.3	1.2×10^{-6}	9.8	5.5×10^{11}	1.1×10^{15}	1.176
9,000	7.069	.6830	6.295	.2808	.7395	303.8	305.6	39.47	15.19	1.2×10^{-3}	3.9×10^{-6}	1.5×10^{17}	1.6×10^{12}	1.7	1.177
9,500	7.451	.6743	6.635	.2751	.7249	346.8	348.7	40.55	16.27	1.65	2.0×10^{-5}	2.3	7.4×10^{12}	2.5	1.182
10,000	7.853	.6678	6.993	.2707	.7137	392.3	394.4	41.59	17.31	2.3	5.5×10^{-5}	3.4	1.8×10^{13}	3.8	1.188
11,000	8.677	.6654	7.727	.2645	.6977	483.4	485.6	43.65	19.37	4.0	1.5×10^{-4}	6.7	4.5×10^{13}	7.6	1.205

TABLE IV.- NORMAL SHOCK PARAMETERS - Continued

(b) For geopotential altitude of 59,800 ft; T_1 = 217° K; a_1 = 968 ft/sec; p_1 = 0.7135 × 10^{-1} atm

T_2, °K	u_1, ft/sec	M_1	Z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log\frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
800	3.697×10^{3}	3.819	1.001	16.98	1.008	1.202	19.20	4.600	1.030	0.4094	-0.3879	----------	3.69	0.9785	------	-----	370
1,200	4.864	5.025	1.002	29.79	1.017	2.109	33.06	5.375	1.073	.4784	-.3202	----------	5.53	.9455	------	-----	497
1,600	5.853	6.046	1.002	43.50	1.024	3.080	47.83	5.890	1.116	.5242	-.2805	----------	7.37	.9158	------	-----	618
2,000	6.753	6.976	1.005	58.37	1.031	4.132	63.74	6.300	1.157	.5607	-.2513	----------	9.22	.8863	2,041	-----	747
2,200	7.178	7.415	1.004	66.19	1.034	4.686	72.08	6.499	1.181	.5784	-.2378	----------	10.14	.8718	------	-----	802
2,400	7.591	7.842	1.004	74.25	1.037	5.257	80.68	6.690	1.205	.5954	-.2252	----------	11.06	.8575	2,442	-----	855
2,600	8.018	8.284	1.007	83.21	1.041	5.891	90.13	6.900	1.234	.6141	-.2117	----------	11.98	.8388	------	-----	902
2,800	8.458	8.737	1.010	92.96	1.045	6.582	100.5	7.132	1.266	.6348	-.1974	----------	12.90	.8172	2,840	-----	949
3,000	8.925	9.220	1.017	104.0	1.050	7.363	112.0	7.404	1.306	.6590	-.1811	----------	13.82	.7910	------	-----	988
3,200	9.414	9.725	1.024	116.2	1.055	8.229	124.9	7.693	1.350	.6847	-.1645	----------	14.75	.7629	3,236	-----	1,022
3,400	9.903	10.23	1.032	129.5	1.060	9.167	138.4	8.010	1.398	.7128	-.1470	----------	15.67	.7356	------	-----	1,053
3,600	10.48	10.83	1.047	145.8	1.066	10.32	155.5	8.393	1.458	.7470	-.1267	1.328×10^{-2}	16.59	.6984	3,633	1,460	1,070
3,800	11.06	11.43	1.067	163.0	1.070	11.54	173.5	8.722	1.509	.7763	-.1100	1.212	17.51	.6646	------	1,600	1,076
4,000	11.56	11.94	1.072	178.5	1.074	12.64	189.6	9.032	1.559	.8042	-.09464	1.113	18.43	.6430	4,034	1,740	1,106
4,200	12.12	12.52	1.103	196.8	1.077	13.93	208.6	9.275	1.586	.8206	-.08586	1.035	19.35	.6159	------	1,910	1,099
4,400	12.62	13.04	1.112	213.9	1.080	15.15	226.4	9.487	1.628	.8443	-.07349	9.55×10^{-3}	20.28	.5966	4,437	2,050	1,119
4,600	13.09	13.52	1.131	230.3	1.081	16.30	243.6	9.605	1.644	.8548	-.06814	8.92	21.20	.5813	------	2,200	1,127
4,800	13.52	13.97	1.141	246.1	1.082	17.42	260.1	9.750	1.666	.8677	-.06161	8.32	22.12	.5691	4,843	2,320	1,146
5,000	13.93	14.39	1.158	261.3	1.082	18.50	276.0	9.792	1.671	.8715	-.05972	7.76	23.04	.5594	5,046	2,430	1,157
5,500	14.82	15.30	1.181	295.9	1.083	20.95	312.3	9.880	1.682	.8794	-.05582	7.08	25.35	.5453	5,551	2,620	1,205
6,000	15.73	16.25	1.202	334.2	1.085	23.66	352.5	10.06	1.708	.8950	-.04816	6.60	27.65	.5286	6,050	2,760	1,249
6,500	16.85	17.41	1.240	384.7	1.088	27.23	404.9	10.36	1.754	.9217	-.03540	6.10	29.95	.5002	6,546	2,910	1,251
7,000	18.14	18.74	1.281	447.4	1.092	31.68	469.9	10.83	1.830	.9636	-.01608	5.625	32.26	.4660	7,042	3,060	1,232
7,500	19.64	20.29	1.339	526.7	1.097	37.29	551.8	11.38	1.920	1.013	.00555	5.13	34.56	.4269	7,540	3,240	1,178
8,000	21.23	21.93	1.400	618.3	1.102	43.78	646.4	11.98	2.017	1.066	.02790	4.79	36.87	.3902	8,039	3,480	1,113
8,500	23.08	23.84	1.494	733.0	1.106	51.89	765.0	12.53	2.106	1.115	.04726	4.03	39.17	.3515	8,539	4,045	1,006
9,000	24.80	25.62	1.577	849.1	1.109	60.12	884.5	12.99	2.181	1.156	.06288	3.35	41.47	.3226	9,040	4,660	923
9,500	26.50	27.37	1.666	971.2	1.111	68.76	1,011	13.32	2.234	1.185	.07374	3.02	43.78	.2985	9,543	5,025	841
10,000	28.02	28.95	1.749	1,088	1.112	77.01	1,131	13.49	2.262	1.201	.07951	2.78	46.08	.2811	10,047	5,260	778
11,000	30.36	31.37	1.869	1,277	1.112	90.40	1,327	13.48	2.258	1.200	.07908	2.46	50.69	.2637	11,061	5,560	713

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2/\frac{R}{m_0}T_0$	$h_t/\frac{R}{m_0}T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm^3	$N_{e,w}$, per cm^3	$N_{e,fw}$, per cm^3	γ_2^*
800	1.891	0.9737	1.684	0.4390	0.9975	10.49	10.84	27.28	1.85	---------	---------	--------	--------	--------	-----
1,200	2.277	.9413	2.028	.4105	.9896	16.31	16.73	28.32	2.89	---------	---------	--------	--------	--------	-----
1,600	2.607	.9189	2.322	.3936	.9750	22.50	22.99	29.16	3.73	5.2×10^{-17}	---------	7.3×10^{2}	--------	4.4×10^{1}	-----
2,000	2.897	.8983	2.580	.3822	.9615	29.05	29.68	29.82	4.39	2.4×10^{-13}	---------	3.6×10^{6}	--------	1.7×10^{5}	1.276
2,200	3.026	.8869	2.695	.3770	.9539	32.50	33.16	30.15	4.72	4.5×10^{-12}	---------	7.0×10^{7}	--------	2.9×10^{6}	1.264
2,400	3.144	.8753	2.800	.3729	.9479	36.12	36.77	30.45	5.02	5.2×10^{-11}	---------	8.4×10^{8}	--------	3.1×10^{7}	1.251
2,600	3.257	.8616	2.900	.3687	.9408	39.99	40.71	30.77	5.34	4.0×10^{-10}	---------	6.6×10^{9}	--------	2.3×10^{8}	1.236
2,800	3.363	.8463	2.995	.3643	.9329	44.17	44.00	31.10	5.67	2.3×10^{-9}	---------	4.0×10^{10}	--------	1.3×10^{9}	1.220
3,000	3.478	.8319	3.097	.3581	.9201	48.77	49.78	31.41	5.98	9.9×10^{-9}	---------	1.8×10^{11}	--------	5.2×10^{9}	1.206
3,200	3.586	.8156	3.193	.3525	.9083	53.96	55.07	31.80	6.37	3.4×10^{-8}	---------	6.4×10^{11}	--------	1.7×10^{10}	1.195
3,400	3.702	.8022	3.297	.3450	.8910	59.76	60.64	32.18	6.75	9.9×10^{-8}	---------	2.0×10^{12}	--------	4.9×10^{10}	1.188
3,600	3.818	.7835	3.400	.3380	.8754	66.18	67.60	32.56	7.13	2.5×10^{-7}	3.3×10^{-17}	5.3×10^{12}	1.2×10^{1}	1.2×10^{11}	1.185
3,800	3.949	.7695	3.517	.3319	.8612	73.33	74.97	32.95	7.52	5.9×10^{-7}	1.5×10^{-15}	1.3×10^{13}	4.9×10^{2}	2.9	1.185
4,000	4.088	.7635	3.640	.3232	.8401	80.49	81.63	33.31	7.88	1.2×10^{-6}	4.7×10^{-14}	2.8	1.4×10^{4}	5.6	1.189
4,200	4.239	.7560	3.775	.3204	.8342	88.02	89.45	33.71	8.28	2.3	8.0×10^{-13}	5.6	2.2×10^{5}	1.1×10^{12}	1.195
4,400	4.389	.7527	3.908	.3132	.8163	95.41	96.73	34.10	8.67	4.2	8.6×10^{-12}	1.1×10^{14}	2.2×10^{6}	2.0	1.204
4,600	4.537	.7509	4.040	.3102	.8097	102.6	103.9	34.42	8.99	7.0	6.0×10^{-11}	1.8	1.4×10^{7}	3.2	1.214
4,800	4.686	.7514	4.173	.3058	.7984	109.5	110.6	34.76	9.33	1.15×10^{-5}	2.9×10^{-10}	3.1	6.5×10^{7}	5.2	1.223
5,000	4.829	.7522	4.300	.3043	.7953	116.0	117.2	35.09	9.66	1.8	9.2×10^{-10}	4.9	2.0×10^{8}	8.1	1.234
5,500	5.115	.7503	4.555	.3027	.7922	131.6	132.3	35.74	10.31	4.5	6.0×10^{-9}	1.3×10^{15}	1.2×10^{9}	1.9×10^{13}	1.228
6,000	5.354	.7403	4.768	.3018	.7909	148.3	148.9	36.32	10.89	1.0×10^{-4}	1.8×10^{-8}	2.9	3.4×10^{9}	4.2	1.209
6,500	5.592	.7226	4.980	.3006	.7886	168.5	170.4	37.09	11.66	1.8	5.7×10^{-8}	5.5	1.0×10^{10}	7.5	1.188
7,000	5.867	.7052	5.225	.2950	.7747	194.1	197.0	37.93	12.50	3.2	1.3×10^{-7}	1.1×10^{16}	2.2	1.4×10^{14}	1.174
7,500	6.182	.6869	5.505	.2884	.7583	226.3	230.3	38.93	13.50	5.05	3.6×10^{-7}	1.8	5.8	2.2	1.168
8,000	6.542	.6731	5.826	.2798	.7363	265.3	268.9	40.01	14.58	7.3	1.1×10^{-6}	2.9	1.7×10^{11}	3.4	1.166
8,500	6.940	.6578	6.180	.2742	.7221	310.7	317.2	41.29	15.86	1.1×10^{-3}	9.3×10^{-6}	4.9	1.2×10^{12}	5.7	1.169
9,000	7.369	.6498	6.562	.2677	.7054	360.4	365.7	42.63	17.20	1.6	4.1×10^{-5}	7.8	4.6	9.0	1.175
9,500	7.805	.6445	6.950	.2634	.6946	411.7	417.1	43.92	18.49	2.3	8.8×10^{-5}	1.2×10^{17}	9.1	1.4×10^{15}	1.184
10,000	8.248	.6444	7.345	.2601	.6861	461.8	466.2	45.14	19.71	3.15	1.3×10^{-4}	1.8	1.3×10^{13}	2.1	1.195
11,000	9.068	.6538	8.075	.2567	.6775	548.7	546.7	47.12	21.69	6.0	2.0×10^{-4}	3.6	1.8×10^{13}	4.4	1.223

TABLE IV.- NORMAL SHOCK PARAMETERS - Continued

(c) For geopotential altitude of 82,200 ft; $T_1 = 217^\circ$ K; $a_1 = 968$ ft/sec; $p_1 = 0.2438 \times 10^{-1}$ atm

T_2, °K	u_1, ft/sec	M_1	Z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log \frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
800	3.697×10^{3}	3.816	1.000	16.95	1.008	0.4163	19.17	4.597	1.029	0.1423	-0.8469	---------	3.687	0.9790	------	-----	371
1,200	4.864	5.021	1.000	29.73	1.017	.7302	33.01	5.375	1.073	.1664	-.7790	---------	5.530	.9468	------	-----	498
1,600	5.853	6.042	1.000	43.44	1.024	1.067	47.77	5.890	1.116	.1823	-.7392	---------	7.373	.9172	------	-----	619
2,000	6.753	6.963	1.001	58.16	1.031	1.428	63.52	6.305	1.159	.1950	-.7101	---------	9.217	.8891	2,040	-----	750
2,200	7.183	7.407	1.001	66.06	1.034	1.623	71.94	6.509	1.183	.2013	-.6963	---------	10.14	.8734	------	-----	805
2,400	7.605	7.843	1.002	74.34	1.038	1.826	80.72	6.707	1.209	.2074	-.6832	---------	11.06	.8572	2,440	-----	857
2,600	8.049	8.301	1.004	83.66	1.042	2.055	90.56	6.954	1.243	.2150	-.6676	---------	11.98	.8356	------	-----	905
2,800	8.519	8.784	1.008	94.17	1.048	2.313	101.6	7.238	1.284	.2238	-.6502	---------	12.90	.8093	2,836	-----	947
3,000	9.024	9.305	1.015	106.3	1.054	2.611	114.2	7.573	1.335	.2341	-.6305	---------	13.82	.7776	------	-----	983
3,200	9.571	9.869	1.026	120.3	1.060	2.954	128.8	7.951	1.393	.2459	-.6093	---------	14.75	.7417	3,031	-----	1,011
3,400	10.16	10.48	1.040	136.4	1.066	3.350	145.5	8.368	1.458	.2588	-.5871	4.84×10^{-3}	15.67	.7031	------	1,390	1,031
3,600	10.78	11.11	1.058	154.4	1.072	3.791	164.1	8.792	1.525	.2719	-.5657	4.26	16.59	.6647	3,628	1,575	1,041
3,800	11.42	11.774	1.079	174.1	1.077	4.276	184.6	9.212	1.590	.2848	-.5454	3.80	17.51	.6278	------	1,770	1,047
4,000	11.99	12.36	1.100	192.6	1.081	4.729	203.8	9.498	1.635	.2937	-.5321	3.54	18.43	.6012	4,031	1,900	1,052
4,200	12.54	12.93	1.120	211.1	1.083	5.184	223.0	9.737	1.671	.3011	-.5214	3.28	19.35	.5787	------	2,050	1,058
4,400	13.04	13.45	1.138	228.7	1.085	5.618	241.4	9.910	1.697	.3064	-.5137	3.00	20.28	.5617	4,436	2,230	1,067
4,600	13.49	13.91	1.154	244.8	1.086	6.013	258.3	10.01	1.711	.3095	-.5094	2.76	21.20	.5499	------	2,340	1,079
4,800	13.89	14.33	1.167	260.0	1.086	6.385	274.2	10.07	1.720	.3115	-.5066	2.66	22.12	.5414	4,843	2,430	1,095
5,000	14.27	14.72	1.178	274.4	1.086	6.738	289.3	10.11	1.724	.3126	-.5051	2.57	23.04	.5352	5,046	2,490	1,114
5,500	15.18	15.65	1.202	310.4	1.087	7.625	327.2	10.19	1.732	.3150	-.5017	2.40	25.35	.5218	5,546	2,640	1,161
6,000	16.22	16.73	1.231	355.5	1.089	8.730	374.1	10.44	1.771	.3229	-.4910	2.29	27.65	.4994	6,042	2,765	1,229
6,500	17.52	18.07	1.273	416.5	1.094	10.23	437.3	10.93	1.849	.3379	-.4713	2.09	29.95	.4648	6,537	2,920	1,173
7,000	19.10	19.70	1.331	497.4	1.099	12.22	520.7	11.59	1.956	.3582	-.4458	1.88	32.26	.4221	7,034	3,100	1,121
7,500	20.90	21.55	1.407	598.8	1.105	14.71	625.0	12.31	2.072	.3807	-.4194	1.68	34.56	.3786	7,533	3,410	1,042
8,000	22.85	23.56	1.499	718.8	1.110	17.65	748.5	13.01	2.187	.4022	-.3956	1.35	36.87	.3385	8,033	4,080	942
8,500	24.84	25.61	1.600	852.3	1.114	20.93	885.8	13.60	2.284	.4206	-.3762	1.15	39.17	.3048	8,534	4,650	843
9,000	26.68	27.51	1.700	985.1	1.116	24.19	1,023	13.98	2.345	.43211	-.3644	1.02	41.48	.2800	9,037	4,970	762
9,500	28.30	29.19	1.789	1,110	1.117	27.26	1,152	14.18	2.376	.4383	-.3582	9.55×10^{-4}	43.78	.2628	9,543	5,175	702
10,000	29.64	30.57	1.861	1,218	1.117	29.91	1,263	14.20	2.379	.4390	-.3575	8.92	46.08	.2523	10,049	5,310	665
11,000	31.63	32.62	1.956	1,384	1.115	33.99	1,437	13.96	2.338	.4317	-.3648	8.32	50.69	.2439	11,067	5,465	635
12,000	33.05	34.08	2.005	1,509	1.114	37.07	1,568	13.61	2.279	.4213	-.3754	7.96	55.30	.2438	12,081	5,575	639

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2 \Big/ \frac{R}{m_0}T_0$	$h_t \Big/ \frac{R}{m_0}T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm³	$N_{e,w}$, per cm³	$N_{e,fw}$, per cm³	γ_2^*
800	1.890	0.9737	1.683	0.4392	0.9975	10.49	10.84	28.34	1.846	---------	---------	--------	--------	--------	-----
1,200	2.274	.9408	2.025	.4109	.9906	16.31	16.73	29.38	2.893	---------	---------	--------	--------	--------	-----
1,600	2.605	.9185	2.320	.3939	.9757	22.50	22.99	30.22	3.730	1.5×10^{-16}	---------	7.3×10^{2}	--------	4.4×10^{1}	-----
2,000	2.897	.8997	2.580	.3811	.9587	29.07	29.68	30.90	4.410	5.9×10^{-13}	---------	3.1×10^{6}	--------	1.4×10^{5}	1.275
2,200	3.024	.8876	2.693	.3764	.9522	32.54	33.21	31.21	4.720	1.0×10^{-11}	---------	5.4×10^{7}	--------	2.2×10^{6}	1.261
2,400	3.140	.8739	2.796	.3724	.9466	36.25	36.89	31.53	5.040	1.1×10^{-10}	---------	6.1×10^{8}	--------	2.3×10^{7}	1.243
2,600	3.243	.8564	2.888	.3681	.9395	40.32	41.00	31.86	5.370	8.1×10^{-10}	---------	4.7×10^{9}	--------	1.6×10^{8}	1.224
2,800	3.346	.8382	2.980	.3627	.9290	44.85	45.59	32.20	5.710	4.5×10^{-9}	---------	2.7×10^{10}	--------	8.6×10^{8}	1.205
3,000	3.459	.8203	3.080	.3553	.9134	50.05	50.82	32.58	6.090	1.65×10^{-8}	---------	1.1×10^{11}	--------	3.1×10^{9}	1.190
3,200	3.571	.8009	3.180	.3476	.8963	56.06	56.82	33.02	6.530	5.5×10^{-8}	---------	3.7×10^{11}	--------	9.8×10^{9}	1.180
3,400	3.697	.7834	3.292	.3386	.8754	62.94	63.67	33.43	6.940	1.6×10^{-7}	1.2×10^{-17}	1.2×10^{12}	1.6	2.8×10^{10}	1.175
3,600	3.841	.7688	3.420	.3291	.8533	70.56	71.31	33.92	7.430	4.1	1.4×10^{-15}	3.2	1.6×10^{2}	7.1×10^{10}	1.176
3,800	3.987	.7550	3.550	.3206	.8327	78.88	79.69	34.42	7.930	9.1	1.0×10^{-13}	7.5	1.0×10^{4}	1.6×10^{11}	1.180
4,000	4.147	.7490	3.693	.3139	.8170	86.90	87.59	34.81	8.320	1.8×10^{-6}	1.3×10^{-12}	1.6×10^{13}	1.2×10^{5}	3.1	1.189
4,200	4.309	.7451	3.837	.3081	.8030	94.89	95.52	35.24	8.750	3.5	1.6×10^{-11}	3.2	1.4×10^{6}	6.0	1.199
4,400	4.469	.7437	3.980	.3036	.7921	102.4	103.1	35.63	9.140	6.1	1.7×10^{-10}	5.7	1.4×10^{7}	1.0×10^{12}	1.212
4,600	4.624	.7446	4.118	.3005	.7848	109.3	110.1	35.97	9.480	1.0×10^{-5}	6.0×10^{-10}	9.6	4.6×10^{7}	1.7	1.224
4,800	4.761	.7448	4.240	.2987	.7807	115.7	116.7	36.28	9.790	1.6	1.6×10^{-9}	1.6×10^{14}	1.2×10^{8}	2.6	1.232
5,000	4.894	.7459	4.358	.2975	.7778	121.9	123.0	36.54	10.05	2.55	2.8×10^{-9}	2.5	2.0	4.1	1.238
5,500	5.134	.7366	4.572	.2993	.7835	137.7	138.7	37.22	10.73	6.10	1.2×10^{-8}	6.2	8.2	9.5	1.212
6,000	5.353	.7195	4.767	.2993	.7847	157.1	158.1	37.95	11.46	1.3×10^{-4}	2.9	1.4×10^{15}	1.9×10^{9}	1.9×10^{13}	1.185
6,500	5.634	.7019	5.017	.2935	.7705	182.9	184.0	38.89	12.40	2.4	9.0	2.8	5.5×10^{9}	3.7	1.166
7,000	5.954	.6814	5.302	.2855	.7503	216.9	218.0	40.03	13.54	4.1	2.5×10^{-7}	5.3	1.4×10^{10}	6.6	1.160
7,500	6.337	.6633	5.643	.2762	.7268	259.5	260.6	41.40	14.91	6.1	1.2×10^{-6}	8.8	6.4×10^{10}	1.1×10^{14}	1.159
8,000	6.768	.6483	6.027	.2677	.7050	309.9	310.9	42.85	16.36	9.2	1.3×10^{-5}	1.5×10^{16}	5.7×10^{11}	1.8	1.161
8,500	7.221	.6368	6.430	.2608	.6872	365.3	366.8	44.42	17.93	1.4×10^{-3}	5.0	2.5	1.9×10^{12}	3.0	1.168
9,000	7.690	.6319	6.848	.2559	.6748	421.6	422.8	45.97	19.48	2.15	9.9	4.2	3.5	5.1	1.176
9,500	8.150	.6313	7.258	.2527	.6666	474.0	475.6	47.29	20.80	3.1	1.4×10^{-4}	6.5	4.9	8.0	1.189
10,000	8.588	.6352	7.648	.2508	.6619	519.9	521.4	48.42	21.93	4.6	1.7	1.0×10^{17}	5.7	1.3×10^{15}	1.206
11,000	9.349	.6483	8.325	.2499	.6597	590.9	593.1	50.03	23.54	9.5	2.1	2.2	6.9	2.7	1.237
12,000	9.961	.6614	8.870	.2514	.6637	644.6	647.5	51.23	24.74	2.0×10^{-2}	2.4	4.5	7.8	5.6	1.251

TABLE IV.- NORMAL SHOCK PARAMETERS - Continued

(d) For geopotential altitude of 100,000 ft; T_1 = 233° K; a_1 = 1,005 ft/sec; $p_1 = 0.1067 \times 10^{-1}$ atm

T_2, °K	u_1, ft/sec	M_1	Z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log \frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
800	3.649×10^{3}	3.631	1.00	15.35	1.009	0.1639	17.40	4.481	1.030	0.5606×10^{-1}	-1.251	----------	3.433	0.9816	------	-----	381
1,200	4.827	4.803	1.00	27.21	1.017	.2906	30.25	5.296	1.074	.6625	-1.179	----------	5.150	.9495	------	-----	508
1,600	5.823	5.794	1.00	39.94	1.024	.4266	43.97	5.833	1.117	.7297	-1.137	----------	6.867	.9195	2,042	-----	633
2,000	6.735	6.701	1.002	53.87	1.031	.5753	58.86	6.266	1.160	.7839	-1.106	----------	8.584	.8877	------	-----	764
2,200	7.178	7.142	1.004	61.44	1.035	.6562	66.92	6.484	1.186	.8112	-1.091	----------	9.442	.8697	2,439	-----	818
2,400	7.617	7.579	1.007	67.49	1.039	.7208	75.45	6.709	1.215	.8393	-1.076	----------	10.30	.8506	------	-----	874
2,600	8.084	8.044	1.010	78.72	1.045	.8407	85.13	6.986	1.254	.8740	-1.059	----------	11.16	.8251	2,633	-----	915
2,800	8.594	8.551	1.013	89.47	1.050	.9555	96.44	7.350	1.308	.9195	-1.036	----------	12.02	.7927	------	-----	956
3,000	9.184	9.138	1.028	102.9	1.058	1.100	110.4	7.769	1.372	.9719	-1.012	----------	12.88	.7495	3,027	-----	979
3,200	9.783	9.734	1.036	117.6	1.065	1.256	125.7	8.266	1.450	1.034	-.9855	2.165×10^{-3}	13.73	.7091	------	1,350	1,007
3,400	10.48	10.43	1.062	136.1	1.073	1.453	144.7	8.783	1.531	1.099	-.9591	1.915	14.59	.6604	3,426	1,530	1,008
3,600	11.14	11.09	1.085	154.6	1.079	1.651	163.7	9.215	1.591	1.148	-.9402	1.69	15.45	.6222	------	1,730	1,012
3,800	11.72	11.66	1.102	171.8	1.084	1.835	181.6	9.535	1.674	1.212	-.9164	1.51	16.31	.5955	3,831	1,925	1,027
4,000	12.34	12.28	1.127	191.0	1.087	2.039	201.4	9.867	1.699	1.235	-.9085	1.35	17.17	.5674	------	2,090	1,025
4,200	12.86	12.79	1.133	207.6	1.088	2.218	218.9	10.07	1.746	1.272	-.8955	1.245	18.03	.5500	4,238	2,230	1,048
4,400	13.37	13.30	1.166	224.5	1.088	2.398	236.6	10.20	1.747	1.275	-.8944	1.20	18.88	.5344	------	2,340	1,042
4,600	13.74	13.67	1.170	237.2	1.089	2.533	249.9	10.27	1.758	1.285	-.8910	1.15	19.74	.5296	4,644	2,415	1,070
4,800	14.14	14.07	1.187	251.2	1.089	2.683	264.6	10.28	1.756	1.285	-.8910	1.11	20.60	.5226	4,844	2,475	1,082
5,000	14.53	14.45	1.195	265.4	1.089	2.834	279.4	10.35	1.766	1.295	-.8879	1.085	21.46	.5163	5,040	2,515	1,104
5,500	15.49	15.42	1.222	302.2	1.090	3.227	318.0	10.48	1.783	1.311	-.8824	1.035	23.61	.5006	5,535	2,650	1,143
6,000	16.75	16.67	1.264	354.3	1.093	3.784	372.2	10.88	1.847	1.362	-.8660	9.66×10^{-4}	25.75	.4684	6,031	2,780	1,142
6,500	18.27	18.18	1.312	423.6	1.099	4.524	443.7	11.57	1.957	1.447	-.8395	8.52	27.90	.4279	6,529	2,950	1,115
7,000	20.15	20.05	1.390	518.2	1.105	5.534	541.0	12.41	2.095	1.553	-.8089	7.59	30.04	.3799	7,029	3,250	1,035
7,500	22.22	22.11	1.490	633.9	1.111	6.770	659.7	13.22	2.225	1.654	-.7816	6.03	32.19	.3352	7,530	4,025	928
8,000	24.38	24.26	1.605	766.1	1.116	8.182	795.3	13.91	2.338	1.740	-.7595	5.01	34.34	.2976	8,033	4,585	818
8,500	26.29	26.16	1.694	893.3	1.119	9.541	925.7	14.46	2.427	1.809	-.7426	4.47	36.48	.2723	8,537	4,870	749
9,000	28.06	27.92	1.797	1,019	1.120	10.88	1,056	14.68	2.462	1.836	-.7360	4.12	38.63	.2532	9,044	5,070	681
9,500	29.49	29.34	1.875	1,125	1.120	12.01	1,166	14.71	2.466	1.841	-.7350	3.98	40.77	.2421	9,553	5,190	641
10,000	30.47	30.32	1.919	1,200	1.119	12.82	1,244	14.58	2.442	1.823	-.7391	3.85	42.92	.2389	10,070	5,270	529
11,000	32.34	32.17	2.003	1,350	1.117	14.41	1,400	14.27	2.390	1.786	-.7482	3.63	47.21	.2335	11,077	5,375	613
12,000	33.67	33.44	2.038	1,455	1.115	15.54	1,510	13.86	2.320	1.734	-.7611	3.42	51.50	.2358	12,078	5,450	629
13,000	35.22	34.99	2.091	1,590	1.114	16.98	1,652	13.63	2.280	1.705	-.7684	3.23	55.79	.2335	------	5,570	626

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2 \Big/ \frac{R}{m_0}T_0$	$h_t \Big/ \frac{R}{m_0}T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm^3	$N_{e,w}$, per cm^3	$N_{e,fw}$, per cm^3	γ_2^*
800	1.824	0.9754	1.686	0.4442	0.9953	10.49	10.84	29.27	1.70	---------	---------	--------	--------	--------	-----
1,200	2.196	.9429	2.030	.4130	.9876	16.31	16.73	30.31	2.73	---------	---------	--------	--------	--------	-----
1,600	2.507	.9176	2.318	.3963	.9761	22.51	22.99	31.13	3.56	3.4×10^{-16}	---------	6.7×10^{2}	--------	4.1×10^{1}	-----
2,000	2.791	.8974	2.580	.3831	.9599	29.08	29.74	31.82	4.25	1.1×10^{-12}	---------	2.3×10^{6}	--------	1.1×10^{5}	1.274
2,200	2.910	.8832	2.690	.3785	.9544	32.61	33.38	32.13	4.56	1.8×10^{-11}	---------	3.9×10^{7}	--------	1.7×10^{6}	1.256
2,400	3.012	.8655	2.785	.3750	.9503	36.43	37.21	32.46	4.89	1.9×10^{-10}	---------	4.2×10^{8}	--------	1.7×10^{7}	1.235
2,600	3.115	.8472	2.880	.3697	.9414	40.75	41.54	32.82	5.25	1.4×10^{-9}	---------	3.3×10^{9}	--------	1.2×10^{8}	1.212
2,800	3.209	.8241	2.967	.3625	.9271	45.77	46.56	33.20	5.63	7.3×10^{-9}	---------	1.8×10^{10}	--------	2.1×10^{8}	1.191
3,000	3.321	.8012	3.070	.3542	.9094	51.73	52.75	33.65	6.08	2.5×10^{-8}	---------	6.7×10^{10}	--------	2.0×10^{9}	1.177
3,200	3.443	.7823	3.183	.3420	.8812	58.76	59.46	34.10	6.53	8.3×10^{-8}	7.0×10^{-18}	2.4×10^{11}	4.1×10^{-1}	6.5×10^{9}	1.168
3,400	3.578	.7611	3.308	.3320	.8583	66.80	67.82	34.60	7.03	2.3×10^{-7}	7.8×10^{-16}	7.2×10^{11}	4.0×10^{1}	1.8×10^{10}	1.167
3,600	3.732	.7488	3.450	.3238	.8395	75.58	76.23	35.17	7.60	5.9×10^{-7}	7.6×10^{-14}	2.0×10^{12}	3.5×10^{3}	4.6	1.171
3,800	3.892	.7436	3.598	.3092	.8029	84.62	84.04	35.69	8.12	1.2×10^{-6}	3.2×10^{-12}	4.3	1.3×10^{5}	9.2	1.180
4,000	4.056	.7375	3.750	.3067	.7981	92.98	92.83	36.15	8.58	2.6	4.1×10^{-11}	9.7	1.5×10^{6}	2.0×10^{11}	1.193
4,200	4.218	.7368	3.900	.2984	.7775	100.7	100.6	36.58	9.01	4.7	2.5×10^{-10}	1.8×10^{13}	8.8×10^{6}	3.5	1.209
4,400	4.375	.7360	4.045	.2982	.7778	107.7	108.4	36.96	9.39	8.1	8.4×10^{-10}	3.2	2.8×10^{7}	6.1	1.224
4,600	4.511	.7388	4.170	.2949	.7700	114.0	114.3	37.26	9.69	1.3×10^{-5}	1.9×10^{-9}	5.3	6.2×10^{7}	9.5	1.233
4,800	4.634	.7380	4.284	.2954	.7715	120.1	120.9	37.55	9.98	2.1	3.9	8.6	1.2×10^{8}	1.5×10^{12}	1.233
5,000	4.738	.7349	4.380	.2948	.7705	126.1	127.5	37.77	10.20	3.2	5.3	1.3×10^{14}	1.7	2.3	1.231
5,500	4.940	.7193	4.567	.2979	.7798	143.4	144.6	38.55	10.98	7.8	1.75×10^{-8}	3.4	5.2	5.4	1.191
6,000	5.177	.6983	4.786	.2958	.7756	167.0	168.6	39.45	11.88	1.7×10^{-4}	5.0×10^{-8}	7.9	1.4×10^{9}	1.2×10^{13}	1.165
6,500	5.478	.6784	5.064	.2869	.7532	199.8	200.0	40.66	13.09	3.0	1.6×10^{-7}	1.5×10^{15}	4.3×10^{9}	2.1	1.153
7,000	5.845	.6573	5.404	.2763	.7263	243.3	242.5	42.13	14.56	5.0	7.0×10^{-7}	2.9	1.7×10^{10}	3.8	1.151
7,500	6.279	.6408	5.805	.2664	.7011	297.1	294.4	43.85	16.28	7.9	1.3×10^{-5}	5.2	2.5×10^{11}	6.7	1.153
8,000	6.744	.6279	6.235	.2587	.6815	357.3	353.7	45.66	18.09	1.2×10^{-3}	5.3	9.0	9.1×10^{11}	1.2×10^{14}	1.161
8,500	7.213	.6229	6.668	.2508	.6612	417.5	410.7	47.38	19.81	1.95	9.8	1.6×10^{16}	1.6×10^{12}	2.0	1.171
9,000	7.674	.6214	7.095	.2480	.6540	472.7	467.7	48.88	21.31	3.15	1.4×10^{-4}	2.8	2.1	4.0	1.185
9,500	8.106	.6245	7.494	.2460	.6489	518.7	516.2	50.08	22.51	4.9	1.7	4.5	2.6	6.0	1.204
10,000	8.496	.6336	7.855	.2449	.6463	556.1	550.9	50.99	23.42	7.6	1.9	7.1	2.9	1.1×10^{15}	1.225
11,000	9.135	.6424	8.445	.2467	.6511	614.6	620.0	52.31	24.74	1.45×10^{-2}	2.2	1.4×10^{17}	3.2	1.9	1.245
12,000	9.621	.6510	8.895	.2571	.6787	667.2	672.1	53.50	25.93	3.0	2.5	2.9	3.6	3.7	1.238
13,000	10.08	.6522	9.321	.2547	.6724	729.5	735.3	54.67	27.10	4.9	2.6	4.6	3.7	6.1	1.224

TABLE IV.- NORMAL SHOCK PARAMETERS - Continued

(e) For geopotential altitude of 120,300 ft; $T_1 = 252^\circ$ K; a_1 = 1,043 ft/sec; $p_1 = 0.4462 \times 10^{-2}$ atm

T_2, °K	u_1, ft/sec	M_1	Z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log \frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
800	3.597×10^3	3.449	1.00	13.83	1.009	0.6251×10^{-1}	15.74	4.351	1.030	0.2136×10^{-1}	-1.670	---------	3.187	0.9818	------	-----	403
1,200	4.788	4.591	1.00	24.85	1.018	1.123	27.68	5.208	1.074	.2557	-1.592	---------	4.781	.9494	------	-----	522
1,600	5.791	5.552	1.00	36.68	1.025	1.658	40.41	5.770	1.118	.2833	-1.548	---------	6.375	.9194	------	-----	648
2,000	6.711	6.434	1.002	49.71	1.032	2.247	54.32	6.224	1.162	.3056	-1.515	---------	7.968	.8865	2,040	-----	781
2,200	7.160	6.864	1.004	56.80	1.036	2.568	61.88	6.458	1.190	.3171	-1.499	---------	8.765	.8677	------	-----	835
2,400	7.627	7.313	1.008	64.80	1.041	2.929	70.31	6.722	1.225	.3301	-1.481	---------	9.562	.8434	2,437	-----	883
2,600	8.136	7.801	1.013	74.25	1.048	3.356	80.20	7.079	1.276	.3476	-1.459	---------	10.36	.8110	------	-----	926
2,800	8.719	8.360	1.020	85.94	1.056	3.884	92.39	7.553	1.349	.3708	-1.431	---------	11.16	.7677	2,828	-----	960
3,000	9.384	8.997	1.038	100.4	1.065	4.538	107.4	8.093	1.432	.3973	-1.401	---------	11.95	.7166	------	-----	977
3,200	10.08	9.668	1.058	117.0	1.074	5.287	124.4	8.723	1.531	.4283	-1.368	8.36×10^{-4}	12.75	.6670	3,023	1,480	987
3,400	10.88	10.43	1.082	137.3	1.082	6.205	145.3	9.365	1.632	.4598	-1.337	7.28	13.55	.6127	------	1,700	985
3,600	11.54	11.06	1.105	155.1	1.086	7.011	163.7	9.836	1.706	.4830	-1.316	6.41	14.34	.5796	3,624	1,930	991
3,800	12.16	11.66	1.130	172.8	1.090	7.809	182.0	10.21	1.764	.5013	-1.300	5.85	15.14	.5531	------	2,105	991
4,000	12.72	12.19	1.152	189.3	1.091	8.556	199.3	10.43	1.797	.5123	-1.291	5.49	15.94	.5338	4,031	2,230	999
4,200	13.19	12.64	1.170	203.5	1.092	9.199	214.2	10.52	1.807	.5163	-1.287	5.22	16.73	.5225	------	2,325	1,012
4,400	13.60	13.04	1.182	216.2	1.091	9.772	227.7	10.52	1.805	.5165	-1.287	5.05	17.53	.5158	4,439	2,390	1,033
4,600	13.96	13.38	1.192	227.8	1.091	10.30	239.8	10.48	1.794	.5143	-1.289	4.91	18.33	.5125	------	2,440	1,057
4,800	14.36	13.76	1.204	241.1	1.091	10.90	253.6	10.46	1.789	.5135	-1.289	4.79	19.12	.5062	4,842	2,485	1,076
5,000	14.77	14.16	1.214	255.1	1.092	11.53	268.3	10.57	1.806	.5191	-1.285	4.69	19.92	.4991	5,040	2,520	1,095
5,500	15.89	15.24	1.245	296.3	1.094	13.39	311.2	10.88	1.853	.5344	-1.272	4.33	21.91	.4754	5,533	2,650	1,122
6,000	17.44	16.72	1.296	358.6	1.099	16.21	375.6	11.55	1.960	.5672	-1.246	3.97	23.90	.4321	6,028	2,790	1,106
6,500	19.38	18.58	1.372	445.6	1.107	20.14	465.1	12.59	2.128	.6180	-1.209	3.46	25.90	.3805	6,525	3,040	1,025
7,000	21.58	20.69	1.472	556.0	1.113	25.13	578.5	13.57	2.288	.6663	-1.176	2.63	27.89	.3312	7,025	3,870	920
7,500	23.96	22.97	1.594	688.5	1.118	31.12	714.2	14.37	2.418	.7057	-1.151	2.18	29.88	.2886	7,526	4,470	803
8,000	26.22	25.13	1.715	826.9	1.122	37.37	856.1	14.99	2.517	.7359	-1.133	1.96	31.87	.2574	8,028	4,745	708
8,500	27.86	26.71	1.806	935.5	1.124	42.28	967.6	15.30	2.567	.7511	-1.124	1.80	33.87	.2424	8,533	4,915	657
9,000	29.33	28.12	1.887	1,036	1.123	46.84	1,072	15.29	2.563	.7505	-1.125	1.70	35.86	.2318	9,040	5,025	620
9,500	30.41	29.15	1.945	1,113	1.122	50.30	1,152	15.12	2.534	.7422	-1.129	1.64	37.85	.2277	9,549	5,100	604
10,000	31.30	30.01	1.981	1,178	1.121	53.22	1,219	14.84	2.488	.7288	-1.137	1.59	39.84	.2263	10,057	5,150	619
11,000	32.81	31.46	2.034	1,292	1.118	58.39	1,339	14.49	2.428	.7117	-1.148	1.51	43.83	.2265	11,068	5,240	607
12,000	34.33	32.87	2.078	1,408	1.117	63.60	1,460	14.17	2.372	.6957	-1.158	1.42	47.81	.2266	12,067	5,360	615
13,000	36.23	34.69	2.150	1,567	1.116	70.80	1,626	14.07	2.355	.6909	-1.161	1.33	51.79	.2204	13,066	5,465	599
14,000	38.45	36.81	2.253	1,764	1.116	79.70	1,830	14.04	2.349	.6893	-1.162	1.25	55.78	.2109	14,067	5,600	561

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2 \Big/ \frac{R}{m_0} T_0$	$h_t \Big/ \frac{R}{m_0} T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm³	$N_{e,w}$, per cm³	$N_{e,fw}$, per cm³	γ_2*
800	1.758	0.9756	1.686	0.4509	0.9951	10.49	10.85	30.23	1.54	---------	---------	--------	--------	--------	-----
1,200	2.114	.9416	2.028	.4170	.9886	16.31	16.74	31.26	2.57	---------	---------	--------	--------	--------	-----
1,600	2.411	.9160	2.312	.3991	.9772	22.51	23.00	32.08	3.39	7.3×10^{-16}	---------	5.6×10^2	--------	3.7×10^1	-----
2,000	2.690	.8970	2.580	.3843	.9586	29.10	29.78	32.77	4.08	1.9×10^{-12}	---------	1.6×10^6	--------	8.1×10^4	1.270
2,200	2.797	.8801	2.683	.3801	.9548	32.71	33.45	33.10	4.41	2.2×10^{-11}	---------	1.9×10^7	--------	8.7×10^5	1.249
2,400	2.891	.8586	2.773	.3764	.9512	36.73	37.53	33.44	4.75	3.2×10^{-10}	---------	2.9×10^8	--------	1.2×10^7	1.222
2,600	2.989	.8361	2.867	.3687	.9365	41.46	42.27	33.80	5.11	2.2×10^{-9}	---------	2.1×10^9	--------	7.9×10^7	1.196
2,800	3.086	.8095	2.960	.3586	.9155	47.21	48.07	34.24	5.55	1.2×10^{-8}	---------	1.2×10^{10}	--------	4.2×10^8	1.175
3,000	3.201	.7836	3.070	.3472	.8909	54.22	55.17	34.79	6.10	3.8×10^{-8}	---------	4.2×10^{10}	--------	1.3×10^9	1.163
3,200	3.336	.7629	3.200	.3322	.8557	62.59	63.20	35.34	6.65	1.2×10^{-7}	3.4×10^{-16}	1.5×10^{11}	7.6	4.0×10^9	1.159
3,400	3.482	.7407	3.340	.3199	.8270	71.92	73.08	35.95	7.26	3.4	6.0×10^{-14}	4.6×10^{11}	1.2×10^3	1.1×10^{10}	1.162
3,600	3.639	.7315	3.490	.3091	.8010	81.54	81.79	36.53	7.84	8.3	5.2×10^{-12}	1.2×10^{12}	9.0×10^4	2.8	1.172
3,800	3.806	.7274	3.650	.3000	.7790	90.87	90.45	37.09	8.40	1.75×10^{-6}	7.2×10^{-11}	2.6	1.1×10^6	5.9	1.187
4,000	3.978	.7280	3.815	.2938	.7643	98.74	98.66	37.53	8.84	3.5	3.8×10^{-10}	5.5	5.7×10^6	1.2×10^{11}	1.206
4,200	4.136	.7307	3.967	.2907	.7568	105.8	105.8	37.95	9.26	6.2	1.2×10^{-9}	1.0×10^{13}	1.7×10^7	2.0	1.224
4,400	4.275	.7335	4.100	.2899	.7555	112.0	112.3	38.25	9.56	1.1×10^{-5}	2.3	1.8	3.2	3.5	1.236
4,600	4.386	.7333	4.207	.2913	.7600	117.9	118.2	38.55	9.86	1.75	3.8	2.9	5.2	5.5	1.235
4,800	4.478	.7285	4.295	.2939	.7674	123.8	124.8	38.84	10.15	2.7	5.8	4.5	7.8	8.3	1.223
5,000	4.562	.7221	4.375	.2934	.7665	130.2	131.9	39.06	10.37	4.1	8.0	6.9	1.1×10^8	1.2×10^{12}	1.212
5,500	4.760	.7012	4.565	.2942	.7698	150.6	152.3	40.02	11.33	9.8	2.5×10^{-8}	1.8×10^{14}	3.1	2.9	1.169
6,000	5.022	.6754	4.817	.2883	.7559	180.8	182.7	41.15	12.46	1.95×10^{-4}	7.6×10^{-8}	3.9	9.1	5.9	1.149
6,500	5.377	.6518	5.157	.2745	.7209	223.3	224.8	42.72	14.03	3.4	2.1×10^{-7}	7.7	2.3×10^9	1.1×10^{13}	1.144
7,000	5.789	.6309	5.552	.2634	.6926	279.2	278.1	44.69	16.00	5.7	9.8×10^{-6}	1.5×10^{15}	8.4×10^{10}	2.1	1.146
7,500	6.261	.6150	6.005	.2553	.6724	344.2	342.0	46.80	18.11	9.1	5.0×10^{-5}	2.8	3.7×10^{11}	3.8	1.152
8,000	6.741	.6057	6.465	.2489	.6559	409.8	408.8	48.75	20.06	1.5×10^{-3}	8.9×10^{-5}	5.1	6.2	7.0	1.163
8,500	7.205	.6096	6.910	.2424	.6391	468.0	461.4	50.43	21.74	2.5	1.3×10^{-4}	9.1	8.8	1.3×10^{14}	1.179
9,000	7.637	.6139	7.325	.2410	.6355	514.8	510.9	51.73	23.04	4.1	1.5	1.6×10^{16}	9.9	2.2	1.200
9,500	8.018	.6220	7.690	.2405	.6344	550.9	548.9	52.67	23.98	6.4	1.7	2.5	1.1×10^{12}	3.5	1.223
10,000	8.346	.6289	8.005	.2422	.6389	580.6	581.3	53.41	24.72	1.1×10^{-2}	1.85	4.3	1.2	5.9	1.238
11,000	8.842	.6357	8.480	.2454	.6477	634.6	638.7	54.62	25.93	2.3	2.1	9.0	1.3	1.3×10^{15}	1.235
12,000	9.280	.6387	8.900	.2500	.6598	694.5	698.9	55.96	27.27	4.2	2.5	1.6×10^{17}	1.6	2.3	1.216
13,000	9.780	.6380	9.380	.2521	.6655	772.7	778.1	57.44	28.75	6.5	2.9	2.6	1.8	3.6	1.203
14,000	10.36	.6374	9.94	.2530	.6679	872.1	875.8	59.19	30.50	1.0×10^{-1}	3.8	4.2	2.3	5.9	1.199

TABLE IV.- NORMAL SHOCK PARAMETERS - Continued

(f) For geopotential altitude of 154,800 ft; T_1 = 283 °K; a_1 = 1,106 ft/sec; p_1 = 0.1161 × 10^{-2} atm

T_2, °K	u_1, ft/sec	M_1	z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log\frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
800	3.508×10^3	3.172	1.000	11.68	1.010	0.1388×10^{-1}	13.38	4.132	1.031	0.4735×10^{-2}	-2.324	----------	2.827	0.9792	------	-----	411
1,200	4.719	4.267	1.000	21.46	1.018	.2552	23.97	5.060	1.075	.5809	-2.236	----------	4.24	.9471	------	-----	543
1,600	5.735	5.185	1.000	31.98	1.025	.3802	35.32	5.660	1.118	.6498	-2.187	----------	5.654	.9168	------	-----	672
2,000	6.671	6.021	1.001	43.54	1.033	.5177	47.64	6.154	1.167	.7062	-2.151	----------	7.067	.8847	2,040	-----	809
2,200	7.139	6.443	1.003	50.11	1.038	.5958	54.61	6.427	1.200	.7376	-2.132	----------	7.774	.8627	------	-----	863
2,400	7.664	6.917	1.008	58.19	1.045	.6919	63.08	6.809	1.253	.7814	-2.107	----------	8.481	.8279	2,432	-----	908
2,600	8.287	7.479	1.018	68.69	1.055	.8167	74.00	7.344	1.333	.8429	-2.074	----------	9.187	.7776	------	-----	941
2,800	9.023	8.144	1.036	82.36	1.066	.9793	88.10	8.037	1.440	.9224	-2.035	----------	9.894	.7150	2,822	-----	956
3,000	9.855	8.895	1.062	99.27	1.077	1.180	105.5	8.821	1.563	1.012	-1.995	2.184×10^{-4}	10.60	.6493	------	1,490	957
3,200	10.74	9.691	1.094	118.9	1.086	1.413	125.7	9.613	1.687	1.103	-1.957	1.88	11.31	.5888	3,019	1,730	948
3,400	11.55	10.43	1.126	138.4	1.092	1.646	145.8	10.23	1.783	1.174	-1.930	1.61	12.01	.5440	------	2,010	940
3,600	12.23	11.04	1.154	155.6	1.095	1.850	163.6	10.60	1.838	1.216	-1.915	1.48	12.72	.5164	3,624	2,165	941
3,800	12.78	11.53	1.175	170.0	1.096	2.021	178.6	10.77	1.863	1.236	-1.908	1.405	13.43	.5011	------	2,260	952
4,000	13.19	11.91	1.188	181.2	1.096	2.154	190.4	10.79	1.862	1.239	-1.907	1.37	14.13	.4957	4,035	2,300	976
4,200	13.55	12.23	1.197	191.1	1.095	2.272	200.8	10.76	1.852	1.234	-1.909	1.325	14.84	.4940	------	2,360	1,004
4,400	13.90	12.55	1.205	200.9	1.095	2.389	211.1	10.72	1.843	1.230	-1.910	1.297	15.55	.4929	4,439	2,395	1,031
4,600	14.26	12.87	1.213	211.4	1.094	2.514	222.2	10.72	1.841	1.231	-1.910	1.27	16.25	.4902	------	2,425	1,058
4,800	14.68	13.25	1.223	224.2	1.095	2.665	235.5	10.81	1.853	1.241	-1.906	1.233	16.96	.4835	4,834	2,470	1,077
5,000	15.16	13.68	1.235	239.3	1.096	2.845	251.2	10.97	1.876	1.259	-1.900	1.197	17.67	.4732	5,031	2,515	1,090
5,500	16.73	15.10	1.285	293.2	1.102	3.486	306.7	11.74	1.999	1.347	-1.871	1.09	19.43	.4291	5,525	2,650	1,075
6,000	18.92	17.07	1.371	377.8	1.111	4.492	393.4	12.99	2.203	1.491	-1.826	9.39×10^{-5}	21.20	.3680	6,021	2,925	995
6,500	21.56	19.46	1.495	494.7	1.120	5.883	513.0	14.40	2.432	1.653	-1.782	6.78	22.97	.3078	6,520	3,910	863
7,000	24.31	27.94	1.642	631.6	1.125	7.510	653.1	15.55	2.618	1.785	-1.748	5.67	24.74	.2617	7,020	4,400	733
7,500	26.71	24.10	1.781	764.4	1.128	9.089	789.3	16.20	2.722	1.859	-1.731	5.07	26.50	.2327	7,523	4,630	640
8,000	28.49	25.71	1.884	870.4	1.128	10.35	898.5	16.34	2.744	1.875	-1.727	4.70	28.27	.2182	8,029	4,770	590
8,500	29.69	26.79	1.948	944.1	1.127	11.23	975.1	16.14	2.708	1.852	-1.732	4.51	30.04	.2137	8,539	4,820	574
9,000	30.56	27.59	1.985	999.4	1.126	11.88	1,033	15.83	2.655	1.817	-1.741	4.34	31.80	.2136	9,049	4,900	575
9,500	31.31	28.26	2.011	1,047	1.124	12.45	1,083	15.51	2.601	1.780	-1.750	4.225	33.57	.2149	9,554	4,940	582
10,000	32.02	28.90	2.034	1,094	1.123	13.00	1,132	15.21	2.551	1.746	-1.758	4.12	35.34	.2163	10,057	4,980	591
11,000	33.72	30.44	2.093	1,211	1.121	14.40	1,255	14.89	2.495	1.709	-1.767	3.94	38.87	.2146	11,054	5,040	592
12,000	35.88	32.39	2.176	1,372	1.121	16.31	1,420	14.87	2.490	1.707	-1.768	3.59	42.40	.2069	12,053	5,250	571
13,000	38.64	34.88	2.308	1,592	1.122	18.93	1,647	15.01	2.512	1.723	-1.764	----------	45.94	.1934	13,051	-----	522
14,000	41.87	37.79	2.485	1,870	1.123	22.24	1,934	15.21	2.544	1.747	-1.756	----------	49.47	.1776	14,053	-----	456

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2/\frac{R}{m_0}T_0$	$h_t/\frac{R}{m_0}T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm³	$N_{e,w}$, per cm³	$N_{e,fw}$, per cm³	γ_2^*
800	1.656	0.9747	1.685	0.4635	0.9953	10.49	10.87	31.74	1.29	---------	---------	--------	--------	--------	-----
1,200	1.990	.9405	2.025	.4237	.9890	16.31	16.75	32.74	2.29	---------	---------	--------	--------	--------	-----
1,600	2.264	.9118	2.303	.4048	.9809	22.51	23.02	33.55	3.10	2.0×10^{-15}	---------	3.5×10^2	--------	2.6×10^1	-----
2,000	2.523	.8925	2.567	.3877	.9597	29.19	29.86	34.25	3.80	4.5×10^{-12}	---------	8.5×10^5	--------	4.9×10^4	1.263
2,200	2.615	.8711	2.660	.3833	.9566	32.99	33.67	34.55	4.10	6.9×10^{-11}	---------	1.4×10^7	--------	7.0×10^5	1.232
2,400	2.699	.8429	2.746	.3763	.9457	37.56	38.27	34.96	4.51	6.9×10^{-10}	---------	1.5×10^8	--------	6.6×10^6	1.197
2,600	2.796	.8133	2.845	.3643	.9223	43.39	44.13	35.44	4.99	4.4×10^{-9}	---------	1.0×10^9	--------	4.1×10^7	1.169
2,800	2.907	.7817	2.958	.3486	.8884	50.91	51.64	36.03	5.58	2.2×10^{-8}	---------	5.6×10^9	--------	2.0×10^8	1.153
3,000	3.037	.7515	3.090	.3320	.8511	60.25	60.92	36.74	6.29	7.1×10^{-8}	9.2×10^{-16}	2.0×10^{10}	5.4	6.5×10^8	1.147
3,200	3.190	.7280	3.246	.3160	.8140	70.91	71.63	37.38	6.93	2.2×10^{-7}	2.3×10^{-13}	7.1×10^{10}	1.2×10^3	2.0×10^9	1.152
3,400	3.357	.7144	3.415	.3037	.7852	81.62	82.37	38.19	7.74	5.9×10^{-7}	3.5×10^{-11}	2.1×10^{11}	1.5×10^5	5.5×10^9	1.165
3,600	3.526	.7105	3.587	.2954	.7655	91.18	91.86	38.81	8.36	1.3×10^{-6}	3.0×10^{-10}	4.9×10^{11}	1.2×10^6	1.2×10^{10}	1.186
3,800	3.696	.7139	3.760	.2896	.7518	99.13	99.94	39.28	8.83	2.7	9.5×10^{-10}	1.1×10^{12}	3.7	2.5	1.213
4,000	3.846	.7204	3.913	.2869	.7458	105.4	106.3	39.61	9.16	5.2	1.5×10^{-9}	2.1	5.7	4.7	1.236
4,200	3.971	.7248	4.040	.2864	.7451	111.1	112.0	39.94	9.49	9.3	2.9	3.7	1.1×10^7	8.1	1.242
4,400	4.054	.7216	4.125	.2887	.7516	116.7	117.6	40.23	9.78	1.6×10^{-5}	4.3	6.4	1.6	1.4×10^{11}	1.231
4,600	4.125	.7163	4.197	.2910	.7582	122.8	123.6	40.52	10.07	2.6	5.9	1.0×10^{13}	2.1	2.1	1.211
4,800	4.192	.7077	4.265	.2924	.7625	129.8	130.8	40.89	10.44	4.0	9.1	1.6	3.2	3.2	1.189
5,000	4.268	.6985	4.342	.2924	.7632	138.2	139.2	41.27	10.82	5.9	1.4×10^{-8}	2.5	4.9	4.7	1.172
5,500	4.511	.6704	4.590	.2852	.7462	167.9	168.8	42.55	12.10	1.3×10^{-4}	4.3×10^{-8}	6.0	1.4×10^8	1.1×10^{12}	1.141
6,000	4.839	.6374	4.923	.2715	.7122	213.8	214.8	44.36	13.91	2.6	2.7×10^{-7}	1.4×10^{14}	8.1×10^8	2.3	1.134
6,500	5.273	.6104	5.365	.2563	.6736	276.9	278.1	46.72	16.27	4.3	1.5×10^{-5}	2.9	3.4×10^{10}	4.4	1.135
7,000	5.754	.5919	5.854	.2452	.6453	351.3	352.2	49.34	18.89	7.3	5.7×10^{-5}	5.7	1.1×10^{11}	8.7	1.144
7,500	6.238	.5846	6.347	.2386	.6286	423.3	424.5	51.74	21.29	1.3×10^{-3}	1.1×10^{-4}	1.2×10^{15}	2.1	1.8×10^{13}	1.158
8,000	6.698	.5886	6.815	.2350	.6192	481.1	482.6	53.51	23.06	2.4	1.2	2.3	2.2	3.6	1.182
8,500	7.106	.5997	7.230	.2336	.6159	522.5	523.7	54.73	24.28	4.5	1.3	4.4	2.4	6.8	1.210
9,000	7.445	.6102	7.575	.2342	.6176	553.2	554.9	55.58	25.13	7.8	1.5	7.6	2.7	1.2×10^{14}	1.233
9,500	7.706	.6165	7.840	.2365	.6237	579.9	582.0	56.27	25.82	1.25×10^{-2}	1.6	1.2×10^{16}	2.8	1.9	1.237
10,000	7.917	.6195	8.055	.2400	.6331	607.0	608.5	56.94	26.49	2.1	1.75	2.0	3.1	3.1	1.226
11,000	8.325	.6185	8.470	.2455	.6479	672.2	674.7	58.43	27.98	4.6	1.95	4.4	3.4	6.8	1.199
12,000	8.826	.6166	8.980	.2468	.6514	760.3	763.6	60.34	29.90	8.2	2.80	8.2	4.7	1.3×10^{15}	1.183
13,000	9.446	.6130	9.610	.2460	.6494	881.4	885.0	62.65	32.21	1.3×10^{-1}	---------	1.4×10^{17}	--------	2.2	1.180
14,000	10.18	.6101	10.36	.2439	.6442	1,035	1,038	65.38	34.93	1.8×10^{-1}	---------	2.1×10^{17}	--------	3.5	1.179

TABLE IV.- NORMAL SHOCK PARAMETERS - Continued

(g) For geopotential altitude of 173,500 ft; T_1 = 283° K; a_1 = 1,106 ft/sec; $p_1 = 0.5826 \times 10^{-3}$ atm

T_2, °K	u_1, ft/sec	M_1	Z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log \frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
800	3.508×10^{3}	3.172	1.00	11.68	1.010	0.6723×10^{-2}	13.38	4.132	1.031	0.2297×10^{-2}	-2.639	---------	2.827	0.9792	------	-----	411
1,200	4.719	4.267	1.00	21.46	1.018	1.235	23.97	5.06	1.075	.2813	-2.551	---------	4.240	.9471	------	-----	543
1,600	5.735	5.185	1.00	31.98	1.025	1.841	35.31	5.657	1.118	.3145	-2.502	---------	5.654	.9168	------	-----	672
2,000	6.675	6.025	1.002	43.61	1.033	2.510	47.71	6.161	1.168	.3423	-2.466	---------	7.067	.8837	2,038	-----	808
2,200	7.170	6.471	1.004	50.62	1.039	2.913	55.11	6.484	1.209	.3603	-2.443	---------	7.774	.8561	------	-----	859
2,400	7.735	6.981	1.011	59.44	1.048	3.421	64.33	6.933	1.274	.3852	-2.414	---------	8.481	.8141	2,428	-----	900
2,600	8.432	7.610	1.025	71.43	1.060	4.112	76.74	7.587	1.373	.4216	-2.375	---------	9.187	.7531	------	-----	925
2,800	9.266	8.364	1.048	87.35	1.072	5.028	93.13	8.423	1.504	.4680	-2.330	---------	9.894	.6804	2,819	-----	931
3,000	10.20	9.202	1.080	106.9	1.084	6.154	113.2	9.336	1.648	.5188	-2.285	9.79×10^{-5}	10.60	.6089	------	1,610	922
3,200	11.11	10.03	1.116	127.9	1.092	7.361	134.8	10.13	1.772	.5629	-2.250	8.26	11.31	.5520	3,218	1,900	909
3,400	11.89	10.73	1.149	147.2	1.096	8.471	154.7	10.66	1.854	.5924	-2.227	7.46	12.01	.5149	------	2,085	903
3,600	12.50	11.28	1.173	162.8	1.098	9.373	171.0	10.91	1.890	.6063	-2.217	6.99	12.72	.4954	3,625	2,200	911
3,800	12.95	11.69	1.189	175.0	1.098	10.08	183.7	10.97	1.894	.6093	-2.216	6.73	13.43	.4878	------	2,260	930
4,000	13.32	12.02	1.198	184.8	1.097	10.64	194.0	10.91	1.882	.6063	-2.217	6.58	14.13	.4868	4,037	2,295	959
4,200	13.66	12.33	1.205	194.3	1.096	11.18	204.0	10.86	1.869	.6034	-2.219	6.43	14.84	.4867	------	2,330	990
4,400	14.02	12.65	1.213	204.5	1.096	11.77	214.8	10.85	1.864	.6026	-2.219	6.25	15.55	.4849	4,436	2,375	1,017
4,600	14.42	13.01	1.221	216.4	1.096	12.46	227.2	10.90	1.870	.6056	-2.218	6.10	16.25	.4800	------	2,410	1,042
4,800	14.89	13.44	1.233	231.1	1.097	13.30	242.5	11.05	1.892	.6138	-2.212	5.95	16.96	.4703	4,829	2,445	1,056
5,000	15.45	13.95	1.249	249.4	1.099	14.35	261.3	11.30	1.931	.6277	-2.202	5.74	17.67	.4557	5,026	2,495	1,060
5,500	17.36	15.67	1.316	317.2	1.108	18.26	331.0	12.41	2.110	.6894	-2.162	4.94	19.43	.3991	5,522	2,670	1,014
6,000	19.93	17.99	1.426	421.8	1.117	24.28	437.9	13.95	2.360	.7750	-2.111	3.92	21.20	.3319	6,018	3,320	900
6,500	22.87	20.64	1.575	559.3	1.125	32.19	578.4	15.46	2.607	.8590	-2.066	2.98	22.97	.2740	6,518	4,155	758
7,000	25.65	23.16	1.733	706.3	1.129	40.66	729.0	16.48	2.772	.9156	-2.038	2.60	24.74	.2351	7,020	4,445	643
7,500	27.78	25.07	1.860	829.2	1.130	47.73	855.2	16.82	2.826	.9346	-2.029	2.36	26.50	.2151	7,524	4,620	575
8,000	29.19	26.35	1.938	915.2	1.130	52.68	944.1	16.70	2.804	.9282	-2.032	2.235	28.27	.2079	8,033	4,705	551
8,500	30.13	27.19	1.981	973.3	1.128	56.03	1,005	16.36	2.745	.9090	-2.041	2.155	30.04	.2075	8,544	4,760	551
9,000	30.86	27.85	2.007	1,020	1.126	58.69	1,053	15.97	2.679	.8874	-2.052	2.100	31.80	.2095	9,050	4,800	560
9,500	31.60	28.52	2.030	1,068	1.125	61.45	1,104	15.66	2.627	.8704	-2.060	2.05	33.57	.2109	9,553	4,840	564
10,000	32.41	29.25	2.057	1,122	1.124	64.56	1,160	15.43	2.587	.8576	-2.067	1.995	35.34	.2112	10,052	4,875	574
11,000	34.39	31.04	2.133	1,261	1.122	72.61	1,305	15.21	2.549	.8453	-2.073	1.87	38.87	.2065	11,047	4,980	563
12,000	37.06	33.45	2.248	1,466	1.124	84.40	1,516	15.38	2.575	.8551	-2.068	---------	42.40	.1941	12,045	-----	524
13,000	40.37	36.44	2.422	1,743	1.125	100.3	1,800	15.66	2.620	.8706	-2.060	---------	45.94	.1773	13,045	-----	459
14,000	44.13	39.83	2.642	2,085	1.126	120.0	2,153	15.95	2.667	.8868	-2.052	---------	49.47	.1598	14,048	-----	389

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2/\frac{R}{m_0}T_0$	$h_t/\frac{R}{m_0}T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm³	$N_{e,w}$, per cm³	$N_{e,fw}$, per cm³	γ_2*
800	1.656	0.9747	1.685	0.4635	0.9953	10.49	10.87	32.46	1.29	---------	---------	--------	--------	--------	-----
1,200	1.989	.9400	2.024	.4242	.9902	16.31	16.75	33.46	2.29	---------	---------	--------	--------	--------	-----
1,600	2.260	.9102	2.299	.4057	.9830	22.51	23.02	34.28	3.11	3.1×10^{-15}	---------	2.6×10^{2}	--------	2.0×10^{1}	-----
2,000	2.516	.8897	2.560	.3887	.9621	29.25	29.90	34.98	3.81	6.5×10^{-12}	---------	6.0×10^{5}	--------	3.4×10^{4}	1.256
2,200	2.605	.8643	2.650	.3831	.9563	33.23	33.94	35.30	4.13	1.0×10^{-10}	---------	9.7×10^{6}	--------	4.9×10^{5}	1.220
2,400	2.691	.8336	2.738	.3741	.9411	38.22	38.90	35.75	4.58	9.5×10^{-10}	---------	9.9×10^{7}	--------	4.5×10^{6}	1.183
2,600	2.788	.7982	2.837	.3598	.9120	44.85	45.56	36.30	5.13	6.1×10^{-9}	---------	7.1×10^{8}	--------	2.8×10^{7}	1.156
2,800	2.909	.7629	2.960	.3414	.8716	53.66	54.27	36.98	5.81	2.9×10^{-8}	---------	3.8×10^{9}	--------	1.3×10^{8}	1.144
3,000	3.054	.7318	3.107	.3228	.8294	64.33	64.95	37.78	6.61	9.3×10^{-8}	2.5×10^{-14}	1.4×10^{10}	6.6×10^{1}	4.3×10^{8}	1.143
3,200	3.224	.7125	3.280	.3070	.7921	75.82	76.41	38.58	7.41	2.8×10^{-7}	8.1×10^{-12}	4.7×10^{10}	1.8×10^{4}	1.3×10^{9}	1.153
3,400	3.398	.7034	3.457	.2962	.7668	86.48	87.02	39.33	8.16	7.4×10^{-7}	1.4×10^{-10}	1.4×10^{11}	2.8×10^{5}	3.5	1.172
3,600	3.578	.7060	3.640	.2889	.7494	95.13	95.73	39.90	8.73	1.65×10^{-6}	6.9×10^{-10}	3.2	1.3×10^{6}	7.6	1.202
3,800	3.740	.7128	3.805	.2851	.7405	102.0	102.6	40.33	9.16	3.4	1.3×10^{-9}	6.6	2.4	1.5×10^{10}	1.232
4,000	3.879	.7195	3.947	.2840	.7384	107.6	108.3	40.60	9.43	6.3	2.0	1.2×10^{12}	3.7	2.8	1.246
4,200	3.971	.7190	4.040	.2859	.7440	112.9	113.7	40.91	9.74	1.15×10^{-5}	2.9	2.2	5.3	4.9	1.238
4,400	4.043	.7142	4.113	.2885	.7511	118.7	119.5	41.22	10.05	1.9	4.8	3.7	8.5	7.9	1.216
4,600	4.101	.7048	4.172	.2911	.7587	125.4	126.3	41.55	10.38	3.1	6.8	6.2	1.2×10^{7}	1.3×10^{11}	1.192
4,800	4.174	.6952	4.247	.2915	.7603	133.6	134.5	41.97	10.80	4.7	1.0×10^{-8}	9.6	1.7	1.9	1.169
5,000	4.261	.6843	4.335	.2897	.7566	143.7	144.5	42.42	11.25	7.0	1.6	1.5×10^{13}	2.7	2.8	1.154
5,500	4.543	.6510	4.622	.2780	.7281	180.5	181.5	44.03	12.86	1.6×10^{-4}	6.2	3.9	9.5	6.7	1.132
6,000	4.929	.6168	5.015	.2617	.6871	237.3	238.1	46.28	15.11	2.9	2.1×10^{-6}	8.6	2.7×10^{9}	1.4×10^{12}	1.129
6,500	5.406	.5905	5.500	.2470	.6495	311.5	312.4	49.10	17.93	5.0	3.7×10^{-5}	1.8×10^{14}	3.8×10^{10}	2.8	1.134
7,000	5.914	.5764	6.017	.2376	.6258	390.9	392.0	51.92	20.75	9.0	7.2×10^{-5}	3.8	6.8	5.9	1.146
7,500	6.402	.5768	6.513	.2328	.6134	458.3	459.1	54.19	23.02	1.7×10^{-3}	1.0×10^{-4}	7.9	9.2	1.3×10^{13}	1.168
8,000	6.841	.5867	6.960	.2305	.6077	505.4	506.6	55.62	24.45	3.2	1.2	1.5×10^{15}	1.0×10^{11}	2.5	1.200
8,500	7.216	.5998	7.342	.2305	.6079	538.0	539.3	56.58	25.41	6.2	1.3	3.0	1.1	4.8	1.230
9,000	7.497	.6085	7.627	.2327	.6137	564.6	565.6	57.32	26.15	1.1×10^{-2}	1.4	5.3	1.2	8.3	1.237
9,500	7.706	.6111	7.840	.2363	.6232	591.2	593.0	58.02	26.85	1.8	1.5	8.5	1.3	1.4×10^{14}	1.225
10,000	7.901	.6111	8.038	.2400	.6331	621.2	623.4	58.75	27.58	2.9	1.6	1.4×10^{16}	1.4	2.1	1.207
11,000	8.347	.6084	8.492	.2444	.6450	700.0	701.5	60.56	29.39	6.2	1.9	3.0	1.6	4.7	1.182
12,000	8.925	.6039	9.080	.2436	.6431	811.0	814.1	62.95	31.78	1.1×10^{-1}	---------	5.7	--------	8.9	1.173
13,000	9.642	.5990	9.810	.2413	.6372	962.4	965.7	65.86	34.68	1.4	---------	7.9	--------	1.3×10^{15}	1.171
14,000	10.48	.5956	10.66	.2383	.6294	1,150	1,153	69.19	38.02	1.7	---------	1.1×10^{17}	--------	1.9×10^{15}	1.170

TABLE IV.- NORMAL SHOCK PARAMETERS - Continued

(h) For geopotential altitude of 200,100 ft; $T_1 = 247^{\circ}$ K; $a_1 = 1{,}034$ ft/sec; $p = 2.052 \times 10^{-4}$ atm

T_2, °K	u_1, ft/sec	M_1	z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log \frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
800	3.611×10^3	3.492	1.00	14.19	1.009	0.2911×10^{-2}	16.13	4.387	1.031	0.9963×10^{-3}	-3.002	---------	3.239	0.9803	------	-----	389
1,200	4.797	4.639	1.00	25.37	1.017	.5207	28.25	5.229	1.074	1.188	-2.925	---------	4.858	.9485	------	-----	518
1,600	5.799	5.608	1.00	37.42	1.024	.7678	41.23	5.785	1.118	1.314	-2.882	---------	6.478	.9182	------	-----	645
2,000	6.755	6.533	1.006	51.31	1.034	1.053	56.03	6.300	1.173	1.431	-2.844	---------	8.097	.8766	2,035	-----	773
2,200	7.258	7.019	1.011	59.71	1.042	1.225	64.82	6.670	1.224	1.515	-2.820	---------	8.907	.8471	------	-----	819
2,400	7.909	7.649	1.019	71.67	1.052	1.471	77.27	7.236	1.309	1.643	-2.784	---------	9.717	.7888	2,424	-----	851
2,600	8.719	8.433	1.037	88.32	1.066	1.812	94.43	8.092	1.443	1.838	-2.736	---------	10.53	.7128	------	-----	865
2,800	9.674	9.355	1.072	110.2	1.080	2.262	116.8	9.069	1.598	2.060	-2.686	3.97×10^{-5}	11.34	.6312	2,816	1,415	857
3,000	10.68	10.33	1.107	135.8	1.091	2.787	143.1	10.10	1.762	2.294	-2.639	3.21	12.15	.5597	------	1,750	839
3,200	11.58	11.20	1.143	160.6	1.098	3.295	168.6	10.85	1.880	2.463	-2.609	2.81	12.96	.5113	3,218	1,980	828
3,400	12.30	11.89	1.175	181.4	1.100	3.722	190.1	11.22	1.935	2.547	-2.594	2.615	13.77	.4841	------	2,100	826
3,600	12.76	12.34	1.189	195.5	1.101	4.011	204.8	11.28	1.941	2.562	-2.592	2.495	14.58	.4771	3,628	2,175	848
3,800	13.14	12.71	1.203	207.1	1.100	4.249	217.0	11.19	1.922	2.541	-2.595	2.43	15.39	.4757	------	2,215	871
4,000	13.48	13.04	1.211	217.6	1.098	4.466	228.3	11.10	1.904	2.521	-2.598	2.39	16.19	.4764	4,036	2,235	901
4,200	13.82	13.36	1.214	228.4	1.098	4.686	239.5	11.06	1.895	2.513	-2.600	2.33	17.00	.4772	------	2,275	933
4,400	14.26	13.79	1.228	243.3	1.098	4.993	255.2	11.12	1.902	2.526	-2.598	2.27	17.81	.4700	4,431	2,315	949
4,600	14.69	14.21	1.234	258.5	1.099	5.305	271.0	11.25	1.921	2.555	-2.593	2.22	18.62	.4634	------	2,350	973
4,800	15.32	14.82	1.262	282.3	1.101	5.792	295.4	11.51	1.961	2.613	-2.583	2.14	19.43	.4450	4,824	2,390	963
5,000	16.01	15.48	1.278	308.7	1.104	6.334	322.6	11.93	2.030	2.710	-2.567	2.055	20.24	.4256	5,021	2,440	961
5,500	18.43	17.82	1.372	413.0	1.115	8.476	429.2	13.52	2.289	3.070	-2.513	1.745	22.27	.3552	5,518	2,710	876
6,000	21.46	20.75	1.517	565.1	1.124	11.60	584.5	15.33	2.585	3.482	-2.458	1.194	24.29	.2867	6,016	3,800	737
6,500	24.57	23.76	1.682	744.7	1.131	15.28	767.9	16.83	2.829	3.821	-2.418	9.98×10^{-6}	26.32	.2377	6,516	4,215	613
7,000	27.21	26.32	1.844	915.3	1.133	18.78	943.0	17.52	2.940	3.978	-2.400	8.91	28.34	.2090	7,020	4,410	525
7,500	28.81	27.86	1.940	1,026	1.133	21.06	1,057	17.42	2.921	3.956	-2.403	8.33	30.36	.1999	7,528	4,510	493
8,000	29.76	28.78	1.981	1,093	1.131	22.43	1,127	17.03	2.856	3.868	-2.413	8.02	32.39	.1999	8,039	4,565	495
8,500	30.53	29.52	2.011	1,148	1.129	23.56	1,184	16.59	2.781	3.768	-2.424	7.79	34.41	.2020	8,547	4,610	503
9,000	31.26	30.23	2.038	1,202	1.127	24.66	1,241	16.18	2.712	3.675	-2.435	7.61	36.44	.2040	9,048	4,640	510
9,500	32.07	31.01	2.061	1,263	1.126	25.92	1,305	15.94	2.670	3.620	-2.441	7.40	38.46	.2047	9,547	4,680	517
10,000	33.06	31.98	2.097	1,343	1.125	27.56	1,387	15.82	2.649	3.593	-2.445	7.19	40.49	.2027	10,043	4,725	515
11,000	35.66	34.49	2.227	1,562	1.125	32.06	1,614	15.75	2.637	3.578	-2.446	6.67	44.53	.1917	11,040	4,840	477
12,000	38.93	37.60	2.368	1,859	1.127	38.15	1,919	16.16	2.703	3.670	-2.435	---------	48.58	.1761	12,038	-----	431
13,000	43.00	41.52	2.605	2,271	1.129	46.60	2,342	16.57	2.769	3.762	-2.425	---------	52.63	.1565	13,040	-----	357
14,000	47.34	45.72	2.884	2,756	1.130	56.55	2,841	16.86	2.816	3.828	-2.417	---------	56.68	.1391	14,044	-----	287

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2/\frac{R}{m_0}T_0$	$h_t/\frac{R}{m_0}T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm³	$N_{e,w}$, per cm³	$N_{e,fw}$, per cm³	γ_2*
800	1.772	0.9747	1.685	0.4492	0.9951	10.49	10.85	33.30	1.57	---------	---------	--------	--------	--------	-----
1,200	2.129	.9408	2.024	.4168	.9898	16.31	16.73	34.33	2.60	---------	---------	--------	--------	--------	-----
1,600	2.410	.9070	2.291	.4023	.9865	22.51	23.00	35.15	3.42	5.0×10^{-15}	---------	1.8×10^{2}	--------	1.2×10^{1}	-----
2,000	2.684	.8829	2.552	.3863	.9655	29.36	30.07	35.85	4.12	1.0×10^{-11}	---------	3.9×10^{5}	--------	2.0×10^{4}	1.246
2,200	2.773	.8551	2.637	.3794	.9552	33.65	34.23	36.24	4.51	1.6×10^{-10}	---------	6.5×10^{6}	--------	2.9×10^{5}	1.203
2,400	2.861	.8151	2.720	.3695	.9373	39.38	40.05	36.72	4.99	1.4×10^{-9}	---------	6.3×10^{7}	--------	2.5×10^{6}	1.165
2,600	2.980	.7754	2.833	.3498	.8937	47.38	48.01	37.41	5.68	8.9×10^{-9}	---------	4.6×10^{8}	--------	1.6×10^{7}	1.143
2,800	3.130	.7386	2.976	.3295	.8470	57.96	58.37	38.24	6.51	4.1×10^{-8}	2.2×10^{-16}	2.4×10^{9}	2.3×10^{-1}	7.2×10^{7}	1.136
3,000	3.306	.7099	3.143	.3093	.7992	70.10	70.48	39.14	7.41	1.3×10^{-7}	8.4×10^{-13}	8.9×10^{9}	7.3×10^{2}	2.3×10^{8}	1.142
3,200	3.502	.6958	3.330	.2948	.7645	81.93	82.29	40.04	8.31	3.8	5.0×10^{-11}	2.9×10^{10}	3.8×10^{4}	6.9×10^{8}	1.159
3,400	3.702	.6942	3.520	.2863	.7440	91.50	92.42	40.71	8.98	9.7	2.9×10^{-10}	7.8×10^{10}	2.1×10^{5}	1.8×10^{9}	1.191
3,600	3.897	.7051	3.705	.2808	.7307	98.60	99.21	41.17	9.44	2.1×10^{-6}	7.7×10^{-10}	1.7×10^{11}	5.3	3.7	1.228
3,800	4.051	.7121	3.852	.2804	.7306	104.3	105.0	41.53	9.80	4.4	1.3×10^{-9}	3.6	8.9	7.6	1.250
4,000	4.165	.7143	3.960	.2820	.7349	109.5	110.3	41.78	10.05	8.1	1.6	6.6	1.1×10^{6}	1.4×10^{10}	1.244
4,200	4.235	.7091	4.027	.2851	.7438	115.0	115.8	42.12	10.39	1.4×10^{-5}	2.5	1.1×10^{12}	1.7	2.3	1.220
4,400	4.294	.6973	4.083	.2887	.7536	121.5	123.1	42.45	10.72	2.4	4.1	2.0	2.7	3.8	1.191
4,600	4.365	.6885	4.150	.2894	.7560	129.6	130.4	42.85	11.12	3.75	5.9	3.2	3.8	5.8	1.166
4,800	4.454	.6742	4.235	.2892	.7563	139.9	141.7	43.37	11.64	5.9	8.9	5.2	5.6	9.2	1.148
5,000	4.565	.6623	4.340	.2842	.7440	153.0	154.5	43.98	12.25	8.3	1.4×10^{-8}	7.7	8.7	1.3×10^{11}	1.139
5,500	4.927	.6623	4.685	.2675	.7019	201.3	203.6	46.11	14.38	1.75×10^{-4}	1.2×10^{-7}	2.0×10^{13}	6.7×10^{7}	3.0	1.124
6,000	5.420	.5891	5.153	.2497	.6566	273.1	275.0	49.01	17.28	3.3	1.7×10^{-5}	4.7×10^{13}	6.8×10^{9}	6.7	1.125
6,500	5.981	.5685	5.687	.2362	.6222	358.6	359.4	52.27	20.54	6.0	5.3	1.0×10^{14}	1.9×10^{10}	1.5×10^{12}	1.135
7,000	6.531	.5611	6.210	.2301	.6066	436.3	440.2	55.08	23.35	1.2×10^{-3}	8.1	2.4	2.8	3.4	1.155
7,500	7.044	.5718	6.697	.2271	.5989	490.2	493.0	56.92	25.19	2.4	9.8	4.9	3.3	7.3	1.189
8,000	7.480	.5876	7.112	.2259	.5959	524.4	525.8	57.94	26.21	4.9	1.1×10^{-4}	1.0×10^{15}	3.6	1.5×10^{13}	1.228
8,500	7.793	.5972	7.410	.2283	.6022	550.7	553.2	58.72	26.99	9.3	1.2	1.9	3.9	2.8	1.238
9,000	8.014	.5999	7.620	.2331	.6149	576.9	579.8	59.44	27.71	1.65×10^{-2}	1.3	3.3	4.2	4.9	1.223
9,500	8.212	.5990	7.808	.2369	.6252	607.1	610.0	60.24	28.51	2.75	1.4	5.5	4.5	8.0	1.202
10,000	8.440	.5969	8.025	.2396	.6324	644.3	648.3	61.15	29.42	4.4	1.5	8.9	4.8	1.3×10^{14}	1.184
11,000	9.008	.5911	8.565	.2431	.6418	747.6	753.6	63.53	31.80	1.0×10^{-1}	1.9	2.1×10^{16}	5.9	3.2	1.165
12,000	9.760	.5877	9.280	.2384	.6295	895.9	897.8	66.71	34.98	1.5	---------	3.5	--------	5.2	1.162
13,000	10.68	.5825	10.16	.2347	.6201	1,093	1,094	70.51	38.78	2.0	---------	5.3	--------	8.4	1.167
14,000	11.70	.5794	11.12	.2319	.6128	1,324	1,326	74.66	42.94	2.5	---------	7.4	--------	1.3×10^{15}	1.176

TABLE IV.- NORMAL SHOCK PARAMETERS - Continued

(i) For geopotential altitude of 230,400 ft; $T_1 = 205^\circ$ K; $a_1 = 942$ ft/sec; $p = 5.042 \times 10^{-5}$ atm

T_2, °K	u_1, ft/sec	M_1	Z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log \frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
800	3.729×10^{3}	3.961	1.00	18.28	1.008	0.9217×10^{-3}	20.62	4.685	1.030	0.3145×10^{-3}	-3.502	---------	3.902	0.9787	------	-----	363
1,200	4.888	5.192	1.00	31.80	1.017	1.603	35.27	5.431	1.073	.3646	-3.438	---------	5.854	.9471	------	-----	487
1,600	5.874	6.239	1.00	46.31	1.024	2.335	50.90	5.932	1.116	.3982	-3.400	---------	7.805	.9172	------	-----	609
2,000	6.848	7.256	1.00	63.39	1.034	3.196	68.95	6.482	1.183	.4352	-3.361	---------	9.747	.8720	2,030	-----	735
2,200	7.435	7.878	1.010	75.46	1.044	3.805	81.58	6.966	1.254	.4676	-3.330	---------	10.72	.8242	------	-----	772
2,400	8.228	8.718	1.027	93.83	1.060	4.731	100.53	7.809	1.387	.5242	-3.281	---------	11.70	.7442	2,418	-----	788
2,600	9.228	9.777	1.058	120.0	1.077	6.048	127.29	8.944	1.568	.6004	-3.222	---------	12.67	.6487	------	-----	780
2,800	10.36	10.98	1.101	153.3	1.091	7.729	161.46	10.20	1.770	.6847	-3.165	8.65×10^{-6}	13.65	.5596	2,814	1,595	757
3,000	11.37	12.05	1.145	186.1	1.099	9.382	195.1	11.12	1.916	.7461	-3.127	7.23	14.62	.5011	------	1,890	739
3,200	12.13	12.86	1.177	212.5	1.103	10.71	222.5	11.58	1.988	.7772	-3.109	6.68	15.60	.4716	3,219	2,015	736
3,400	12.62	13.38	1.194	230.0	1.103	11.60	240.8	11.63	1.992	.7805	-3.108	6.42	16.57	.4637	------	2,075	754
3,600	12.99	13.76	1.203	243.1	1.101	12.26	254.5	11.52	1.970	.7731	-3.112	6.25	17.54	.4648	3,633	2,110	782
3,800	13.31	14.11	1.209	255.2	1.100	12.87	267.5	11.40	1.948	.7653	-3.116	6.13	18.52	.4673	------	2,140	813
4,000	13.65	14.46	1.215	268.2	1.099	13.52	280.8	11.32	1.932	.7601	-3.119	6.02	19.49	.4683	4,033	2,165	842
4,200	14.06	14.90	1.223	284.7	1.099	14.35	298.2	11.37	1.938	.7633	-3.117	5.91	20.47	.4639	------	2,200	865
4,400	14.57	15.44	1.236	305.8	1.101	15.42	319.2	11.54	1.964	.7748	-3.111	5.70	21.44	.4536	4,424	2,230	877
4,600	15.21	16.12	1.255	334.2	1.103	16.85	348.5	11.89	2.019	.7979	-3.098	5.49	22.42	.4356	------	2,280	877
4,800	16.03	16.98	1.281	372.4	1.107	18.77	387.9	12.42	2.106	.8339	-3.079	5.26	23.39	.4103	4,818	2,330	863
5,000	17.00	18.01	1.318	420.8	1.112	21.22	437.0	13.10	2.217	.8793	-3.056	4.96	24.37	.3805	5,016	2,410	833
5,500	20.15	21.35	1.457	597.4	1.124	30.12	617.1	15.29	2.577	1.027	-2.989	3.37	26.80	.2994	5,513	3,360	702
6,000	23.71	25.12	1.649	833.6	1.132	42.03	858.0	17.29	2.904	1.161	-2.935	2.61	29.24	.2365	6,013	3,990	559
6,500	26.68	28.27	1.827	1,059	1.136	53.39	1,088	18.29	3.068	1.228	-2.911	2.31	31.68	.2027	6,516	4,190	467
7,000	28.49	30.18	1.935	1,207	1.136	60.86	1,241	18.29	3.064	1.228	-2.911	2.15	34.11	.1915	7,023	4,290	432
7,500	29.47	31.22	1.983	1,290	1.134	65.02	1,327	17.79	2.980	1.194	-2.923	2.06	36.55	.1918	7,535	4,350	434
8,000	30.20	32.00	2.009	1,352	1.132	68.18	1,393	17.27	2.892	1.159	-2.936	2.01	38.99	.1948	8,043	4,370	444
8,500	30.94	32.78	2.031	1,416	1.130	71.41	1,460	16.84	2.819	1.130	-2.947	1.96	41.42	.1974	8,542	4,410	454
9,000	31.81	33.71	2.060	1,496	1.128	75.43	1,544	16.56	2.771	1.111	-2.954	1.90	43.86	.1977	9,039	4,450	458
9,500	32.89	34.85	2.103	1,598	1.128	80.58	1,650	16.42	2.747	1.102	-2.958	1.84	46.30	.1952	9,536	4,490	453
10,000	34.27	36.31	2.162	1,735	1.128	87.50	1,790	16.47	2.755	1.106	-2.956	1.76	48.73	.1894	10,033	4,560	439
11,000	37.84	40.09	2.344	2,119	1.130	107.8	2,185	16.86	2.819	1.132	-2.946	1.58	53.61	.1710	11,032	4,740	381
12,000	42.49	45.02	2.602	2,679	1.133	135.1	2,757	17.61	2.942	1.182	-2.927	1.17	58.48	.1480	12,032	5,900	306
13,000	47.43	50.25	2.927	3,342	1.135	168.5	3,438	18.01	3.007	1.209	-2.918	9.07×10^{-7}	63.42	.1289	13,035	7,100	235

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2 / \frac{R}{m_0} T_0$	$h_t / \frac{R}{m_0} T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm^3	$N_{e,w}$, per cm^3	$N_{e,fw}$, per cm^3	γ_2^*
800	1.945	0.9744	1.686	0.4347	0.9968	10.49	10.82	34.45	1.97	---------	---------	--------	--------	--------	-----
1,200	2.336	.9397	2.025	.4091	.9913	16.31	16.72	35.51	3.03	---------	---------	--------	--------	--------	-----
1,600	2.633	.9023	2.282	.3994	.9930	22.52	22.98	36.35	3.87	9.7×10^{-15}	---------	1.0×10^{2}	--------	5.9	-----
2,000	2.925	.8747	2.535	.3827	.9664	29.62	30.29	37.11	4.63	1.8×10^{-11}	---------	2.1×10^{5}	--------	9.1×10^{3}	1.227
2,200	3.015	.8359	2.613	.3751	.9537	34.61	35.24	37.53	5.05	2.7×10^{-10}	---------	3.4×10^{6}	--------	1.3×10^{5}	1.182
2,400	3.127	.7887	2.710	.3570	.9142	41.88	42.57	38.16	5.68	2.5×10^{-9}	---------	3.6×10^{7}	--------	1.2×10^{6}	1.143
2,600	3.286	.7436	2.848	.3327	.8573	52.31	52.87	39.05	6.57	1.4×10^{-8}	---------	2.4×10^{8}	--------	6.6×10^{6}	1.129
2,800	3.479	.7047	3.015	.3094	.8016	65.38	65.96	40.14	7.66	6.3×10^{-8}	6.2×10^{-14}	1.3×10^{9}	1.4×10^{1}	3.1×10^{7}	1.132
3,000	3.702	.6854	3.208	.2928	.7611	78.51	78.95	41.14	8.66	2.0×10^{-7}	2.2×10^{-11}	4.6×10^{9}	4.3×10^{3}	1.0×10^{8}	1.148
3,200	3.935	.6841	3.410	.2822	.7353	88.81	89.49	41.94	9.46	5.4×10^{-7}	1.7×10^{-10}	1.3×10^{10}	3.1×10^{4}	2.7	1.183
3,400	4.165	.6968	3.610	.2762	.7204	95.96	96.66	42.45	9.97	1.3×10^{-6}	2.9	3.3	5.2×10^{4}	6.4	1.229
3,600	4.350	.7080	3.770	.2746	.7168	101.4	102.1	42.81	10.33	3.0	6.0	7.5	1.1×10^{5}	1.4	1.257
3,800	4.462	.7087	3.867	.2773	.7242	106.4	107.1	43.10	10.62	6.0	8.9	1.5×10^{11}	1.5	2.7	1.248
4,000	4.535	.7030	3.930	.2817	.7363	111.8	112.6	43.34	10.86	1.1×10^{-5}	1.3×10^{-9}	2.7	2.2	4.8	1.219
4,200	4.596	.6920	3.983	.2851	.7456	118.4	119.3	43.74	11.26	1.9	2.0	4.8	3.4	8.1	1.185
4,400	4.673	.6796	4.050	.2862	.7490	126.9	127.9	44.18	11.70	3.2	2.8	8.2	4.6	1.4×10^{10}	1.157
4,600	4.777	.6659	4.140	.2839	.7438	138.2	139.2	44.77	12.29	5.0	4.7	1.3×10^{12}	7.6	2.1	1.138
4,800	4.898	.6486	4.245	.2791	.7320	153.1	154.2	45.52	13.04	7.6	8.0	2.2	1.3×10^{6}	3.3	1.126
5,000	5.057	.6318	4.383	.2719	.7138	172.3	173.2	46.40	13.92	1.1×10^{-4}	1.8×10^{-8}	3.4	2.8×10^{6}	4.9	1.121
5,500	5.571	.5888	4.828	.2506	.6593	241.1	242.1	49.50	17.02	2.2	4.5×10^{-6}	8.8	5.0×10^{8}	1.2×10^{11}	1.116
6,000	6.210	.5585	5.382	.2339	.6163	333.5	334.4	53.33	20.85	4.15	3.9×10^{-5}	2.1×10^{13}	3.6×10^{9}	2.8	1.125
6,500	6.856	.5485	5.942	.2254	.5944	421.4	422.7	56.75	24.27	8.3	6.6	5.0×10^{13}	5.8	6.6	1.144
7,000	7.454	.5584	6.460	.2214	.5840	479.9	481.5	58.91	26.43	1.9×10^{-3}	8.0	1.2×10^{14}	6.9	1.6×10^{12}	1.183
7,500	7.962	.5770	6.900	.2205	.5819	514.0	515.1	60.08	27.60	4.3	9.0	2.7	7.7	3.7	1.230
8,000	8.308	.5871	7.200	.2230	.5885	539.3	541.0	60.82	28.34	8.8	9.3	5.5	7.9	7.3	1.239
8,500	8.523	.5886	7.387	.2284	.6030	565.5	567.4	61.59	29.11	1.7×10^{-2}	1.0×10^{-4}	1.0×10^{15}	8.4	1.4×10^{13}	1.217
9,000	8.723	.5858	7.560	.2334	.6162	597.6	599.6	62.48	30.00	3.0	1.1	1.8	9.2	2.4	1.189
9,500	8.994	.5844	7.795	.2361	.6233	639.3	640.8	63.58	31.10	5.0	1.2	3.1	9.9	4.1	1.172
10,000	9.314	.5807	8.072	.2367	.6250	693.3	695.5	64.91	32.43	7.3	1.35	4.7	1.1×10^{10}	6.2	1.156
11,000	10.13	.5723	8.783	.2347	.6201	846.8	847.9	68.44	35.96	1.4×10^{-1}	2.05	1.0×10^{16}	1.6×10^{10}	1.4×10^{14}	1.150
12,000	11.19	.5629	9.695	.2285	.6039	1,066	1,069	73.28	40.80	2.35	5.25×10^{-3}	1.9	3.3×10^{11}	2.8	1.154
13,000	12.40	.5592	10.75	.2250	.5948	1,326	1,330	78.23	45.75	3.0	6.80×10^{-2}	2.9	3.5×10^{11}	4.7	1.164

TABLE IV.- NORMAL SHOCK PARAMETERS - Continued

(j) For geopotential altitude of 259,700 ft; $T_1 = 166^\circ$ K; $a_1 = 847$ ft/sec; $p = 9.631 \times 10^{-6}$ atm

T_2, °K	u_1, ft/sec	M_1	Z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log \frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
800	3.837×10^{3}	4.528	1.00	23.91	1.007	2.303×10^{-4}	26.81	4.961	1.029	7.883×10^{-5}	-4.103	----------	4.819	0.9787	------	-----	337
1,200	4.972	5.868	1.00	40.62	1.016	3.912	44.91	5.618	1.072	8.927	-4.049	----------	7.229	.9467	------	-----	456
1,600	5.943	7.014	1.00	58.56	1.023	5.640	64.22	6.079	1.116	9.660	-4.015	----------	9.639	.9171	------	-----	571
2,000	6.976	8.229	1.009	81.78	1.037	7.877	88.79	6.730	1.204	1.069×10^{-4}	-3.971	----------	12.05	.8539	2,025	-----	681
2,200	7.714	9.099	1.022	101.5	1.052	9.776	109.2	7.494	1.324	1.191	-3.924	----------	13.25	.7779	------	-----	704
2,400	8.750	10.32	1.052	133.2	1.073	1.283×10^{-3}	141.7	8.758	1.528	1.392	-3.856	----------	14.46	.6676	2,413	-----	699
2,600	10.00	11.80	1.099	177.0	1.091	1.705	186.5	10.29	1.776	1.635	-3.787	1.884×10^{-6}	15.66	.5591	------	1,410	672
2,800	11.18	13.19	1.150	223.4	1.102	2.151	233.9	11.52	1.975	1.830	-3.738	1.469	16.87	.4854	2,812	1,780	645
3,000	11.99	14.14	1.185	257.9	1.106	2.484	269.5	12.04	2.057	1.914	-3.718	1.334	18.07	.4536	------	1,915	642
3,200	12.48	14.72	1.202	279.3	1.105	2.690	291.8	12.06	2.055	1.916	-3.718	1.282	19.28	.4475	3,225	1,970	660
3,400	12.82	15.12	1.209	294.4	1.104	2.836	307.8	11.89	2.024	1.889	-3.724	1.244	20.48	.4509	------	2,006	689
3,600	13.13	15.49	1.214	308.4	1.102	2.970	322.7	11.71	1.993	1.861	-3.730	1.222	21.69	.4556	3,632	2,027	719
3,800	13.48	15.90	1.219	324.5	1.101	3.126	339.7	11.62	1.976	1.847	-3.734	1.200	22.89	.4571	------	2,050	746
4,000	13.90	16.40	1.228	345.4	1.101	3.327	361.3	11.67	1.981	1.855	-3.732	1.170	24.10	.4526	4,023	2,077	766
4,200	14.46	17.06	1.242	374.4	1.103	3.606	391.4	11.91	2.019	1.892	-3.723	1.140	25.30	.4398	------	2,115	777
4,400	15.20	17.94	1.265	415.1	1.106	3.998	433.2	12.38	2.095	1.967	-3.706	1.094	26.51	.4175	4,417	2,162	771
4,600	16.17	19.07	1.299	471.5	1.111	4.541	490.8	13.10	2.213	2.081	-3.682	1.040	27.71	.3867	------	2,225	747
4,800	17.35	20.47	1.346	546.0	1.117	5.259	566.9	14.03	2.366	2.229	-3.652	9.683×10^{-7}	28.92	.3509	4,813	2,330	708
5,000	18.75	22.11	1.407	640.5	1.123	6.168	662.9	15.11	2.544	2.401	-3.620	8.128	30.12	.3137	5,012	2,680	654
5,500	22.73	26.81	1.614	950.9	1.134	9.158	979.4	17.78	2.984	2.825	-3.549	5.495	33.13	.2355	5,510	3,713	504
6,000	26.24	30.96	1.825	1,274	1.139	1.227×10^{-2}	1,308	19.31	3.234	3.068	-3.513	4.624	36.14	.1929	6,013	3,950	402
6,500	28.23	33.30	1.947	1,474	1.139	1.419	1,514	19.33	3.236	3.072	-3.513	4.236	39.16	.1808	6,520	4,059	368
7,000	29.21	34.45	1.994	1,575	1.137	1.516	1,618	18.72	3.134	2.976	-3.526	4.121	42.17	.1820	7,033	4,104	370
7,500	29.91	35.28	2.017	1,647	1.134	1.587	1,696	18.08	3.026	2.873	-3.542	4.018	45.18	.1860	7,539	4,134	382
8,000	30.66	36.16	2.039	1,728	1.133	1.664	1,780	17.58	2.941	2.794	-3.554	3.945	48.19	.1888	8,036	4,162	391
8,500	31.60	37.27	2.074	1,834	1.131	1.766	1,890	17.27	2.888	2.744	-3.562	3.802	51.20	.1889	8,532	4,200	394
9,000	32.90	38.81	2.127	1,988	1.131	1.914	2,048	17.23	2.882	2.738	-3.562	3.656	54.22	.1845	9,029	4,251	385
9,500	34.58	40.79	2.206	2,198	1.132	2.117	2,264	17.41	2.910	2.767	-3.558	3.467	57.23	.1764	9,524	4,317	364
10,000	36.69	43.27	2.313	2,476	1.133	2.384	2,550	17.77	2.969	2.823	-3.549	3.327	60.24	.1650	10,025	4,417	333
11,000	41.86	49.37	2.619	3,232	1.136	3.113	3,322	18.62	3.109	2.958	-3.529	2.399	66.26	.1395	11,025	5,490	255
12,000	47.69	56.25	3.003	4,205	1.139	4.050	4,317	19.37	3.233	3.077	-3.512	1.778	72.29	.1173	12,028	6,800	184
13,000	52.88	62.37	3.389	5,171	1.140	4.980	5,307	19.48	3.251	3.095	-3.509	----------	78.31	.1034	13,034	-----	136

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2 / \frac{R}{m_0} T_0$	$h_t / \frac{R}{m_0} T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm³	$N_{e,w}$, per cm³	$N_{e,fw}$, per cm³	γ_2^*
800	2.161	0.9739	1.682	0.4224	0.9986	10.49	10.81	35.84	2.44	---------	---------	--------	--------	--------	-----
1,200	2.596	.9392	2.021	.4025	.9931	16.31	16.71	36.92	3.52	---------	---------	--------	--------	--------	-----
1,600	2.909	.8973	2.265	.3967	.9987	22.54	22.97	37.77	4.37	2.1×10^{-14}	---------	5.4×10^{1}	--------	2.6	-----
2,000	3.220	.8573	2.507	.3797	.9686	30.23	30.83	38.57	5.17	3.7×10^{-11}	---------	1.1×10^{5}	--------	3.8×10^{3}	1.195
2,200	3.327	.8060	2.590	.3650	.9369	36.64	37.23	39.20	5.80	5.2×10^{-10}	---------	1.7×10^{6}	--------	5.2×10^{4}	1.144
2,400	3.489	.7498	2.716	.3377	.8726	46.74	47.30	40.08	6.68	4.5×10^{-9}	---------	1.8×10^{7}	--------	4.6×10^{5}	1.124
2,600	3.708	.7007	2.887	.3094	.8041	60.66	61.17	41.33	7.93	2.5×10^{-8}	1.3×10^{-16}	1.2×10^{8}	6.5×10^{-3}	2.6×10^{6}	1.122
2,800	3.967	.6729	3.088	.2886	.7525	75.37	75.87	42.57	9.17	1.1×10^{-7}	7.0×10^{-12}	6.2×10^{8}	2.8×10^{2}	1.2×10^{7}	1.137
3,000	4.241	.6718	3.302	.2769	.7234	86.46	86.99	43.48	10.08	3.0	7.5×10^{-11}	1.8×10^{9}	2.8×10^{3}	3.3	1.178
3,200	4.518	.6883	3.517	.2703	.7069	93.46	94.05	43.98	10.58	8.1	1.9×10^{-10}	5.0×10^{9}	6.3×10^{3}	8.7	1.237
3,400	4.733	.7023	3.685	.2688	.7033	98.51	99.16	44.35	10.95	1.95×10^{-6}	3.3	1.2×10^{10}	1.2×10^{4}	2.0×10^{8}	1.268
3,600	4.846	.7023	3.773	.2729	.7144	103.2	104.0	44.65	11.25	4.2	4.5	2.5	1.6	4.1	1.254
3,800	4.916	.6946	3.827	.2782	.7287	108.6	109.3	44.97	11.57	8.3	6.0	5.0	2.1	7.9	1.200
4,000	4.980	.6827	3.877	.2821	.7393	115.4	116.1	45.34	11.94	1.6×10^{-5}	8.5	9.8	2.9	1.4×10^{9}	1.176
4,200	5.061	.6672	3.940	.2830	.7422	124.8	125.6	45.86	12.46	2.7	1.4×10^{-9}	1.7×10^{11}	4.7	2.5	1.143
4,400	5.189	.6511	4.040	.2792	.7330	137.8	138.5	46.59	13.19	4.4	2.4	2.9	7.8	4.0	1.126
4,600	5.340	.6308	4.157	.2727	.7163	155.6	156.4	47.48	14.08	6.4	5.0	4.6	1.6×10^{5}	6.1	1.115
4,800	5.549	.6112	4.320	.2630	.6916	179.1	179.9	48.66	15.26	9.5	1.4×10^{-8}	7.6	4.2×10^{5}	9.5	1.110
5,000	5.780	.5899	4.500	.2532	.6663	208.8	209.6	50.12	16.72	1.35×10^{-4}	2.2×10^{-7}	1.2×10^{12}	5.8×10^{6}	1.5×10^{10}	1.109
5,500	6.510	.5489	5.068	.2317	.6109	306.8	307.0	54.62	21.22	2.7	2.4×10^{-5}	3.3	4.6×10^{8}	3.8×10^{10}	1.114
6,000	7.283	.5320	5.670	.2202	.5812	407.7	408.7	58.83	25.43	5.9	4.9	8.8	8.8×10^{8}	1.0×10^{11}	1.133
6,500	7.990	.5428	6.220	.2155	.5689	471.6	472.5	61.39	27.99	1.5×10^{-3}	6.2	2.4×10^{13}	1.1×10^{9}	4.4×10^{11}	1.177
7,000	8.584	.5640	6.683	.2144	.5660	504.5	505.6	62.59	29.19	3.7	7.0	5.9×10^{13}	1.2	1.1×10^{12}	1.236
7,500	8.957	.5749	6.973	.2178	.5751	528.4	530.0	63.41	30.01	8.3	7.4	1.3×10^{14}	1.3	2.4	1.239
8,000	9.171	.5739	7.140	.2243	.5923	555.0	556.8	64.18	30.78	1.7×10^{-2}	8.0	2.6	1.4	3.1	1.204
8,500	9.403	.5713	7.320	.2295	.6060	590.4	591.4	65.24	31.84	3.4	8.8	5.2	1.5	6.1	1.176
9,000	9.717	.5669	7.565	.2317	.6122	639.4	640.9	66.59	33.19	5.8	9.7	9.1	1.6	1.1×10^{13}	1.155
9,500	10.12	.5619	7.880	.2315	.6116	706.1	707.9	68.35	34.95	9.1	1.2×10^{-4}	1.5×10^{15}	2.0	1.8	1.143
10,000	10.62	.5560	8.268	.2293	.6060	793.6	796.1	70.53	37.13	1.3×10^{-1}	1.4×10^{-4}	2.3	2.2	2.8	1.140
11,000	11.87	.5447	9.242	.2234	.5904	1,035	1,036	76.14	42.74	2.25	4.3×10^{-4}	4.7	5.5×10^{9}	6.2	1.142
12,000	13.35	.5379	10.40	.2176	.5752	1,343	1,344	82.77	49.37	3.3	8.8×10^{-2}	8.2	9.1×10^{11}	1.3×10^{14}	1.152
13,000	14.88	.5405	11.58	.2152	.5690	1,648	1,652	88.84	55.44	3.5	---------	9.8	--------	1.8×10^{14}	1.170

TABLE IV.- NORMAL SHOCK PARAMETERS - Continued

(k) For geopotential altitude of 294,800 ft; T_1 = 166° K; a_1 = 847 ft/sec; p = 1.064×10^{-6} atm

T_2, °K	u_1, ft/sec	M_1	Z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log \frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
800	3.837×10^{3}	4.528	1.00	23.91	1.007	2.544×10^{-5}	26.81	4.961	1.029	8.707×10^{-6}	-5.060	----------	4.819	0.9787	------	-----	337
1,200	4.972	5.868	1.00	40.62	1.016	4.322	44.92	5.618	1.072	9.860	-5.006	----------	7.229	.9467	------	-----	456
1,600	5.943	7.014	1.00	58.56	1.023	6.231	64.21	6.079	1.116	1.067×10^{-5}	-4.972	----------	9.639	.9171	------	-----	571
2,000	7.238	8.537	1.018	89.02	1.049	9.472	96.02	7.256	1.292	1.274	-4.895	----------	12.05	.7973	2,027	-----	661
2,200	8.391	9.897	1.051	122.6	1.074	1.305×10^{-4}	130.4	8.803	1.541	1.545	-4.811	----------	13.25	.6630	------	-----	651
2,400	9.879	11.65	1.109	173.6	1.097	1.848	182.4	10.83	1.872	1.902	-4.721	2.037×10^{-7}	14.46	.5287	2,409	1,450	612
2,600	11.19	13.20	1.167	225.4	1.109	2.398	235.2	12.33	2.113	2.164	-4.665	1.622	15.66	.4496	------	1,755	583
2,800	11.95	14.10	1.199	257.4	1.111	2.739	268.3	12.73	2.175	2.235	-4.651	1.514	16.87	.4262	2,816	1,840	587
3,000	12.35	14.57	1.209	274.6	1.109	2.921	286.3	12.56	2.143	2.205	-4.657	1.479	18.07	.4282	------	1,875	614
3,200	12.65	14.93	1.214	287.7	1.107	3.061	300.3	12.30	2.095	2.159	-4.666	1.445	19.28	.4355	3,230	1,900	646
3,400	12.95	15.28	1.222	300.8	1.105	3.200	314.2	12.06	2.054	2.118	-4.674	1.426	20.40	.4422	------	1,923	675
3,600	13.33	15.72	1.223	318.5	1.104	3.388	332.8	12.00	2.041	2.107	-4.676	1.387	21.69	.4424	3,624	1,940	705
3,800	13.86	16.35	1.235	344.8	1.106	3.668	360.0	12.19	2.070	2.140	-4.670	1.349	22.89	.4325	------	1,970	720
4,000	14.60	17.22	1.257	383.6	1.109	4.082	399.9	12.66	2.146	2.223	-4.653	1.303	24.10	.4111	4,014	2,010	719
4,200	15.65	18.46	1.293	443.2	1.114	4.716	460.7	13.55	2.291	2.378	-4.624	1.230	25.30	.3763	------	2,066	695
4,400	17.03	20.09	1.347	528.0	1.122	5.618	547.0	14.78	2.494	2.595	-4.586	1.109	26.51	.3338	4,410	2,085	650
4,600	18.70	22.06	1.423	640.8	1.128	6.818	661.6	16.25	2.736	2.853	-4.545	8.318×10^{-8}	27.71	.2899	------	2,830	587
4,800	20.60	24.30	1.517	781.6	1.134	8.317	804.7	17.82	2.994	3.127	-4.505	----------	28.92	.2498	4,808	-----	519
5,000	22.57	26.62	1.625	941.7	1.139	1.002×10^{-3}	967.3	19.24	3.229	3.378	-4.471	----------	30.12	.2171	5,008	-----	453
5,500	26.51	31.26	1.869	1,305	1.144	1.388	1,337	21.08	3.530	3.700	-4.432	----------	33.13	.1734	5,511	-----	351
6,000	28.29	33.37	1.975	1,486	1.143	1.581	1,523	20.81	3.484	3.653	-4.437	----------	36.14	.1662	6,019	-----	330
6,500	29.02	34.22	2.006	1,559	1.140	1.658	1,600	19.84	3.321	3.483	-4.458	----------	39.16	.1712	6,534	-----	341
7,000	29.71	35.04	2.025	1,631	1.138	1.735	1,675	19.09	3.195	3.352	-4.475	----------	42.17	.1759	7,032	-----	355
7,500	30.60	36.09	2.055	1,727	1.136	1.838	1,776	18.60	3.112	3.265	-4.486	----------	45.18	.1777	7,527	-----	362
8,000	31.91	37.64	2.109	1,878	1.136	1.998	1,931	18.48	3.090	3.243	-4.489	----------	48.19	.1743	8,022	-----	356
8,500	33.80	39.87	2.198	2,108	1.137	2.243	2,167	18.73	3.131	3.288	-4.483	----------	51.20	.1652	8,520	-----	334
9,000	36.32	42.84	2.332	2,439	1.138	2.595	2,505	19.28	3.223	3.385	-4.470	----------	54.22	.1515	9,018	-----	297
9,500	39.43	46.51	2.515	2,879	1.140	3.063	2,954	20.00	3.341	3.511	-4.455	----------	57.23	.1358	9,518	-----	251
10,000	42.95	50.66	2.742	3,422	1.142	3.641	3,508	20.72	3.460	3.637	-4.439	----------	60.24	.1205	10,018	-----	205
11,000	50.02	59.01	3.258	4,651	1.145	4.948	4,763	21.54	3.596	3.782	-4.422	----------	66.26	.09774	11,021	-----	136
12,000	55.20	65.11	3.658	5,663	1.145	6.025	5,797	21.42	3.574	3.760	-4.425	----------	72.29	.08760	12,029	-----	104

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2/\frac{R}{m_0}T_0$	$h_t/\frac{R}{m_0}T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm^3	$N_{e,w}$, per cm^3	$N_{e,fw}$, per cm^3	γ_2^*
800	2.161	0.9739	1.682	0.4224	0.9986	10.49	10.81	38.06	2.46	----------	---------	--------	--------	--------	-----
1,200	2.610	.9443	2.032	.4003	.9877	16.31	16.71	39.12	3.52	----------	---------	--------	--------	--------	-----
1,600	2.986	.9210	2.325	.3864	.9728	22.60	22.97	39.98	4.38	6.3×10^{-14}	---------	1.8×10^{1}	--------	8.6×10^{-1}	-----
2,000	3.162	.8135	2.462	.3721	.9517	32.42	33.02	41.04	5.44	1.0×10^{-10}	---------	3.5×10^{4}	--------	1.2×10^{3}	1.143
2,200	3.324	.7433	2.588	.3382	.8721	43.11	43.67	42.04	6.44	1.3×10^{-9}	---------	5.7×10^{5}	--------	9.7×10^{3}	1.113
2,400	3.558	.6803	2.770	.3024	.7853	59.31	59.71	43.63	8.03	1.0×10^{-8}	1.0×10^{-14}	5.6×10^{6}	5.4×10^{-2}	1.3×10^{5}	1.111
2,600	3.841	.6508	2.990	.2789	.7272	75.66	76.04	45.12	9.52	5.2×10^{-8}	1.4×10^{-11}	3.5×10^{7}	6.2×10^{1}	7.0×10^{5}	1.134
2,800	4.149	.6595	3.230	.2668	.6970	85.90	86.40	46.02	10.42	2.0×10^{-7}	6.5×10^{-11}	1.4×10^{8}	2.8×10^{2}	2.7×10^{6}	1.195
3,000	4.444	.6842	3.460	.2609	.6819	91.55	92.11	46.48	10.88	5.2×10^{-7}	1.2×10^{-10}	3.7	5.0	6.6×10^{6}	1.270
3,200	4.624	.6949	3.600	.2625	.6868	95.94	96.63	46.80	11.20	1.4×10^{-6}	1.8	9.8	7.4	1.7×10^{7}	1.282
3,400	4.696	.6899	3.656	.2697	.7058	100.6	101.1	47.14	11.54	3.3	2.5	2.3×10^{9}	1.0×10^{3}	3.8	1.242
3,600	4.740	.6771	3.690	.2764	.7236	106.4	107.0	47.51	11.91	7.1	3.4	4.9	1.4	7.9	1.192
3,800	4.804	.6602	3.740	.2792	.7317	114.8	115.5	48.03	12.43	1.4×10^{-5}	5.5	9.9	2.2	1.5×10^{8}	1.146
4,000	4.920	.6426	3.830	.2764	.7251	127.4	128.0	48.74	13.14	2.6	1.0×10^{-9}	1.9×10^{10}	3.9	2.8	1.120
4,200	5.076	.6191	3.952	.2685	.7051	146.0	146.7	49.78	14.18	4.4	1.9	3.6	7.2	4.9	1.106
4,400	5.287	.5933	4.116	.2570	.6756	172.5	173.3	51.29	15.69	6.4	2.4	6.0	9.0	7.7	1.100
4,600	5.549	.5676	4.320	.2446	.6437	208.2	208.6	53.17	17.57	9.3	1.2×10^{-6}	1.0×10^{11}	3.3×10^{6}	1.2×10^{9}	1.100
4,800	5.857	.5443	4.560	.2330	.6138	252.1	252.6	55.43	19.83	1.25×10^{-4}	---------	1.6	--------	1.9	1.100
5,000	6.194	.5258	4.822	.2233	.5887	301.8	302.7	57.94	22.34	1.8	---------	2.6	--------	3.1	1.103
5,500	7.039	.5093	5.480	.2107	.5561	416.1	416.9	63.31	27.71	4.4	---------	8.1	--------	9.8	1.128
6,000	7.801	.5289	6.073	.2056	.5428	472.9	474.5	65.72	30.12	1.3×10^{-3}	---------	2.5×10^{12}	--------	3.1×10^{10}	1.196
6,500	8.388	.5548	6.530	.2057	.5430	498.5	499.0	66.76	31.16	4.1×10^{-3}	---------	7.7	--------	9.4×10^{10}	1.260
7,000	8.609	.5561	6.702	.2132	.5628	521.4	523.0	67.60	32.00	1.1×10^{-2}	---------	2.0×10^{13}	--------	2.4	1.223
7,500	8.795	.5514	6.847	.2206	.5825	553.1	554.7	68.66	33.06	2.4	---------	4.3	--------	5.2	1.172
8,000	9.088	.5465	7.075	.2242	.5920	601.4	603.2	70.13	34.53	5.0	---------	9.2	--------	1.1×10^{12}	1.142
8,500	9.499	.5397	7.395	.2241	.5921	674.8	676.2	72.30	36.70	8.8	---------	1.7×10^{14}	--------	2.1	1.129
9,000	10.04	.5307	7.820	.2213	.5847	779.3	780.9	75.[illegible]	39.63	1.4×10^{-1}	---------	3.0	--------	3.7	1.124
9,500	10.73	.5226	8.353	.2167	.5727	918.4	919.7	78.93	43.33	2.0	---------	4.7	--------	6.2	1.125
10,000	11.50	.5143	8.955	.2126	.5620	1,089	1,091	83.27	47.67	2.7	---------	7.2	--------	1.0×10^{13}	1.127
11,000	13.24	.5084	10.30	.2069	.5469	1,478	1,479	92.48	56.88	3.8	---------	1.3×10^{15}	--------	2.2	1.141
12,000	14.87	.5176	11.58	.2044	.5405	1,798	1,800	99.61	64.01	4.5	---------	1.7	--------	3.4	1.171

TABLE IV.- NORMAL SHOCK PARAMETERS - Concluded

(l) For geopotential altitude of 322,900 ft; T_1 = 199° K; a_1 = 930 ft/sec; p = 2.119 × 10^{-7} atm

T_2, °K	u_1, ft/sec	M_1	Z_2	$\frac{p_2}{p_1}$	$K(p_2)$	$\frac{p_2}{p_0}$	$\frac{p_s}{p_1}$	$\frac{\rho_2}{\rho_1}$	$K(\rho_2)$	$\frac{\rho_2}{\rho_0}$	$\log \frac{\rho_2}{\rho_0}$	$\frac{\rho_w}{\rho_0}$	$\frac{T_2}{T_1}$	$K(T_2)$	T_s, °K	T_w, °K	T_{fw}, °K
2,000	7.659×10^3	8.223	1.034	84.00	1.067	1.78×10^{-5}	89.80	8.082	1.447	0.2351×10^{-5}	-5.629	---	10.05	0.7133	2,013	---	663
2,200	9.293	9.977	1.092	127.2	1.097	2.696	133.8	10.54	1.845	.3066	-5.513	---	11.06	.5446	2,206	---	619
3,000	12.41	13.33	1.210	230.1	1.111	4.875	239.8	12.61	2.162	.3670	-5.435	---	15.08	.4250	3,029	---	647
3,400	13.10	14.07	1.219	255.6	1.108	5.417	266.7	12.27	2.097	.3571	-5.447	---	17.09	.4334	3,421	---	711
4,000	15.83	17.00	1.304	377.5	1.121	8.00	391.3	14.40	2.442	.4190	-5.378	---	20.10	.3520	4,009	---	685
4,400	19.61	21.05	1.472	587.5	1.137	1.245×10^{-4}	604.3	18.05	3.042	.5251	-5.280	---	22.11	.2538	4,407	---	548
5,000	25.75	27.65	1.827	1,024	1.148	2.170	1,047	22.32	3.744	.6492	-5.188	---	25.13	.1680	5,008	---	363
6,000	28.69	30.80	1.993	1,267	1.145	2.685	1,298	21.09	3.533	.6135	-5.212	---	30.15	.1626	6,033	---	346
7,000	30.29	32.52	2.044	1,407	1.140	2.981	1,444	19.57	3.277	.5693	-5.245	---	35.18	.1703	7,022	---	371
7,500	31.82	34.17	2.110	1,553	1.140	3.290	1,593	19.53	3.268	.5680	-5.246	---	37.69	.1654	7,517	---	360
8,000	34.22	36.74	2.227	1,798	1.142	3.810	1,844	20.09	3.360	.5843	-5.233	---	40.20	.1526	8,015	---	328
9,000	41.43	44.49	2.659	2,648	1.147	5.610	2,709	22.02	3.679	.6406	-5.193	---	45.23	.1173	9,014	---	222
10,000	49.89	53.56	3.267	3,849	1.150	8.156	3,932	23.44	3.914	.6820	-5.166	---	50.25	$.8993 \times 10^{-1}$	10,024	---	135
11,000	55.59	59.68	3.725	4,776	1.149	1.012×10^{-3}	4,880	23.20	3.871	.6748	-5.171	---	55.28	.7971	11,023	---	101
12,000	58.10	62.38	3.908	5,205	1.147	1.103	5,325	22.09	3.686	.6426	-5.192	---	60.30	.7961	12,049	---	95

T_2, °K	$\frac{a_2}{a_1}$	$K(a_2)$	$\frac{a_2}{a_0}$	M_2	$K(M_2)$	$h_2 / \frac{R}{m_0} T_0$	$h_t / \frac{R}{m_0} T_0$	$\frac{s_2}{R/m_0}$	$\frac{s_2 - s_1}{R/m_0}$	$x_{e,2}$	$x_{e,w}$	$N_{e,2}$, per cm³	$N_{e,w}$, per cm³	$N_{e,fw}$, per cm³	γ_2^*
2,000	2.864	0.7630	2.45	0.3552	0.9059	36.52	37.67	43.31	5.44	---------	---	--------	---	---------	1.112
2,200	3.075	.6825	2.63	.3079	.7943	52.86	54.02	44.99	7.12	---------	---	--------	---	---------	1.103
3,000	4.092	.6870	3.50	.2582	.6734	92.49	93.98	48.72	10.85	8.5×10^{-7}	---	1.0×10^{8}	---	2.0×10^{6}	1.294
3,400	4.183	.6662	3.578	.2740	.7157	102.8	104.4	49.47	11.60	5.2×10^{-6}	---	6.1×10^{8}	---	1.1×10^{7}	1.180
4,000	4.515	.5975	3.862	.2613	.6854	149.1	151.0	52.35	14.48	3.74×10^{-5}	---	5.5×10^{9}	---	8.5×10^{7}	1.094
4,400	5.025	.5384	4.298	.2321	.6106	228.1	230.0	56.85	18.98	8.5×10^{-5}	---	--------	---	2.4×10^{8}	1.092
5,000	6.019	.4921	5.148	.2059	.5429	391.3	394.5	65.45	27.58	2.65×10^{-4}	---	8.4×10^{10}	---	1.1×10^{9}	1.110
6,000	7.378	.5418	6.31	.1980	.5223	485.1	488.9	69.85	31.98	3.05×10^{-3}	---	1.0×10^{12}	---	1.4×10^{10}	1.275
7,000	7.693	.5352	6.58	.2160	.5701	540.4	544.6	71.95	34.08	2.50×10^{-2}	---	7.8×10^{12}	---	1.1×10^{11}	1.159
7,500	7.983	.5288	6.828	.2192	.5786	597.0	600.8	73.87	36.00	5.5×10^{-2}	---	--------	---	2.4	1.128
8,000	8.420	.5188	7.202	.2173	.5737	688.8	694.3	76.78	38.91	1.10×10^{-1}	---	3.8×10^{13}	---	5.2	1.116
9,000	9.759	.4969	8.347	.2070	.5470	1,012	1,016	86.16	48.29	2.5	---	1.1×10^{14}	---	1.8×10^{12}	1.115
10,000	11.47	.4851	9.808	.1993	.5267	1,463	1,472	98.06	60.19	3.95	---	2.4	---	4.6	1.129
11,000	13.06	.4959	11.17	.1970	.5209	1,817	1,827	106.6	68.69	4.6	---	3.1	---	7.1	1.166
12,000	14.51	.5271	12.41	.1947	.5147	1,984	1,996	110.2	72.35	4.98	---	3.4	---	8.2	1.258

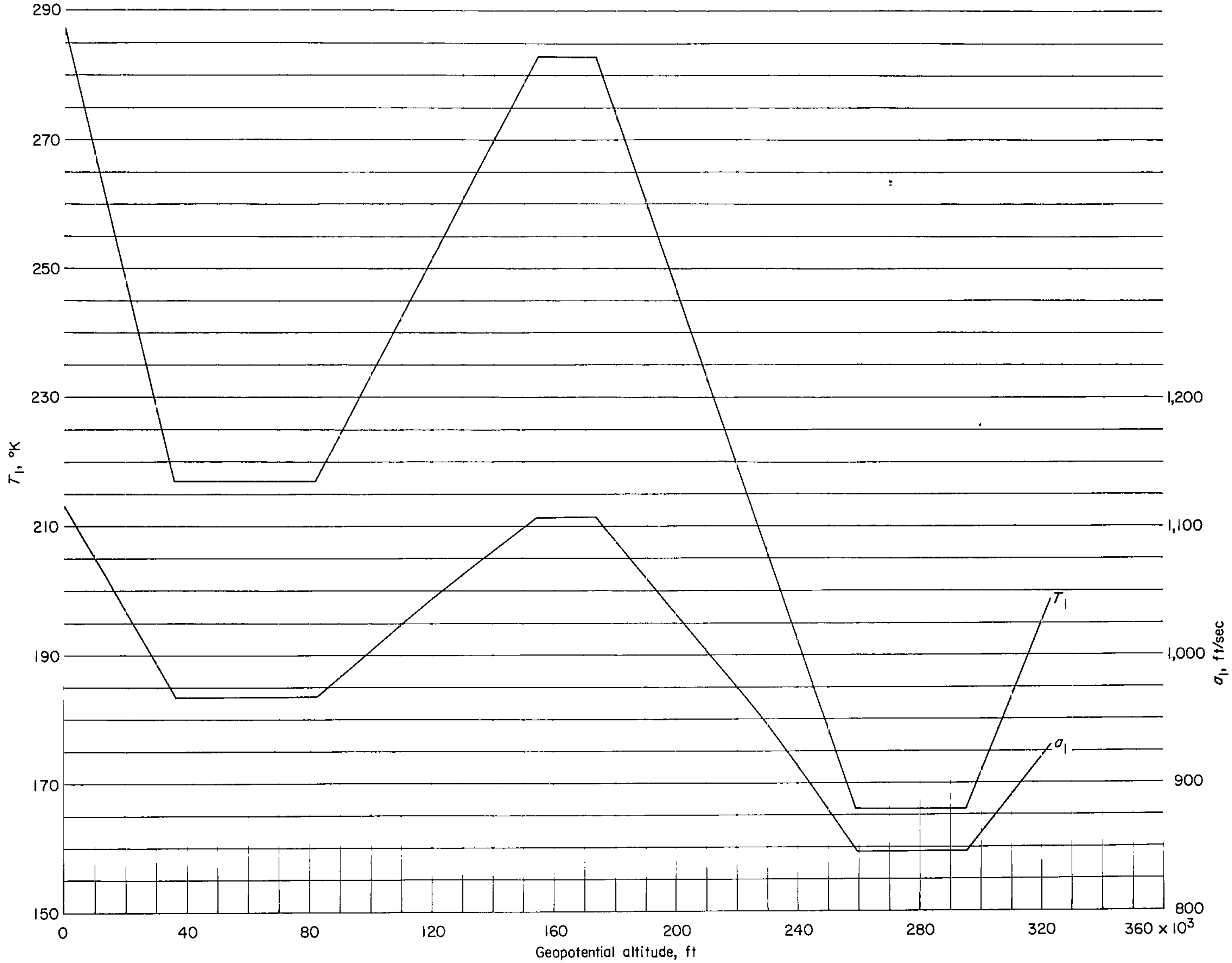


Figure 1.- Variation of ambient temperature and velocity of sound with altitude.

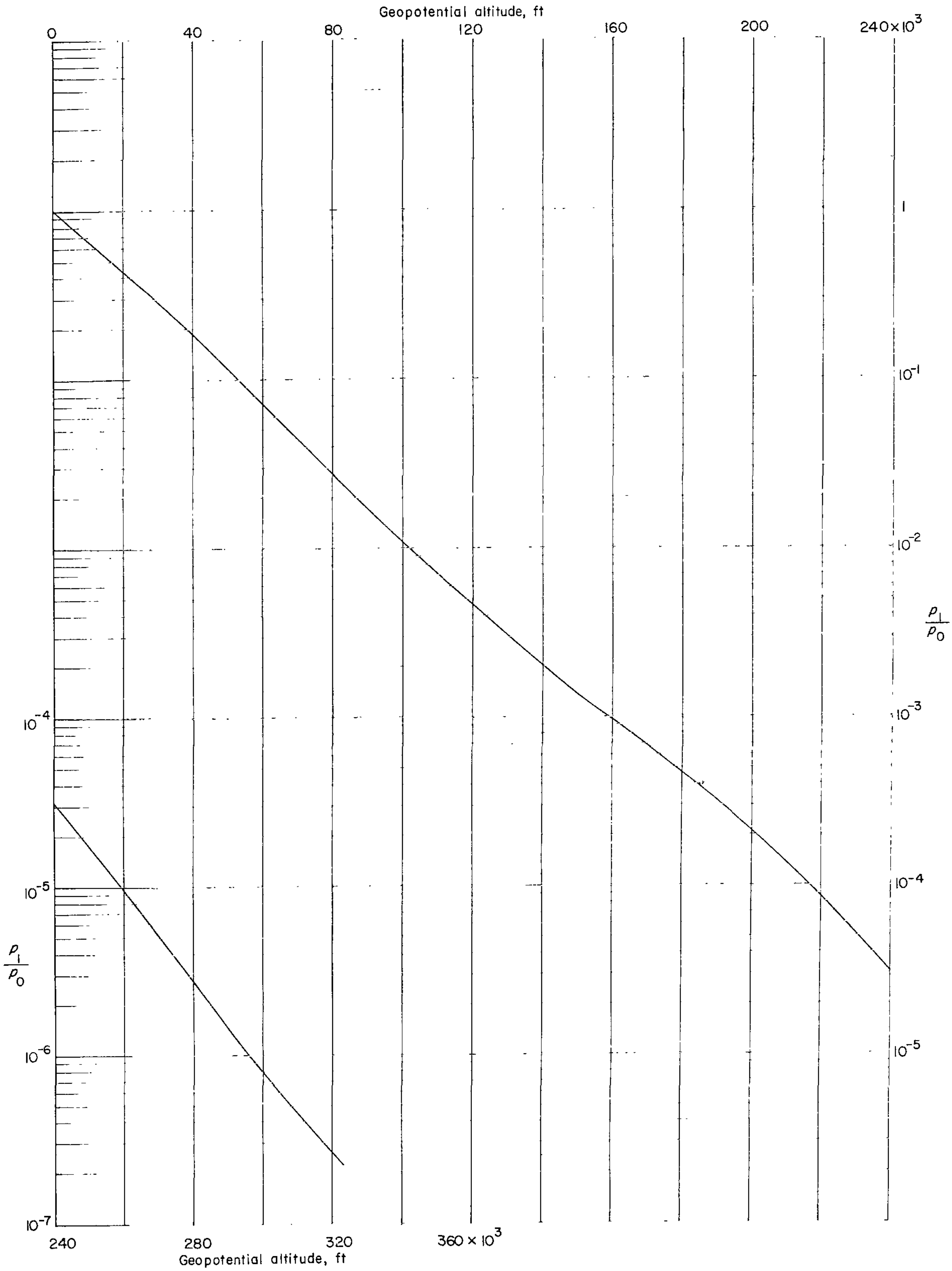


Figure 2.- Variation of ambient pressure with altitude.

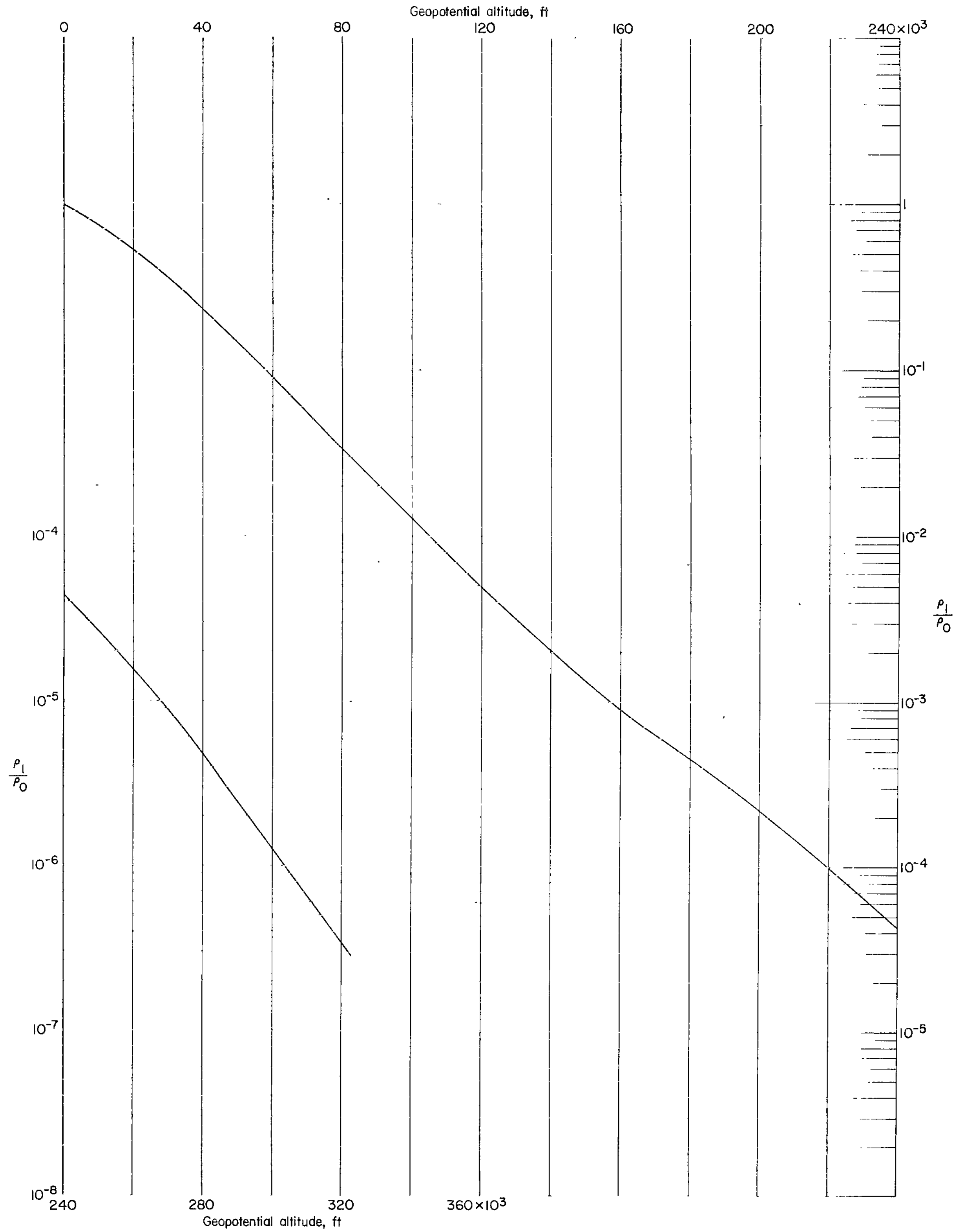
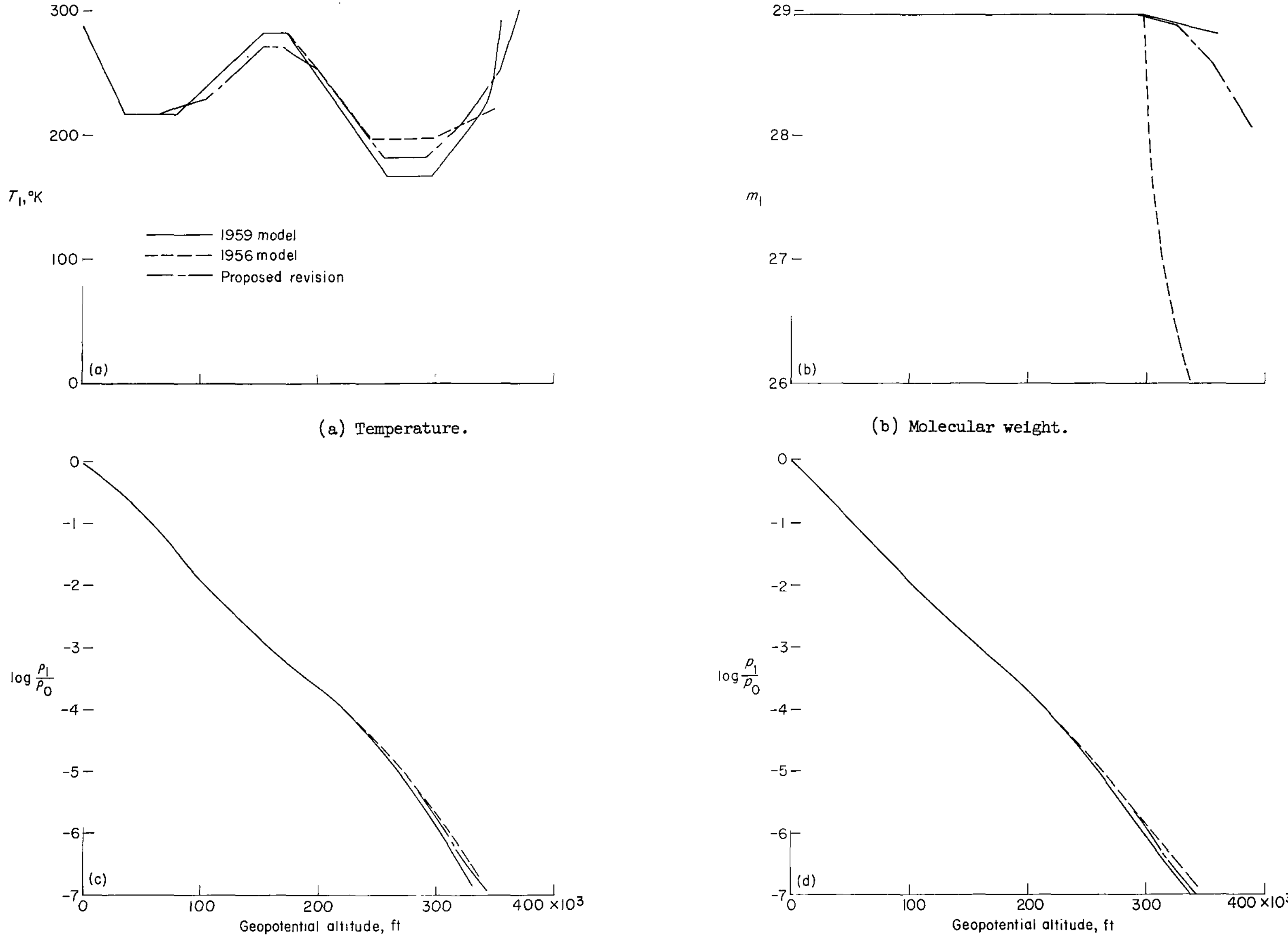


Figure 3.- Variation of ambient density with altitude.

Figure 4.- Variation of ambient entropy and enthalpy with altitude.



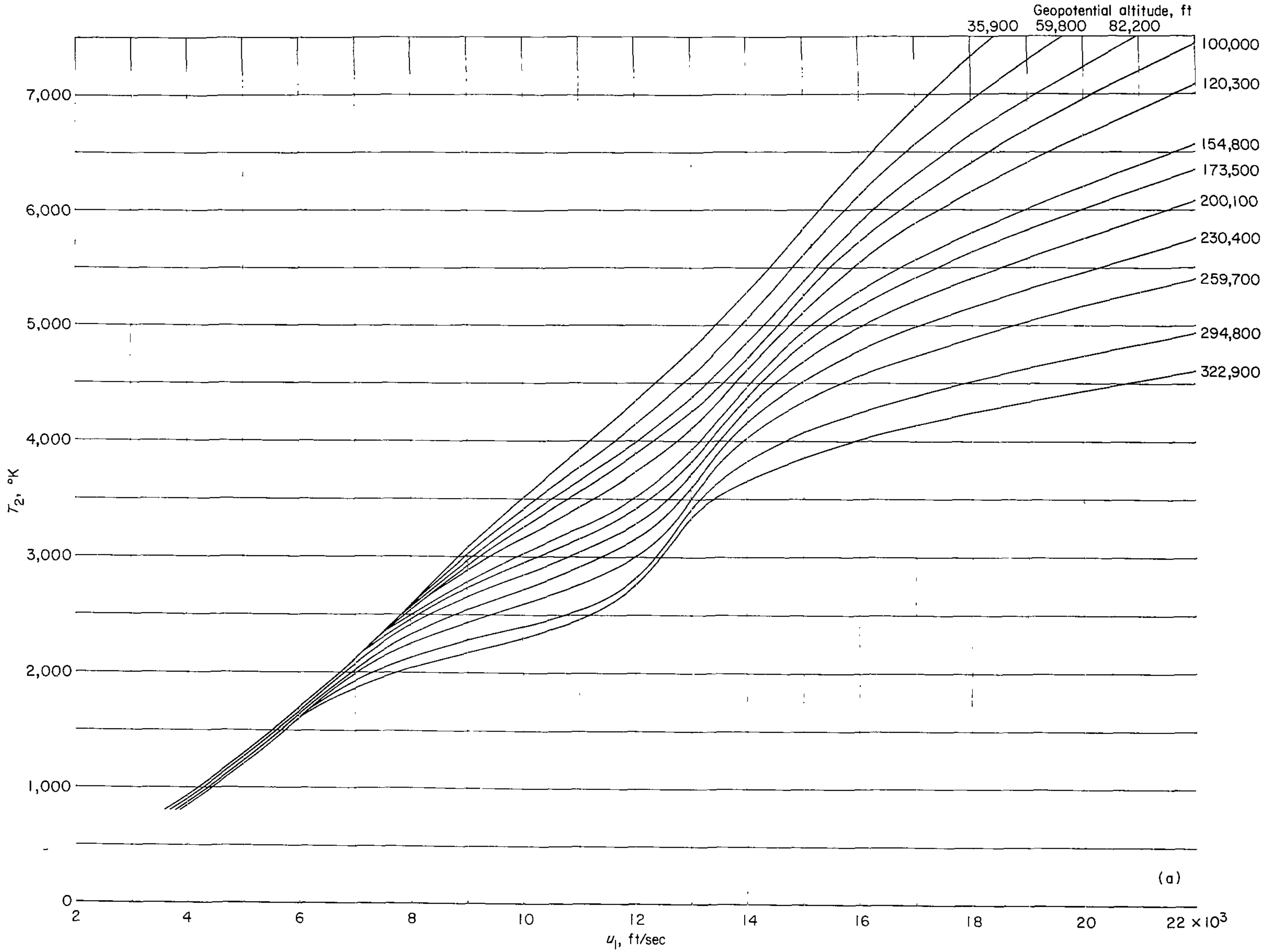
(a) Temperature.

(b) Molecular weight.

(c) Density.

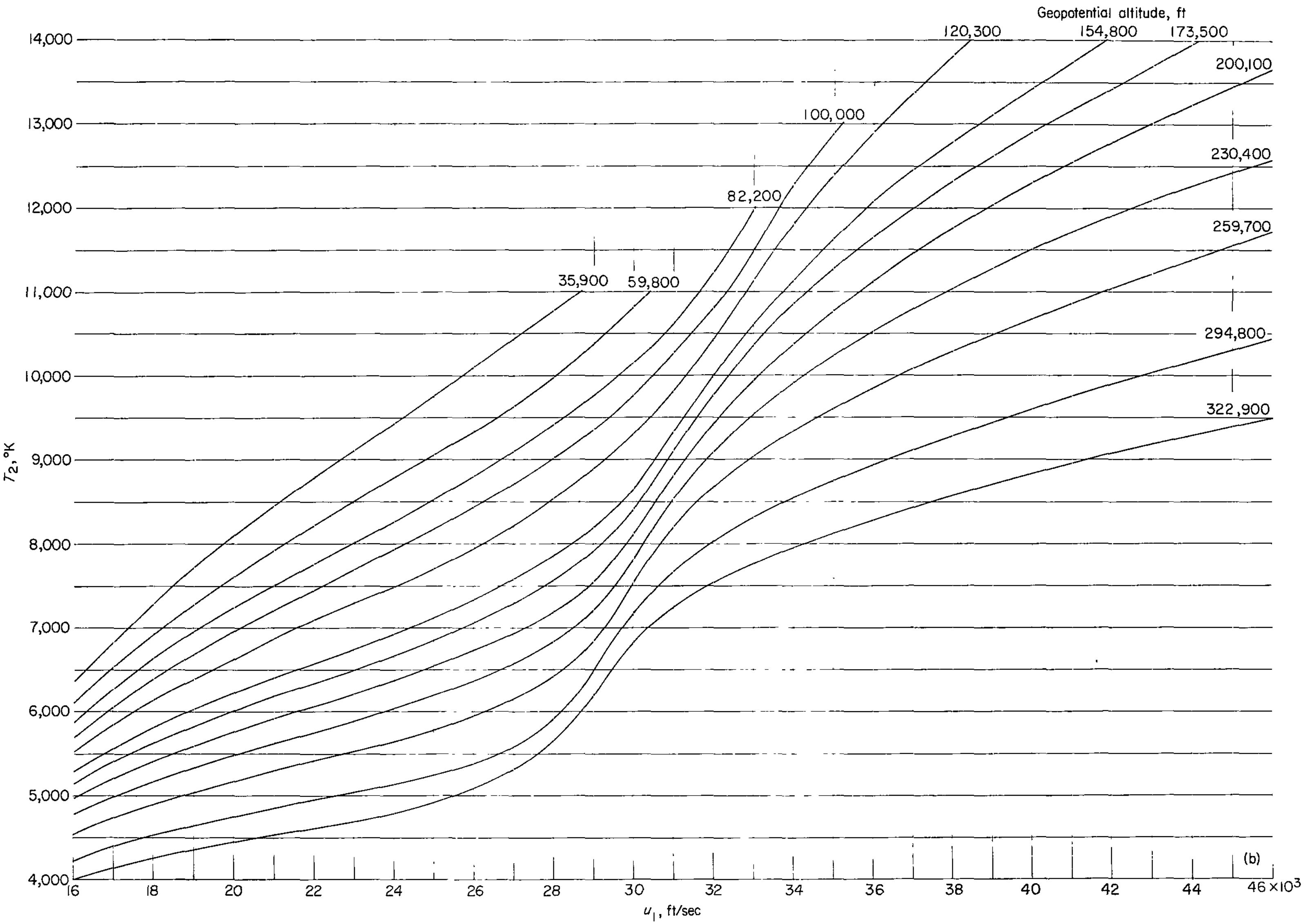
(d) Pressure.

Figure 5.- Comparison of ambient air properties for the 1959 ARDC model atmosphere with the 1956 ARDC model atmosphere.



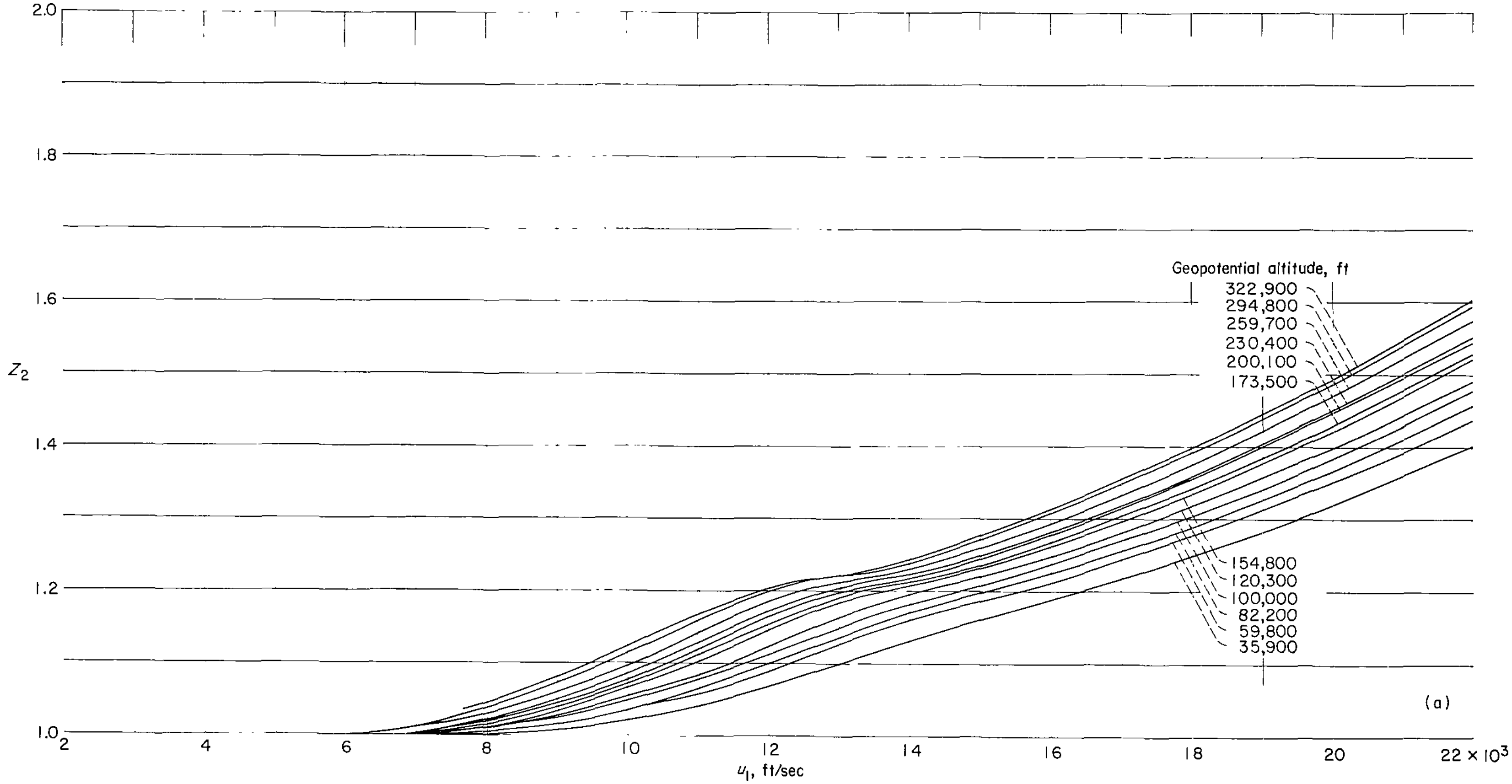
(a) Subsatellite velocity range.

Figure 6.- Variation of normal-shock temperature with velocity and altitude.



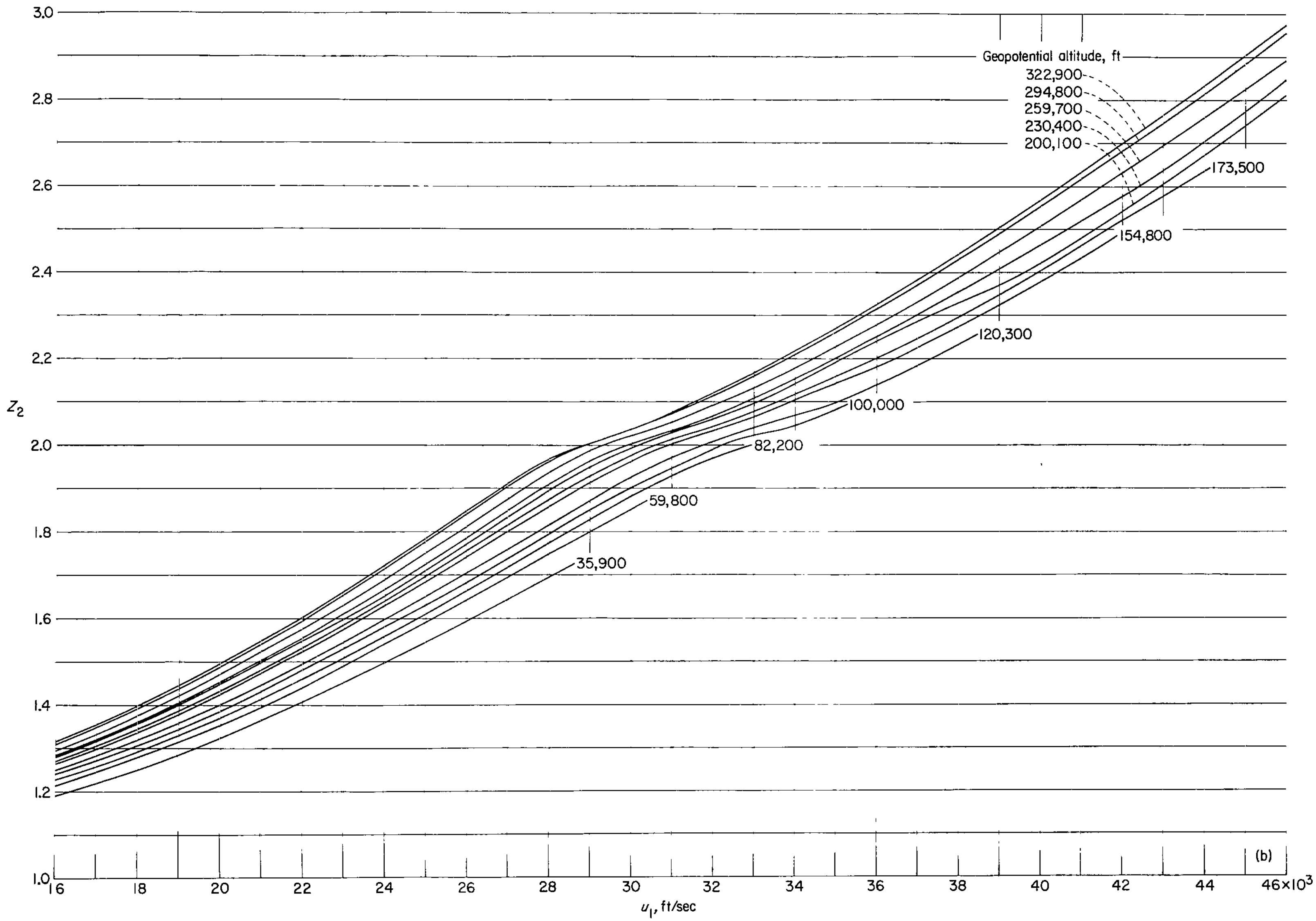
(b) Supersatellite velocity range.

Figure 6.- Concluded.



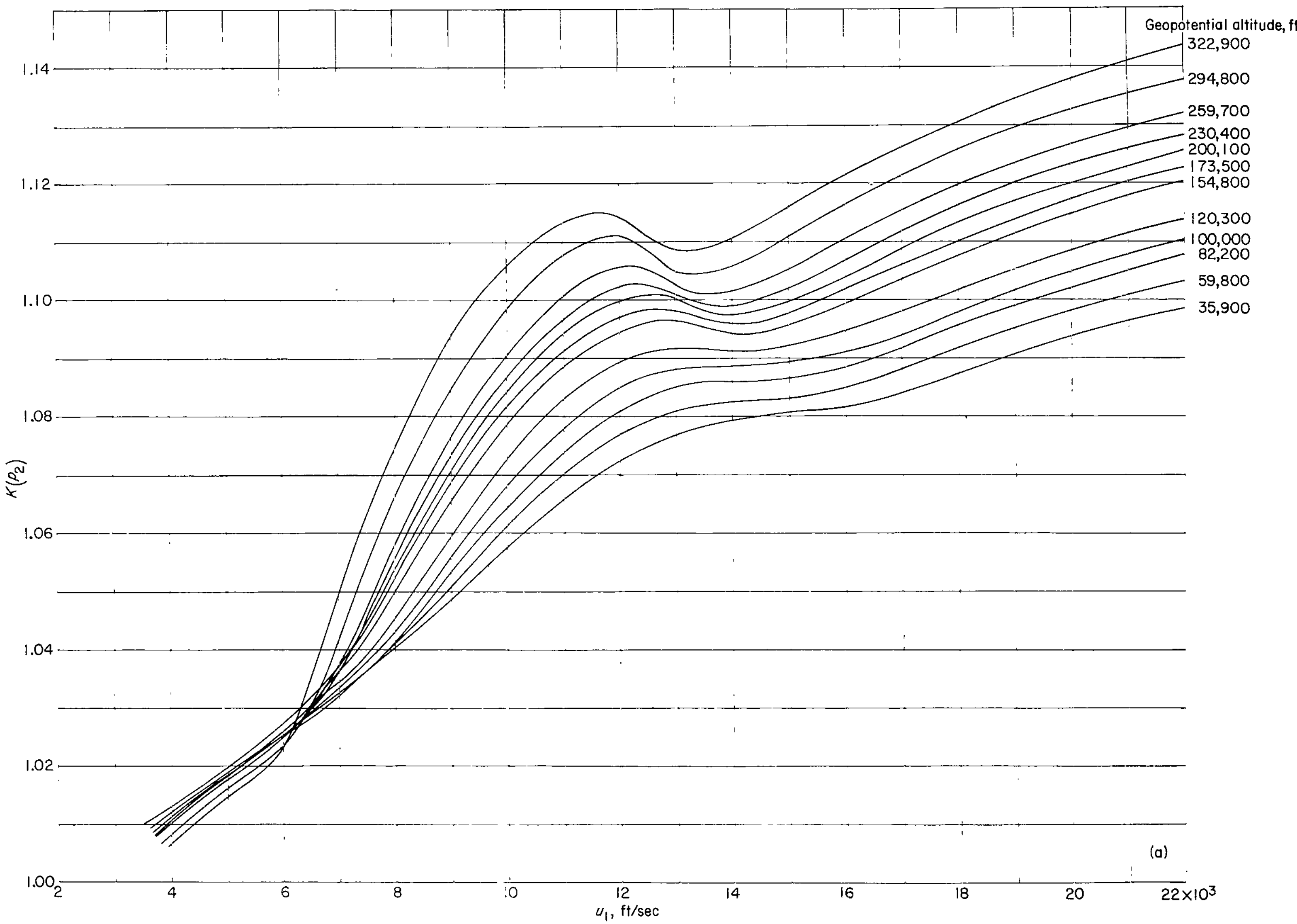
(a) Subsatellite velocity range.

Figure 7.- Variation of normal-shock compressibility factor with velocity and altitude.



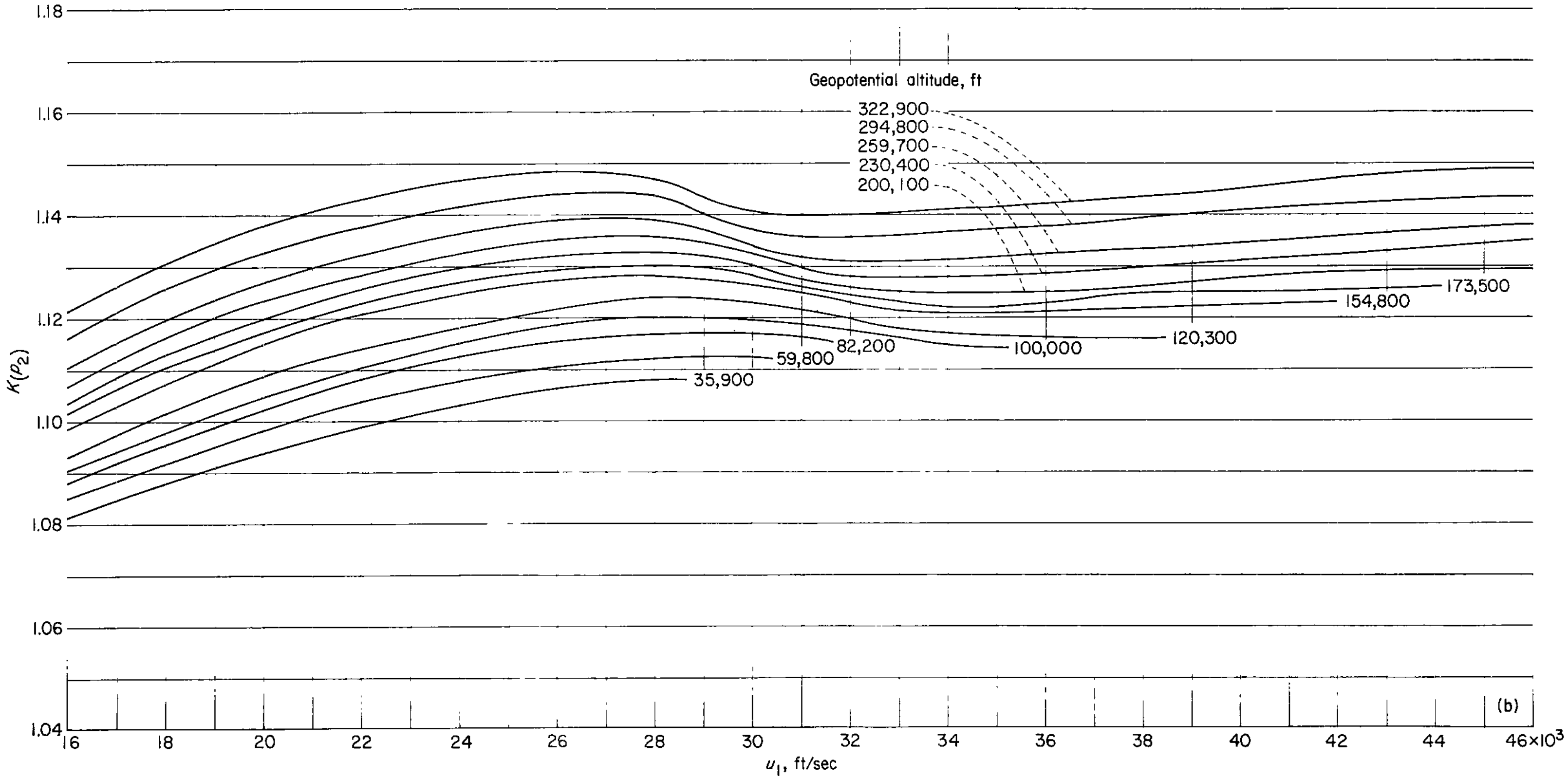
(b) Supersatellite velocity range.

Figure 7.- Concluded.



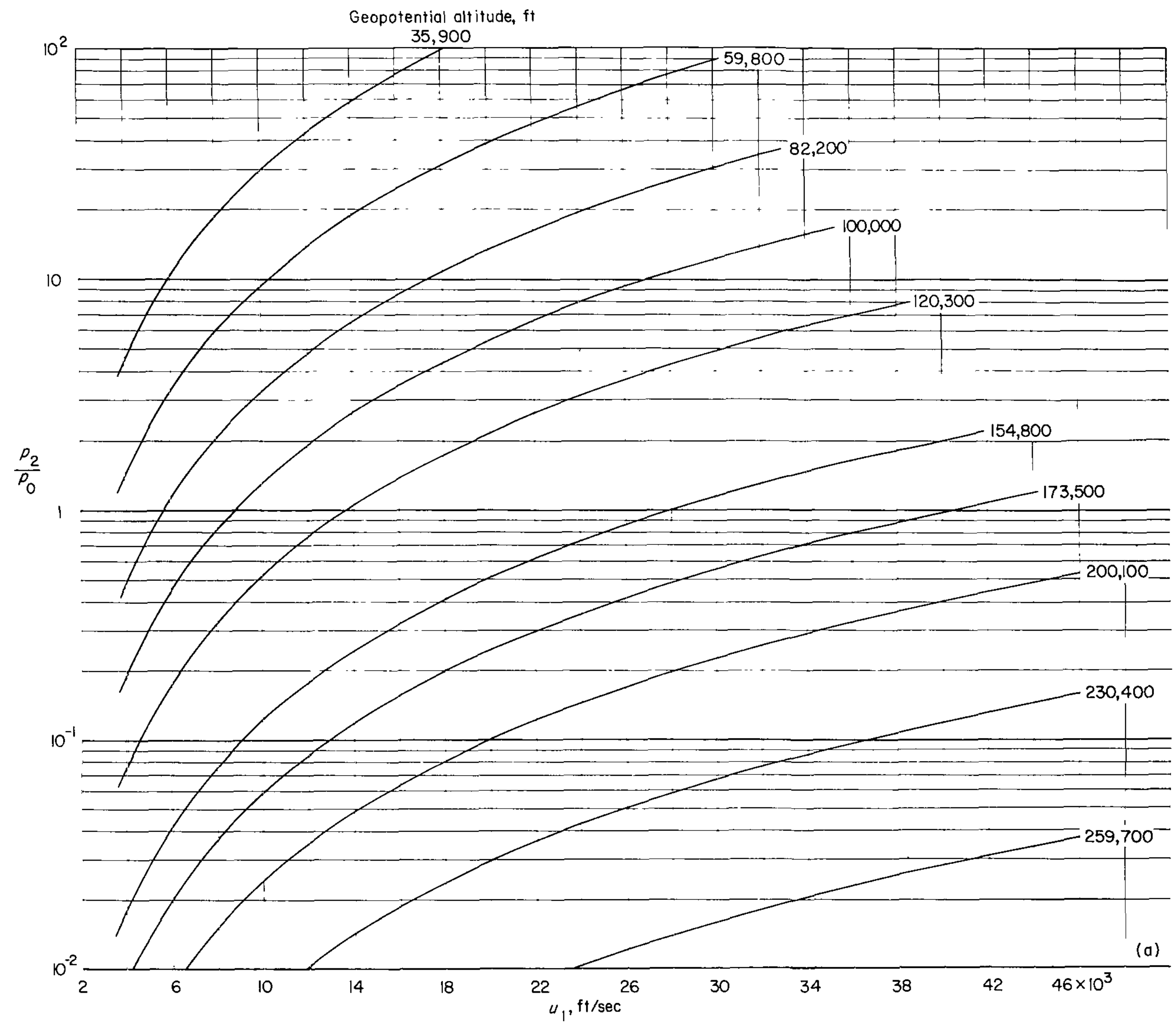
(a) Subsatellite velocity range.

Figure 8.- Variation of normal-shock real-to-ideal pressure ratio with velocity and altitude.



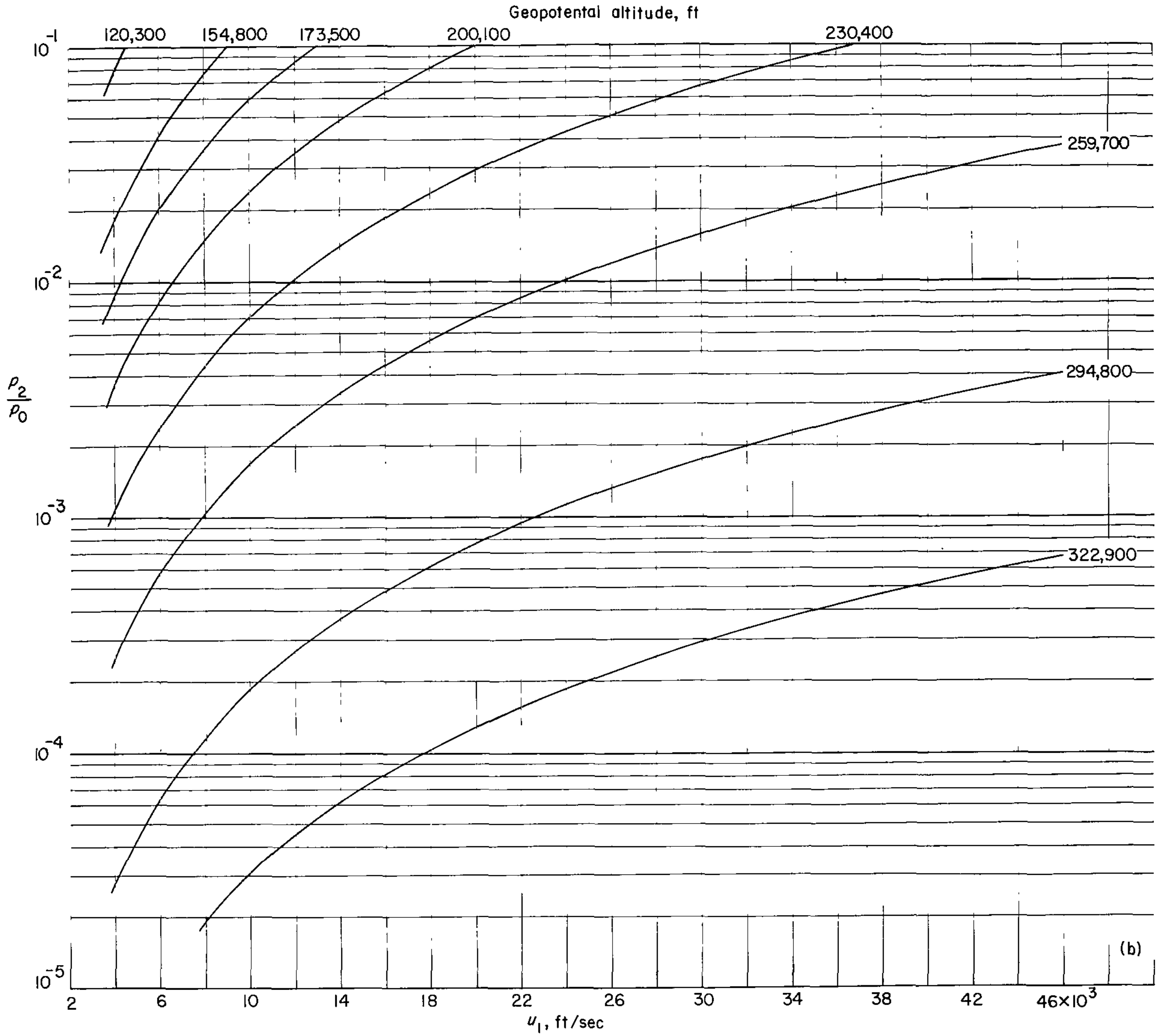
(b) Supersatellite velocity range.

Figure 8.- Concluded.



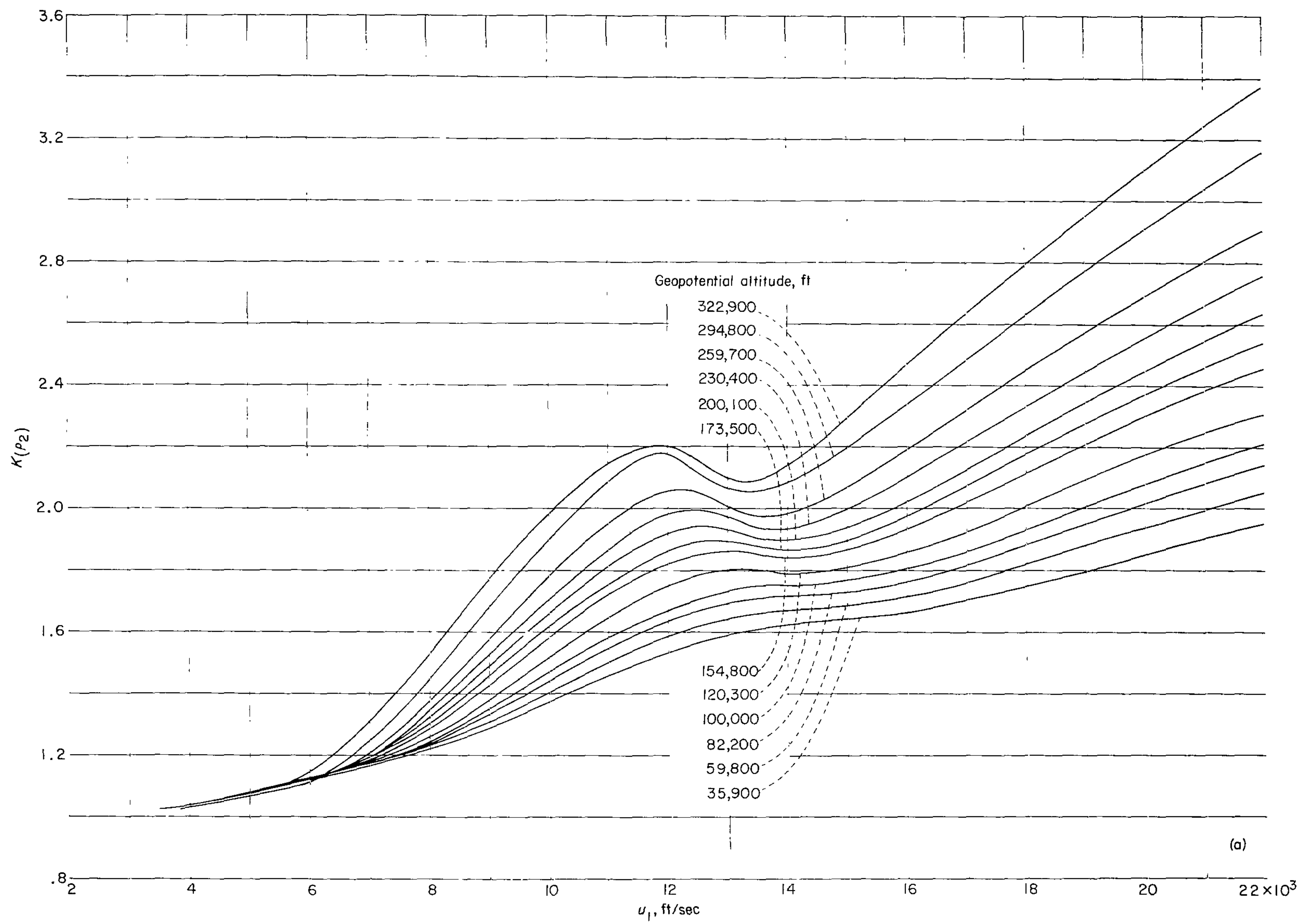
(a) Stratospheric altitude range.

Figure 9.- Variation of normalized normal-shock pressure with velocity and altitude.



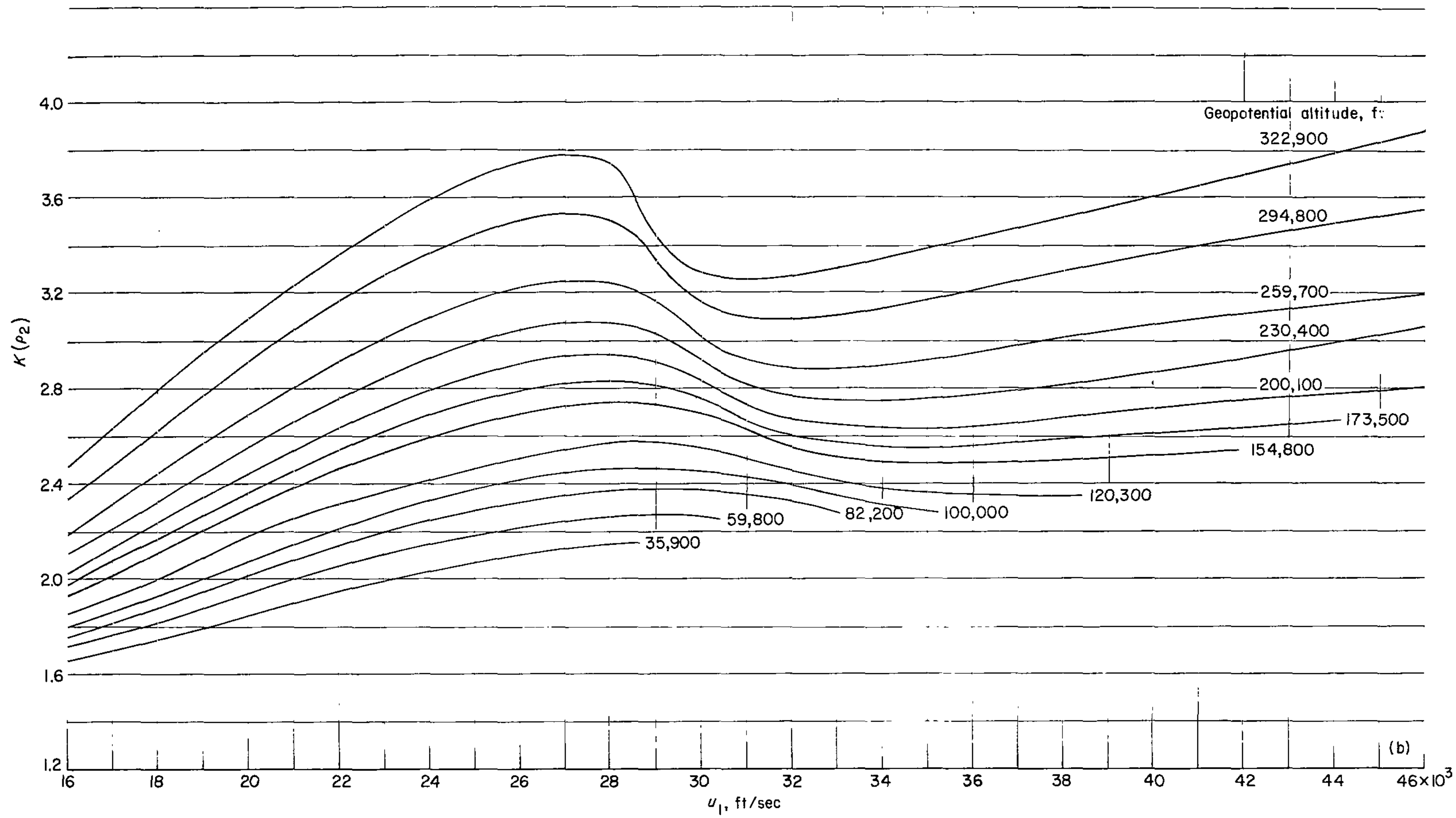
(b) Mesospheric altitude range.

Figure 9.- Concluded.



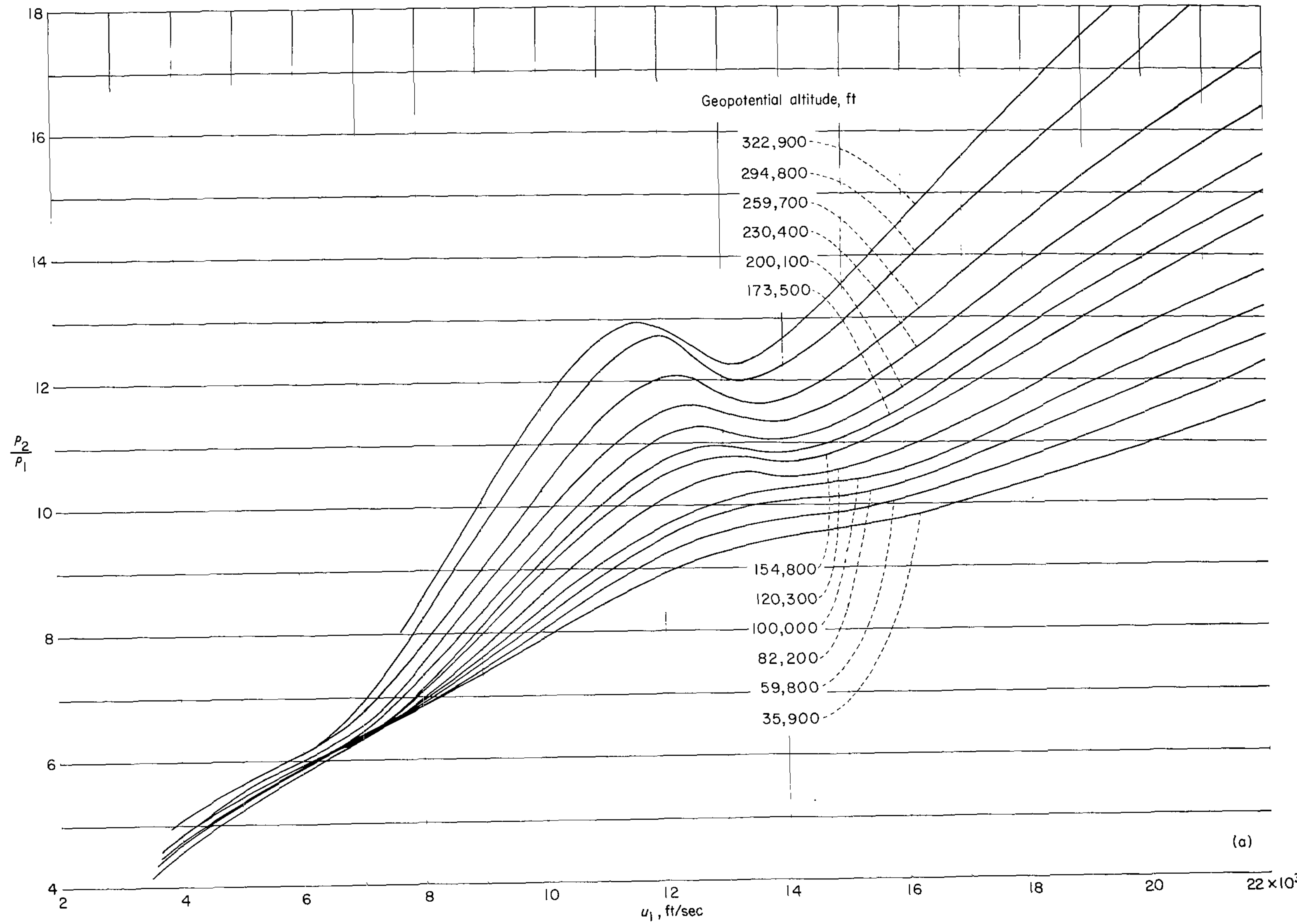
(a) Subsatellite velocity range.

Figure 10.- Variation of normal-shock real-to-ideal density ratio with velocity and altitude.



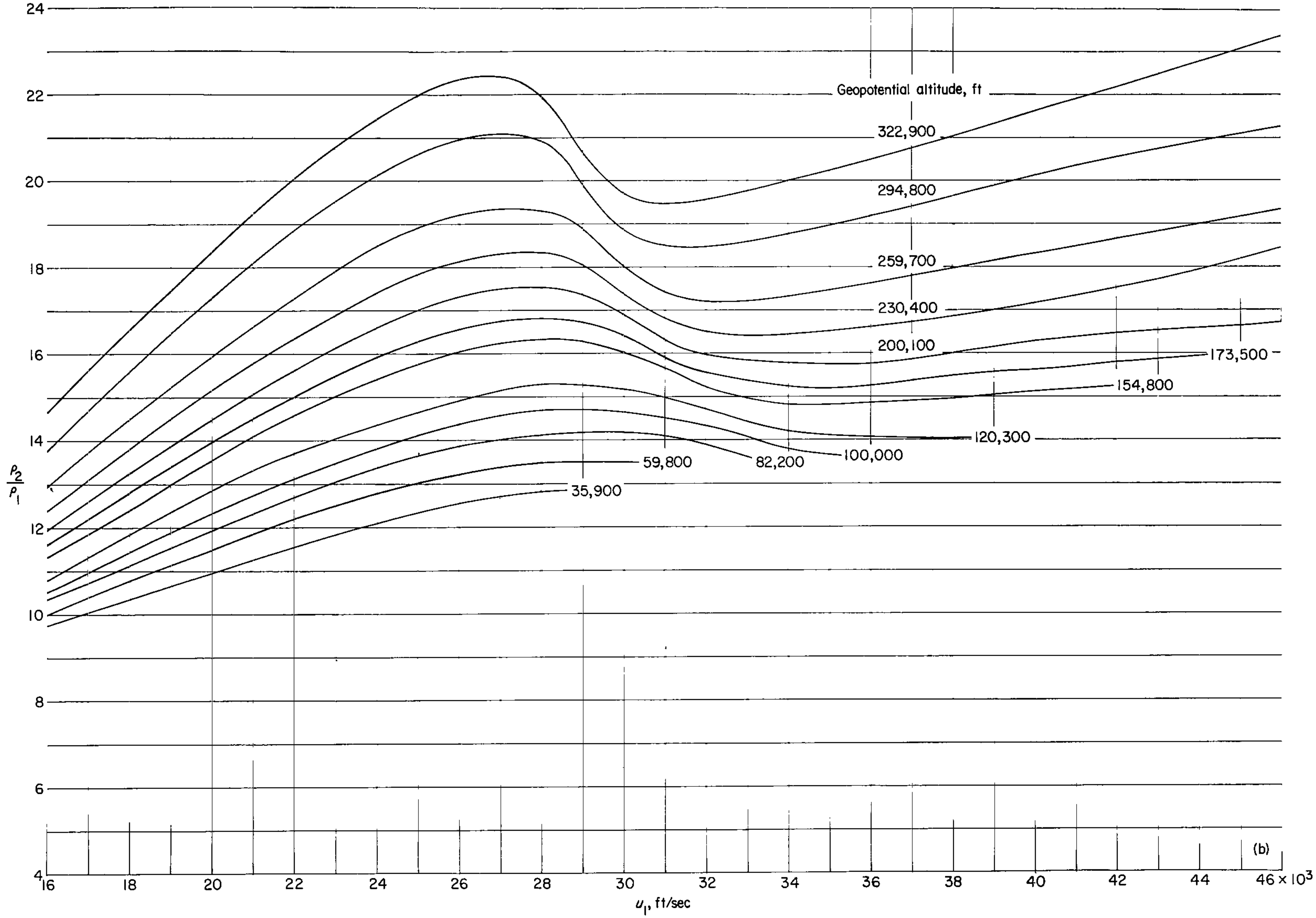
(b) Supersatellite velocity range.

Figure 10.- Concluded.



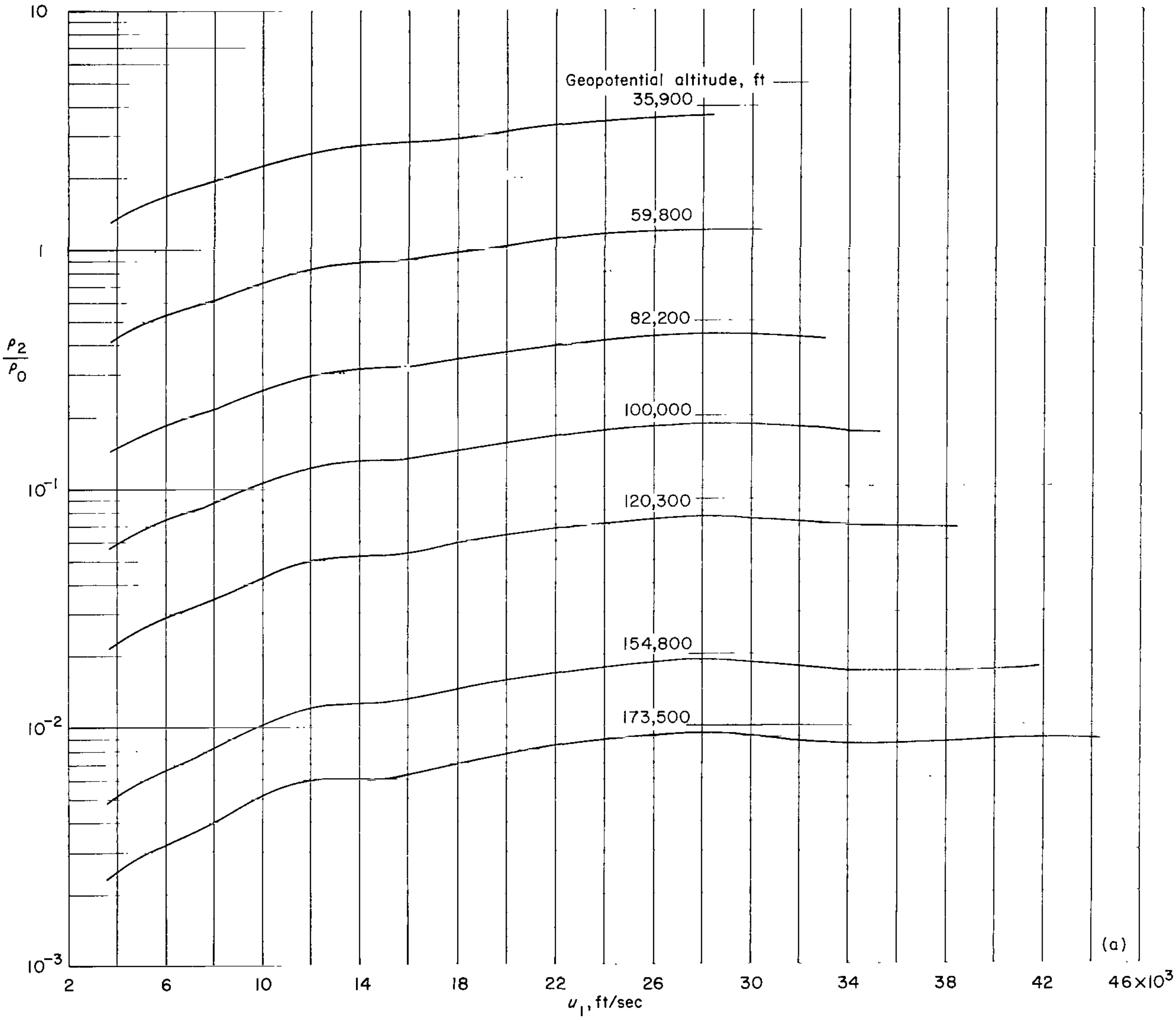
(a) Subsatellite velocity range.

Figure 11.- Variation of normal-shock density ratio with velocity and altitude.



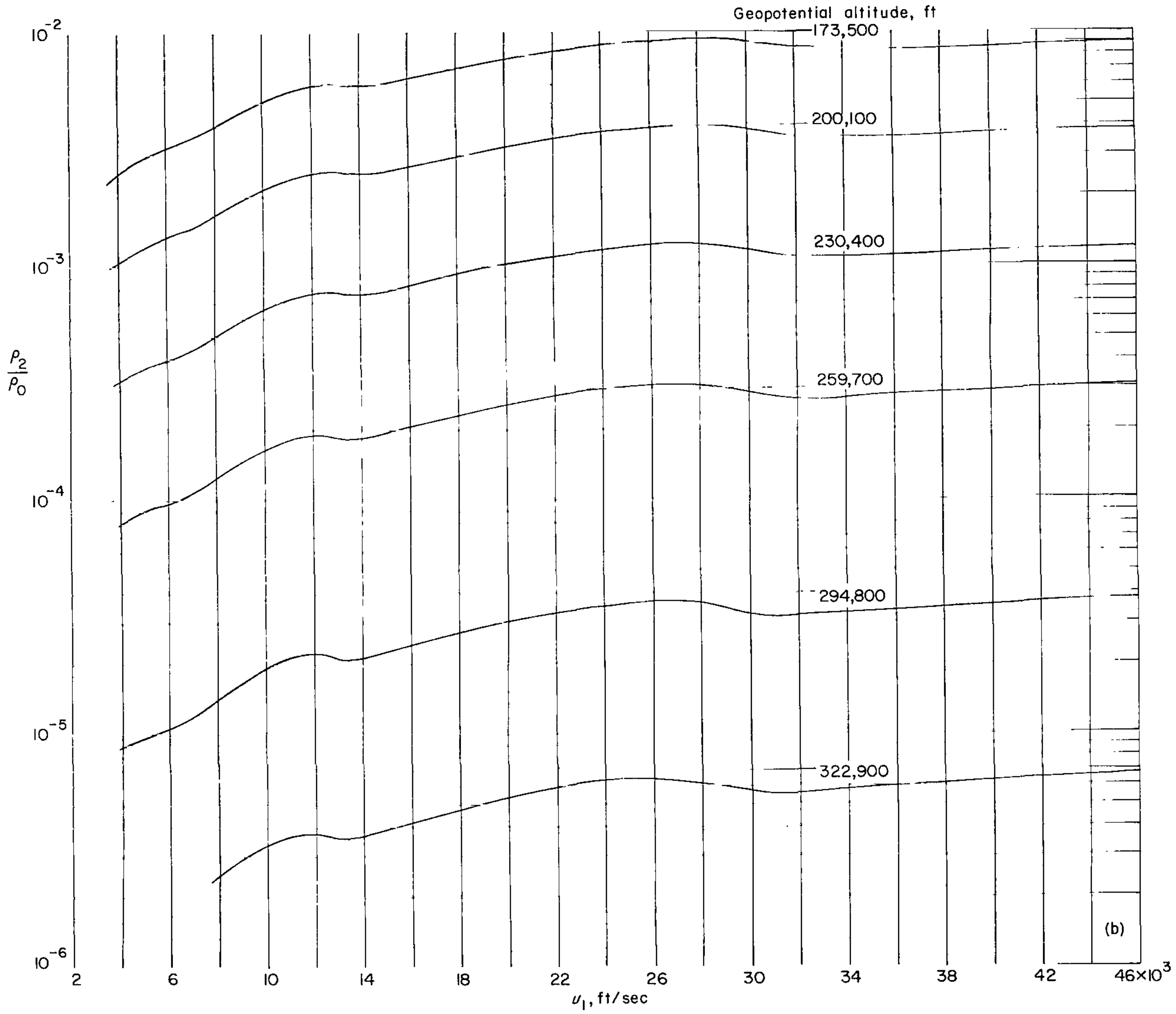
(b) Supersatellite velocity range.

Figure 11.- Concluded.



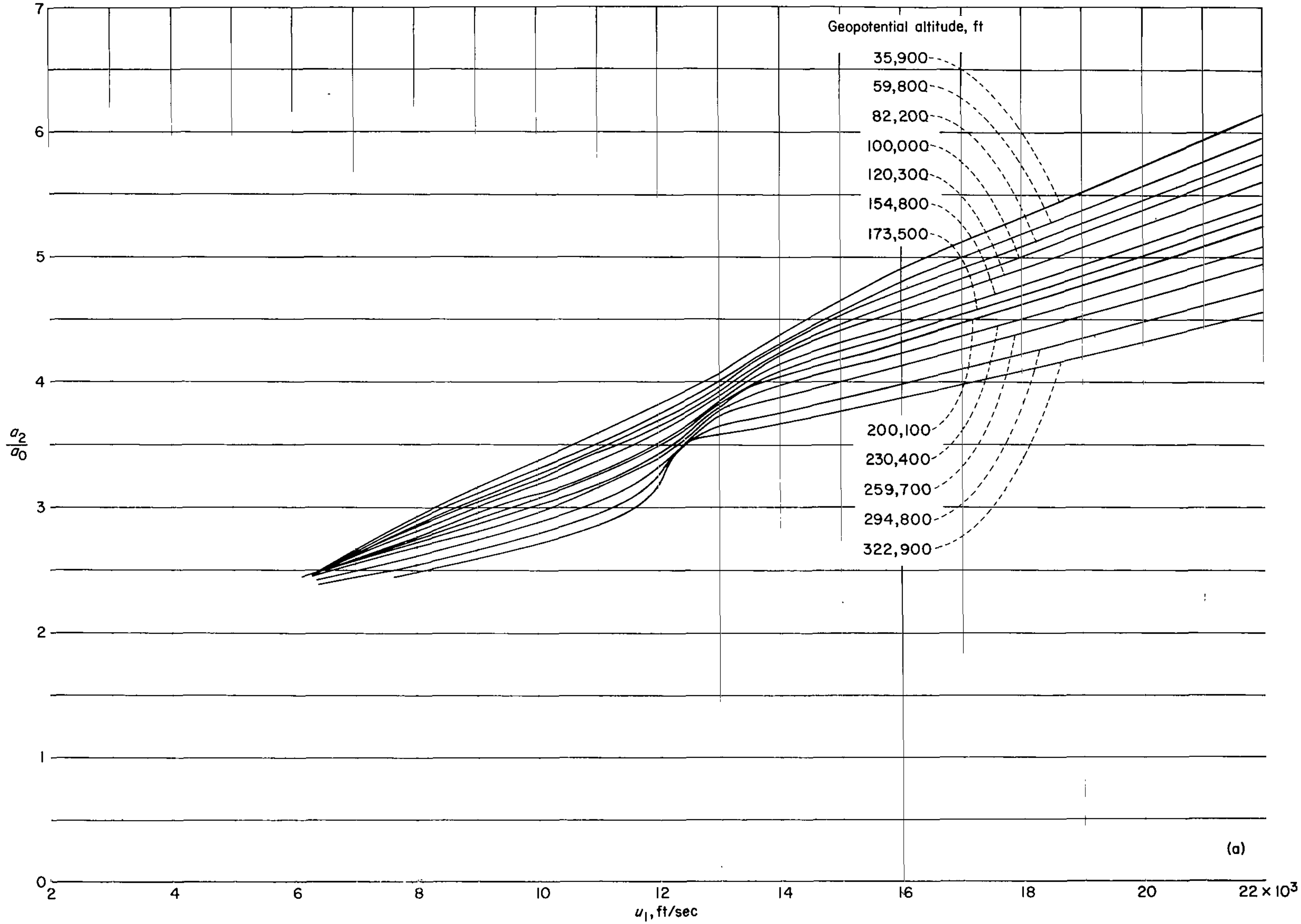
(a) Stratospheric altitude range.

Figure 12.- Variation of normalized normal-shock density with velocity and altitude.



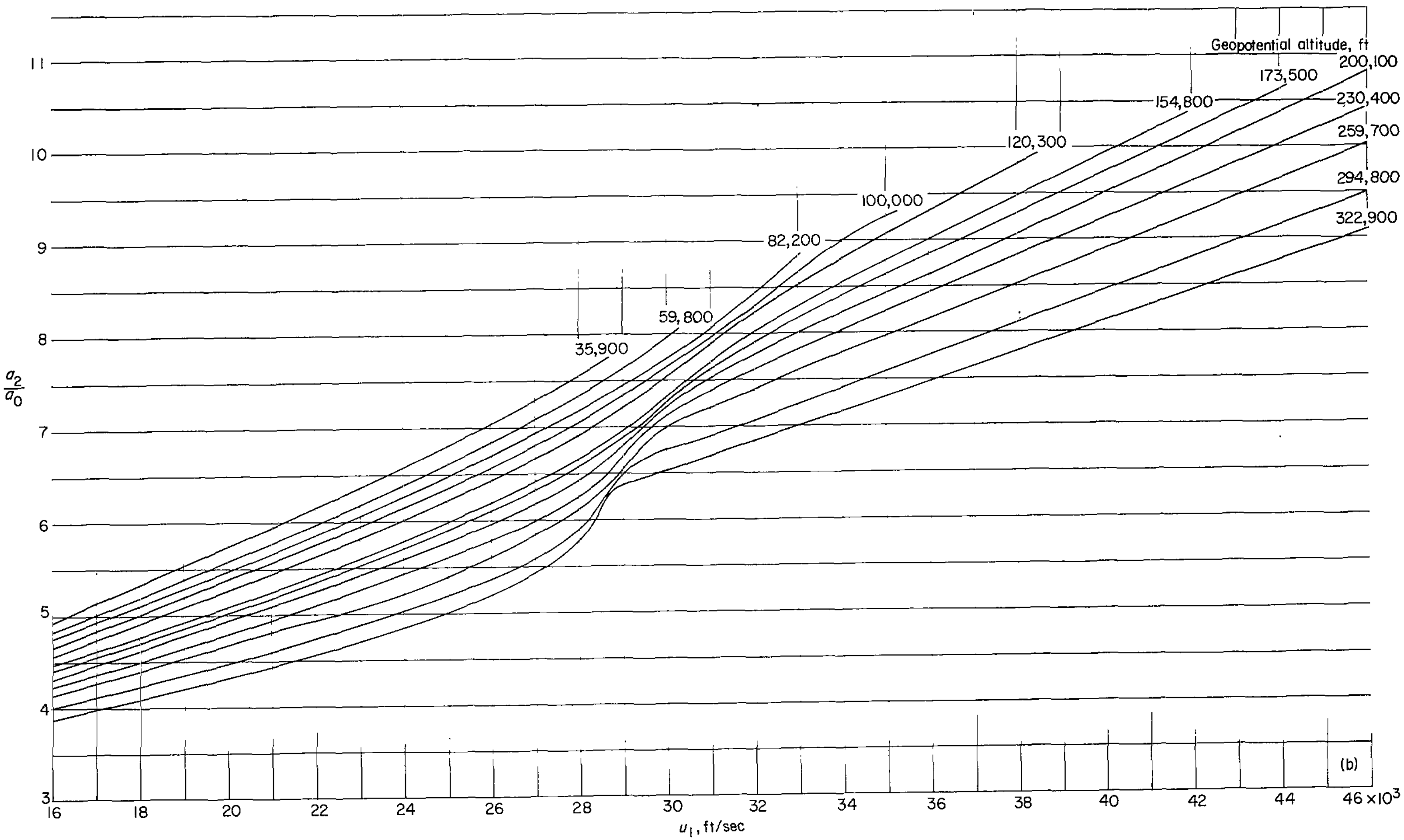
(b) Mesospheric altitude range.

Figure 12.- Concluded.



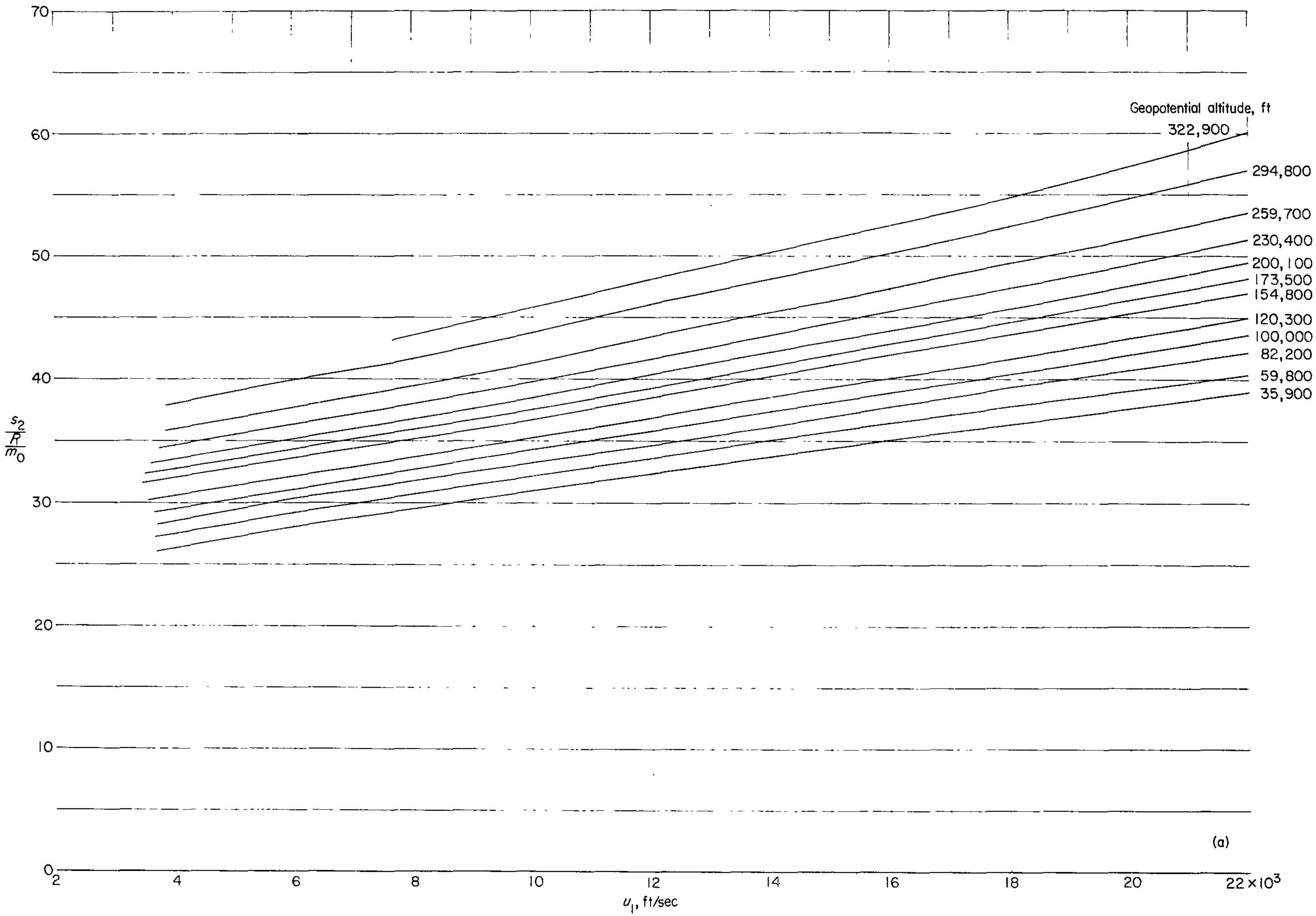
(a) Subsatellite velocity range.

Figure 13.- Variation of normalized normal-shock velocity of sound with velocity and altitude.



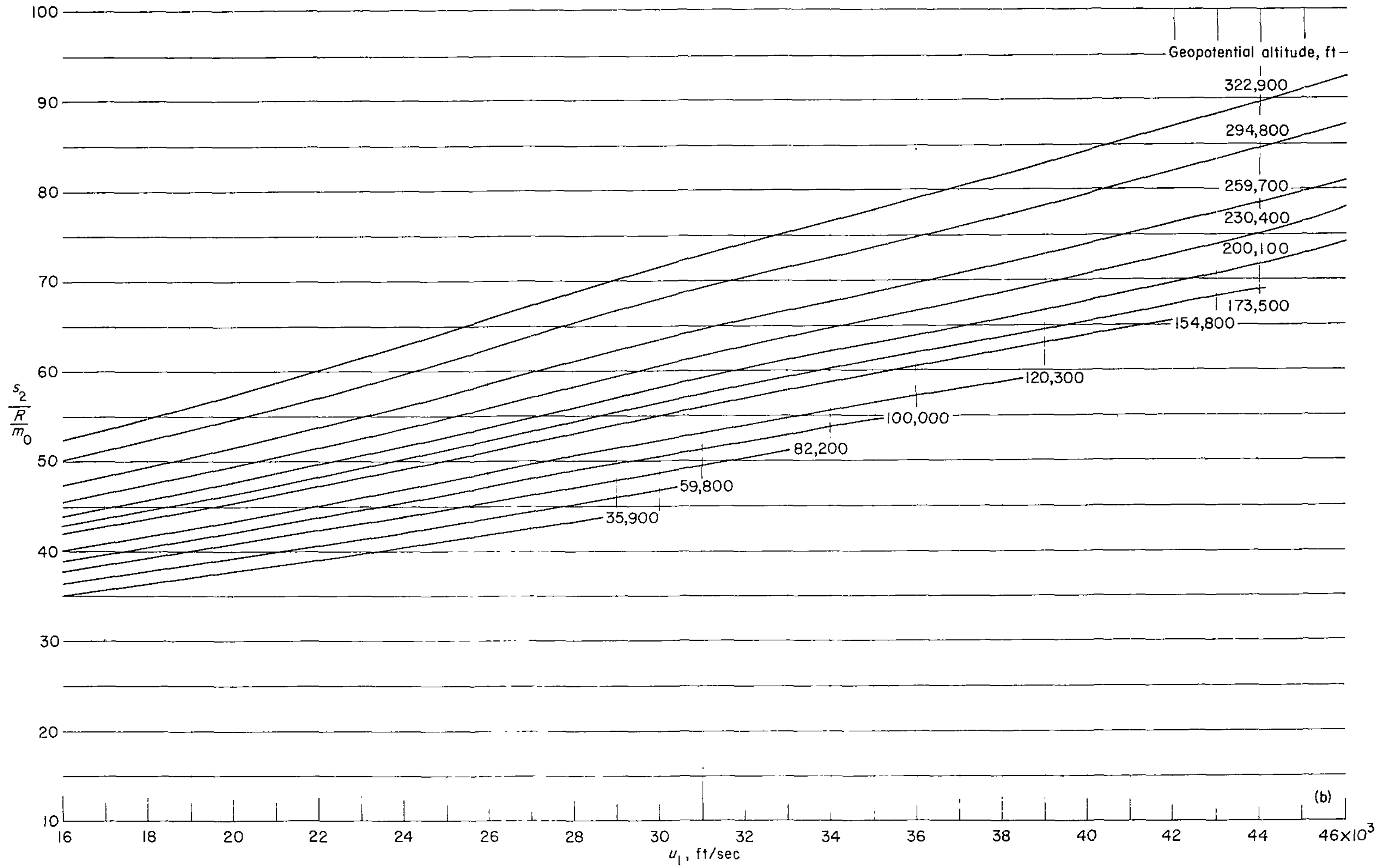
(b) Supersatellite velocity range.

Figure 13.- Concluded.



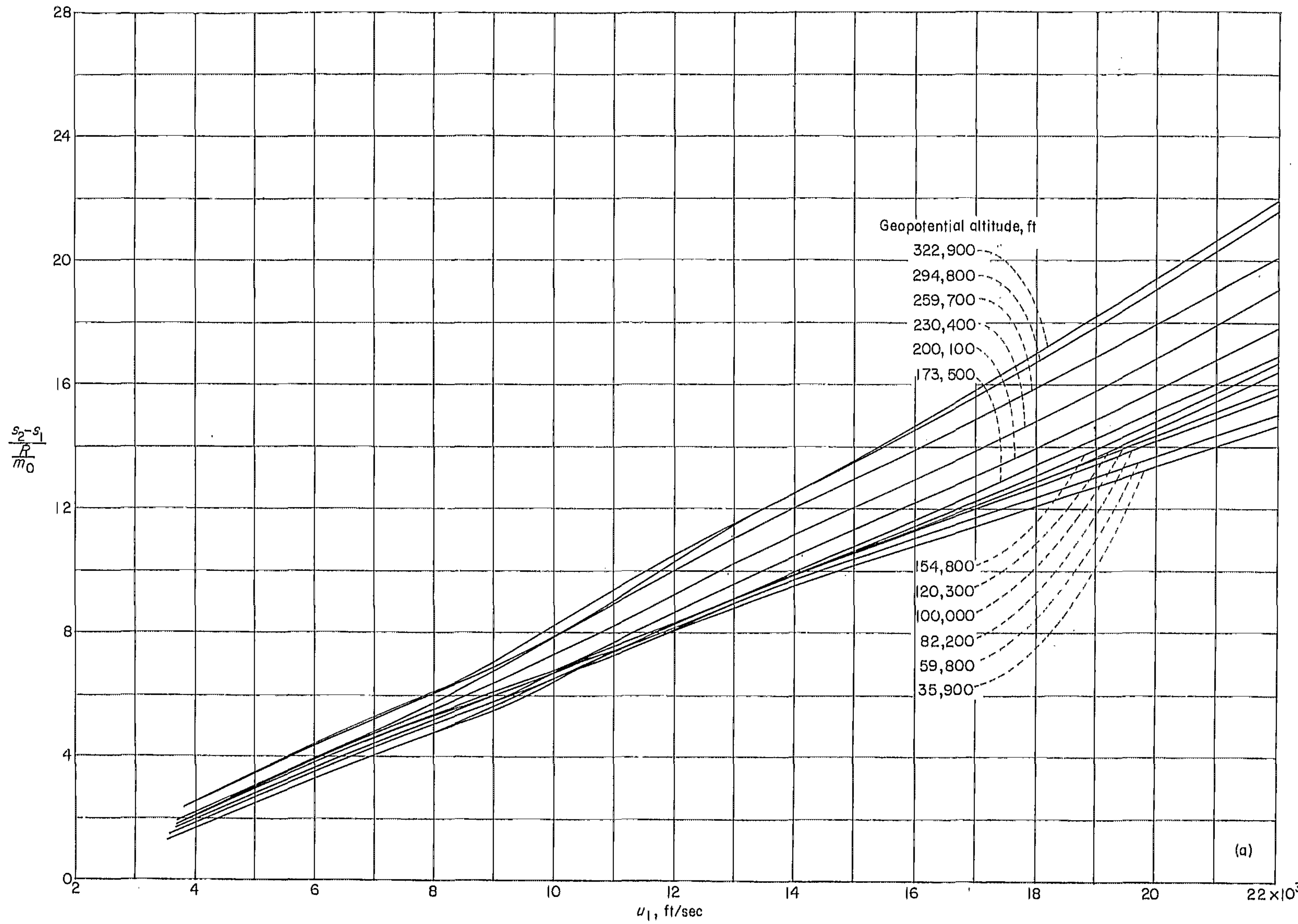
(a) Subsatellite velocity range.

Figure 14.- Variation of normal-shock entropy with velocity and altitude.



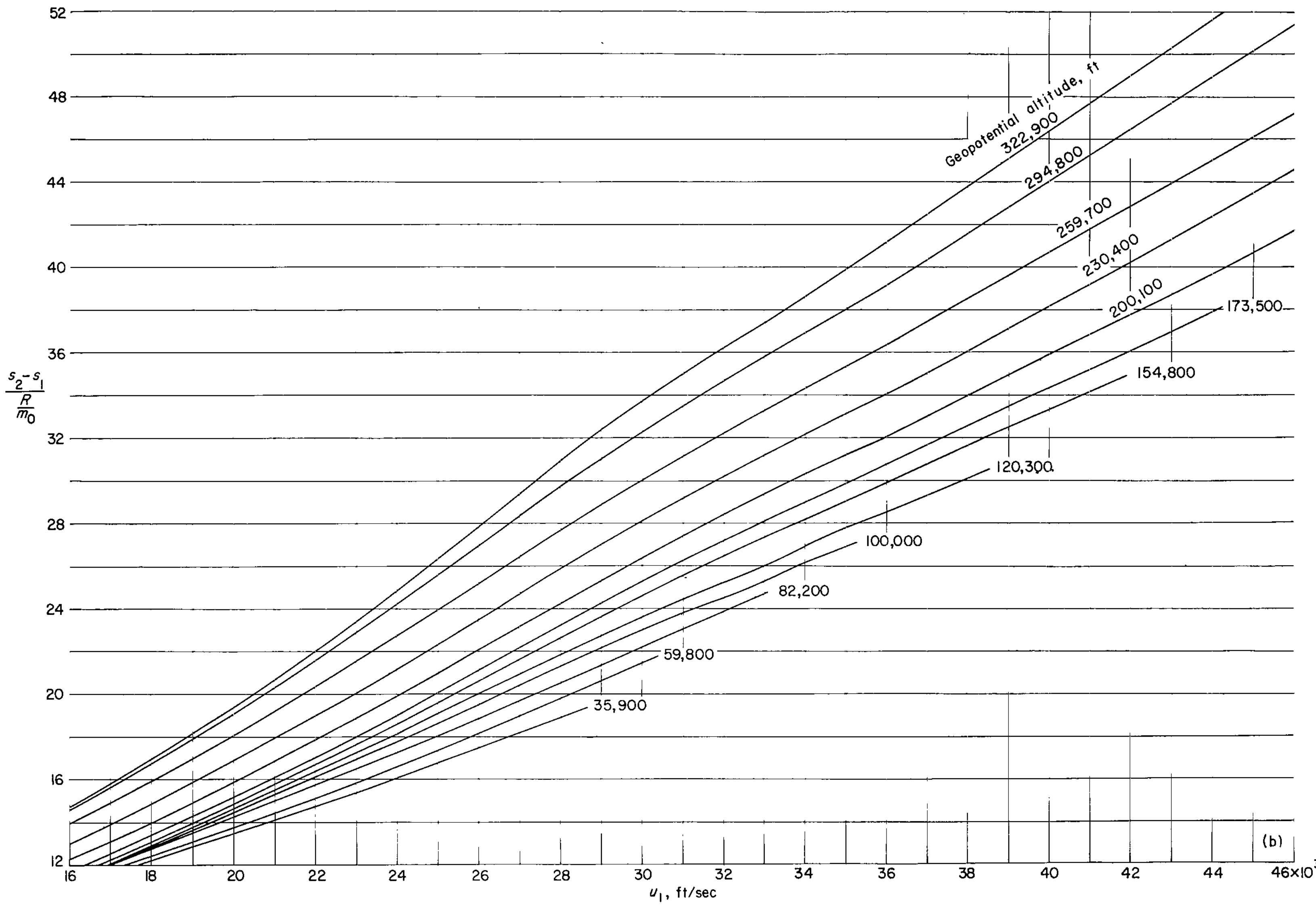
(b) Supersatellite velocity range.

Figure 14.- Concluded.



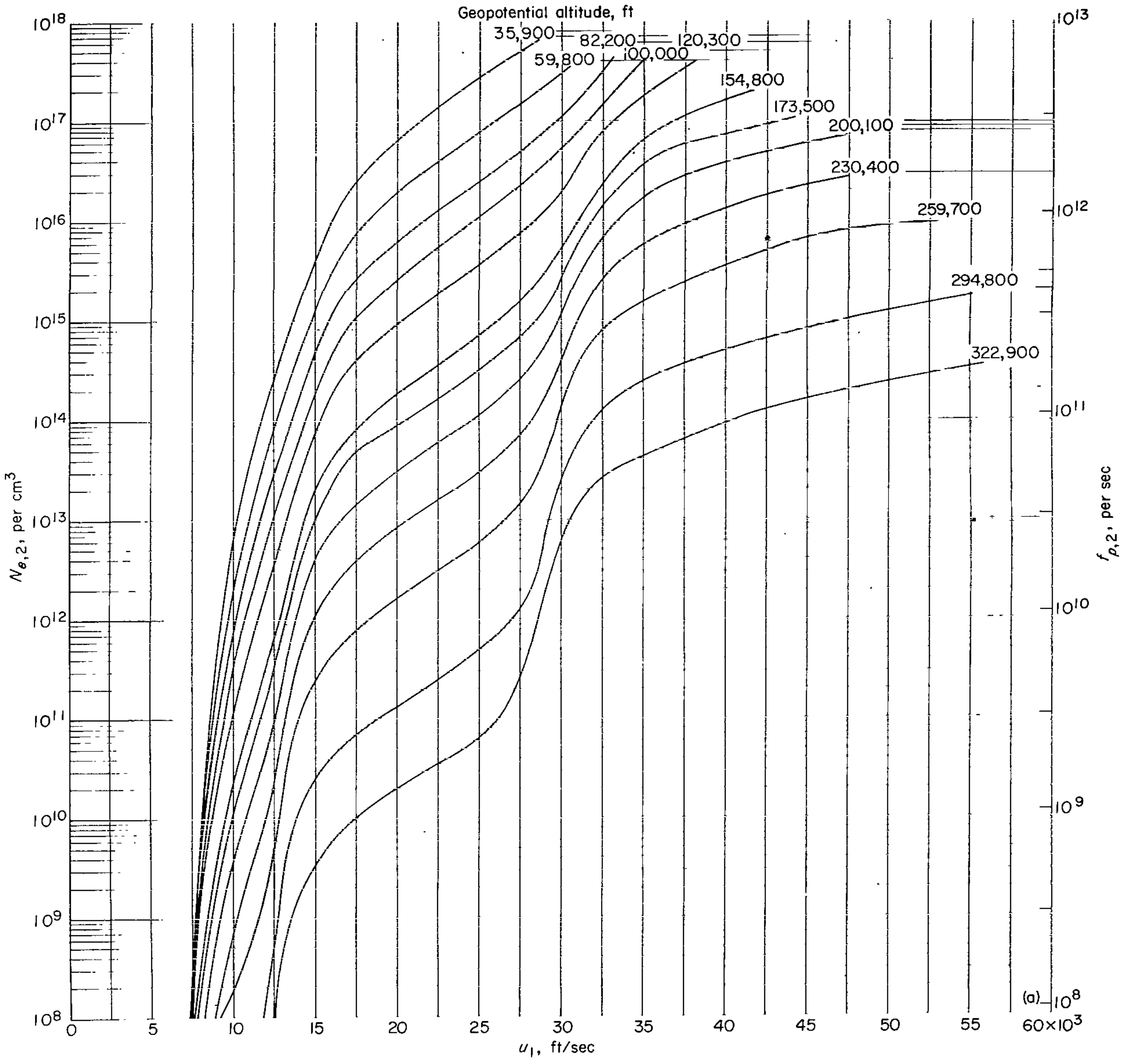
(a) Subsatellite velocity range.

Figure 15.- Variation of normal-shock entropy increase with velocity and altitude.



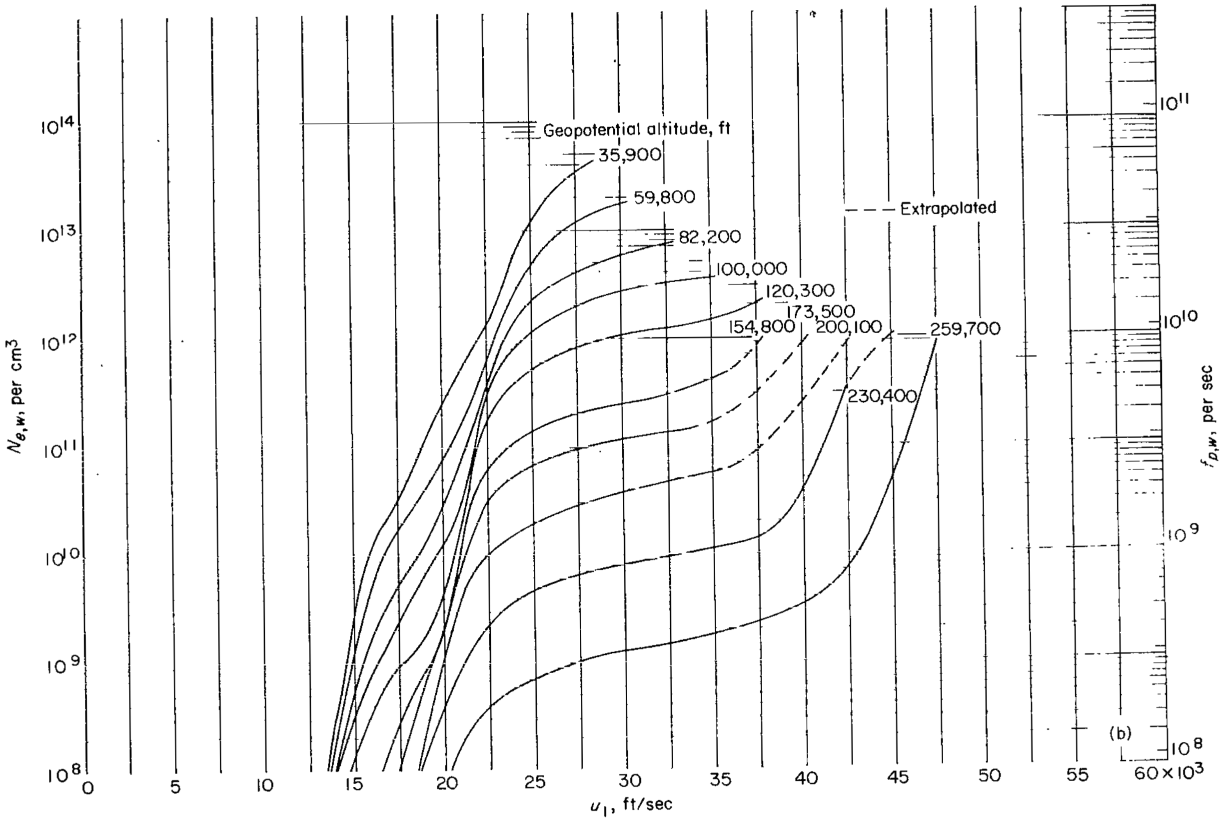
(b) Supersatellite velocity range.

Figure 15.- Concluded.



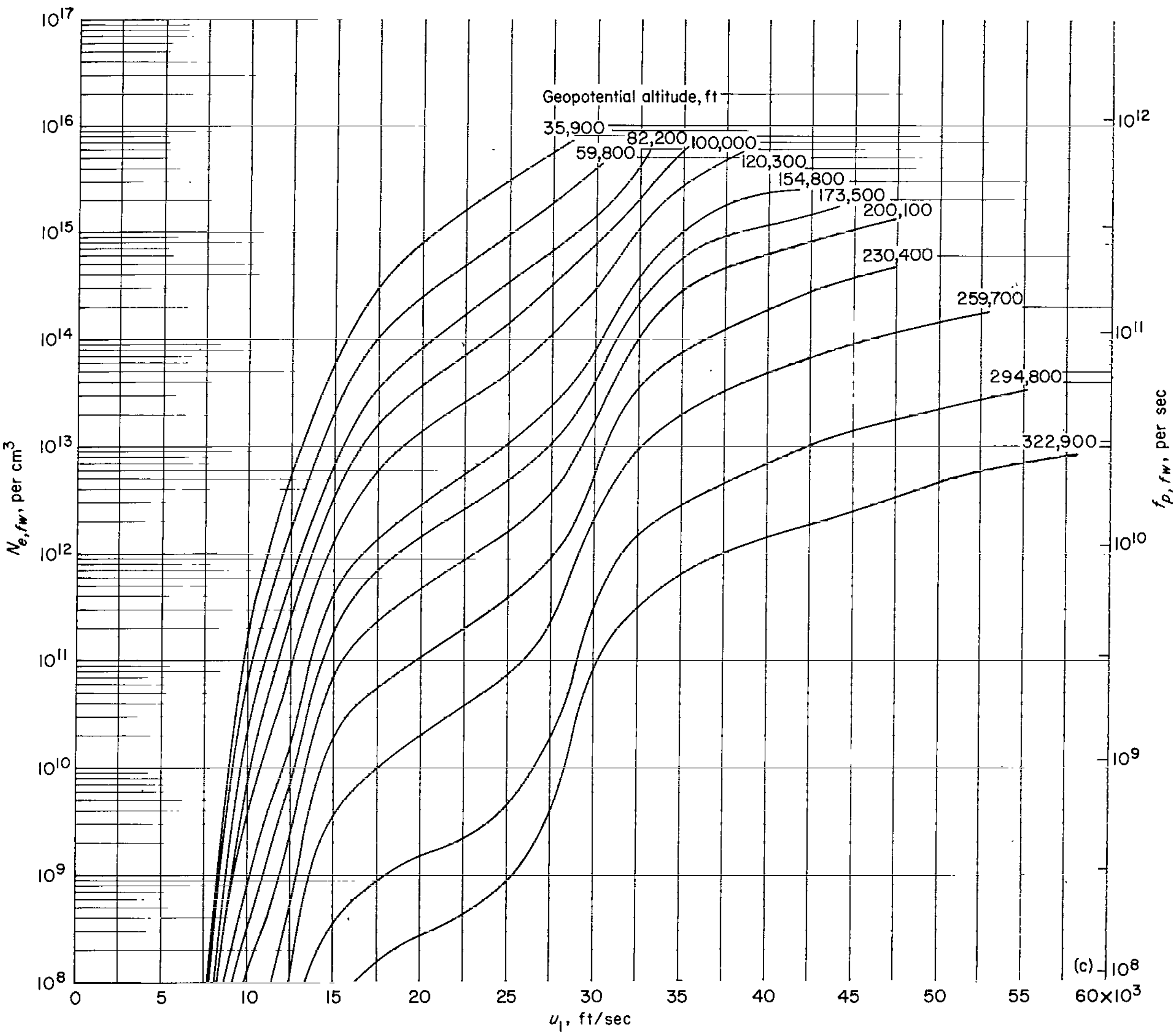
(a) Equilibrium normal-shock flow.

Figure 16.- Variation of electron concentration with velocity and altitude.



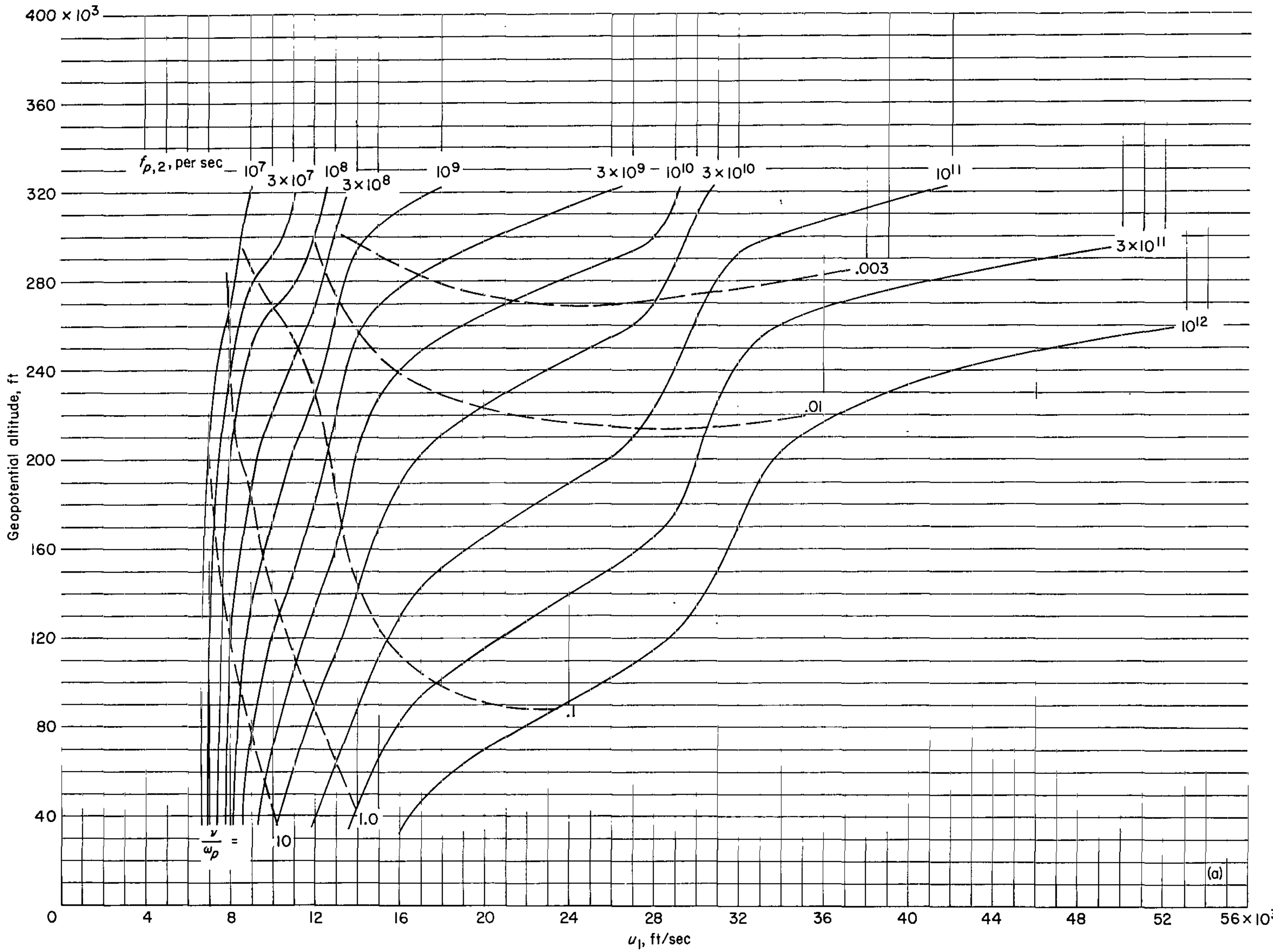
(b) Equilibrium far-wake flow.

Figure 16.- Continued.



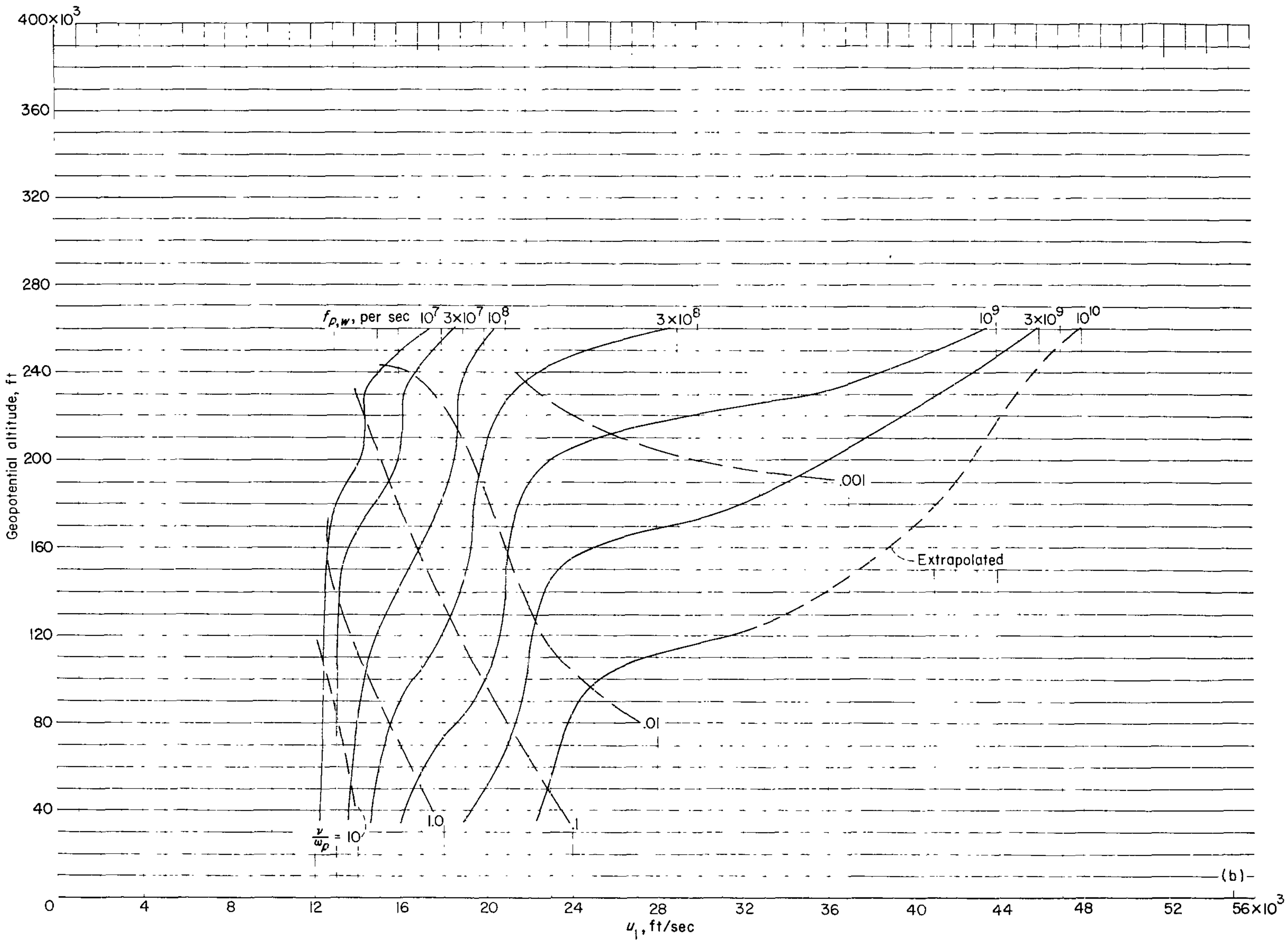
(c) Frozen far-wake flow.

Figure 16.- Concluded.



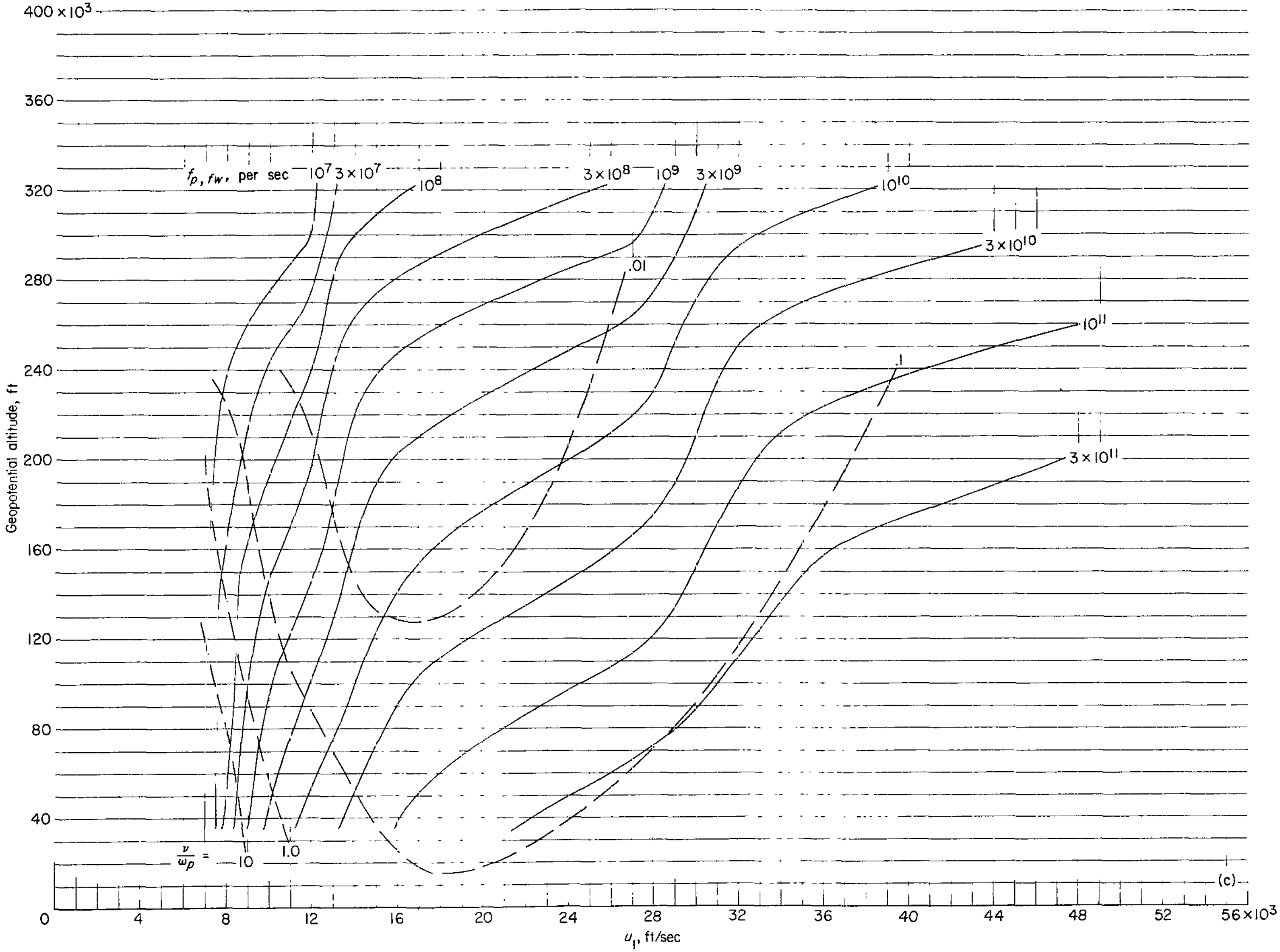
(a) Equilibrium normal-shock flow.

Figure 17.- Variation of plasma frequency with velocity and altitude.



(b) Equilibrium far-wake flow.

Figure 17.- Continued.



(c) Frozen far-wake flow.

Figure 17.- Concluded.

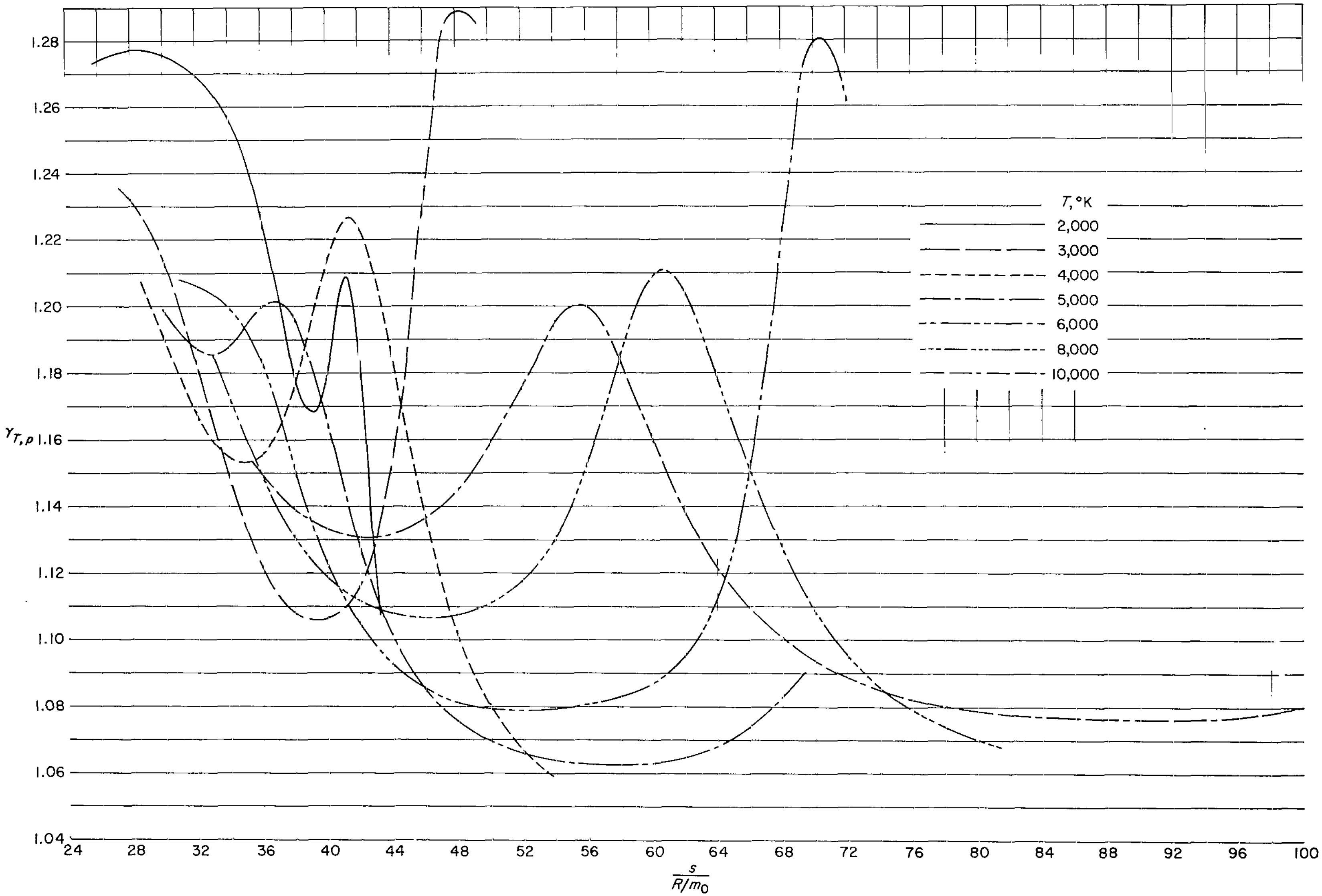
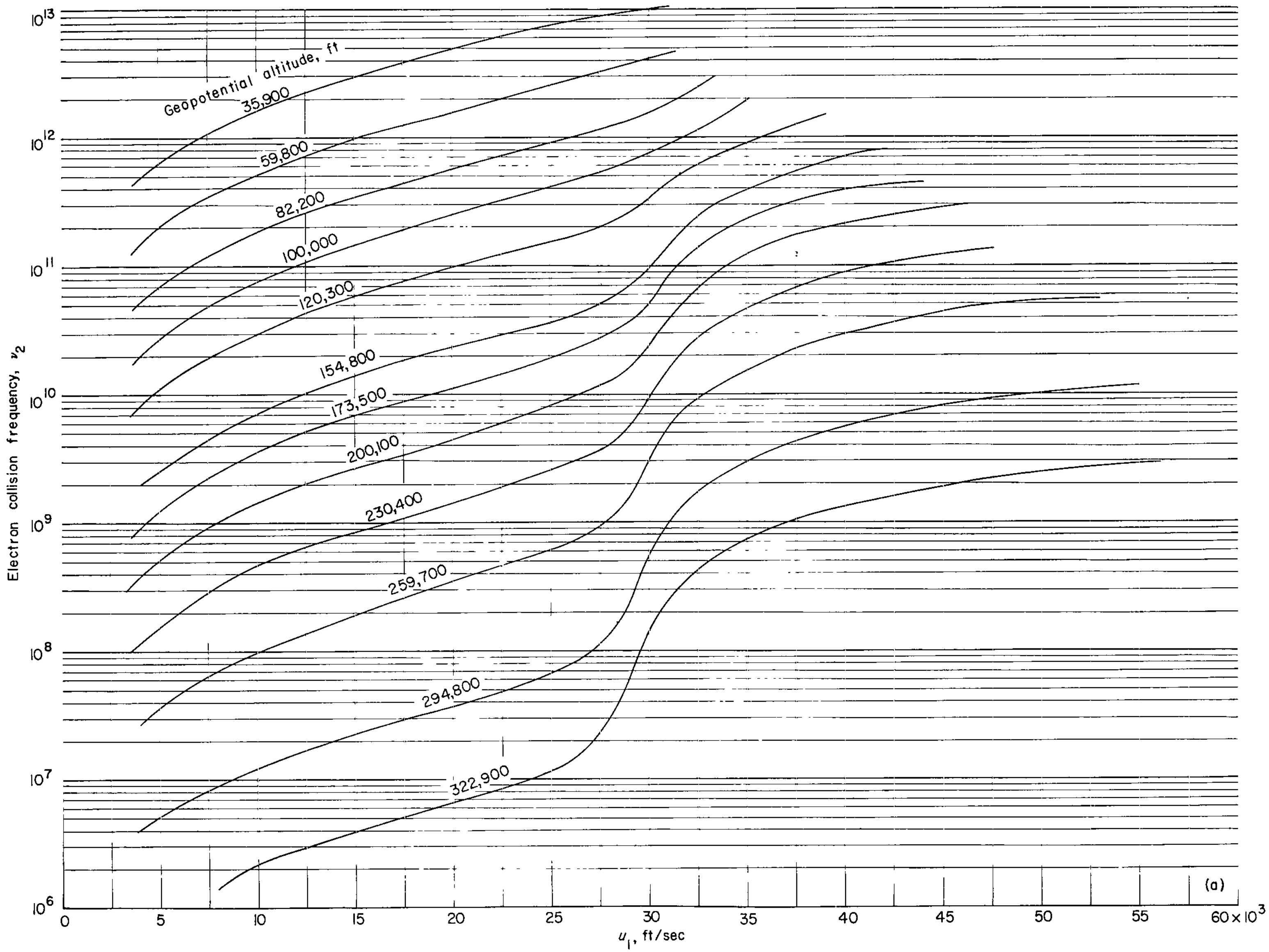
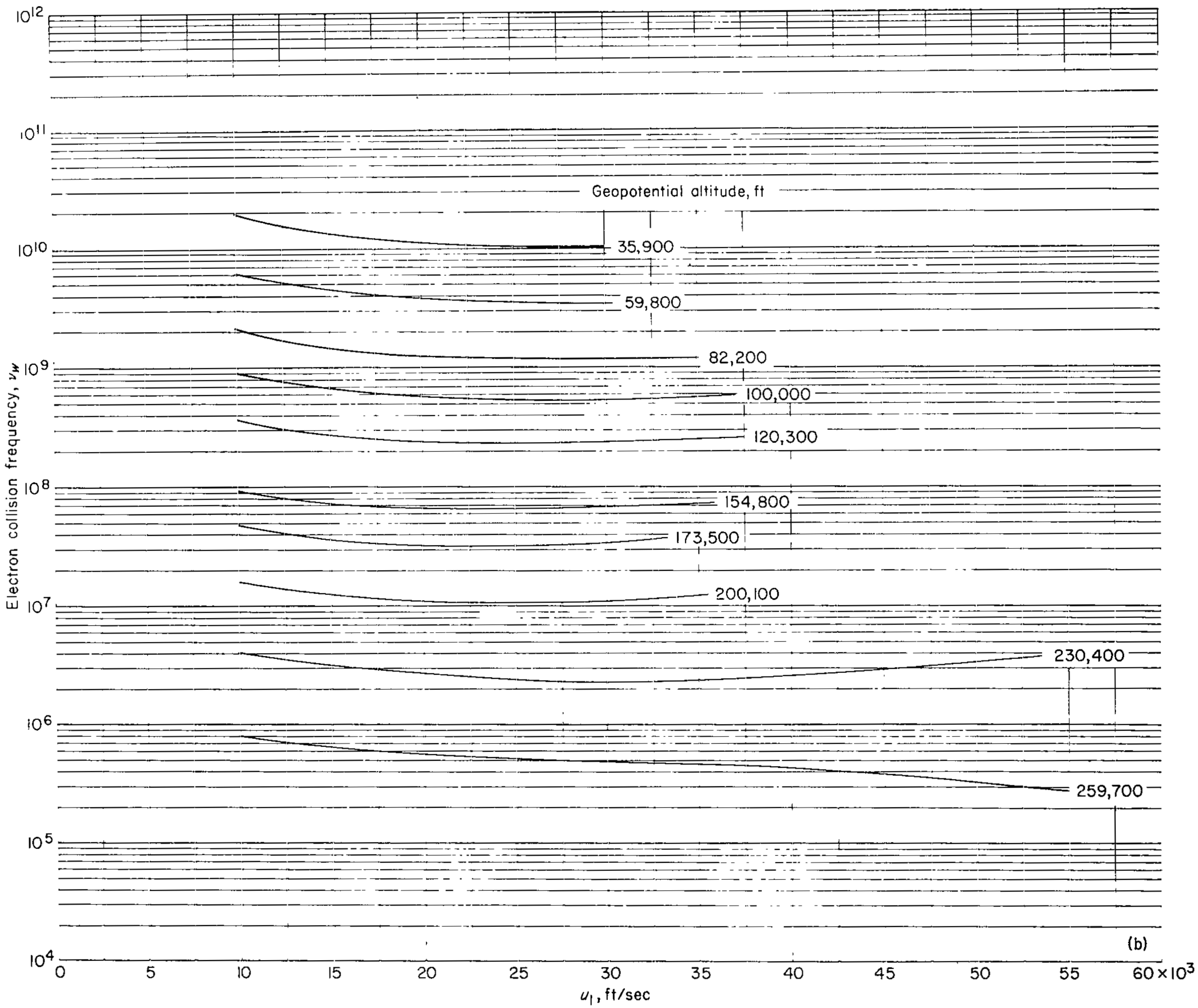


Figure 18.- Variation of the parameter $\gamma_{T,p}$ with temperature and entropy for argon-free air. (Data taken from ref. 15.)



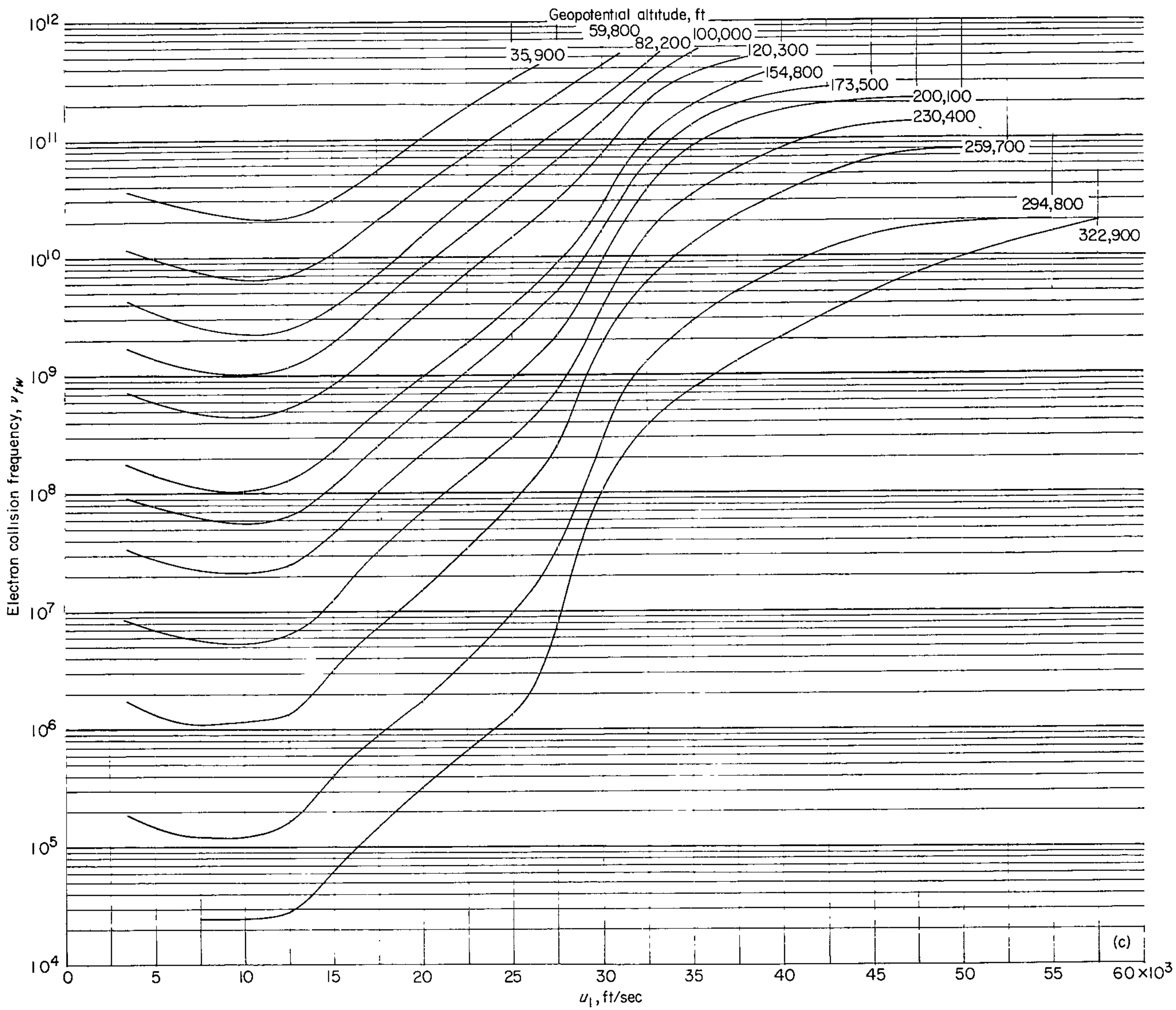
(a) Equilibrium normal-shock flow.

Figure 19.- Variation of electron collision frequency with velocity and altitude.



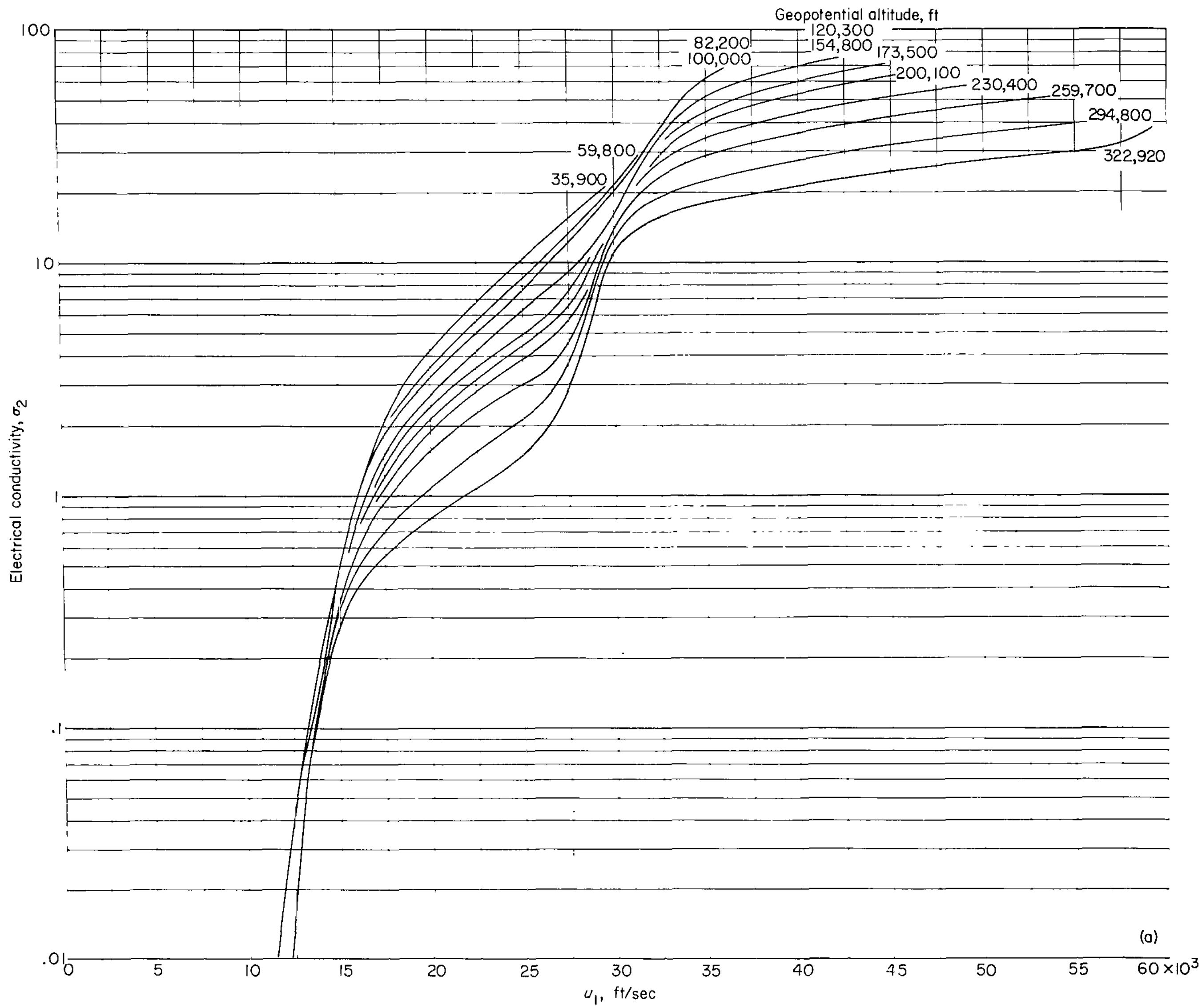
(b) Equilibrium far-wake flow.

Figure 19.- Continued.



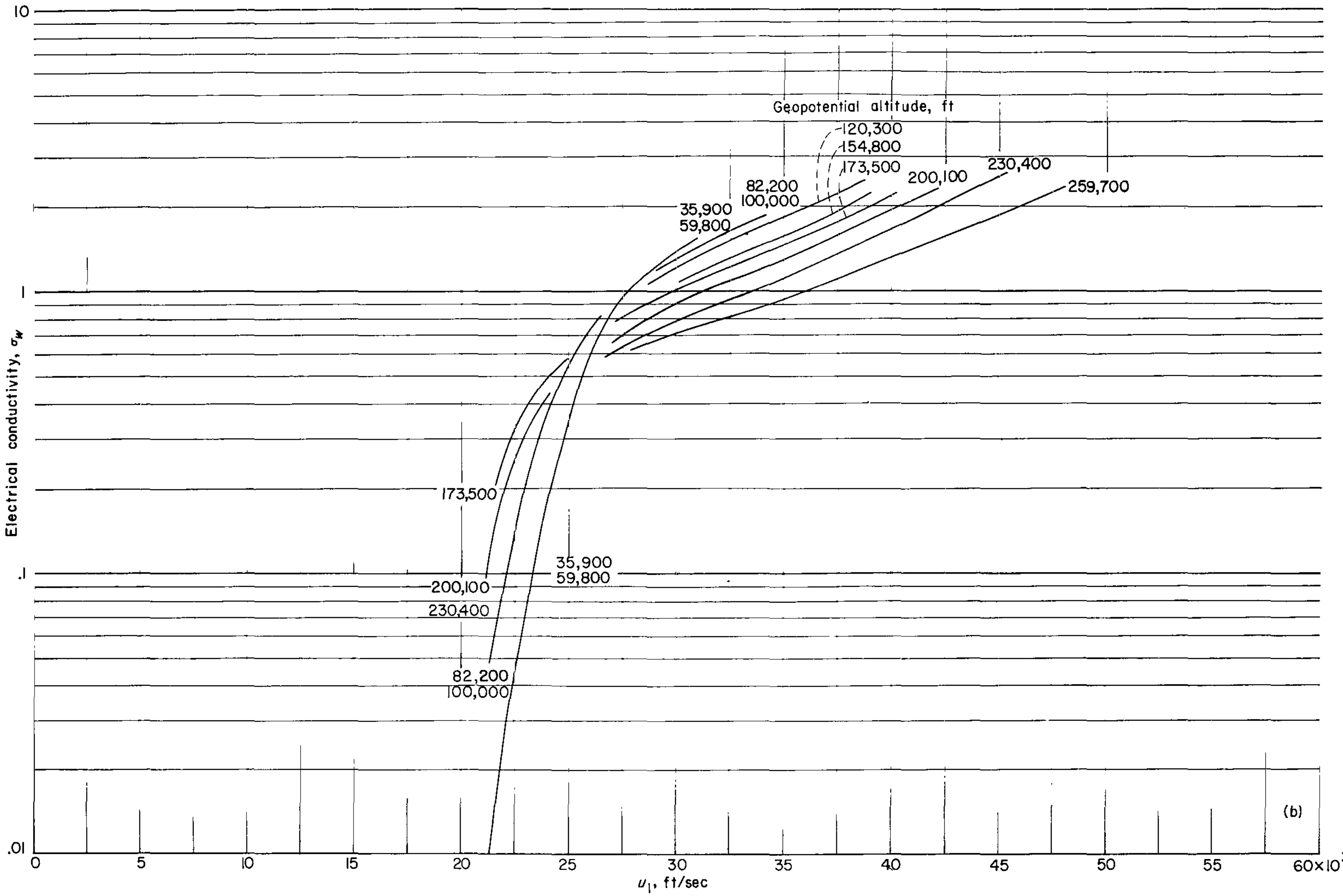
(c) Frozen far-wake flow.

Figure 19.- Concluded.



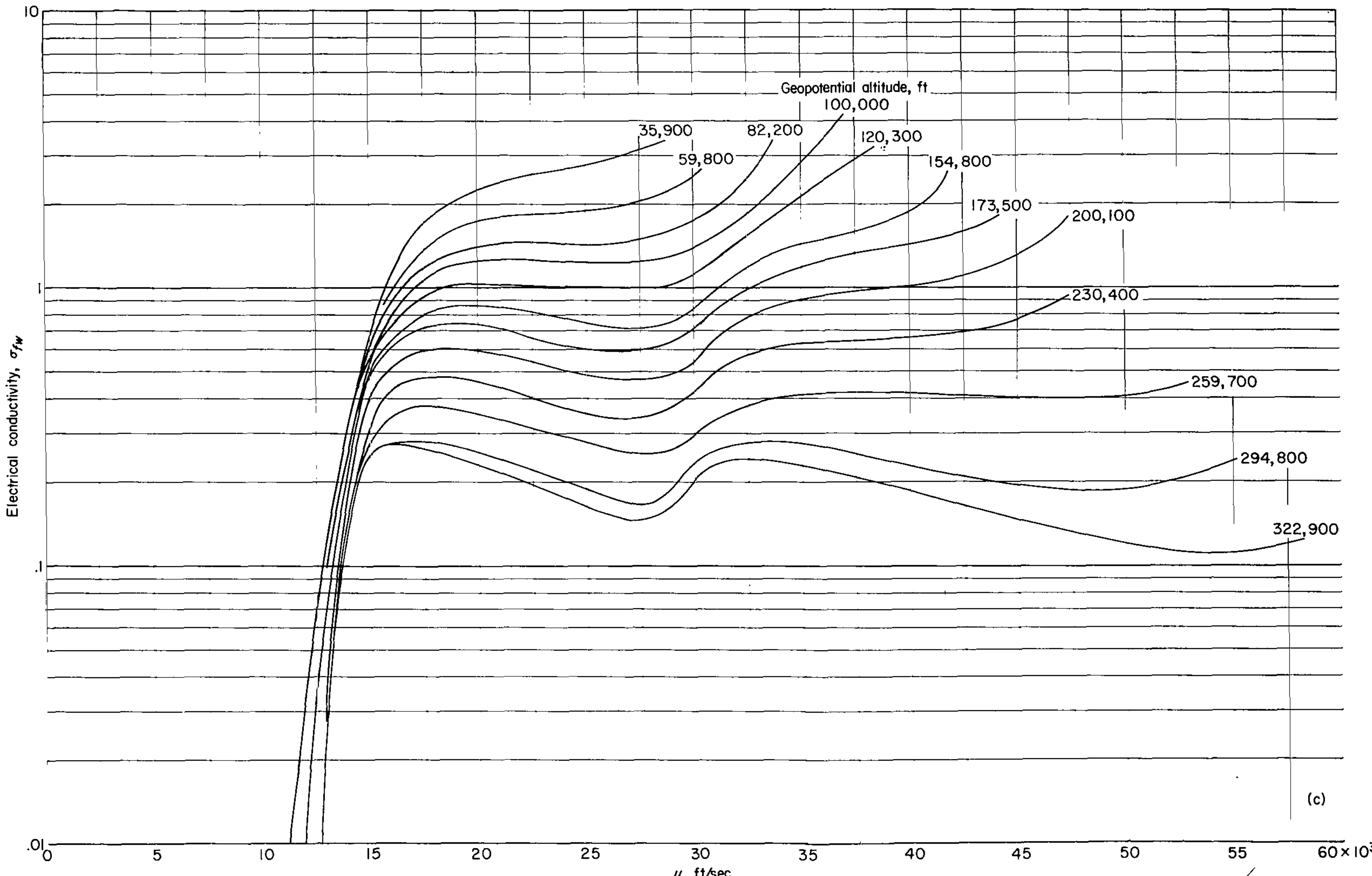
(a) Equilibrium normal-shock flow.

Figure 20.- Variation of d-c electrical conductivity with velocity and altitude.



(b) Equilibrium far-wake flow.

Figure 20.- Continued.



(c) Frozen far-wake flow.

Figure 20.- Concluded.

NASA-Langley, 1964 L-1379

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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