NASA TECHNICAL NOTE

NASA TN D-4292

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NASA TN D-4292

A COMPUTER PROGRAM FOR CALCULATING MODEL PLANETARY ATMOSPHERES

by David E. Pitts

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Houston, Texas

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • FEBRUARY 1968

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ABSTRACT

A computer program is described which provides calculations for model atmospheres to one planetary radius above the surface using the hydrostatic equation and the equation of state. These calculations are based upon a temperature and molecular weight structure and upon the surface pressure, surface gravity, and radius of the planet.

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SUMMARY

The computer program presented here enables calculations to be made of a model atmosphere of a planet to one planetary radius above the surface. The variables calculated are altitude, temperature, pressure, density, specific weight, molecular weight, pressure scale height, density scale height, number density, mean particle velocity, mean free path, collision frequency, speed of sound, coefficient of viscosity, kinematic viscosity, and columnar mass. The calculations are usually made for atmospheres consisting of nitrogen, carbon dioxide, oxygen, argon, neon, hydrogen, helium, water vapor, carbon monoxide, and sulfur dioxide. However, if the printouts of mean free path, collision frequency, coefficient of viscosity, and kinematic viscosity are ignored, calculations may be made for gases of any desired molecular weight.

INTRODUCTION

The model atmosphere, a simplified mathematical construct, offers a self-consistent method for numerically expressing the state of an atmosphere based upon a temperature and molecular weight structure and certain boundary conditions at the surface (for example, surface pressure). Such models are widely used as a scientific tool to enable the investigator to understand physical processes in an atmosphere, for design and conduct of scientific experiments (both remote sensor and in situ), for spacecraft design (for example, reentry), for calculating mission profiles for spacecraft (for example, orbital lifetimes), and for aircraft design.

New data from satellites and sounding rockets and from new theoretical models are continually increasing our understanding of the Earth atmosphere. Thus, the model atmospheres must be updated continuously. A similar situation exists with other planetary atmospheres; however, the amount of data is more scarce and the model atmospheres are more divergent. Consequently, advances in understanding of planetary atmospheres occur more often and offer more extensive changes than for the Earth atmosphere.

In the past, model atmospheres have usually been calculated by hand. This resulted in only the minimum amount of data being given, usually in only one set of units.

When new data were obtained, there was a great deal of time lost calculating a new model atmosphere, and the new atmosphere did not promote good understanding and communication between the scientific and engineering communities. The use of the computer helps solve all of these problems, with the additional advantage of having higher accuracy and greater reliability.

A Fortran computer program was written so that model atmospheres may be calculated easily and quickly, thus reducing the lag time between the receipt of new data and the use of the new model atmospheres. This program was written in the Fortran V computer language for the Univac 1108. However, the program is compatible with Fortran IV for the IBM 7094, and may be easily modified into Fortran II if desired, by changing the input-output and library functions (for example, cos would be changed to cos f). Computational time per model atmosphere is usually less than 30 seconds.

The model atmospheres may be calculated to one planetary radius; however, usually 1000 km or so suffices for most orbital decay and entry studies. Two systems of units (metric and English) are used, and the models calculated are separate but equivalent model atmospheres designed to promote cooperation between different professions. The legend of the scientific and engineering units for the model atmospheres is presented in table I. Since some confusion arises at times concerning pressure scale height and density scale height, an explanation is included in appendix A.

To date, the principal uses of this program have been to calculate model atmospheres for Mars and Venus (ref. 1) and to calculate density and temperature dispersion data for Apollo spacecraft reentry considerations.

SYMBOLS

C_p specific heat at constant pressure, cal mole^{-1} °K^{-1}

C_s speed of sound, m sec^{-1}

C_v specific heat at constant volume, cal mole^{-1} °K^{-1}

erf(x) error function of $x = \frac{2}{\sqrt{\pi}} \int_x^\infty e^{-\xi^2} d\xi = \frac{2}{\sqrt{\pi}} \left(\int_0^\infty e^{-\xi^2} d\xi - \int_0^x e^{-\xi^2} d\xi \right)$

$$= 1 - \frac{2}{\sqrt{\pi}} \int_0^x e^{-\xi^2} d\xi$$

g acceleration caused by gravity, cm sec^{-2}

g_o	surface gravity, cm sec^{-2}
H	geopotential altitude above the surface of the planet, km
H_a	an altitude in geopotential height, km
H_b	an altitude in geopotential height where $H_b > H_a$, km
H_P	pressure scale height, km
$\overline{H}_P$	average pressure scale height, km
H_ρ	density scale height, km
K	Boltzmann constant, ergs $(°K)^{-1}$
L	mean free path, m
M_c	columnar mass, g cm^{-2}
m	molecular weight
m_a	molecular weight at H_a
m_b	molecular weight at H_b
m_i	molecular weight of ith constituent
m_j	molecular weight of jth constituent
m_o	base molecular weight
N	Avogadro's number, 6.0238×10^{23} molecules $(mole)^{-1}$
n	number density, cm^{-3}
P	pressure
P_a	pressure at H_a, mb
P_b	pressure at H_b where $H_b > H_a$, mb

P_o	pressure at zero height, mb
Q	kinematic viscosity, $ft^2\ sec^{-1}$
R	universal gas constant = 8.314×10^7 ergs $mole^{-1}\ {}^\circ K^{-1}$
R_Z	height of the base of the exosphere plus radius of the planet, km
r	the radius of the planet, km
T	temperature (kinetic), °K
T_a	temperature at H_a, °K
T_b	temperature at H_b, °K
T_m	molecular scale temperature, $\frac{T m_o}{m}$, °K
$(T_m)_a$	molecular scale temperature at H_a, °K
$(T_m)_b$	molecular scale temperature at H_b, °K
T_o	temperature at zero height, °K
V	mean particle velocity, $m\ sec^{-1}$
X_i	mole fraction of the ith constituent
y	$\frac{R_Z}{r + Z}$
Z	geometric altitude above the surface of the planet, km
α	$\frac{R_Z}{H_P}$
γ	$\frac{C_p}{C_v}$
ϵ	maximum energy of attraction, ergs

η_i	viscosity for ith constituent, kg m^{-1} sec^{-1}
μ	viscosity for mixture, kg m^{-1} sec^{-1}
ξ	dummy variable used for computation of the error function
ρ	density, g cm^{-3}
σ	zero energy collisional diameter, Å
σ_i	zero energy collisional diameter for the ith constituent, Å
υ	collision frequency, sec^{-1}
Φ_{ij}	coefficient for calculating viscosity
$\Omega_i(T)$	reduced collisional integral for ith constituent
ω	specific weight, slug ft^{-2} sec^{-2}

Subscripts:

i or j=1	nitrogen
i or j=2	carbon dioxide
i or j=3	oxygen
i or j=4	argon
i or j=5	neon
i or j=6	hydrogen
i or j=7	helium
i or j=8	water
i or j=9	carbon monoxide
i or j=10	sulfur dioxide

CALCULATION OF A MODEL ATMOSPHERE

The atmosphere and its variations above the surface of a planet can be described by the use of six variables: density ρ, pressure P, temperature T, molecular weight m, acceleration caused by gravity g, and height Z. There are two equations which relate these quantities. The equation of state, shown in equation (1), which is a form of the ideal gas law, relates P, ρ, T, and m to the universal gas constant R.

$$\rho = \frac{Pm}{RT} \tag{1}$$

The hydrostatic equation, shown in equation (2), relates the pressure gradient to the density and the local value of gravity.

$$\frac{\partial P}{\partial Z} = -\rho g \tag{2}$$

The proper combination of the ideal gas law equation and the hydrostatic equation with certain reasonable and valid assumptions results in equations (3) and (4). A more comprehensive derivation of equations (3) and (4) can be found in appendix B. If $\partial T_m/\partial H \neq 0$, then

$$P_b = P_a\left[\frac{\left(T_m\right)_b}{\left(T_m\right)_a}\right]^{\frac{g_o m_o}{R\frac{\partial T_m}{\partial H}}} \tag{3}$$

and, if $\partial T_m/\partial H = 0$, then

$$P_b = P_a \exp\left[\frac{-g_o m_o\left(H_b - H_a\right)}{R\left(T_m\right)_a}\right] \tag{4}$$

If the surface boundary conditions $\left(g_o, m_o, P_o, T_o\right)$ and the molecular scale temperature structure[1] are known, the pressure as a function of height may be calculated by equations (3) and (4) and the density may be calculated by substitution into equation (1). Typical construction parameters required for use in equations (3) and (4) are given in table II. The values given are for Mars, whereas the appropriate values for any other planet may be selected.

In the calculation of some model atmospheres the temperature and molecular weight structure are the primary variables and are chosen accordingly. In this case, the molecular scale temperature gradient $\partial T_m/\partial H$ is a derived quantity each geometric km. In other words, if molecular weight and temperature are input in linear segments, then molecular scale temperature is not linear with altitude, but is curved. For this case, temperature is calculated by

$$T_b = T_a + \frac{\partial T}{\partial H}\left(H_b - H_a\right) \tag{5}$$

molecular weight is calculated by

$$m_b = m_a + \frac{\partial m}{\partial H}\left(H_b - H_a\right) \tag{6}$$

molecular scale temperature is calculated by

$$\left(T_m\right)_b = \frac{m_o T_b}{m_b} \tag{7}$$

and

$$\frac{\partial T_m}{\partial H} = \frac{\left(T_m\right)_b - \left(T_m\right)_a}{H_b - H_a} \tag{8}$$

[1]The temperature structure is defined by a number of temperatures and molecular weights corresponding to an altitude, either geometric or geopotential as desired. The number of these critical points cannot exceed 99.

In this option the geometric altitude is generated and then is converted into geopotential altitude, which is subsequently used to generate pressure and temperature. This is known as option 1 and is the option usually used for Mars. Table III contains the output for such a model, using the construction parameters shown in table II.

Option zero molecular scale temperature gradients and the temperature gradients may be considered to be the primary variables; in such circumstances, they are taken in linear segments. In this case, molecular weight is the derived quantity which is therefore not linear in altitude. This method is used in calculating models of the type such as the U. S. Standard Atmosphere (ref. 2), and is known as option zero.

For option zero, molecular scale temperature is calculated by

$$\left(T_m\right)_b = \left(T_m\right)_a + \frac{\partial T_m}{\partial H}\left(H_b - H_a\right) \tag{9}$$

temperature is calculated by

$$T_b = T_a + \frac{\partial T}{\partial H}\left(H_b - H_a\right) \tag{10}$$

and molecular weight is calculated by

$$m_b = \frac{m_o T_b}{\left(T_m\right)_b} \tag{11}$$

Table IV contains the output for a sample calculation of this option. The choice of options is left to the discretion of the programer.

At very high altitudes, when the scale height of the atmosphere is approximately equal to the mean free path of the gas molecules, the atmosphere no longer behaves hydrostatically. In order to account for this change in the rate of decay of density with height (the decay rate is less rapid), an analytical expression for a neutral exosphere is used (ref. 3). The following equation describes the density in an exosphere in terms of the density at the base of the exosphere.

$$\rho(Z) = \rho_o(R_Z)\left[e^{-\alpha(1-y)}\left(1 - \frac{1}{2}\operatorname{erf}\sqrt{\alpha y}\right) - \left(\sqrt{1 - y^2}\right)\left(e^{-\frac{\alpha}{1+y}}\right)\left(1 - \frac{1}{2}\operatorname{erf}\sqrt{\frac{\alpha y}{1 + y}}\right) - \left(\sqrt{\frac{\alpha y}{\pi}}\right)\left(1 - \sqrt{1 - y}\right)e^{-\alpha}\right] \tag{12}$$

The use of the exosphere option in the computer program also is left to the discretion of the programer.

When P, T, and ρ are known for the 1-km geometric height increment, additional quantities can be calculated in tabular form according to the following formulas, many of which were used in the U.S. Standard Atmosphere, 1962 (ref. 2). However, some formulas must by necessity be more complex in the general case than for the Earth. For these cases, the number of gases for which calculations can be made were restricted to 10 gases: those high in the solar abundance (hydrogen, helium, and neon), those which comprise outgassing because of vulcanism (water vapor, carbon dioxide, sulfur dioxide, nitrogen, carbon monoxide), those caused by the presence of life and/or dissociation of other compounds (oxygen), and those caused by radioactive decay (argon). Thus, in the calculation of the speed of sound, γ is determined from C_p as a function of temperature (ref. 4) for the mixture as chosen from these 10 gases, as is shown in equation (13).

$$C_s = \left(\gamma \frac{R}{m} T\right)^{1/2} \tag{13}$$

The surface molecular weight of the mixture is also calculated from the mole fractions of the gases as chosen by the programer.

$$m_o = \sum_{i=1}^{10} X_i m_i \tag{14}$$

In the calculation of the mean free path L and collision frequency υ, the collisional diameter σ used is calculated from these 10 gases as shown in the following equations.

$$\sigma = \sum_{i=1}^{10} X_i \sigma_i \tag{15}$$

$$L = \frac{RT}{2^{1/2}\pi N \sigma^2 P} \tag{16}$$

$$\upsilon = 4\sigma^2 N\left(\frac{\pi}{R}\right)^{1/2} \frac{P}{(T)^{1/2} m^{1/2}} \tag{17}$$

The coefficient of viscosity is calculated, using equations (18) to (20), for an atmosphere composed of these 10 gases. Values of Ω were calculated for each constituent for each 100° K from 100° to 700° K from the nomograms given in reference 5.

$$\mu = \sum_{i=1}^{10} \frac{\eta_i}{\left(1 + \sum_{\substack{j=1 \\ j\neq i}}^{10} \Phi ij \frac{X_j}{X_i}\right)} \tag{18}$$

$$\eta_i = 26.693 \left(\frac{1}{\sigma^2} \sqrt{\frac{m\epsilon}{K}}\right) \left[\frac{\sqrt{KT/\epsilon}}{\Omega_i(T)}\right] \tag{19}$$

$$\Phi ij = \frac{\left[1 + \left(\frac{\eta_i}{\eta_j}\right)^{1/2} \left(\frac{m_j}{m_i}\right)^{1/4}\right]^2}{2\sqrt{2}\left(1 + \frac{m_i}{m_j}\right)^{1/2}} \tag{20}$$

The remaining equations, for calculation of mean particle velocity, specific weight, pressure scale height, density scale height, number density, columnar mass, and kinematic viscosity are as follows.

$$V = \left(\frac{8RT}{\pi m}\right)^{1/2} \tag{21}$$

$$\omega = \rho g \tag{22}$$

$$H_P = \frac{RT}{mg} \tag{23}$$

$$H_\rho = \frac{H_P}{1 + \frac{R}{g} \frac{\partial(T/m)}{\partial Z}} \tag{24}$$

$$n = \frac{NP}{RT} \tag{25}$$

$$M_c = \int_0^Z \rho \, dZ \tag{26}$$

$$Q = \frac{\mu}{\rho} \tag{27}$$

The preceding equations, (3) to (27), were programed so that a model atmosphere can be constructed with a minimum of construction parameters.

The model atmospheres are printed in tabular form with 16 variables being given as a function of height in increments chosen by the programer; they were all calculated using 1-km steps, however. The variables calculated are altitude, temperature, pressure, density, specific weight, molecular weight, pressure scale height, density scale height, number density, mean particle velocity, mean free path, collision frequency, speed of sound, coefficient of viscosity, kinematic viscosity, and columnar mass.

A Fortran listing for the planetary model atmosphere computer program and an example of input data are shown in appendix C and appendix D, respectively.

FLOW CHART FOR PLANETARY MODEL ATMOSPHERE COMPUTER PROGRAM

Essentially, the first portion of the program through pivot 1 sets up the input data internally and the output headings externally. Pivot 3 is the beginning of the read cycle for the altitude distribution of molecular weight and temperature. Pivot 11 is the beginning of the altitude-iteration "do" loop. Pivot 5 is the beginning of the exosphere option. After the pressure, temperature, and density are calculated, the subordinate parameters are determined. Viscosity calculations start near pivot 6 and carry through to pivot 9. Once these subordinate quantities are calculated, printout occurs if the altitude agrees with the altitude increments which were input by the programer. Then corresponding engineering values are calculated. The altitude iteration ends at pivot 12; then the engineering data are printed out. The iteration then returns to pivot 13 and is ready to calculate another model atmosphere. The flow chart is illustrated in figure 1.

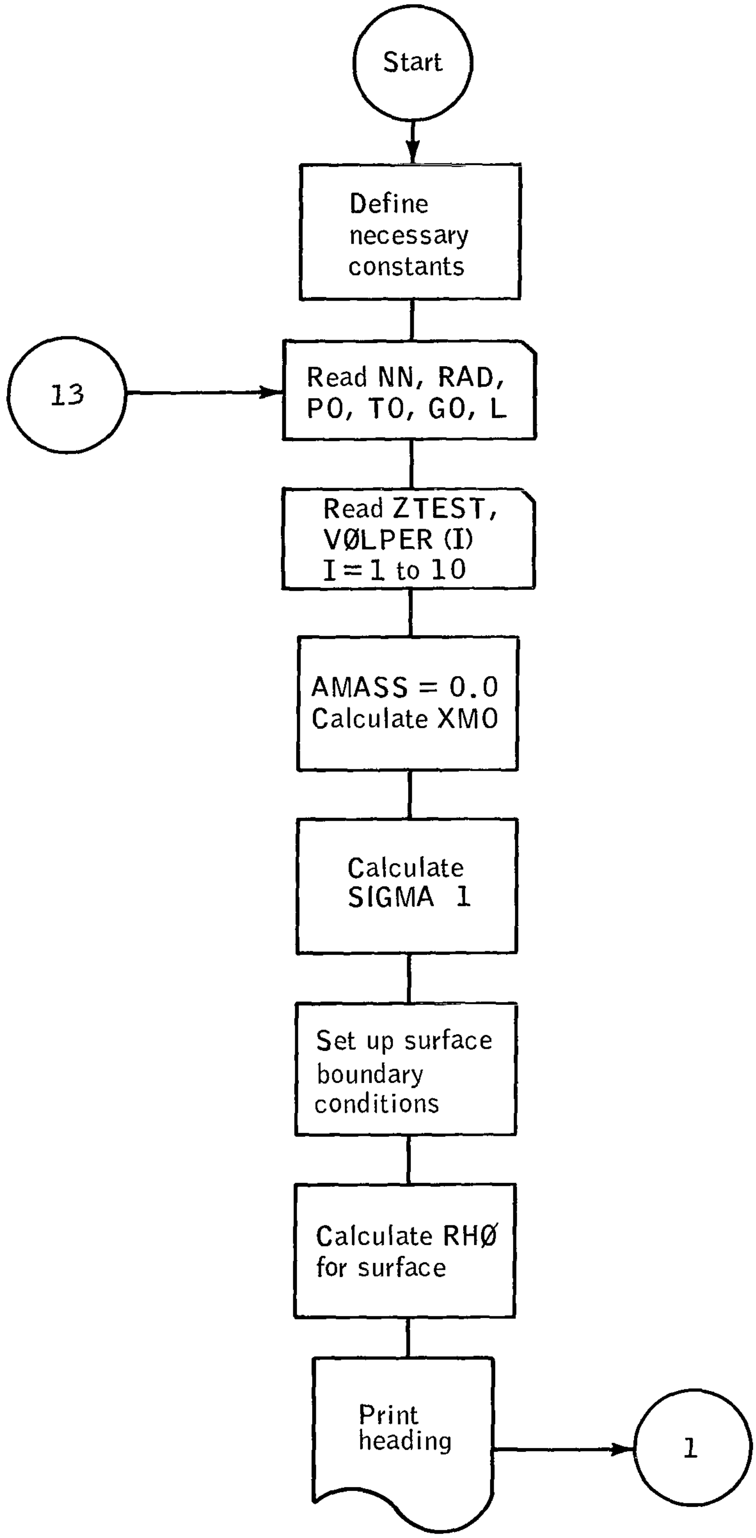


Figure 1. - Flow chart.

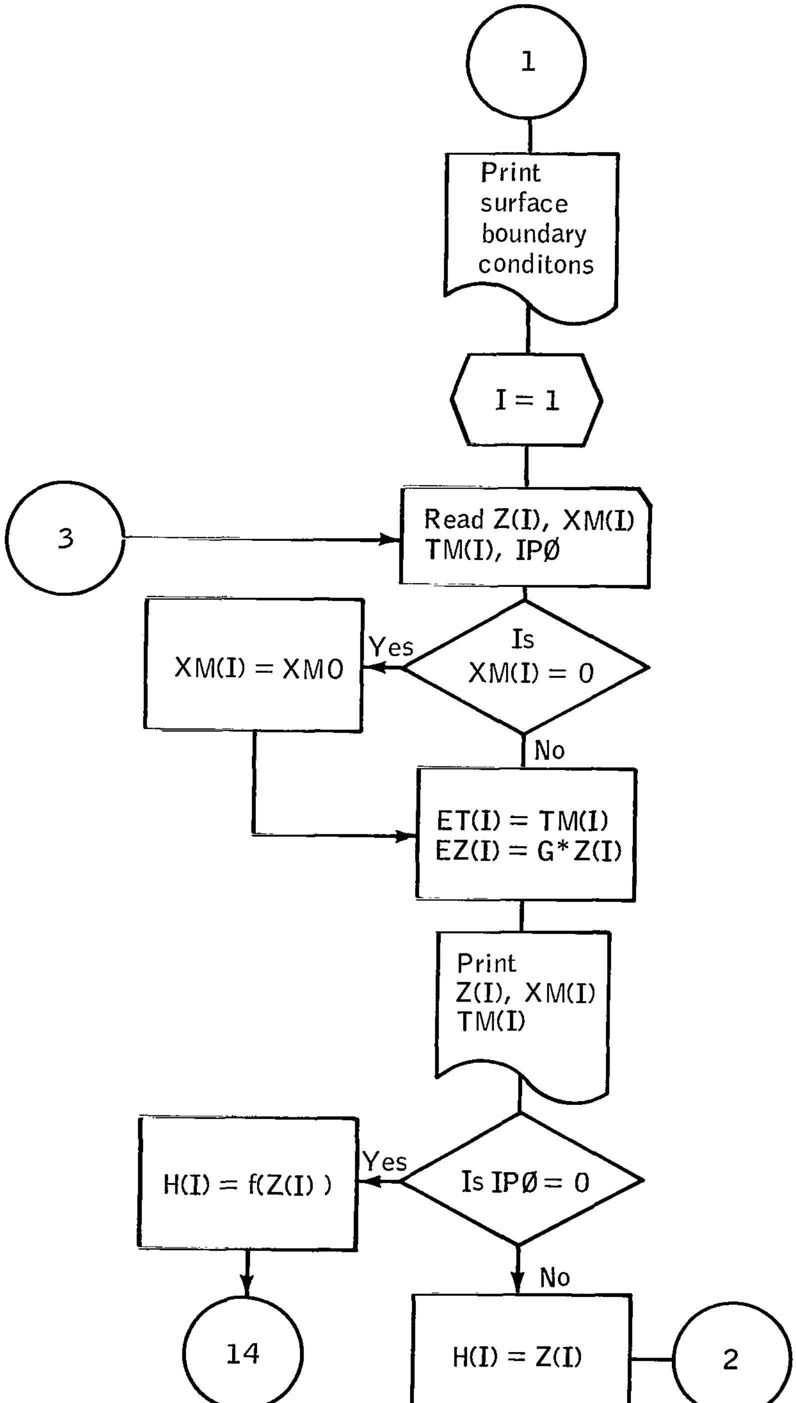


Figure 1. - Continued.

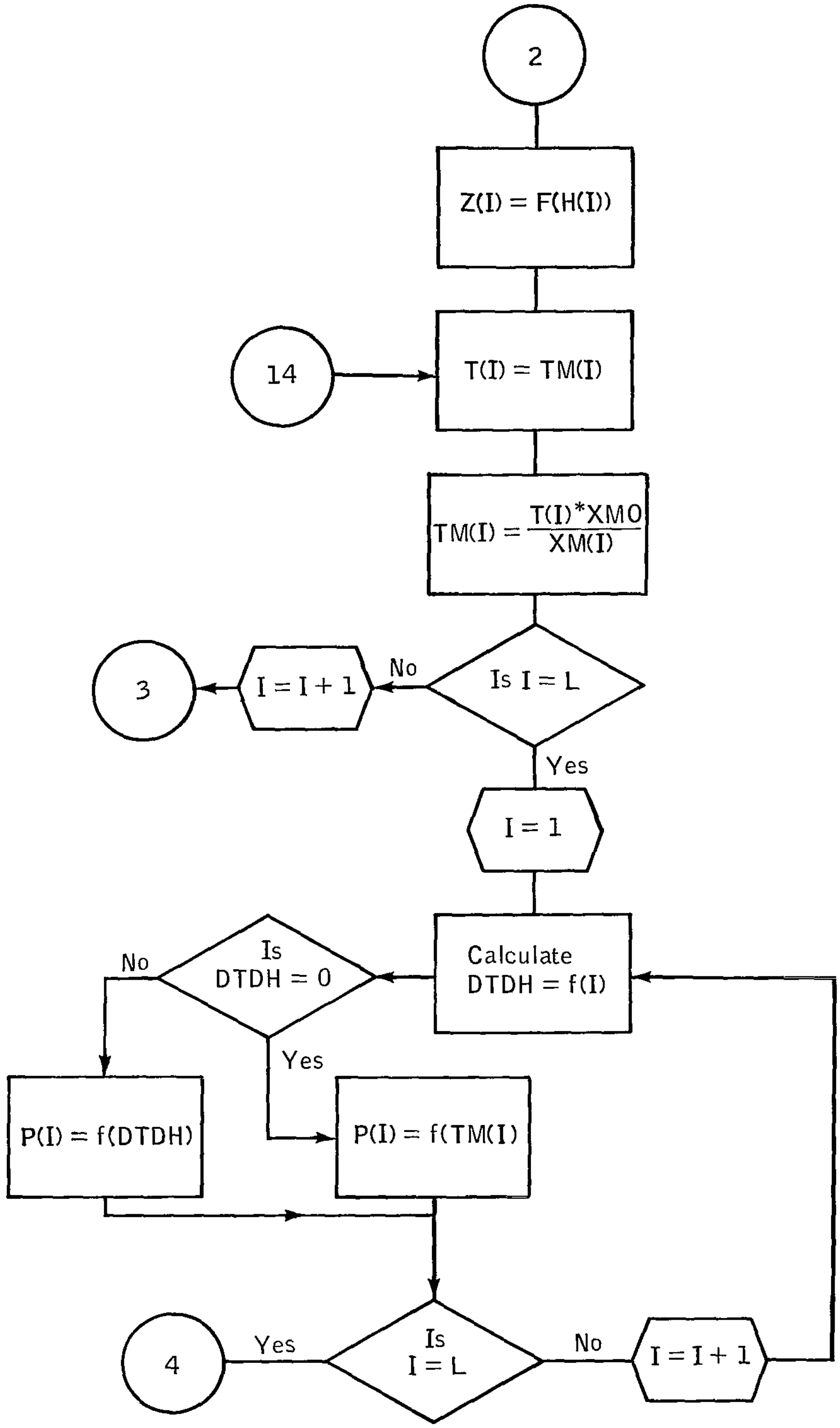


Figure 1. - Continued.

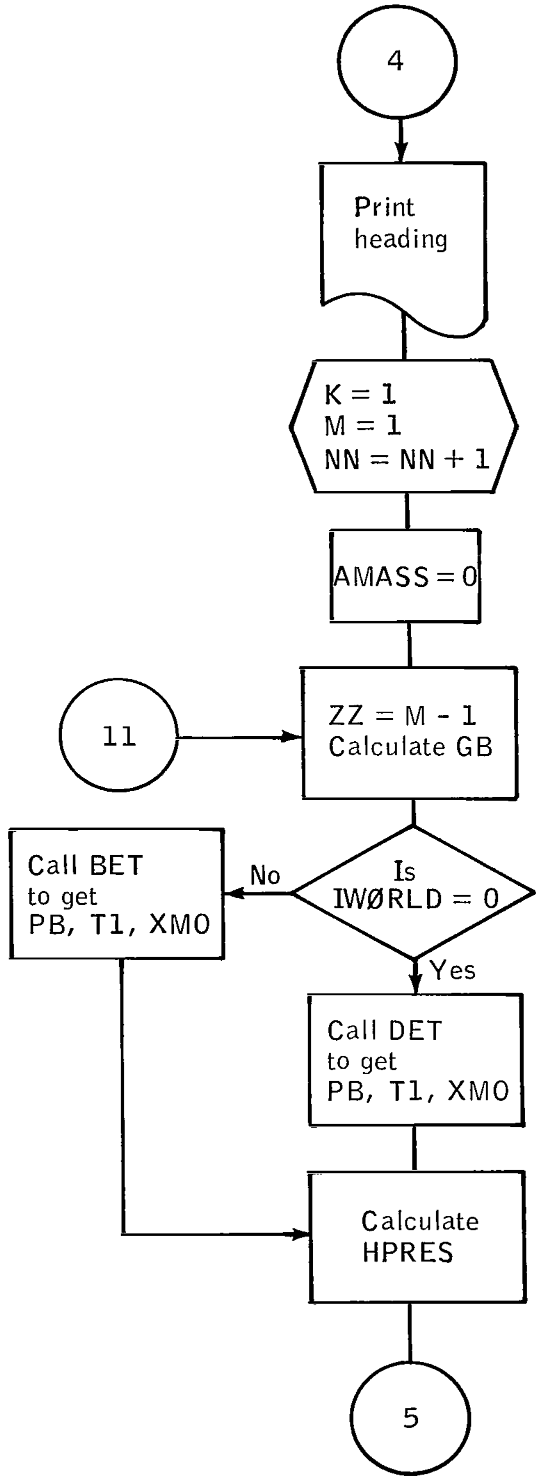


Figure 1. - Continued.

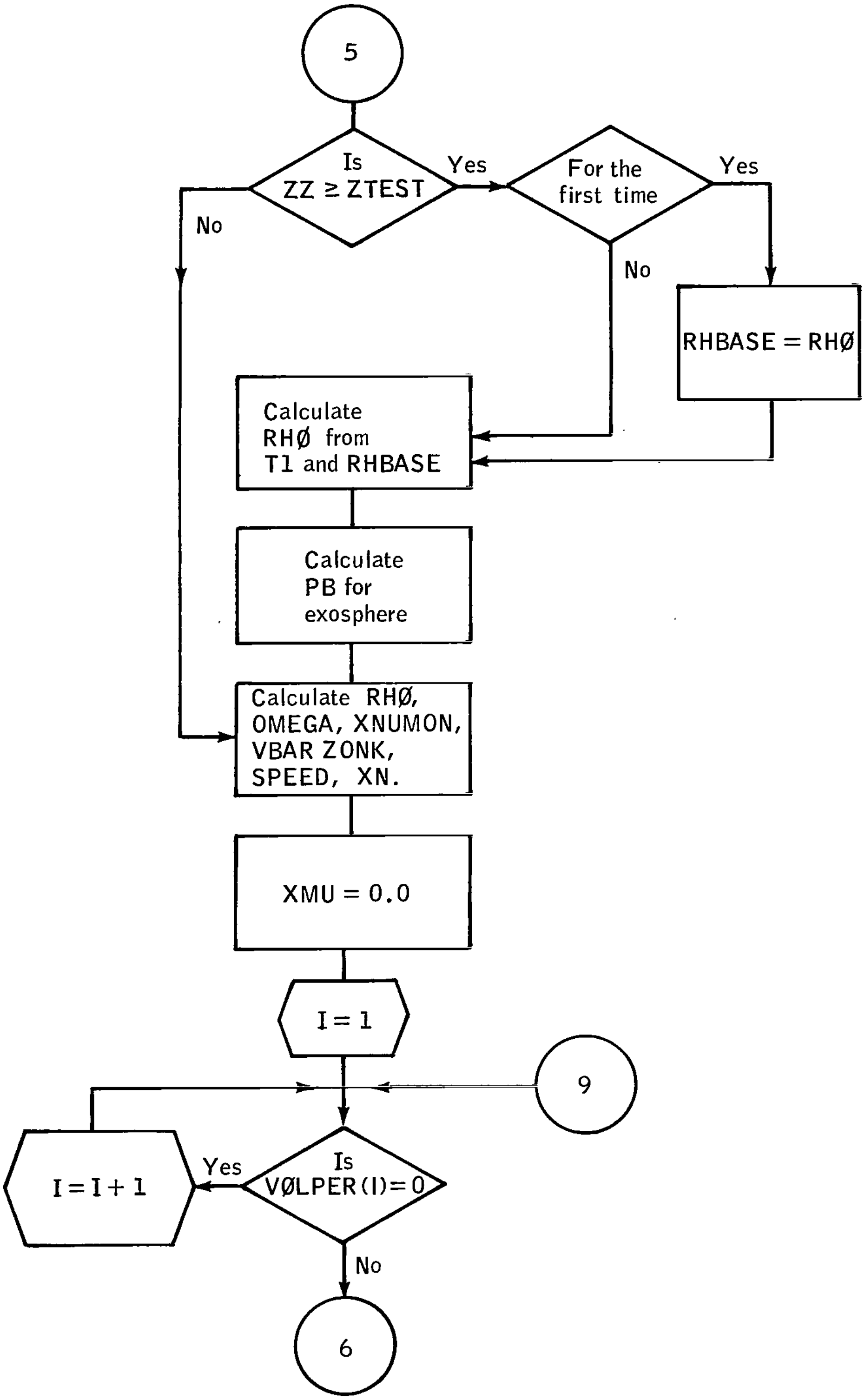


Figure 1. - Continued.

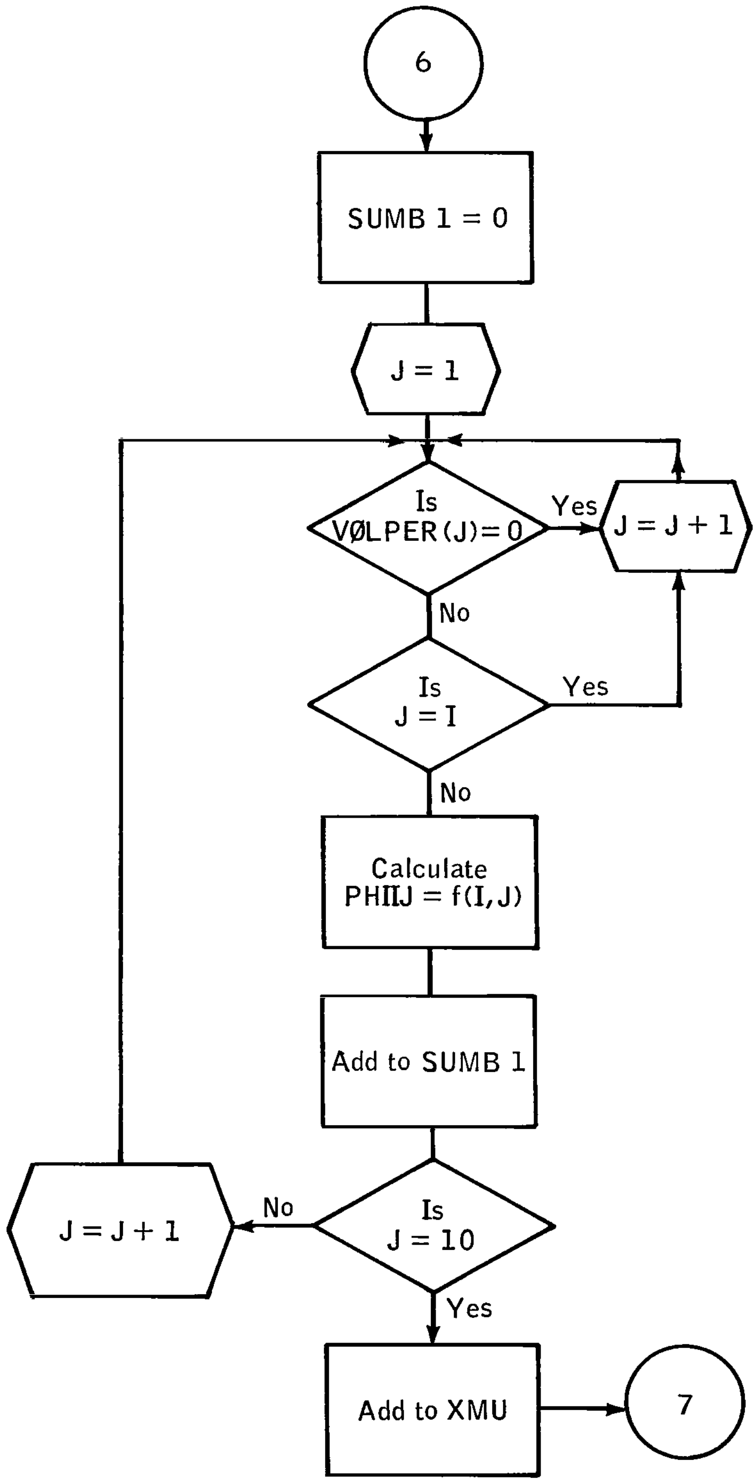


Figure 1. - Continued.

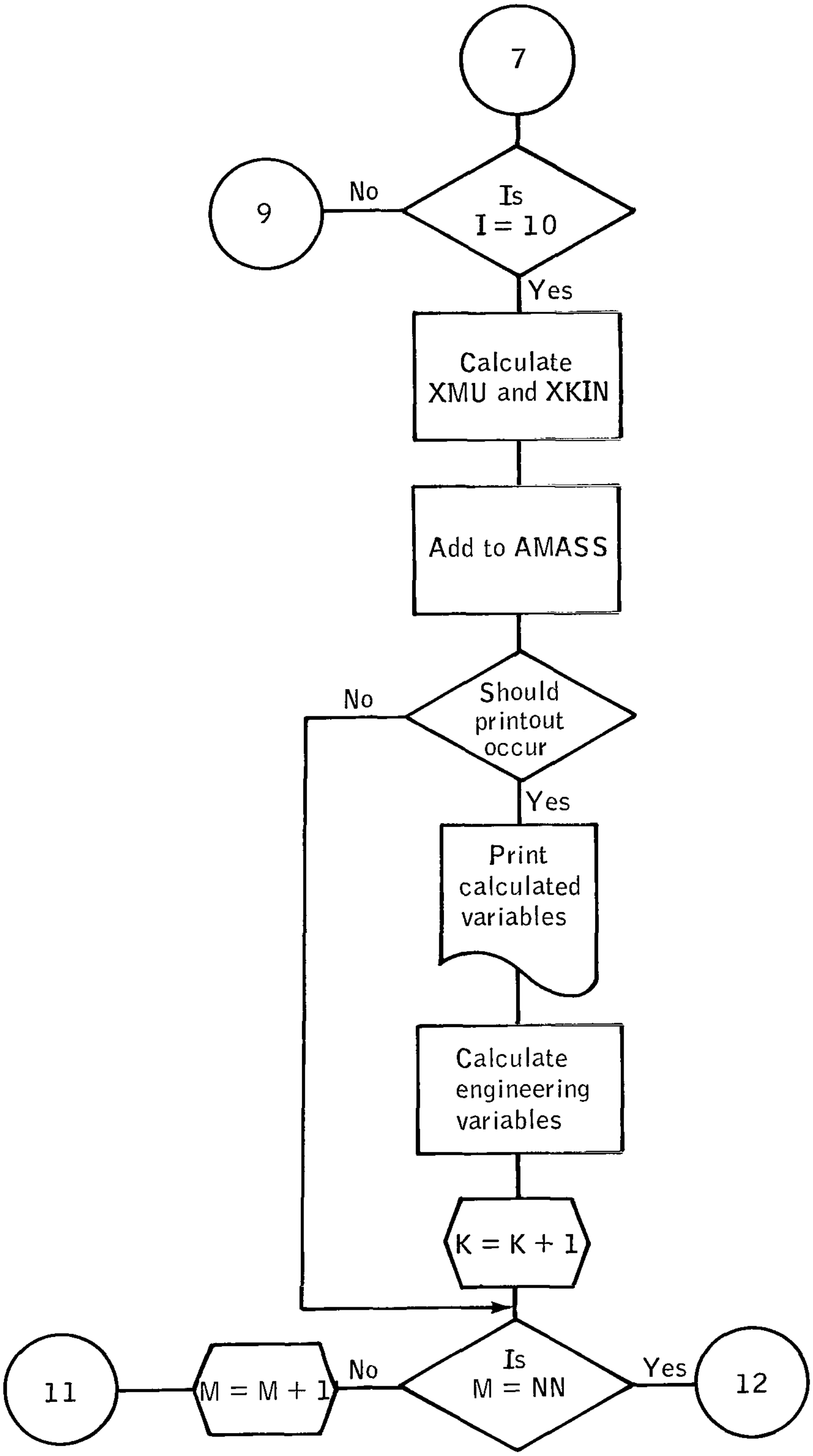


Figure 1. - Continued.

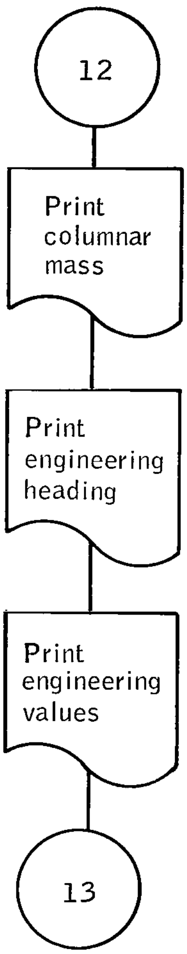


Figure 1. - Concluded.

CONCLUDING REMARKS

Using the computer program just described, wide ranges of model atmospheres may be calculated in order to envelope relatively uncertain conditions in a planetary atmosphere; or, special purpose calculations may be made involving very exact conditions which were measured for a particular location, altitude, and time of day.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, October 30, 1967
981-89-00-00-72

APPENDIX A

PRESSURE AND DENSITY SCALE HEIGHT

Pressure scale height may be defined in many ways. Perhaps the best way is as shown in equation (A1).

$$H_P = \frac{-1}{\frac{1}{P}\frac{\partial P}{\partial Z}} = \frac{-1}{\frac{\partial \ln P}{\partial Z}} \tag{A1}$$

As may be seen in equation (A1), H_P denotes the rate of decrease of pressure with height. Specifically, H_P is the height necessary for the pressure to be reduced by e (that is, $P\left(Z_{H_P}\right) = P(\text{base})/e$). This is shown in the following discussion. Combining the hydrostatic equation

$$\frac{\partial P}{\partial Z} = -\rho g \tag{A2}$$

with the equation of state

$$\rho = \frac{Pm}{RT} \tag{A3}$$

gives

$$\frac{1}{P}\frac{\partial P}{\partial Z} = \frac{-mg}{RT} \tag{A4}$$

Substituting equation (A4) into equation (A1) gives the simple result

$$H_P = \frac{RT}{mg} \tag{A5}$$

which is the form of the pressure scale height most commonly found in textbooks.

Combining equations (A4) and (A5) by eliminating the term mg/RT gives

$$-\frac{1}{P}\frac{\partial P}{\partial Z} dZ = \frac{dZ}{H_P} \tag{A6}$$

Integrating equation (A6) gives from altitudes a to b

$$\int_{P_a}^{P_b} -\frac{dP}{P} = \int_a^b \frac{1}{H_P} dZ \tag{A7}$$

where $b > a$ gives,

$$\ln \frac{P_a}{P_b} \cong \frac{1}{\overline{H}_P}\left(Z_b - Z_a\right) \tag{A8}$$

If

$$P_b = \frac{P_a}{e} \tag{A9}$$

then

$$\overline{H}_P = \left(Z_b - Z_a\right) \tag{A10}$$

A hypothetical homogeneous atmosphere ($\nabla\rho = 0$) has a height (where $P = 0$) equal to the pressure scale height. Even though it is homogeneous, the atmosphere will still be hydrostatic, but since the density is constant, equation (A2) can easily be integrated

$$\frac{\partial P}{\partial Z} = -\rho g \qquad\qquad P_b - P_a \cong -\rho g\left(Z_b - Z_a\right) \tag{A11}$$

At the top of the atmosphere Z_b, the pressure becomes zero, and at the surface Z_a the pressure has some finite value. Therefore

$$-P_a = -\rho g\left(Z_b - Z_a\right) \tag{A12}$$

However, $Z_a = 0$ since the origin is at the surface so that

$$\frac{P_a}{\rho g} = Z_b \tag{A13}$$

but

$$P = \frac{\rho RT}{m} \tag{A14}$$

so

$$\frac{RT}{mg} = Z_b \tag{A15}$$

Then, using equation (A5),

$$Z_b = H_P \tag{A16}$$

The density scale height is defined in a similar manner

$$H_\rho = \frac{-1}{\frac{1}{\rho}\frac{\partial \rho}{\partial Z}} \tag{A17}$$

and may be said to be the height increment required to reduce the density by the factor e. The relation between the two scale heights is

$$H_\rho = \frac{H_P}{1 + \frac{R}{g}\frac{\partial(T/m)}{\partial Z}} \tag{A18}$$

APPENDIX B

DERIVATION OF ITERATIVE HYDROSTATIC EQUATION

The basic equation describing the rate of change of pressure in the lower regions of the atmosphere is the hydrostatic equation. It relates the vertical gradient of pressure to the local values of density and gravity. The tangent plane coordinate system (fig. B-1) is used as a reference for defining direction.

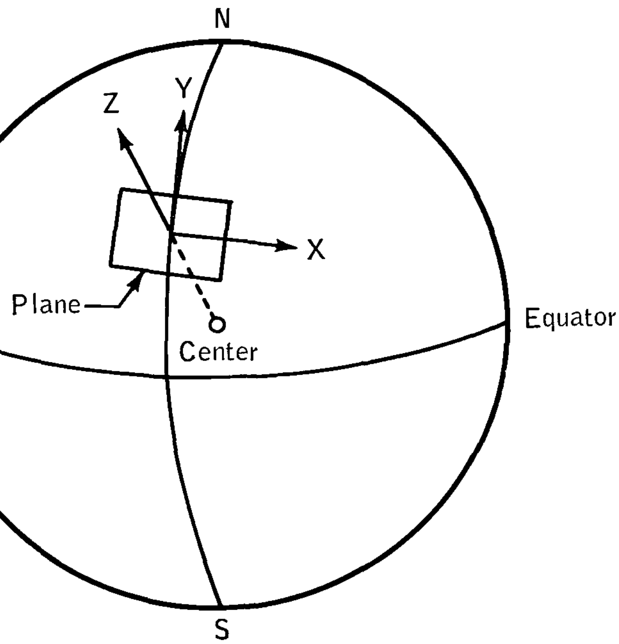


Figure B-1. - The tangent plane coordinate system.

$$\frac{\partial P}{\partial Z} = -\rho g \tag{B1}$$

If density were known as a function of height, equation (B1) would be integrable. However, temperature, not density, is usually the known function in an atmosphere. It is for this reason that the equation of state

$$\rho = \frac{Pm}{RT} \tag{B2}$$

is substituted into (B1), giving

$$\frac{1}{P}\frac{\partial P}{\partial Z}\,dZ = \frac{-mg}{RT}\,dZ \tag{B3}$$

However, this equation is not integrable as it stands. Three variables m, g, and T are functions of Z. Thus a transformation of variables is required. In order to do this, two hypothetical constructs are used. These are the geopotential altitude and the molecular scale temperature. Geopotential altitude H is a fictitious altitude which changes relative to geometric altitude Z such that g becomes a constant. Geopotential altitude is defined as follows

$$dH = \frac{g}{g_o}\,dZ \tag{B4}$$

The acceleration caused by gravity near a spherically symmetric planet is expressed by Newton's law of universal gravitation, which, when placed in terms of the gravitational acceleration at the surface of the planet, becomes

$$g = \frac{g_o r^2}{(r + Z)^2} \tag{B5}$$

Using this result in equation (B4) and integrating gives

$$H = r^2 \int_o^Z \frac{dZ}{(r + Z)^2} = \frac{Zr}{r + Z} \tag{B6}$$

Likewise, molecular scale temperature T_m is simply a device for combining two variables (T and m) into one. It is defined as

$$T_m = \frac{m_o}{m}\,T \tag{B7}$$

If equations (B4) and (B7) are substituted into equation (B3) it becomes

$$\frac{1}{P}\frac{\partial P}{\partial Z} dZ = \frac{-m_o g_o \, dH}{RT_m} \tag{B8}$$

Within an atmospheric layer where $\partial T_m/\partial H$ is constant, then equation (B8) has an exact analytic solution, which is as follows. If $\partial T_m/\partial H \neq 0$

$$P_b = P_a \left[\frac{(T_m)_b}{(T_m)_a}\right]^{\frac{g_o m_o}{R\frac{\partial T_m}{\partial H}}} \tag{B9}$$

and if $\partial T_m/\partial H = 0$

$$P_b = P_a \exp\left[\frac{-g_o m_o (H_b - H_a)}{R(T_m)_a}\right] \tag{B10}$$

These are the final iterative forms of calculating pressure as a function of altitude.

APPENDIX C

FORTRAN LISTING FOR THE PLANETARY MODEL ATMOSPHERE COMPUTER PROGRAM

Because the description of the computer program is included in the flow chart, it will not be duplicated here. The Fortran listing and a key to the variables are included for those who wish to inquire into the mechanics of the program further than the flow chart allows. Although the key does not explain all of the variables, it does include the most important ones. Many of the variables not included are "dummy" variables and are of no consequence, since they are used only as tools for operations such as numerical integration. Variables that have an "E" preceding them are in engineering units. The following is an explanation of the notation used in the program.

AM	molecular weight of each of the 10 constituents
AMASS	quantity used to sum $\rho_i \Delta z_i$ over all i's for columnar mass
BET	subroutine for calculation of pressure where the temperature gradient is the primary variable
CARBØN	columnar mass of CO_2
CCPP	$C_p(T1)$
CCVV	$C_v(T1)$
CP	C_p for each of the 10 constituents for each 100° K from 100° to 700° K
CPS	function for calculation of C_p
DA, TE	the month, date, and year of the computer run
DET	subroutine for calculation of pressure where molecular scale temperature lapse rate is the primary variable
DMDH	molecular weight gradient at ZZ, geopotential
DTDZ	molecular scale temperature gradient, geometric altitude
GAMMA	C_p/C_v
GB	acceleration caused by gravity at ZZ

GO	acceleration caused by gravity at the surface of the planet
H (I)	geopotential altitude of Ith level
HPRES	pressure scale height
HRHØ	density scale height
IENDG	number of total levels to be printed out in the engineering quantities
IFLIP	altitude interval of printout above KFLIP and below KFLØP
IFLØP	altitude interval of printout above KFLØP and below KSLØP
III	designation of which constituent is being used
INF, QOOOFL	variables used for random alpha-numeric information to be printed on output sheet
IPØ	a code for the programer to make input values of altitude either geometric (IPØ = 0) or geopotential (IPØ = 1)
IQF	dummy variable for setting up arrays
ISLØP	altitude interval of printout above KSLØP
IWØRLD	a code to enable the programer to choose between a subroutine for calculating model atmospheres similar to the U. S. Standard, 1962, called DET (IWØRLD = 0) and a subroutine for most planetary atmospheres called BET (IWØRLD = 1)
K	index used for engineering variables
KFLØP	geometric altitude above which the altitude interval IFLØP is used
KLIP	geometric altitude above which the altitude interval IFLIP is used
KSLØP	geometric altitude above which the altitude interval ISLØP is used
L	the ratio of the number of linear temperature segments to the number of altitude segments considered
M	fixed point variable for geometric altitude
NA, ME	name of the planet or celestial body being considered
NN	the maximum height to be considered
ØM	Ω for each of the 10 constituents for each 100° K from 100° to 700° K
ØMEG	function for calculation of Ω for viscosity

ØMEGA	specific weight
PB	pressure at the top of the interval of integration
PHI	π
PHIIJ	coefficient for calculating viscosity
P (I)	pressure at the Ith level
PO	surface pressure
RAD	radius of planet
RAT	$\frac{\epsilon}{K}$ for each of the 10 constituents
RGM	an alpha-numeric variable corresponding with IPØ. If altitude being read in is geometric, RGM = M; if geopotential, RGM = P. Thus either "GEØM" or "GEØP" is printed out.
RHBASE	density at the base of the exosphere
RHØ	density
RO	universal gas constant
SIGMA	zero energy collision diameter for each of the 10 constituents, Å
SIGMA 1	average zero energy collisional diameter
SPEED	speed of sound
T1	temperature
T (I)	kinetic temperature at the Ith level, read-in
TM (I)	molecular scale temperature for the Ith level
TMQ	molecular scale temperature at ZZ
TMQ1	molecular scale temperature at altitude XH1
TO	surface temperature
TQ	temperature at ZZ
VBAR	mean particle velocity
VI	function for calculation of viscosity

VØLPER (1)	mole fraction of nitrogen
VØLPER (2)	mole fraction of carbon dioxide
VØLPER (3)	mole fraction of oxygen
VØLPER (4)	mole fraction of argon
VØLPER (5)	mole fraction of neon
VØLPER (6)	mole fraction of hydrogen
VØLPER (7)	mole fraction of helium
VØLPER (8)	mole fraction of water
VØLPER (9)	mole fraction of carbon monoxide
VØLPER (10)	mole fraction of sulfur dioxide
VIS	$\frac{1}{\sigma^2}\sqrt{\frac{m\epsilon}{K}}$ for each of the 10 constituents
XERR	dummy variable
XH	geopotential altitude
XH1	geopotential altitude corresponding to 1 geometric km below ZZ
XK	1.38026×10^{-16} ergs $(°K)^{-1}$
XKIN	kinematic viscosity
XM (I)	molecular weight for the Ith level, read-in
XMO	molecular weight
XMØLW	surface molecular weight
XMQ	molecular weight at ZZ
XMQ1	molecular weight 1 geometric km below present level
XMU	coefficient of viscosity
XN	Avogadro's number
XNU	collision frequency
XNUMD	number density

XRHØ	density at 1 geometric km below present level
YERR	dummy variable
Z (I)	geometric altitude of Ith level
ZØNK	mean free path
ZTEST	altitude of the base of the exosphere
ZZ	geometric height

APPENDIX D

EXAMPLE OF INPUT DATA

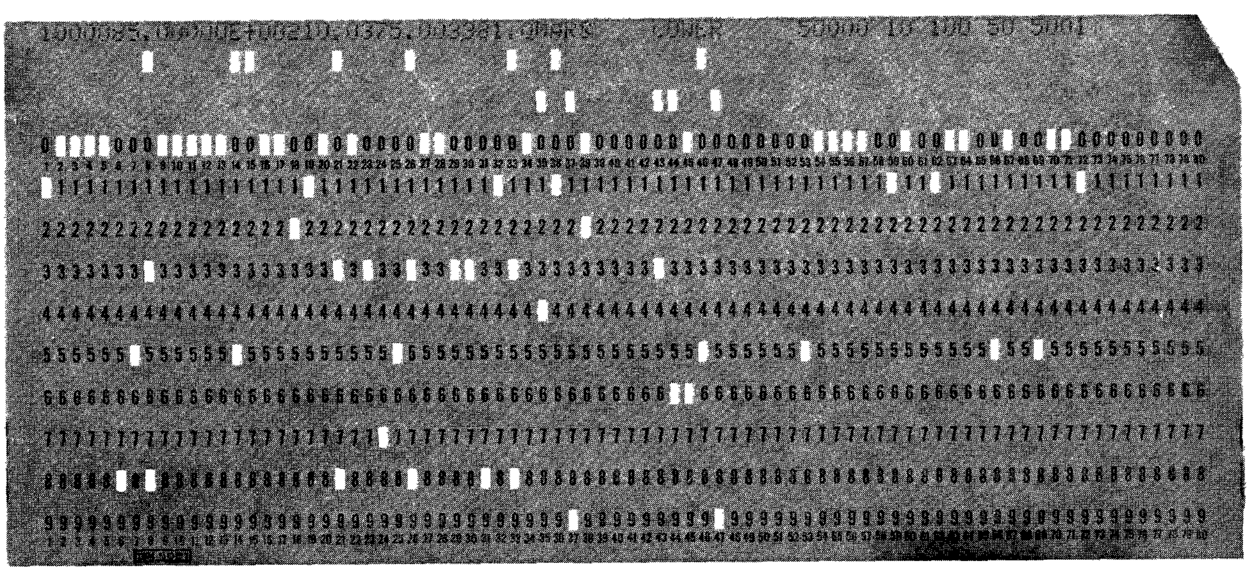
An example of input data for a sample Mars model atmosphere is given on the following pages. The data are also explained in the tabulated key, shown after the example.

Each model atmosphere needs one each of cards 1 and 2. The first two cards determine the extent in altitude of the calculations, the surface boundary conditions, the altitude increments desired, the mole fraction of each of the 10 gases, the calculation procedure to be used for pressure, and the altitude at which the exospheric option is to be used (if it is to be used at all). The number of type 3 cards that will be used depends upon the model atmosphere. However, the temperature and molecular weight must be given at least to the maximum number of levels (km) as specified by card number 1.

KEY TO EXAMPLE OF INPUT DATA

Card 1

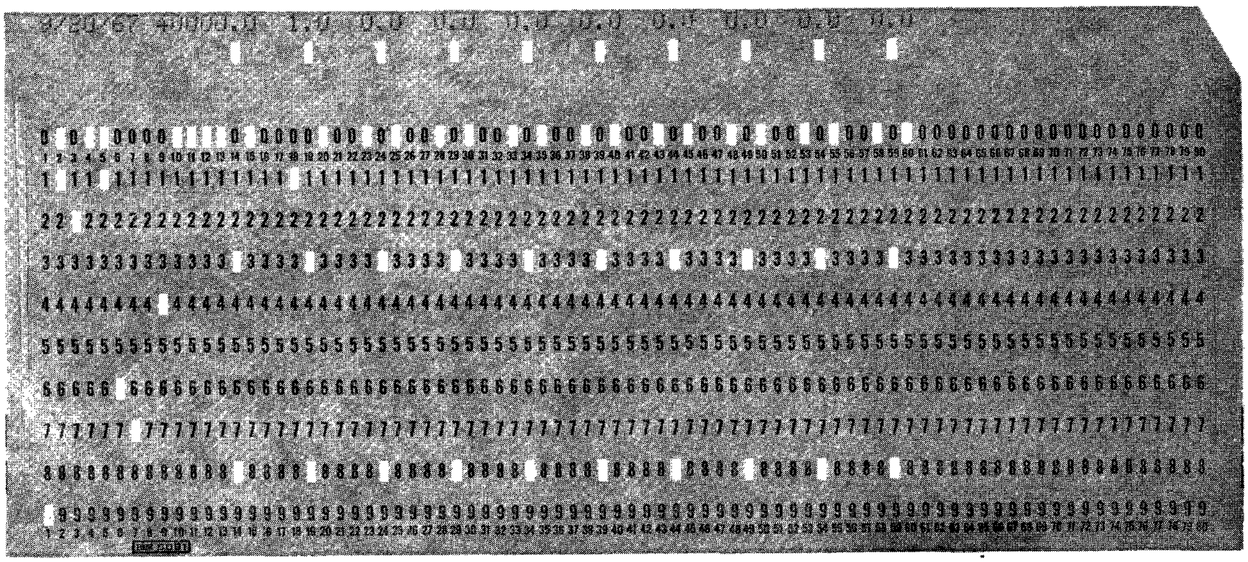
Number of levels km, number of card 3 to be read in, surface pressure mb, surface temperature °K, surface gravity cm sec^{-2}, radius of planet km, planet name, comments, first increment, first altitude, second increment, second altitude, third increment, third altitude, test for type of model: U. S. Standard (IWØRLD = 0), planet (IWØRLD = 1).



Card 1

Card 2

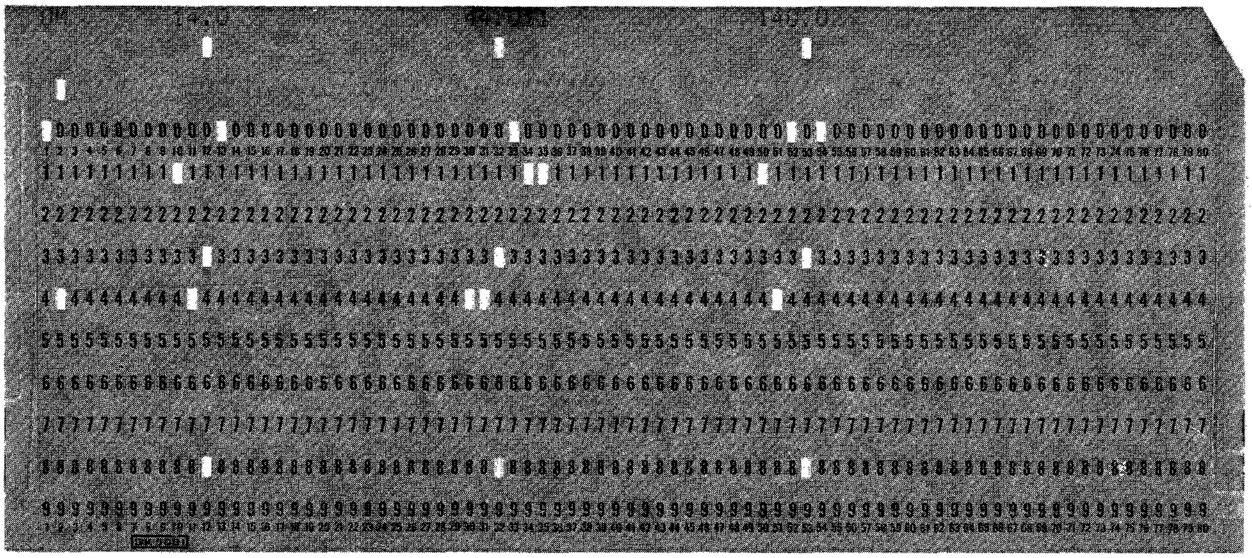
Date, height of the base of the exosphere km, mole fraction of nitrogen, mole fraction of carbon dioxide, mole fraction of oxygen, mole fraction of argon, mole fraction of neon, mole fraction of hydrogen, mole fraction of helium, mole fraction of water, mole fraction of carbon monoxide, mole fraction of sulfur dioxide.

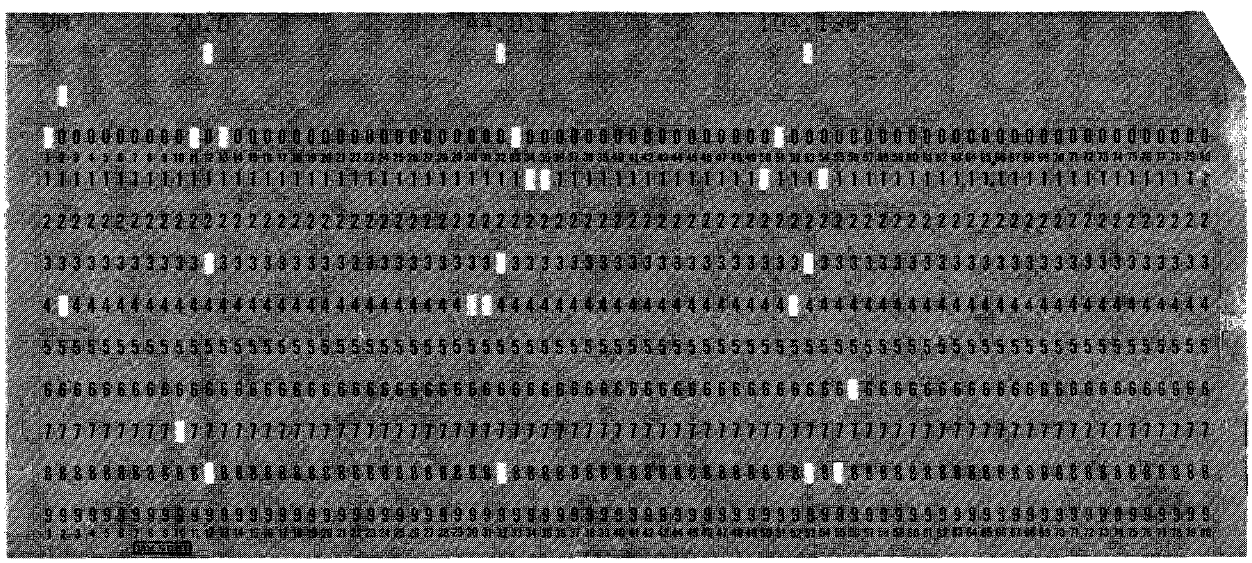


Card 2

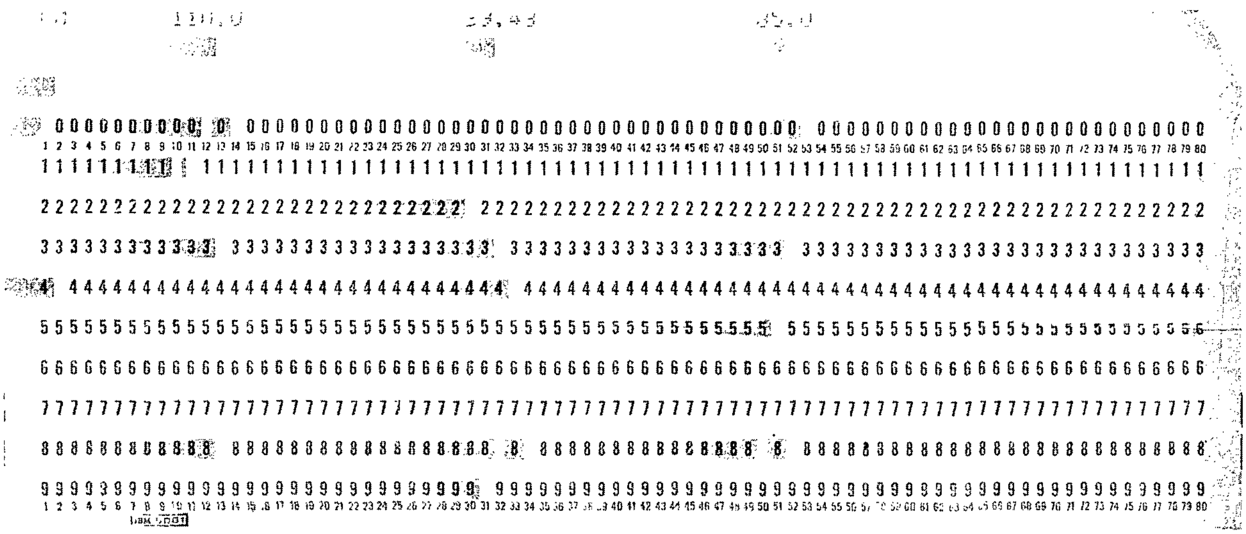
Card 3

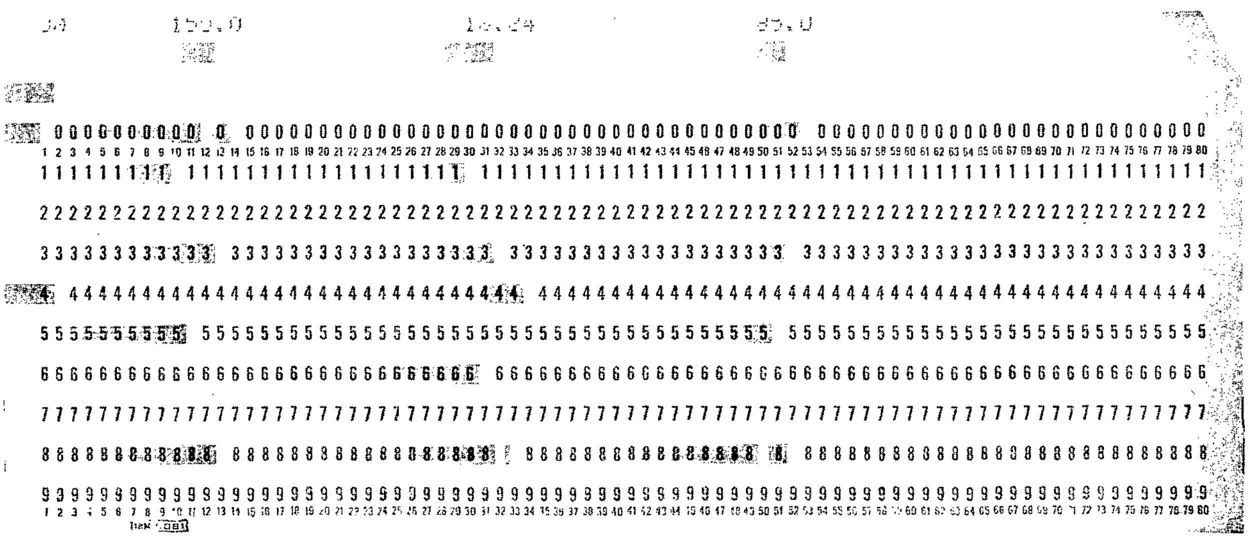
Test for altitude (zero if geometric, one if geopotential), alphabetic variable ("M" if geometric, "P" if geopotential), and altitude km, molecular weight (g/g mole), temperature °K.



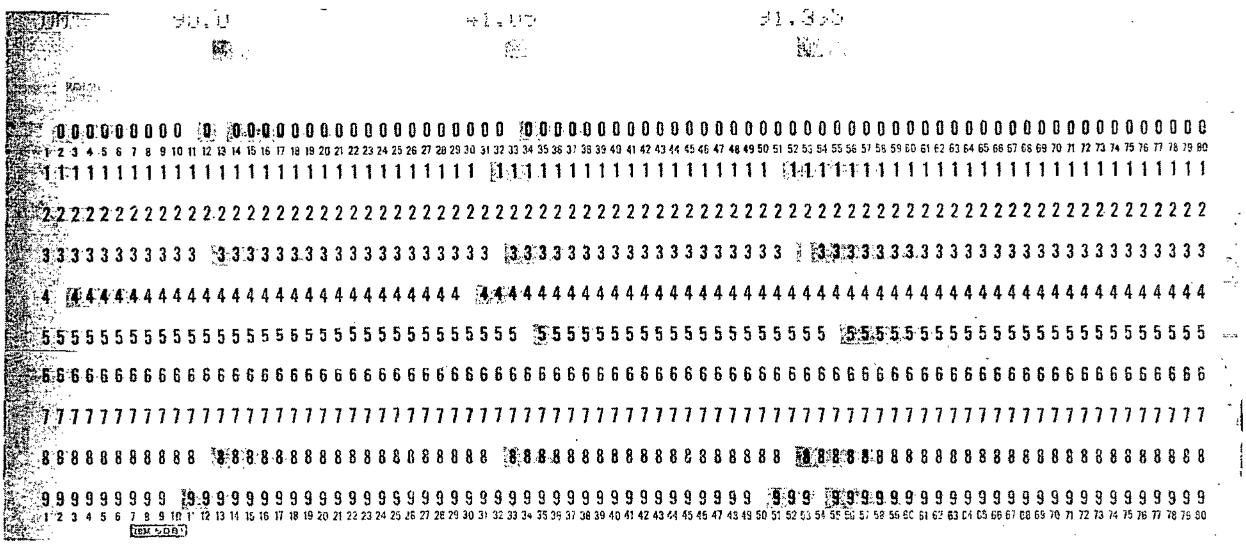


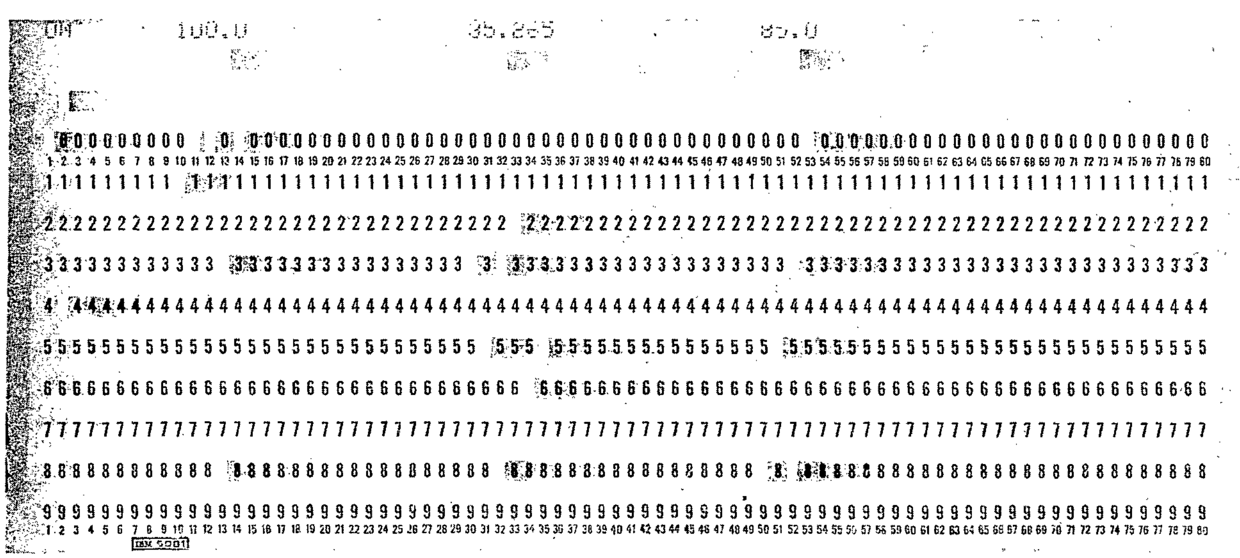
Card 3



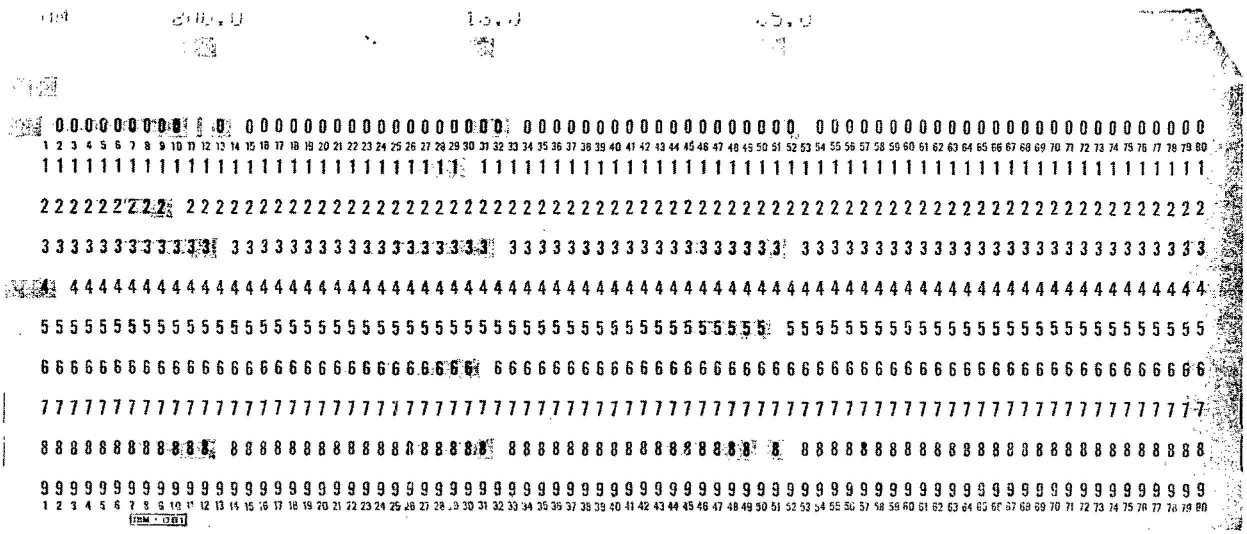


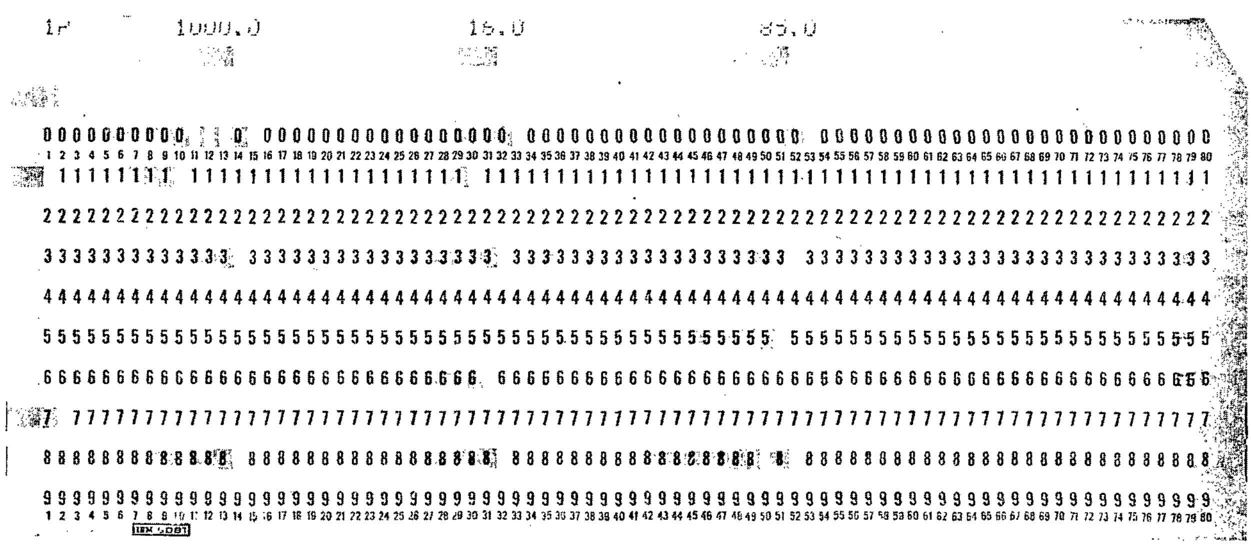
Card 3 - Continued.





Card 3 - Continued.





Card 3 - Concluded.

```
CCOLUMNAR MASS MODEL ATMOSPHERE WITH VAR OF MOL WTG,EXOSPHERE
CDAVID PITTS
      DIMENSION Z(90), ET(90), H(90), TM(90), XM(90), P(90), EZ(
     190), EZZ(251), ET1(251), EPB(251), ERHO(251), ESPEED(251), EHPRES(
     2251), EHRHO(251), ENUMDN(251), EVBAR(251), EXBAR(251), EXMU(251),
     3EXKIN(251), EOMEGA(251),T(90),VOLPER(10),SIGMA(10),VIS(10),RAT(10)
     4,AM(10)
      COMMON H,TM,XM,P,G0,RAD,L,R0,XMOLW,T,TMQ1,XH1,XMQ1,P1,VIS,RAT,AM
      VI(T1,III,IQF)=26.693*VIS(III)*SQRT(T1/RAT(III))/(OMEG(T1,III,IQF)
     1)
      T1=200.0
      J=1
      I=0
      GAMMA=CPS(T1,J,I)
      P0=OMEG(T1,J,I)
      IQF=1
      AM(1)=28.016
      AM(2)=44.011
      AM(3)=32.0
      AM(4)=39.944
      AM(5)=20.183
      AM(6)=2.016
      AM(7)=4.003
      AM(8)=18.016
      AM(9)=28.011
      AM(10)=64.066
      SIGMA(1)=3.681
      SIGMA(2)=3.952
      SIGMA(3)=3.499
      SIGMA(4)=3.421
      SIGMA(5)=2.858
      SIGMA(6)=2.915
      SIGMA(7)=2.576
      SIGMA(8)=2.99
      SIGMA(9)=3.678
      SIGMA(10)=4.290
      RAT(1)=91.5
      RAT(2)=200.0
      RAT(3)=100.0
      RAT(4)=119.5
      RAT(5)=27.5
```

```
      RAT(6)=38.0
      RAT(7)=10.22
      RAT(8)=498.2
      RAT(9)=94.5
      RAT(10)=252.0
      VIS(1)=3.737
      VIS(2)=6.01
      VIS(3)=4.620
      VIS(4)=5.90
      VIS(5)=2.884
      VIS(6)=1.030
      VIS(7)=0.964
      VIS(8)=10.597
      VIS(9)=3.803
      VIS(10)=6.91
      XK=1.38026*10.0**(-16)
      XN=6.02257E+23
      PHI=3.14159
      BETA=1.458E-06
      R0=8.31432E+07
   25 READ (5,9) NN,L,P0,T0,G0,RAD,NA,ME,INF,QOOOFL,IFLIP,KFLIP,IFLOP,KF
     1LOP,ISLOP,KSLOP,IWORLD
    9 FORMAT (I4,I2,E11.5,F5.2,F6.3,F6.0,4A4,3(I3,I4),I1)
      READ (5,4) DA,TF,ZTEST,(VOLPER(I),I=1,10)
    4 FORMAT (A5,A3,F4.0,10F5.2)
      XM0=0.0
      SIGMA1=0.0
      DO 1111 IVV=1,10
      XM0=XM0+AM(IVV)*VOLPER(IVV)
 1111 SIGMA1=SIGMA1+SIGMA(IVV)*VOLPER(IVV)*1.0E-08
      IVV=XM0*1000.0
      XM0=IVV
      XM0=XM0/1000.0
      T(1)=T0
      P1=P0
      TMO1=T0
      XMO1=XM0
      ZFLIP=KFLIP
      ZFLOP=KFLOP
      ZSLOP=KSLOP
      FLIP=IFLIP
      FLOP=IFLOP
      SLOP=ISLOP
      TM(1) = T0
      ET(1) = TM(1) * 1.8
      XM(1)=XM0
      H(1)=0.0
      P(1)=P0
      XRHO=0.0
      BASS =0.0
      Z(1)=0.0
      EZ(1)=0.0
      EP0=P0*14.7/1013.0
      L=L+1
      EG0=G0/30.48
      RHO=P0*XM0/(R0*T0)*1000.0
      ERHN=RHO*1.943
      ET0=T0*1.8
```

```
      XMOLW=XMO
      WRITE (6,1)NA,ME,INF,QOOOFL
    1 FORMAT (1H1,45X,20HMODEL ATMOSPHERE FOR,1X,2A4,22X,2A4,//)
      WRITE (6,5)DA,TE
    5 FORMAT (2X,23HCONSTRUCTION PARAMETERS,27X,16HSCIENTIFIC UNITS,35X,
     1,5HDATE ,A5,A3//)
      WRITE (6,22)PO,TO,RHO,ZTEST,XMO,GO
   22 FORMAT (2X,19HSURFACE PRESSURE = ,F9.2,3H MB,10X,22HSURFACE TEMPER
     1ATURE = ,F7.2,2H K, 8X,18HSURFACE DENSITY = ,1PE9.2,6H GM/CC,/,
     22X,20HBASE OF EXOSPHERE = ,0PF8.2,4H(KM),9X,19HMOLECULAR WEIGHT =
     3,5X,0PF6.3,5X,18HSURFACE GRAVITY = ,0PF8.3,11H CM/SEC/SEC)
      WRITE (6,556) NA,ME,RAD,(VOLPER(I),I=1,10)
  556 FORMAT (2X,9HRADIUS OF ,1X,2A4,2H= ,F8.2,4H(KM),9X,18HPERCENT NITR
     1OGEN = ,5X,2PF7.3,11X,16HPERCENT CO2    = ,2PF7.3,/,2X,22HPERCENT O
     2XYGEN       =  ,2PF7.3,12X,23HPERCENT ARGON        =       ,2PF7.3,11X,
     316HPERCENT NEON  = 2PF7.3,/,2X,22HPERCENT HYDROGEN    =  ,2PF7.3,
     412X,23HPERCENT HELIUM    =       ,2PF7.3,11X,16HPERCENT WATER = ,
     52PF7.3,/,2X,22HPERCENT CO          =  ,2PF7.3,12X,23HPERCENT SO2
     6  =      ,2PF7.3,///,10X,46HTEMPERATURE AND MOLECULAR WEIGHT DISTR
     7IBUTION,/)
      DO 51 I=2,L
      READ (5,976)IPO,RGM,Z(I),XM(I),TM(I)
  976 FORMAT (I1,A1,7X,3(F10.2,10X))
      IF (XM(I)) 2001,2000,2001
 2000 XM(I)=XMO
 2001 ET(I)=TM(I)*1.8
      WRITE (6,8) Z(I), RGM, TM(I), XM(I)
    8 FORMAT (10X,2HAT,1X,F10.2,3X,3HGEO,A1,1X,2HKM,8X,       12HTEMPERAT
     1URE=,2X,F10.2,2H K,7X,13HAND MOLECULAR,2X,7HWEIGHT=,F10.5)
      EZ(I)=Z(I)*0.003281
      IF (IPO) 630,631,630
  631 H(I) = RAD * Z(I) / (RAD + Z(I))
      GO TO 782
  630 H(I)=Z(I)
      Z(I) = RAD * Z(I) / (RAD - Z(I))
  782 T(I)=TM(I)
   51 TM(I) = TM(I) * XMO / XM(I)
      XH1=-RAD/(RAD+1.0)
      TMQ1=(T(2)-T(1))/(H(2)-H(1))*XH1 +T(1)
      DO 633 I = 2, L
      DTDH = (TM(I)-TM(I-1))/(H(I)-H(I-1))
      IF (DTDH)601, 602, 601
  601 P(I) = P(I-1)*(TM(I-1)/TM(I))**( GO*XMO*1.0E+05/(RO*DTDH))
      GO TO 633
  602 P(I) = P(I-1)*EXP(-GO* XMO*1.0E+05/(RO*TM(I))*(H(I)-H(I-1)))
  633 CONTINUE
      WRITE (6,68)
   68 FORMAT (/  ,1X,21HCALCULATED QUANTITIES,/  )
      WRITE (6,69)
   69 FORMAT (74X,4HMEAN,19X,4HMEAN,/,1X,122HHEIGHT    TEMP   PRESSURE    D
     1ENSITY   SPEED   MOLECULAR  DENS    NUMBER      FREE       VIS-   PRE
     2S PARTICLE COLL      COLUMNAR     ,/,36X,86HOF SOUND   WEIGHT   SCAL
     3E  DENSITY     PATH      COSITY SCALE VELOCITY FREQ         MASS
     4,/,1X,122H (KM)     (K)     (MB)       (GM/CC)  (M/SEC)
     5KM)   (PER CC)     (M)       (E+5)    (KM) (M/SEC) (PER SEC)
     6                            ,/ )
      AMASS=0.0
      K=1
```

```
      NN = NN + 1
      IENDG=KFLOP/IFLIP+(KSLOP-KFLOP)/IFLOP+((NN-1)-KSLOP)/ISLOP
   12 DO 10 N=1,NN
      M=IABS(N-1)
      ZZ = N - 1
      GB = GO * (RAD / (RAD + ZZ))**2
      IF (IWORLD) 731,730,731
  730 CALL DET(ZZ,PB,T1,TMQ,XMO,DTDZ)
      GO TO 732
  731 CALL BET(ZZ,PB,T1,TMQ,XMO,DTDZ)
  732 HPRES=RO*T1/(XMO*GB)*.00001
      IF(ZZ-ZTEST) 701,701,702
  702 IF (BASS) 311,312,311
  312 RHBASE=RHO
  311 BASS=1.0
      ZTER=ZTEST+RAD
      ZR=ZZ+RAD
      XERR=SQRT(ZTER **2/(HPRES*ZR))
      IF (XERR-3.0) 304,306,306
  304 SUM=XERR
      TERM=XERR
      DO 301 LL= 1,100
      XL=LL
      TERM=TERM*(-XERR**2)*(2.0*XL-1.0)/(XL*(2.0*XL+1.0))
  301 SUM=SUM+TERM
      GO TO 307
  306 SUM=SQRT(PHI)/2.0
  307 ERFX=1.0-2.0/(SQRT(PHI))*SUM
      YERR=SQRT(ZTER **2*ZR/((HPRES*ZR)*(ZZ+ZTER )))
      IF (YERR-3.0) 308,310,310
  308 SUMB=YERR
      TERMB=YERR
      DO 305 KK= 1,100
      XK=KK
      TERMB=TERMB*(-YERR**2)*(2.0*XK-1.0)/(XK*(2.0*XK+1.0))
  305 SUMB=SUMB+TERMB
      GO TO 309
  310 SUMB=SQRT(PHI)/2.0
  309 ERFY=1.0-2.0/(SQRT(PHI))*SUMB
      RHO=RHBASE*(EXP((-ZTER /HPRES)*(1.0-ZTER /ZR))*(1.0-0.5*ERFX)-    S
     1QRT(1.0-ZTER **2/ZR**2)*EXP((-ZTER /HPRES)*(ZR/(ZR+ZTER )))*(1.0-0
     2.5*ERFY)-(XERR/SQRT(PHI))*(1.0-SQRT(1.0-ZTER /ZR))*EXP(-ZTER /HPRE
     3S))
      PB=RHO*T1*RO/(XMO*1000.0)
  701 CONTINUE
      RHO=PB*XMO*1000.0/(RO*T1)
      OMEGA=RHO*GB
      HRHO=HPRES/(1.0+RO/(XMOLW*GB)*DTDZ*.00001)
      XNUMDN=XN*PB*1000.0/(RO*T1)
      VBAR=.01*(8.0*RO*T1/(PHI*XMO))**.5
      XBAR=RO*T1/(1.414*PHI*XN*PB*1000.0*(SIGMA1**2))
      ZONK=XBAR*.01
      CCPP=0.0
      CCVV=0.0
      DO 2100 IQV=1,10
      CCPP=CCPP+CPS(T1,IQV,IQF)*VOLPER(IQV)
 2100 CCVV=CCVV+(CPS(T1,IQV,IQF)-1.9862)*VOLPER(IQV)
      GAMMA=CCPP/CCVV
```

```
      SPEED=0.01*(GAMMA*RO*T1/XMO)**0.5
      XNU=VBAR*100.0/XBAR
      XMU=0.0
      DO 1001 III=1,10
      IF (VOLPER(III)) 1005,1001,1005
 1005 SUMB1=0.0
      DO 1002 JJJ=1,10
      IF (VOLPER(JJJ)) 1191,1002,1191
 1191 IF (III-JJJ) 1003,1002,1003
 1003 PHIIJ=(1.0+SQRT(VI(T1,III,IQF)/VI(T1,JJJ,IQF))*(AM(JJJ)/ AM(III))*
     1*(1.0/4.0))**2/(2.82842712*SQRT(1.0+AM(III)/AM(JJJ)))
      SUMB1=SUMB1+PHIIJ*VOLPER(JJJ)/VOLPER(III)
 1002 CONTINUE
      XMU=XMU+VI(T1,III,IQF)/(1.0+SUMB1)
 1001 CONTINUE
      XMU=XMU*.1
      XKIN=10.0*XMU/RHO*.00001
      AMASS=AMASS+(10.0**5)*(RHO*XRHO)**(.5)
      XRHO=RHO
      IF (ZZ-ZSLOP) 116,116,118
  118 NQV=M/ISLOP
      ZZQV=NQV
      IF (ZZ/SLOP-ZZQV) 16,16,15
  116 IF (ZZ-ZFLOP) 27,27,20
   20 NM=M/IFLOP
      ZZM=NM
      IF (ZZ/FLOP-ZZM) 16,16,15
   27 IF (ZZ-ZFLIP) 16,16,18
   18 NK=M/IFLIP
      ZZP=NK
      IF (ZZ/FLIP-ZZP) 16,16,15
   16 WRITE (6,31) M,T1,PB,RHO,SPEED,XMO,HRHO,XNUMDN,ZONK,XMU,HPRES,VBAR
     1,XNU,AMASS
   31 FORMAT (1X,I4,F9.1,1P2E10.2,0PF8.0,1X, 0PF8.1,0PF9.2,1P2E10.2,0PF8
     1.2,0PF7.2,0PF6.0,1PE10.2,1PE11.3)
      ET1(K)=T1*1.8
      EPB(K)=PB*14.7/1013.0
      ERHO(K)=RHO*1.943
      ESPEED(K)=SPEED*3.281
      EHPRES(K)=HPRES*0.003281
      EHRHO(K)=HRHO*0.003281
      ENUMDN(K)=XNUMDN*28320.0
      EVBAR(K)=VBAR*3.281
      EXMU(K)=XMU*0.67195*3.108
      EXKIN(K)=XKIN*0.0010764
      EZZ(K)=ZZ*0.003281
      EXBAR(K)=XBAR*0.03281
      EOMEGA(K)=ERHO(1)*GB/30.48
      K=K+1
   15 CONTINUE
   10 CONTINUE
      CMASS=AMASS
      CARBON=VOLPER(2)*CMASS*44.011/(XMOLW)
      WRITE (6,50) CMASS,CARBON
   50 FORMAT (/ ,10X,16HCOLUMNAR MASS = ,F8.3,2X,5HGM/CC,20X,23HCOLUMNAR
     1 MASS FOR CO2 = ,F8.3,2X,5HGM/CC)
      ERAD=RAD*0.621
      ECMASS=CMASS*0.06375
```

```
      WRITE (6,1)NA,ME,INF,Q000FL
      WRITE (6,64)DA,TE
   64 FORMAT (2X,23HCONSTRUCTION PARAMETERS,26X,17HENGINEERING UNITS,35X
     1,5HDATE ,A5,A3,///)
      WRITE (6,67) EP0,ET0,ERHN,VOLPER(2),XMOLW,EG0
   67 FORMAT (2X,19HSURFACE PRESSURE = ,F8.3,9H LB/SQ IN,5X,22HSURFACE T
     1EMPERATURE = ,F5.1,2H R,5X,18HSURFACE DENSITY = ,1PE9.2,11H SLUG/C
     2U FT,//,2X,26HPER CENT CARBON DIOXIDE = ,2PF5.1,10X,19HMOLECULAR W
     3EIGHT = ,0PF5.2,13X,18HSURFACE GRAVITY = ,0PF6.2,11H FT/SEC/SEC,//
     4//)
      WRITE (6,68)
      WRITE (6,62)
   62 FORMAT (86X,4HMEAN,7X,4HMEAN,/,2X,120HHEIGHT     TEMP     PRESSURE
     1  DENSITY    SPEED     SPECIFIC  PRES     DENS     NUMBER    PARTICLE
     2 FREE      VIS-      KINETIC,/,33X,87H(SLUG/    OF SOUND   WEIGHT   S
     3CALE    SCALE   DENSITY  VELOCITY   PATH      COSITY     VISC,/,2X,48H
     4(MIL.FT)   (R)     (LB/SQ IN)     CU FT)   (FT/SEC),14X,47H(MIL,FT)
     5 (PER CU FT) (FT/SEC)   (FT)      (E+5),//)
      DO 115 N=1,IENDG
      WRITE (6,65)EZZ(N),ET1(N),EPB(N),ERHO(N),ESPEED(N),     EOMEGA(N),E
     1HPRES(N),EHRHO(N),ENUMDN(N),EVBAR(N),EXBAR(N),EXMU(N), EXKIN(N)
      ERHO(N)=ERHO(N)*10.0**15
  115 CONTINUE
   65 FORMAT (2X,F7.4,F8.1,1PE11.2,1PE11.2,0PF9.0,1PE11.1,0PF8.3,0PF7.3,
     11PE11.1,0PF7.0,1PE10.1,0PF9.2,1PE11.1)
      WRITE (6,60)ECMASS,ERAD
   60 FORMAT (////,10X,16HCOLUMNAR MASS = ,F6.3,11H SLUG/SQ FT,10X,
     119HPLANETARY RADIUS = ,F7.1,6H MILES)
      GO TO 25
      END
```

```
      SUBROUTINE BET(Z,PQ,TQ,TMQ,XMQ,DTDZ)
      DIMENSION H(90),TM(90),XM(90),P(90),T(90),VIS(10),RAT(10),AM(10)
      COMMON H,TM,XM,P,GO,RAD,L,RO,XMOLW,T,TMQ1,XH1,XMQ1,P1,VIS,RAT,AM
      XH=Z*RAD/(RAD+Z)
      DO 1 I=2,L
      IF (H(I)-XH) 1,2,3
    1 CONTINUE
    3 I=I-1
      IF (H(1)-XH) 4,45,4
   45 PQ=P(1)
      TQ=T(1)
      XMQ=XM(1)
      TMQ=TQ*XMOLW/XMQ
      GO TO 9
    2 TQ=T(I)
      XMQ=XM(I)
      TMQ=TQ*XMOLW/XMQ
      GO TO 25
    4 DTDH=( T(I+1)- T(I))/(H(I+1)-H(I))
      TQ=T(I)+DTDH*(XH-H(I))
      DMDH=(XM(I+1)-XM(I))/(H(I+1)-H(I))
      XMQ=XM(I)+DMDH*(XH-H(I))
      TMQ=TQ*XMOLW/XMQ
   25 DTDH=(TMQ-TMQ1)/(XH-XH1)
      IF (DTDH) 5,6,5
    5 PQ=P1   *(TMQ1 /TMQ)**( GO*XMOLW*1.0E+05/(RO*DTDH))
      GO TO 9
    6 PQ=P1   *EXP(-GO*XMOLW*1.0E+05/(RO*TMQ)*(XH-XH1))
    9 T1=TMQ1*XMQ1/XMOLW
      DTDZ=TMQ-TMQ1
      XH1=XH
      TMQ1=TMQ
      XMQ1=XMQ
      P1=PQ
      RETURN
      END
```

```
      SUBROUTINE DET(Z,PQ,TQ,TMQ,XMQ,DTDZ)
      DIMENSION H(90),TM(90),XM(90),P(90),T(90),VIS(10),RAT(10),AM(10)
      COMMON H,TM,XM,P,GO,RAD,L,RO,XMOLW,T,TMQ1,XH1,XMQ1,P1,VIS,RAT,AM
      XH=Z*RAD/(RAD*Z)
      DO 1 I=2,L
      IF (H(I)-XH) 1,2,3
    1 CONTINUE
    3 I=I-1
      IF (H(1)-XH) 4,45,4
   45 PQ=P(1)
      TQ=T(1)
      XMQ=XM(1)
      TMQ=TM(1)
      GO TO 9
    2 TMQ=TM(I)
      XMQ=XM(I)
      TQ=T(I)
      PQ=P(I)
      GO TO 9
    4 DTDH=(TM(I+1)-TM(I))/(H(I+1)-H(I))
      TMQ=TM(I)+DTDH*(XH-H(I))
      TQ=T(I)+(XH-H(I))*(T(I+1)-T(I))/(H(I+1)-H(I))
      XMQ=TQ*XMOLW/TMQ
      IF (DTDH) 5,6,5
    5 PQ=P(I)*(TM(I)/TMQ)**( GO*XMOLW*1.0E+05/(RO*DTDH))
      GO TO 9
    6 PQ=P(I)*EXP(-GO*XMOLW*1.0E+05/(RO*TMQ)*(XH-H(I)))
    9 T1=TMQ1*XMQ1/XMOLW
      DTDZ=TMQ-TMQ1
      TMQ1=TMQ
      XMQ1=XMQ
      RETURN
      END
```

```
      FUNCTION OMEG (XT,J,IQF)
      DIMENSION H(90),TM(90),XM(90),P(90),T(90),VIS(10),RAT(10),AM(10),Q
     1T(7),OM(7,10)
      COMMON H,TM,XM,P,G0,RAD,L,R0,XMOLW,T,TMQ1,XH1,XMQ1,P1,VIS,RAT,AM
      IF (IQF) 9,8,9
    8 CONTINUE
      QT(1)=100.0
      QT(2)=200.0
      QT(3)=300.0
      QT(4)=400.0
      QT(5)=500.0
      QT(6)=600.0
      QT(7)=700.0
C OM( ,1) IS NITROGEN (MOLECULAR I.E.  N2)
      OM(1,1)=13.36
      OM(2,1)=11.47
      OM(3,1)=9.60
      OM(4,1)=9.43
      OM(5,1)=9.137
      OM(6,1)=8.68
      OM(7,1)=8.509
C OM( ,2) IS CARBON DIOXIDE
      OM(1,2)=23.604
      OM(2,2)=15.708
      OM(3,2)=13.26
      OM(4,2)=11.62
      OM(5,2)=10.73
      OM(6,2)=10.28
      OM(7,2)=9.83
C OM( ,3) IS OXYGEN (MOLECULAR I.E. O2)
      OM(1,3)=16.12
      OM(2,3)=11.7
      OM(3,3)=10.22
      OM(4,3)=9.45
      OM(5,3)=9.10
      OM(6,3)=8.81
      OM(7,3)=8.59
C OM( ,4) IS ARGON
      OM(1,4)=17.15
      OM(2,4)=12.58
      OM(3,4)=10.75
      OM(4,4)=10.00
      OM(5,4)=9.65
      OM(6,4)=9.49
      OM(7,4)=8.86
C OM( ,5) IS NEON
      OM(1,5)=9.72
      OM(2,5)=8.65
      OM(3,5)=8.239
      OM(4,5)=7.903
      OM(5,5)=7.470
      OM(6,5)=7.422
      OM(7,5)=7.203
C OM( ,6) IS HYDROGEN (MOLECULAR I.E. H2)
      OM(1,6)=11.04
      OM(2,6)=9.28
      OM(3,6)=8.53
```

```
      OM(4,6)=8.18
      OM(5,6)=8.11
      OM(6,6)=7.80
      OM(7,6)=7.52
C OM( ,7) IS HELIUM
      OM(1,7)=8.13
      OM(2,7)=7.2
      OM(3,7)=6.97
      OM(4,7)=6.62
      OM(5,7)=6.43
      OM(6,7)=6.28
      OM(7,7)=6.05
C OM( ,8) IS WATER (H2O)
      OM(1,8)=37.27
      OM(2,8)=23.89
      OM(3,8)=20.14
      OM(4,8)=17.48
      OM(5,8)=15.92
      OM(6,8)=14.57
      OM(7,8)=13.52
C OM( ,9)=CARBON MONOXIDE
      OM(1,9)=15.58
      OM(2,9)=11.27
      OM(3,9)=10.28
      OM(4,9)=9.49
      OM(5,9)=9.05
      OM(6,9)=8.76
      OM(7,9)=8.50
C OM( ,10) IS SULFUR DIOXIDE
      OM(1,10)=24.21
      OM(2,10)=17.96
      OM(3,10)=14.69
      OM(4,10)=12.91
      OM(5,10)=11.92
      OM(6,10)=11.03
      OM(7,10)=10.60
    9 DO 1 I=1,7
      IF (QT(I)-XT) 1,2,3
    1 CONTINUE
      GO TO 2
    3 IF (I-1) 6,2,6
    6 I=I-1
      OMEG=(OM(I+1,J)-OM(I,J))/(QT(I+1)-QT(I))*(XT-QT(I))+OM(I,J)
      GO TO 4
    2 OMEG=OM(I,J)
    4 RETURN
      END
```

```
      FUNCTION CPS (T1,J,IQF)
      DIMENSION H(90),TM(90),XM(90),P(90),T(90),VIS(10),RAT(10),AM(10),Q
     1T(7),CP(7,10)
      COMMON H,TM,XM,P,G0,RAD,L,R0,XMOLW,T,TMQ1,XH1,XMQ1,P1,VIS,RAT,AM
      IF (IQF) 9,8,9
    8 CONTINUE
      QT(1)=100.0
      QT(2)=200.0
      QT(3)=300.0
      QT(4)=400.0
      QT(5)=500.0
      QT(6)=600.0
      QT(7)=700.0
C CP( ,1) =NITROGEN
      CP(1,1) =6.9562
      CP(2,1) =6.9571
      CP(3,1) =6.9613
      CP(4,1) =6.9910
      CP(5,1) =7.0703
      CP(6,1) =7.1968
      CP(7,1) =7.3509
C CP( ,2) = CARBON DIOXIDE
      CP(1,2) =6.9806
      CP(2,2) =7.7331
      CP(3,2) =8.8942
      CP(4,2) =9.8762
      CP(5,2) =10.6646
      CP(6,2)=11.3098
      CP(7,2) =11.8456
C CP( ,3) = MOLECULAR OXYGEN
      CP(1,3) =6.9567
      CP(2,3) =6.9615
      CP(3,3) =7.0237
      CP(4,3) =7.1961
      CP(5,3) =7.4315
      CP(6,3) =7.6704
      CP(7,3) =7.8837
C CP( ,4) = ARGON
      CP(1,4) =4.9681
      CP(2,4) =4.9681
      CP(3,4) =4.9681
      CP(4,4) =4.9681
      CP(5,4) =4.9681
      CP(6,4) =4.9681
      CP(7,4) =4.9681
C CP( ,5) = NEON
      CP(1,5) = 4.9681
      CP(2,5) = 4.9681
      CP(3,5) = 4.9681
      CP(4,5) = 4.9681
      CP(5,5) = 4.9681
      CP(6,5) = 4.9681
      CP(7,5) = 4.9681
```

```
C CP( ,6) = HYDROGEN
      CP(1,6)=5,3934
      CP(2,6)=6,5182
      CP(3,6)=6,8938
      CP(4,6)=6,9753
      CP(5,6)=6,9932
      CP(6,6)=7,0091
      CP(7,6)=7,0369
C CP( ,7) = HELIUM
      CP(1,7) =4,9681
      CP(2,7) =4,9681
      CP(3,7) =4,9681
      CP(4,7) =4,9681
      CP(5,7) =4,9681
      CP(6,7) =4,9681
      CP(7,7) =4,9681
C CP( ,8) = WATER
      CP(1,8)=7,9606
      CP(2,8)=7,9694
      CP(3,8)=8,0276
      CP(4,8)=8,1864
      CP(5,8)=8,4161
      CP(6,8)=8,6779
      CP(7,8)=8,9571
C CP( ,9) = CARBON MONOXIDE
      CP(1,9)=6,9564
      CP(2,9)=6,9574
      CP(3,9)=6,9656
      CP(4,9)=7,0129
      CP(5,9)=7,1211
      CP(6,9)=7,2760
      CP(7,9)=7,4507
C CP( ,10) = SULFUR DIOXIDE
      CP(1,10)=8,0134
      CP(2,10)=8,6948
      CP(3,10)=9,5451
      CP(4,10)=10,3919
      CP(5,10)=11,1292
      CP(6,10)=11,7189
      CP(7,10)=12,1755
    9 DO 1 I=1,7
      IF (QT(I)-T1) 1,2,3
    1 CONTINUE
      GO TO 2
    3 I=I-1
      CPS =(CP(I+1,J)-CP(I,J))/(QT(I+1)-QT(I))*(T1-QT(I))+CP(I,J)
      GO TO 4
    2 CPS=CP(I,J)
    4 RETURN
      END
```

TABLE I. - THE LEGEND FOR THE MODEL ATMOSPHERES

Computer printout heading	Parameter	Units	
		Scientific	Engineering
Height	Geometric height	km	ft $\times 10^6$
Temp	Temperature	$^\circ$K	$^\circ$R
Pressure	Pressure	mb	lb in.$^{-2}$
Density	Density	gcm^{-3}	slug ft^{-3}
Speed of sound	Speed of sound	m sec^{-1}	ft sec^{-1}
Molecular weight	Molecular weight	g(g mole)$^{-1}$	g(g mole)$^{-1}$
Dens scale	Density scale height	km	ft $\times 10^6$
Number density	Number density	cm^{-3}	ft^{-3}
Mean free path	Mean free path	m	ft
Viscosity	Coefficient of viscosity	kg-m^{-1}sec^{-1} $\times 10^5$	slug ft^{-1}sec^{-1} $\times 10^5$
Pres scale	Pressure scale height	km	ft $\times 10^6$
Mean particle velocity	Mean particle velocity	m-sec^{-1}	ft sec^{-1}
Coll freq	Collision frequency	sec^{-1}	-
Columnar mass	Columnar mass	g-cm^{-2}	-
Kinetic viscosity	Kinematic viscosity	-	ft^{2}sec^{-1}
Specific weight	Specific weight	-	slug ft^{-2}sec^{-2}

TABLE II. - TYPICAL CONSTRUCTION PARAMETERS FOR A MARS MODEL ATMOSPHERE

Surface Boundary Conditions		
Parameter	Symbol	Value
Mean acceleration caused by gravity at the surface	g_0, cm sec^{-2}	375.0
Planetary radius	r, km	3381.0
Atmospheric temperature near the surface	T, °K	210.0
Mean molecular mass	m, g$\left(\text{g mole}^{-1}\right)$	44.011
Atmospheric pressure near the surface	P, mb	5.0
CO_2, volume percent	$X_2 \times 100$	100.0

Temperature and Molecular Weight Distribution		
Z, km	T, °K	m
14	140	44.011
70	104.19	44.011
90	91.39	41.05
100	85.0	35.265
110	85.0	29.48
150	85.0	16.84
200	85.0	16.0
1000	85.0	16.0

TABLE III. - MODEL ATMOSPHERE FOR MARS

MODEL ATMOSPHERE FOR MARS LOWER

CONSTRUCTION PARAMETERS SCIENTIFIC UNITS DATE 9/20/67

SURFACE PRESSURE =	5.00 MB	SURFACE TEMPERATURE =	210.00 K	SURFACE DENSITY =	1.26-05 GM/CC
BASE OF EXOSPHERE =	4000.00(KM)	MOLECULAR WEIGHT =	44.010	SURFACE GRAVITY =	375.000 CM/SEC/SEC
RADIUS OF MARS =	3381.00(KM)	PERCENT NITROGEN =	.000	PERCENT CO2 =	100.000
PERCENT OXYGEN =	.000	PERCENT ARGON =	.000	PERCENT NEON =	.000
PERCENT HYDROGEN =	.000	PERCENT HELIUM =	.000	PERCENT WATER =	.000
PERCENT CO =	.000	PERCENT SO2 =	.000		

TEMPERATURE AND MOLECULAR WEIGHT DISTRIBUTION.

AT	14.00	GEOM KM	TEMPERATURE=	140.00 K	AND MOLECULAR WEIGHT=	44.01100
AT	70.00	GEOM KM	TEMPERATURE=	104.19 K	AND MOLECULAR WEIGHT=	44.01100
AT	90.00	GEOM KM	TEMPERATURE=	91.39 K	AND MOLECULAR WEIGHT=	41.05000
AT	100.00	GEOM KM	TEMPERATURE=	85.00 K	AND MOLECULAR WEIGHT=	35.26500
AT	110.00	GEOM KM	TEMPERATURE=	85.00 K	AND MOLECULAR WEIGHT=	29.48000
AT	150.00	GEOM KM	TEMPERATURE=	85.00 K	AND MOLECULAR WEIGHT=	16.84000
AT	200.00	GEOM KM	TEMPERATURE=	85.00 K	AND MOLECULAR WEIGHT=	16.00000
AT	1000.00	GEOP KM	TEMPERATURE=	85.00 K	AND MOLECULAR WEIGHT=	16.00000

CALCULATED QUANTITIES

HEIGHT (KM)	TEMP (K)	PRESSURE (MB)	DENSITY (GM/CC)	SPEED OF SOUND (M/SEC)	MOLECULAR WEIGHT	DENS SCALE (KM)	NUMBER DENSITY (PER CC)	MEAN FREE PATH (M)	VIS-COSITY (E+5)	PRES SCALE (KM)	MEAN PARTICLE VELOCITY (M/SEC)	COLL FREQ (PER SEC)	COLUMNAR MASS
0	210.0	5.00+00	1.26-05	230.	44.0	14.16	1.72+17	8.36-06	1.06	10.58	318.	3.80+07	0.000
5	184.9	3.02+00	8.66-06	217.	44.0	12.51	1.18+17	1.22-05	.91	9.34	298.	2.45+07	5.272+00
10	159.9	1.70+00	5.64-06	203.	44.0	10.85	7.72+16	1.87-05	.76	8.11	277.	1.49+07	8.809+00
15	139.4	8.74-01	3.32-06	190.	44.0	7.32	4.54+16	3.17-05	.65	7.08	259.	8.16+06	1.104+01
20	136.1	4.28-01	1.67-06	188.	44.0	7.18	2.28+16	6.32-05	.64	6.94	256.	4.05+06	1.224+01
25	132.9	2.07-01	8.24-07	186.	44.0	7.03	1.13+16	1.28-04	.62	6.79	253.	1.98+06	1.283+01
30	129.6	9.83-02	4.01-07	184.	44.0	6.87	5.49+15	2.63-04	.61	6.65	250.	9.51+05	1.313+01
35	126.4	4.59-02	1.92-07	182.	44.0	6.72	2.63+15	5.48-04	.59	6.50	247.	4.50+05	1.327+01
40	123.2	2.11-02	9.06-08	180.	44.0	6.57	1.24+15	1.16-03	.58	6.36	243.	2.10+05	1.334+01
45	120.0	9.52-03	4.20-08	177.	44.0	6.42	5.75+14	2.51-03	.56	6.21	240.	9.58+04	1.337+01
50	116.8	4.21-03	1.91-08	175.	44.0	6.27	2.61+14	5.52-03	.55	6.06	237.	4.30+04	1.338+01
55	113.7	1.83-03	8.51-09	173.	44.0	6.12	1.17+14	1.24-02	.54	5.91	234.	1.89+04	1.339+01
60	110.5	7.77-04	3.72-09	170.	44.0	5.96	5.00+13	2.83-02	.52	5.77	231.	8.14+03	1.339+01
65	107.3	3.23-04	1.59-09	168.	44.0	5.81	2.18+13	6.62-02	.51	5.62	227.	3.43+03	1.339+01
70	104.2	1.31-04	6.65-10	166.	44.0	5.65	9.10+12	1.58-01	.50	5.47	224.	1.41+03	1.339+01
75	101.0	5.22-05	2.69-10	165.	43.3	5.49	3.74+12	3.85-01	.48	5.41	222.	5.77+02	1.339+01
80	97.8	2.06-05	1.08-10	163.	42.5	5.43	1.52+12	9.45-01	.48	5.34	221.	2.33+02	1.339+01
85	94.6	8.02-06	4.26-11	163.	41.8	5.36	6.14+11	2.35+00	.47	5.27	219.	9.33+01	1.339+01
90	91.4	3.09-06	1.67-11	160.	41.0	5.30	2.45+11	5.89+00	.46	5.20	217.	3.69+01	1.339+01
95	88.2	1.20-06	6.26-12	163.	38.2	5.20	9.89+10	1.46+01	.45	5.42	221.	1.52+01	1.339+01
100	85.0	4.88-07	2.44-12	166.	35.3	5.40	4.16+10	3.47+01	.44	5.66	226.	6.52+00	1.339+01
110	85.0	9.70-08	4.05-13	182.	29.5	6.03	8.26+09	1.74+02	.44	6.82	247.	1.42+00	1.339+01
120	85.0	2.43-08	9.04-14	193.	26.3	7.04	2.07+09	6.96+02	.44	7.69	262.	3.76-01	1.339+01
130	85.0	7.18-09	2.35-14	206.	23.1	7.86	6.12+08	2.36+03	.44	8.79	279.	1.19-01	1.339+01
140	85.0	2.49-09	7.05-15	221.	20.0	8.83	2.13+08	6.78+03	.44	10.23	300.	4.43-02	1.339+01
150	85.0	1.02-09	2.42-15	241.	16.8	9.90	8.66+07	1.66+04	.44	12.21	327.	1.96-02	1.339+01

TABLE III. - MODEL ATMOSPHERE FOR MARS - CONTINUED

160	85.0	4.51-10	1.06-15	242.	16.7	12.25	3.84+07	3.25+04	.44	12.40	329.	8.76-03	1.339+01
170	85.0	2.03-10	4.73-16	243.	16.5	12.44	1.73+07	6.35+04	.44	12.60	330.	3.95-03	1.339+01
180	85.0	9.22-11	2.13-16	245.	16.3	12.63	7.95+06	1.84+05	.44	12.80	332.	1.81-03	1.339+01
190	85.0	4.25-11	9.71-17	246.	16.2	12.83	3.62+06	3.98+05	.44	13.00	334.	8.37-04	1.339+01
200	85.0	1.96-11	4.48-17	247.	16.0	13.04	1.62+06	8.54+05	.44	13.21	335.	3.93-04	1.339+01
210	85.0	9.31-12	2.11-17	247.	16.0	13.29	7.93+05	1.82+06	.44	13.29	335.	1.95-04	1.339+01
220	85.0	4.39-12	9.95-18	247.	16.0	13.36	3.70+05	3.85+06	.44	13.36	335.	8.71-05	1.339+01
230	85.0	2.06-12	4.72-18	247.	16.0	13.44	1.78+05	8.12+06	.44	13.44	335.	4.13-05	1.339+01
240	85.0	9.92-13	2.25-18	247.	16.0	13.51	8.45+04	1.71+07	.44	13.51	335.	1.97-05	1.339+01
250	85.0	4.74-13	1.07-18	247.	16.0	13.58	4.04+04	3.57+07	.44	13.58	335.	9.40-06	1.339+01
260	85.0	2.28-13	5.15-19	247.	16.0	13.66	1.94+04	7.43+07	.44	13.66	335.	4.51-06	1.339+01
270	85.0	1.10-13	2.48-19	247.	16.0	13.73	9.34+03	1.54+08	.44	13.73	335.	2.17-06	1.339+01
280	85.0	5.30-14	1.20-19	247.	16.0	13.81	4.52+03	3.19+08	.44	13.81	335.	1.05-06	1.339+01
290	85.0	2.58-14	5.83-20	247.	16.0	13.89	2.20+03	6.56+08	.44	13.89	335.	5.11-07	1.339+01
300	85.0	1.26-14	2.84-20	247.	16.0	13.96	1.07+03	1.35+09	.44	13.96	335.	2.49-07	1.339+01
310	85.0	6.15-15	1.39-20	247.	16.0	14.04	5.24+02	2.75+09	.44	14.04	335.	1.22-07	1.339+01
320	85.0	3.02-15	6.84-21	247.	16.0	14.11	2.58+02	5.60+09	.44	14.11	335.	5.99-08	1.339+01
330	85.0	1.49-15	3.36-21	247.	16.0	14.19	1.27+02	1.13+10	.44	14.19	335.	2.96-08	1.339+01
340	85.0	7.38-16	1.67-21	247.	16.0	14.27	6.29+01	2.29+10	.44	14.27	335.	1.46-08	1.339+01
350	85.0	3.67-16	8.31-22	247.	16.0	14.34	3.13+01	4.61+10	.44	14.34	335.	7.28-09	1.339+01
360	85.0	1.83-16	4.14-22	247.	16.0	14.42	1.56+01	9.24+10	.44	14.42	335.	3.63-09	1.339+01
370	85.0	9.17-17	2.08-22	247.	16.0	14.50	7.81+00	1.84+11	.44	14.50	335.	1.82-09	1.339+01
380	85.0	4.61-17	1.04-22	247.	16.0	14.58	3.93+00	3.67+11	.44	14.58	335.	9.14-10	1.339+01
390	85.0	2.32-17	5.26-23	247.	16.0	14.65	1.98+00	7.28+11	.44	14.65	335.	4.61-10	1.339+01
400	85.0	1.19-17	2.66-23	247.	16.0	14.73	1.00+00	1.44+12	.44	14.73	335.	2.33-10	1.339+01
410	85.0	5.98-18	1.35-23	247.	16.0	14.81	5.10-01	2.83+12	.44	14.81	335.	1.19-10	1.339+01
420	85.0	3.05-18	6.90-24	247.	16.0	14.89	2.60-01	5.55+12	.44	14.89	335.	6.05-11	1.339+01
430	85.0	1.56-18	3.53-24	247.	16.0	14.97	1.33-01	1.08+13	.44	14.97	335.	3.09-11	1.339+01
440	85.0	8.01-19	1.81-24	247.	16.0	15.04	6.83-02	2.11+13	.44	15.04	335.	1.59-11	1.339+01
450	85.0	4.13-19	9.35-25	247.	16.0	15.12	3.52-02	4.10+13	.44	15.12	335.	8.19-12	1.339+01
460	85.0	2.13-19	4.83-25	247.	16.0	15.20	1.82-02	7.92+13	.44	15.20	335.	4.23-12	1.339+01
470	85.0	1.11-19	2.51-25	247.	16.0	15.28	9.44-03	1.53+14	.44	15.28	335.	2.20-12	1.339+01
480	85.0	5.77-20	1.31-25	247.	16.0	15.36	4.91-03	2.93+14	.44	15.36	335.	1.14-12	1.339+01
490	85.0	3.01-20	6.82-26	247.	16.0	15.44	2.57-03	5.61+14	.44	15.44	335.	5.97-13	1.339+01
500	85.0	1.58-20	3.58-26	247.	16.0	15.52	1.35-03	1.07+15	.44	15.52	335.	3.13-13	1.339+01
550	85.0	6.56-22	1.49-27	247.	16.0	15.92	5.59-05	2.58+16	.44	15.92	335.	1.30-14	1.339+01
600	85.0	2.95-23	6.69-29	247.	16.0	16.33	2.52-06	5.73+17	.44	16.33	335.	5.86-16	1.339+01
650	85.0	1.44-24	3.25-30	247.	16.0	16.74	1.22-07	1.18+19	.44	16.74	335.	2.85-17	1.339+01
700	85.0	7.52-26	1.70-31	247.	16.0	17.16	6.41-09	2.25+20	.44	17.16	335.	1.49-18	1.339+01
750	85.0	4.23-27	9.57-33	247.	16.0	17.58	3.60-10	4.00+21	.44	17.58	335.	8.38-20	1.339+01
800	85.0	2.55-28	5.76-34	247.	16.0	18.01	2.17-11	6.64+22	.44	18.01	335.	5.05-21	1.339+01
850	85.0	1.64-29	3.71-35	247.	16.0	18.45	1.40-12	1.03+24	.44	18.45	335.	3.25-22	1.339+01
900	85.0	1.12-30	2.55-36	247.	16.0	18.88	9.59-14	1.50+25	.44	18.88	335.	2.23-23	1.339+01
950	85.0	8.21-32	1.86-37	247.	16.0	19.33	7.00-15	2.06+26	.44	19.33	335.	1.63-24	1.339+01
1000	85.0	6.36-33	1.44-38	247.	16.0	19.78	5.42-16	2.66+27	.44	19.78	335.	1.26-25	1.339+01

COLUMNAR MASS = 13.395 GM/CC COLUMNAR MASS FOR CO2 = 13.395 GM/CC

TABLE III. - MODEL ATMOSPHERE FOR MARS - CONTINUED

MODEL ATMOSPHERE FOR MARS — LOWER

CONSTRUCTION PARAMETERS — ENGINEERING UNITS — DATE 9/20/67

SURFACE PRESSURE = .073 LB/SQ IN — SURFACE TEMPERATURE = 378.0 R — SURFACE DENSITY = 2.45-05 SLUG/CU FT

PER CENT CARBON DIOXIDE = 100.0 — MOLECULAR WEIGHT = 44.01 — SURFACE GRAVITY = 12.30 FT/SEC/SEC

CALCULATED QUANTITIES

HEIGHT (MIL.FT)	TEMP (R)	PRESSURE (LB/SQ IN)	DENSITY (SLUG/ CU FT)	SPEED OF SOUND (FT/SEC)	SPECIFIC WEIGHT	PRES SCALE (MIL.FT)	DENS SCALE (MIL.FT)	NUMBER DENSITY (PER CU FT)	MEAN PARTICLE VELOCITY (FT/SEC)	MEAN FREE PATH (FT)	VIS-COSITY (E+5)	KINETIC VISC
.0000	378.0	7.26-02	2.45-05	756.	3.0-04	.035	.046	4.9+21	1043.	2.7-05	2.22	9.1-03
.0164	332.9	4.39-02	1.68-05	713.	3.0-04	.031	.041	3.4+21	979.	4.0-05	1.91	1.1-02
.0328	287.9	2.47-02	1.10-05	666.	3.0-04	.027	.036	2.2+21	910.	6.1-05	1.59	1.5-02
.0492	250.8	1.27-02	6.45-06	624.	3.0-04	.023	.024	1.3+21	849.	1.0-04	1.36	2.1-02
.0656	245.0	6.22-03	3.24-06	617.	3.0-04	.023	.024	6.5+20	840.	2.1-04	1.33	4.1-02
.0820	239.2	3.00-03	1.60-06	610.	3.0-04	.022	.023	3.2+20	830.	4.2-04	1.30	8.1-02
.0984	233.4	1.43-03	7.80-07	603.	3.0-04	.022	.023	1.6+20	819.	8.6-04	1.27	1.6-01
.1148	227.6	6.67-04	3.74-07	596.	3.0-04	.021	.022	7.5+19	809.	1.8-03	1.24	3.3-01
.1312	221.8	3.06-04	1.76-07	589.	2.9-04	.021	.022	3.5+19	799.	3.8-03	1.21	6.9-01
.1476	216.1	1.38-04	8.16-08	582.	2.9-04	.020	.021	1.6+19	788.	8.2-03	1.18	1.4+00
.1640	210.3	6.12-05	3.71-08	574.	2.9-04	.020	.021	7.4+18	778.	1.8-02	1.15	3.1+00
.1805	204.6	2.65-05	1.65-08	567.	2.9-04	.019	.020	3.3+18	767.	4.1-02	1.12	6.8+00
.1969	198.9	1.13-05	7.23-09	559.	2.9-04	.019	.020	1.4+18	756.	9.3-02	1.09	1.5+01
.2133	193.2	4.68-06	3.09-09	551.	2.9-04	.018	.019	6.2+17	746.	2.2-01	1.07	3.5+01
.2297	187.5	1.90-06	1.29-09	544.	2.9-04	.018	.019	2.6+17	735.	5.2-01	1.04	8.1+01
.2461	181.8	7.57-07	5.22-10	540.	2.9-04	.018	.018	1.1+17	729.	1.3+00	1.01	1.9+02
.2625	176.0	2.99-07	2.09-10	536.	2.9-04	.018	.018	4.3+16	724.	3.1+00	.99	4.8+02
.2789	170.2	1.16-07	8.28-11	535.	2.9-04	.017	.018	1.7+16	718.	7.7+00	.98	1.2+03
.2953	164.5	4.48-08	3.24-11	525.	2.9-04	.017	.017	6.9+15	712.	1.9+01	.96	3.0+03
.3117	158.7	1.75-08	1.22-11	535.	2.9-04	.018	.017	2.8+15	726.	4.8+01	.94	7.8+03
.3281	153.0	7.08-09	4.73-12	546.	2.8-04	.019	.018	1.2+15	741.	1.1+02	.93	2.0+04
.3609	153.0	1.41-09	7.86-13	597.	2.8-04	.022	.020	2.3+14	811.	5.7+02	.93	1.2+05
.3937	153.0	3.53-10	1.76-13	633.	2.8-04	.025	.023	5.9+13	858.	2.3+03	.93	5.3+05
.4265	153.0	1.04-10	4.57-14	675.	2.8-04	.029	.026	1.7+13	915.	7.7+03	.93	2.0+06
.4593	153.0	3.62-11	1.37-14	726.	2.8-04	.034	.029	6.0+12	985.	2.2+04	.93	6.8+06
.4921	153.0	1.47-11	4.71-15	790.	2.8-04	.040	.033	2.5+12	1073.	5.5+04	.93	2.0+07
.5250	153.0	6.54-12	2.07-15	794.	2.7-04	.041	.040	1.1+12	1078.	1.2+05	.93	4.5+07
.5578	153.0	2.94-12	9.19-16	799.	2.7-04	.041	.041	4.9+11	1084.	2.7+05	.93	1.0+08
.5906	153.0	1.34-12	4.14-16	803.	2.7-04	.042	.041	2.2+11	1089.	6.0+05	.93	2.2+08
.6234	153.0	6.16-13	1.89-16	807.	2.7-04	.043	.042	1.0+11	1095.	1.3+06	.93	4.9+08
.6562	153.0	2.87-13	8.71-17	811.	2.7-04	.043	.043	4.8+10	1100.	2.8+06	.93	1.1+09
.6890	153.0	1.35-13	4.09-17	811.	2.7-04	.044	.044	2.2+10	1100.	6.0+06	.93	2.3+09
.7218	153.0	6.38-14	1.93-17	811.	2.7-04	.044	.044	1.1+10	1100.	1.3+07	.93	4.8+09
.7546	153.0	3.02-14	9.16-18	811.	2.6-04	.044	.044	5.0+09	1100.	2.7+07	.93	1.0+10
.7874	153.0	1.44-14	4.30-18	811.	2.6-04	.044	.044	2.4+09	1100.	5.6+07	.93	2.1+10

TABLE III. - MODEL ATMOSPHERE FOR MARS - CONCLUDED

.8202	153.0	6.88-15	2.09-18	811.	2.6-04	.045	.045	1.1+09	1100.	1.2+08	.93	4.4+10
.8531	153.0	3.30-15	1.00-18	811.	2.6-04	.045	.045	5.5+08	1100.	2.4+08	.93	9.3+10
.8859	153.0	1.59-15	4.82-19	811.	2.6-04	.045	.045	2.6+08	1100.	5.1+08	.93	1.9+11
.9187	153.0	7.70-16	2.33-19	811.	2.6-04	.045	.045	1.3+08	1100.	1.0+09	.93	4.0+11
.9515	153.0	3.74-16	1.13-19	811.	2.6-04	.046	.046	6.2+07	1100.	2.2+09	.93	8.2+11
.9843	153.0	1.82-16	5.53-20	811.	2.5-04	.046	.046	3.0+07	1100.	4.4+09	.93	1.7+12
1.0171	153.0	8.92-17	2.71-20	811.	2.5-04	.046	.046	1.5+07	1100.	9.0+09	.93	3.4+12
1.0499	153.0	4.39-17	1.33-20	811.	2.5-04	.046	.046	7.3+06	1100.	1.8+10	.93	7.0+12
1.0827	153.0	2.16-17	6.56-21	811.	2.5-04	.047	.047	3.6+06	1100.	3.7+10	.93	1.4+13
1.1155	153.0	1.07-17	3.25-21	811.	2.5-04	.047	.047	1.8+06	1100.	7.5+10	.93	2.9+13
1.1483	153.0	5.33-18	1.61-21	811.	2.5-04	.047	.047	8.9+05	1100.	1.5+11	.93	5.7+13
1.1812	153.0	2.66-18	8.05-22	811.	2.5-04	.047	.047	4.4+05	1100.	3.0+11	.93	1.2+14
1.2140	153.0	1.33-18	4.03-22	811.	2.4-04	.048	.048	2.2+05	1100.	6.1+11	.93	2.3+14
1.2468	153.0	6.69-19	2.03-22	811.	2.4-04	.048	.048	1.1+05	1100.	1.2+12	.93	4.6+14
1.2796	153.0	3.37-19	1.02-22	811.	2.4-04	.048	.048	5.6+04	1100.	2.4+12	.93	9.1+14
1.3124	153.0	1.71-19	5.18-23	811.	2.4-04	.048	.048	2.8+04	1100.	4.7+12	.93	1.8+15
1.3452	153.0	8.68-20	2.63-23	811.	2.4-04	.049	.049	1.4+04	1100.	9.3+12	.93	3.5+15
1.3780	153.0	4.42-20	1.34-23	811.	2.4-04	.049	.049	7.4+03	1100.	1.8+13	.93	6.9+15
1.4108	153.0	2.26-20	6.86-24	811.	2.4-04	.049	.049	3.8+03	1100.	3.6+13	.93	1.4+16
1.4436	153.0	1.16-20	3.52-24	811.	2.4-04	.049	.049	1.9+03	1100.	6.9+13	.93	2.6+16
1.4764	153.0	5.99-21	1.82-24	811.	2.3-04	.050	.050	1.0+03	1100.	1.3+14	.93	5.1+16
1.5093	153.0	3.10-21	9.39-25	811.	2.3-04	.050	.050	5.2+02	1100.	2.6+14	.93	9.9+16
1.5421	153.0	1.61-21	4.87-25	811.	2.3-04	.050	.050	2.7+02	1100.	5.0+14	.93	1.9+17
1.5749	153.0	8.37-22	2.54-25	811.	2.3-04	.050	.050	1.4+02	1100.	9.6+14	.93	3.7+17
1.6077	153.0	4.37-22	1.33-25	811.	2.3-04	.051	.051	7.3+01	1100.	1.8+15	.93	7.0+17
1.6405	153.0	2.29-22	6.95-26	811.	2.3-04	.051	.051	3.8+01	1100.	3.5+15	.93	1.3+18
1.8045	153.0	9.52-24	2.89-27	811.	2.2-04	.052	.052	1.6+00	1100.	8.5+16	.93	3.2+19
1.9686	153.0	4.29-25	1.30-28	811.	2.2-04	.054	.054	7.1-02	1100.	1.9+18	.93	7.1+20
2.1326	153.0	2.08-26	6.32-30	811.	2.1-04	.055	.055	3.5-03	1100.	3.9+19	.93	1.5+22
2.2967	153.0	1.09-27	3.31-31	811.	2.1-04	.056	.056	1.8-04	1100.	7.4+20	.93	2.8+23
2.4607	153.0	6.13-29	1.86-32	811.	2.0-04	.058	.058	1.0-05	1100.	1.3+22	.93	5.0+24
2.6248	153.0	3.70-30	1.12-33	811.	2.0-04	.059	.059	6.1-07	1100.	2.2+23	.93	8.3+25
2.7888	153.0	2.38-31	7.21-35	811.	1.9-04	.061	.061	4.0-08	1100.	3.4+24	.93	1.3+27
2.9529	153.0	1.63-32	4.95-36	811.	1.9-04	.062	.062	2.7-09	1100.	4.9+25	.93	1.9+28
3.1169	153.0	1.19-33	3.61-37	811.	1.8-04	.063	.063	2.0-10	1100.	6.8+26	.93	2.6+29

COLUMNAR MASS = .854 SLUG/SQ FT   PLANETARY RADIUS = 2099.6 MILES

TABLE IV. - MODEL ATMOSPHERE FOR EARTH

MODEL ATMOSPHERE FOR EARTH U.S.1962

CONSTRUCTION PARAMETERS — SCIENTIFIC UNITS — DATE 9/20/67

SURFACE PRESSURE = 1013.25 MB	SURFACE TEMPERATURE = 288.15 K	SURFACE DENSITY = 1.22-03 GM/CC
BASE OF EXOSPHERE = 4000.00(KM)	MOLECULAR WEIGHT = 28.963	SURFACE GRAVITY = 980.665 CM/SEC/SEC
RADIUS OF EARTH = 6378.40(KM)	PERCENT NITROGEN = 78.080	PERCENT CO2 = .030
PERCENT OXYGEN = 20.950	PERCENT ARGON = .930	PERCENT NEON = .000
PERCENT HYDROGEN = .000	PERCENT HELIUM = .000	PERCENT WATER = .000
PERCENT CO = .000	PERCENT SO2 = .000	

TEMPERATURE AND MOLECULAR WEIGHT DISTRIBUTION,

AT	11.00	GEOP KM	TEMPERATURE=	216.65 K	AND MOLECULAR	WEIGHT=	28.96440
AT	20.00	GEOP KM	TEMPERATURE=	216.65 K	AND MOLECULAR	WEIGHT=	28.96440
AT	32.00	GEOP KM	TEMPERATURE=	228.65 K	AND MOLECULAR	WEIGHT=	28.96440
AT	47.00	GEOP KM	TEMPERATURE=	270.65 K	AND MOLECULAR	WEIGHT=	28.96440
AT	52.00	GEOP KM	TEMPERATURE=	270.65 K	AND MOLECULAR	WEIGHT=	28.96440
AT	61.00	GEOP KM	TEMPERATURE=	252.65 K	AND MOLECULAR	WEIGHT=	28.96440
AT	79.00	GEOP KM	TEMPERATURE=	180.65 K	AND MOLECULAR	WEIGHT=	28.96440
AT	90.00	GEOM KM	TEMPERATURE=	180.65 K	AND MOLECULAR	WEIGHT=	28.96440
AT	100.00	GEOM KM	TEMPERATURE=	210.02 K	AND MOLECULAR	WEIGHT=	28.87777
AT	110.00	GEOM KM	TEMPERATURE=	257.00 K	AND MOLECULAR	WEIGHT=	28.55880
AT	120.00	GEOM KM	TEMPERATURE=	349.49 K	AND MOLECULAR	WEIGHT=	28.06812
AT	150.00	GEOM KM	TEMPERATURE=	892.79 K	AND MOLECULAR	WEIGHT=	26.91836
AT	160.00	GEOM KM	TEMPERATURE=	1022.20 K	AND MOLECULAR	WEIGHT=	26.65773
AT	170.00	GEOM KM	TEMPERATURE=	1103.40 K	AND MOLECULAR	WEIGHT=	26.39848
AT	190.00	GEOM KM	TEMPERATURE=	1205.40 K	AND MOLECULAR	WEIGHT=	25.84954
AT	230.00	GEOM KM	TEMPERATURE=	1322.30 K	AND MOLECULAR	WEIGHT=	24.69908
AT	300.00	GEOM KM	TEMPERATURE=	1432.10 K	AND MOLECULAR	WEIGHT=	22.65857
AT	400.00	GEOM KM	TEMPERATURE=	1487.40 K	AND MOLECULAR	WEIGHT=	19.93921
AT	500.00	GEOM KM	TEMPERATURE=	1499.20 K	AND MOLECULAR	WEIGHT=	17.93875
AT	600.00	GEOM KM	TEMPERATURE=	1506.10 K	AND MOLECULAR	WEIGHT=	16.83874
AT	700.00	GEOM KM	TEMPERATURE=	1507.60 K	AND MOLECULAR	WEIGHT=	16.16897
AT	1000.00	GEOM KM	TEMPERATURE=	1507.60 K	AND MOLECULAR	WEIGHT=	16.00000

CALCULATED QUANTITIES

HEIGHT (KM)	TEMP (K)	PRESSURE (MB)	DENSITY (GM/CC)	SPEED OF SOUND (M/SEC)	MOLECULAR WEIGHT	DENS SCALE (KM)	NUMBER DENSITY (PER CC)	MEAN FREE PATH (M)	VIS- COSITY (E+5)	PRES SCALE (KM)	MEAN PARTICLE VELOCITY (M/SEC)	COLL FREQ (PER SEC)	COLUMNAR MASS
0	288.1	1.01+03	1.22-03	340.	29.0	10.42	2.55+19	6.67-08	1.85	8.43	459.	6.88+09	0.000
5	255.7	5.40+02	7.36-04	321.	29.0	9.26	1.53+19	1.11-07	1.65	7.50	432.	3.90+09	4.821+02
10	223.3	2.65+02	4.14-04	300.	29.0	8.10	8.60+18	1.98-07	1.46	6.56	404.	2.04+09	7.635+02
15	216.6	1.21+02	1.95-04	295.	29.0	6.37	4.05+18	4.20-07	1.42	6.37	398.	9.49+08	9.106+02
20	216.6	5.53+01	8.89-05	295.	29.0	6.38	1.85+18	9.19-07	1.42	6.38	398.	4.33+08	9.780+02
25	221.6	2.55+01	4.01-05	298.	29.0	6.35	8.33+17	2.04-06	1.45	6.54	402.	1.97+08	1.009+03
30	226.5	1.20+01	1.84-05	302.	29.0	6.50	3.83+17	4.44-06	1.48	6.69	407.	9.17+07	1.022+03
35	236.5	5.75+00	8.46-06	308.	29.0	6.47	1.76+17	9.65-06	1.54	7.00	416.	4.31+07	1.029+03
40	250.4	2.87+00	4.00-06	317.	29.0	6.86	8.31+16	2.04-05	1.62	7.42	428.	2.09+07	1.032+03
45	264.2	1.49+00	1.97-06	326.	29.0	7.25	4.09+16	4.16-05	1.70	7.84	439.	1.06+07	1.033+03
50	270.6	7.98-01	1.03-06	330.	29.0	8.05	2.13+16	7.96-05	1.74	8.05	445.	5.59+06	1.034+03
55	265.6	4.27-01	5.61-07	327.	29.0	8.40	1.17+16	1.46-04	1.71	7.91	441.	3.02+06	1.034+03

TABLE IV. - MODEL ATMOSPHERE FOR EARTH - CONTINUED

60	255.8	2.25-01	3.06-07	321.	29.0	8.10	6.36+15	2.67-04	1.65	7.63	432.	1.62+06	1.035+03
65	239.3	1.14-01	1.67-07	310.	29.0	8.10	7.46+15	4.90-04	1.55	7.15	418.	8.53+05	1.035+03
70	219.7	5.52-02	8.75-08	297.	29.0	7.41	1.82+15	9.34-04	1.44	6.57	401.	4.29+05	1.035+03
75	200.1	2.49-02	4.33-08	284.	29.0	6.79	9.01+14	1.89-03	1.33	6.00	382.	2.03+05	1.035+03
80	180.6	1.04-02	2.00-08	270.	29.0	6.17	4.15+14	4.09-03	1.22	5.42	362.	8.89+04	1.035+03
85	180.6	4.12-03	7.95-09	270.	29.0	5.43	1.65+14	1.03-02	1.22	5.43	363.	3.54+04	1.035+03
90	180.6	1.64-03	3.17-09	270.	29.0	5.44	6.59+13	2.58-02	1.22	5.44	363.	1.41+04	1.035+03
95	195.3	6.80-04	1.21-09	281.	28.9	5.41	2.59+13	6.74-02	1.30	5.90	378.	5.61+03	1.035+03
100	210.0	3.10-04	4.97-10	291.	28.9	5.83	1.04+13	1.64-01	1.39	6.36	392.	2.39+03	1.035+03
110	257.0	7.35-05	9.62-11	324.	28.6	6.96	9.07+12	5.20-01	1.66	7.89	436.	5.32+02	1.035+03
120	349.5	2.52-05	2.43-11	390.	28.1	8.91	5.22+11	3.25+00	2.12	10.96	513.	1.58+02	1.035+03
130	531.1	1.22-05	7.58-12	472.	27.4	10.69	1.66+11	1.02+01	2.78	17.11	641.	6.28+01	1.035+03
140	712.2	7.41-06	3.39-12	576.	27.1	14.45	7.54+10	2.25+01	3.40	23.27	746.	3.31+01	1.035+03
150	892.8	5.06-06	1.84-12	613.	26.9	18.29	4.11+10	4.14+01	3.90	29.46	838.	2.03+01	1.035+03
160	1022.2	3.69-06	1.16-12	649.	26.7	23.39	2.62+10	6.49+01	4.07	34.16	901.	1.39+01	1.035+03
170	1103.4	2.79-06	8.03-13	680.	26.4	28.55	1.83+10	9.27+01	4.23	37.35	941.	1.01+01	1.035+03
180	1154.5	2.15-06	5.86-13	708.	26.1	32.59	1.35+10	1.26+02	4.33	39.64	968.	7.69+00	1.035+03
190	1205.4	1.68-06	4.35-13	727.	25.8	34.46	1.01+10	1.68+02	4.42	41.93	994.	5.92+00	1.035+03
200	1234.8	1.33-06	3.32-13	741.	25.5	37.73	7.82+09	2.17+02	4.47	43.62	1012.	4.66+00	1.035+03
210	1264.0	1.06-06	2.56-13	754.	25.2	39.19	6.10+09	2.78+02	4.53	45.31	1030.	3.70+00	1.035+03
220	1293.2	8.57-07	1.99-13	767.	25.0	40.66	4.80+09	3.54+02	4.58	47.02	1047.	2.96+00	1.035+03
230	1322.3	6.96-07	1.56-13	779.	24.7	42.14	3.81+09	4.46+02	4.63	48.72	1065.	2.30+00	1.035+03
240	1338.1	5.68-07	1.24-13	789.	24.4	44.49	3.09+09	5.52+02	4.66	50.14	1078.	1.95+00	1.035+03
250	1353.9	4.67-07	9.97-14	799.	24.0	45.75	2.50+09	6.80+02	4.69	51.57	1092.	1.61+00	1.035+03
260	1369.6	3.86-07	8.04-14	809.	23.7	47.02	2.04+09	8.33+02	4.71	52.99	1105.	1.33+00	1.035+03
270	1385.3	3.20-07	6.52-14	819.	23.4	48.29	1.67+09	1.02+03	4.74	54.42	1118.	1.10+00	1.035+03
280	1401.0	2.67-07	5.31-14	828.	23.2	49.56	1.30+09	1.23+03	4.77	55.86	1131.	9.19-01	1.035+03
290	1416.6	2.24-07	4.35-14	837.	22.9	50.84	1.14+09	1.48+03	4.79	57.30	1144.	7.71-01	1.035+03
300	1432.1	1.68-07	3.58-14	847.	22.7	52.12	9.53+08	1.78+03	4.82	58.74	1157.	6.49-01	1.035+03
310	1437.7	1.59-07	2.97-14	854.	22.3	54.17	8.02+08	2.12+03	4.83	60.00	1167.	5.51-01	1.035+03
320	1443.3	1.35-07	2.48-14	862.	22.0	55.31	6.77+08	2.51+03	4.84	61.25	1179.	4.69-01	1.035+03
330	1448.9	1.15-07	2.07-14	869.	21.7	56.44	5.74+08	2.96+03	4.85	62.51	1188.	4.01-01	1.035+03
340	1454.4	9.80-08	1.74-14	877.	21.5	57.59	4.88+08	3.48+03	4.86	63.79	1198.	3.44-01	1.035+03
350	1460.0	8.39-08	1.46-14	884.	21.2	58.73	4.16+08	4.08+03	4.87	65.04	1208.	2.96-01	1.035+03
360	1465.5	7.20-08	1.24-14	892.	20.9	59.88	3.56+08	4.77+03	4.87	66.31	1218.	2.55-01	1.035+03
370	1471.0	6.20-08	1.05-14	899.	20.7	61.03	3.06+08	5.56+03	4.88	67.59	1228.	2.21-01	1.035+03
380	1476.5	5.36-08	8.91-15	906.	20.4	62.18	2.63+08	6.46+03	4.89	68.86	1238.	1.92-01	1.035+03
390	1481.9	4.64-08	7.60-15	913.	20.2	63.33	2.27+08	7.49+03	4.90	70.14	1247.	1.67-01	1.035+03
400	1487.4	4.03-08	6.50-15	920.	19.9	64.49	1.96+08	8.66+03	4.91	71.43	1257.	1.45-01	1.035+03
410	1488.6	3.51-08	5.59-15	925.	19.7	66.69	1.71+08	9.96+03	4.91	72.51	1264.	1.27-01	1.035+03
420	1489.8	3.06-08	4.81-15	931.	19.5	67.69	1.49+08	1.14+04	4.91	73.60	1272.	1.11-01	1.035+03
430	1491.0	2.67-08	4.16-15	936.	19.3	68.70	1.30+08	1.31+04	4.92	74.69	1279.	9.78-02	1.035+03
440	1492.2	2.34-08	3.60-15	942.	19.1	69.70	1.14+08	1.50+04	4.92	75.78	1287.	8.60-02	1.035+03
450	1493.3	2.05-08	3.12-15	947.	18.9	70.71	9.95+07	1.71+04	4.92	76.88	1294.	7.58-02	1.035+03
460	1494.5	1.60-08	2.71-15	953.	18.7	71.72	8.74+07	1.94+04	4.92	77.98	1302.	6.70-02	1.035+03
470	1495.7	1.59-08	2.36-15	958.	18.5	72.73	7.69+07	2.21+04	4.92	79.08	1309.	5.92-02	1.035+03
480	1496.9	1.40-08	2.06-15	963.	18.3	73.75	6.78+07	2.51+04	4.93	80.19	1316.	5.25-02	1.035+03
490	1498.0	1.24-08	1.80-15	968.	18.1	74.77	5.98+07	2.84+04	4.93	81.29	1323.	4.66-02	1.035+03
500	1499.2	1.10-08	1.58-15	974.	17.9	75.79	5.29+07	3.21+04	4.93	82.40	1330.	4.14-02	1.035+03
550	1502.7	6.06-09	6.42-16	991.	17.4	81.76	2.92+07	5.82+04	4.94	86.56	1354.	2.33-02	1.035+03
600	1506.1	3.45-09	4.63-16	1007.	16.8	85.73	1.66+07	1.02+05	4.04	90.77	1376.	1.34-02	1.035+03
650	1506.9	2.01-09	2.64-16	1018.	16.5	90.50	9.64+06	1.76+05	4.94	94.04	1391.	7.89-03	1.035+03
700	1507.6	1.19-09	1.53-16	1028.	16.2	93.69	5.72+06	2.97+05	4.94	97.35	1405.	4.73-03	1.035+03
750	1507.6	7.15-10	9.20-17	1029.	16.1	98.56	3.43+06	4.95+05	4.94	98.91	1406.	2.94-03	1.035+03
800	1507.6	4.33-10	5.56-17	1030.	16.1	100.13	2.08+06	8.17+05	4.94	100.49	1408.	1.72-03	1.035+03
850	1507.6	2.64-10	3.39-17	1031.	16.1	101.71	1.27+06	1.34+06	4.04	102.07	1409.	1.05-03	1.035+03
900	1507.6	1.62-10	2.08-17	1032.	16.1	103.30	7.81+05	2.18+06	4.94	103.67	1410.	6.48-04	1.035+03
950	1507.6	1.01-10	1.29-17	1033.	16.0	104.90	4.84+05	3.51+06	4.94	105.28	1411.	4.02-04	1.035+03
1000	1507.6	6.28-11	8.02-18	1034.	16.0	106.52	3.02+05	5.63+06	4.94	106.90	1412.	2.51-04	1.035+03

COLUMNAR MASS = 1034.797 GM/CC COLUMNAR MASS FOR CO_2 = .472 GM/CC

TABLE IV. - MODEL ATMOSPHERE FOR EARTH - CONTINUED

MODEL ATMOSPHERE FOR EARTH U.S.1962

CONSTRUCTION PARAMETERS ENGINEERING UNITS DATE 9/20/67

SURFACE PRESSURE = 14.704 LB/SQ IN SURFACE TEMPERATURE = 518.7 R SURFACE DENSITY = 2.38-03 SLUG/CU FT

PER CENT CARBON DIOXIDE = .0 MOLECULAR WEIGHT = 28.96 SURFACE GRAVITY = 32.17 FT/SEC/SEC

CALCULATED QUANTITIES

HEIGHT (MIL.FT)	TEMP (R)	PRESSURE (LB/SQ IN)	DENSITY (SLUG/ CU FT)	SPEED OF SOUND (FT/SEC)	SPECIFIC WEIGHT	PRES SCALE (MIL.FT)	DENS SCALE (MIL.FT)	NUMBER DENSITY (PER CU FT)	MEAN PARTICLE VELOCITY (FT/SEC)	MEAN FREE PATH (FT)	VIS-COSITY (E+5)	KINETIC VISC
.0000	518.7	1.47+01	2.38-03	1116.	7.7-02	.028	.034	7.2+23	1506.	2.2-07	3.87	1.6-04
.0164	460.2	7.84+00	1.43-03	1052.	7.6-02	.025	.030	4.3+23	1418.	3.6-07	3.44	2.4-04
.0328	401.9	3.85+00	8.03-04	983.	7.6-02	.022	.027	2.4+23	1325.	6.5-07	3.05	3.8-04
.0492	390.0	1.76+00	3.78-04	968.	7.6-02	.021	.021	1.1+23	1306.	1.4-06	2.97	7.9-04
.0656	390.0	8.02-01	1.73-04	968.	7.6-02	.021	.021	5.2+22	1306.	3.0-06	2.97	1.7-03
.0820	398.8	3.70-01	7.79-05	979.	7.6-02	.021	.021	2.4+22	1320.	6.7-06	3.03	3.9-03
.0984	407.7	1.74-01	3.58-05	990.	7.6-02	.022	.021	1.1+22	1335.	1.5-05	3.09	8.6-03
.1148	425.7	8.34-02	1.64-05	1012.	7.6-02	.023	.021	5.0+21	1364.	3.2-05	3.21	2.0-02
.1312	450.6	4.17-02	7.76-06	1041.	7.6-02	.024	.023	2.4+21	1404.	6.7-05	3.38	4.4-02
.1476	475.5	2.16-02	3.82-06	1069.	7.6-02	.026	.024	1.2+21	1442.	1.4-04	3.55	9.3-02
.1640	487.2	1.16-02	1.99-06	1082.	7.5-02	.026	.026	6.0+20	1459.	2.6-04	3.63	1.8-01
.1805	478.1	6.20-03	1.09-06	1072.	7.5-02	.026	.028	3.3+20	1446.	4.8-04	3.57	3.3-01
.1969	460.4	3.26-03	5.94-07	1052.	7.5-02	.025	.027	1.8+20	1419.	8.8-04	3.44	5.8-01
.2133	430.7	1.66-03	3.24-07	1018.	7.5-02	.023	.027	9.8+19	1372.	1.6-03	3.24	1.0+00
.2297	395.4	8.01-04	1.70-07	975.	7.5-02	.022	.024	5.2+19	1315.	3.1-03	3.01	1.8+00
.2461	360.2	3.61-04	8.42-08	931.	7.5-02	.020	.022	2.6+19	1255.	6.2-03	2.78	3.3+00
.2625	325.2	1.50-04	3.88-08	884.	7.5-02	.018	.020	1.2+19	1192.	1.3-02	2.54	6.6+00
.2789	325.2	5.98-05	1.54-08	884.	7.5-02	.018	.018	4.7+18	1192.	3.4-02	2.54	1.6+01
.2953	325.2	2.38-05	6.15-09	884.	7.4-02	.018	.018	1.9+18	1192.	8.5-02	2.54	4.1+01
.3117	351.6	9.86-06	2.35-09	920.	7.4-02	.019	.018	7.1+17	1241.	2.2-01	2.72	1.2+02
.3281	378.0	4.36-06	9.66-10	955.	7.4-02	.021	.019	2.9+17	1287.	5.4-01	2.90	3.0+02
.3609	462.6	1.07-06	1.91-10	1062.	7.4-02	.026	.023	5.9+16	1432.	2.7+00	3.46	1.8+03
.3937	629.1	3.66-07	4.73-11	1248.	7.4-02	.036	.028	1.5+16	1685.	1.1+01	4.42	9.4+03
.4265	956.1	1.77-07	1.47-11	1549.	7.4-02	.056	.035	4.7+15	2102.	3.3+01	5.81	3.9+04
.4593	1282.0	1.08-07	6.59-12	1791.	7.3-02	.076	.047	2.1+15	2448.	7.4+01	7.10	1.1+05
.4921	1607.0	7.34-08	3.57-12	2012.	7.3-02	.097	.060	1.2+15	2749.	1.4+02	7.95	2.2+05
.5250	1840.0	5.36-08	2.25-12	2164.	7.3-02	.112	.077	7.4+14	2956.	2.1+02	8.50	3.8+05
.5578	1986.1	4.05-08	1.56-12	2259.	7.3-02	.123	.094	5.2+14	3087.	3.0+02	8.83	5.7+05
.5906	2078.1	3.12-08	1.14-12	2323.	7.2-02	.130	.107	3.8+14	3175.	4.1+02	9.04	8.0+05
.6234	2169.7	2.44-08	8.44-13	2386.	7.2-02	.138	.113	2.9+14	3260.	5.5+02	9.23	1.1+06
.6562	2222.6	1.94-08	6.44-13	2430.	7.2-02	.143	.124	2.2+14	3320.	7.1+02	9.34	1.5+06
.6890	2275.2	1.55-08	4.97-13	2473.	7.2-02	.149	.129	1.7+14	3379.	9.1+02	9.45	1.9+06
.7218	2327.8	1.24-08	3.87-13	2515.	7.2-02	.154	.133	1.4+14	3437.	1.2+03	9.56	2.5+06
.7546	2380.1	1.01-08	3.04-13	2557.	7.1-02	.160	.138	1.1+14	3493.	1.5+03	9.67	3.2+06
.7874	2408.6	8.25-09	2.42-13	2590.	7.1-02	.165	.146	8.7+13	3538.	1.8+03	9.73	4.0+06

TABLE IV. - MODEL ATMOSPHERE FOR EARTH - CONCLUDED

.8202	2437.0	6.78-09	1.94-13	2622.	7.1-02	.169	.150	7.1+13	3583.	2.2+03	9.79	5.1+06
.8531	2465.4	5.60-09	1.56-13	2654.	7.1-02	.174	.154	5.8+13	3627.	2.7+03	9.84	6.3+06
.8859	2493.6	4.65-09	1.27-13	2686.	7.0-02	.179	.158	4.7+13	3670.	3.3+03	9.90	7.8+06
.9187	2521.7	3.87-09	1.03-13	2717.	7.0-02	.183	.163	3.9+13	3712.	4.0+03	9.95	9.7+06
.9515	2549.8	3.25-09	8.46-14	2748.	7.0-02	.188	.167	3.2+13	3754.	4.9+03	10.01	1.2+07
.9843	2577.8	2.73-09	6.96-14	2778.	7.0-02	.193	.171	2.7+13	3795.	5.9+03	10.06	1.4+07
1.0171	2587.9	2.31-09	5.78-14	2803.	7.0-02	.197	.178	2.3+13	3830.	7.0+03	10.08	1.7+07
1.0499	2597.9	1.96-09	4.81-14	2828.	6.9-02	.201	.181	1.9+13	3864.	8.2+03	10.10	2.1+07
1.0827	2608.0	1.67-09	4.02-14	2853.	6.9-02	.205	.185	1.6+13	3898.	9.7+03	10.12	2.5+07
1.1155	2618.0	1.42-09	3.38-14	2877.	6.9-02	.209	.189	1.4+13	3931.	1.1+04	10.14	3.0+07
1.1483	2627.9	1.22-09	2.84-14	2901.	6.9-02	.213	.193	1.2+13	3964.	1.3+04	10.16	3.6+07
1.1812	2637.9	1.05-09	2.40-14	2925.	6.9-02	.218	.196	1.0+13	3997.	1.6+04	10.18	4.2+07
1.2140	2647.8	9.00-10	2.04-14	2949.	6.8-02	.222	.200	8.7+12	4029.	1.8+04	10.20	5.0+07
1.2468	2657.6	7.78-10	1.73-14	2972.	6.8-02	.226	.204	7.4+12	4061.	2.1+04	10.22	5.9+07
1.2796	2667.5	6.73-10	1.48-14	2995.	6.8-02	.230	.208	6.4+12	4092.	2.5+04	10.24	6.9+07
1.3124	2677.3	5.85-10	1.26-14	3018.	6.8-02	.234	.212	5.6+12	4123.	2.8+04	10.26	8.1+07
1.3452	2679.5	5.09-10	1.09-14	3036.	6.8-02	.238	.219	4.8+12	4148.	3.3+04	10.26	9.5+07
1.3780	2681.6	4.44-10	9.35-15	3054.	6.7-02	.241	.222	4.2+12	4173.	3.7+04	10.26	1.1+08
1.4108	2683.8	3.88-10	8.08-15	3072.	6.7-02	.245	.225	3.7+12	4198.	4.3+04	10.27	1.3+08
1.4436	2685.9	3.39-10	6.99-15	3090.	6.7-02	.249	.229	3.2+12	4222.	4.9+04	10.27	1.5+08
1.4764	2688.0	2.98-10	6.06-15	3108.	6.7-02	.252	.232	2.8+12	4246.	5.6+04	10.28	1.7+08
1.5093	2690.1	2.62-10	5.27-15	3126.	6.7-02	.256	.235	2.5+12	4270.	6.4+04	10.28	2.0+08
1.5421	2692.3	2.30-10	4.59-15	3143.	6.6-02	.259	.239	2.2+12	4294.	7.2+04	10.29	2.2+08
1.5749	2694.4	2.03-10	4.00-15	3160.	6.6-02	.263	.242	1.9+12	4318.	8.2+04	10.29	2.6+08
1.6077	2696.5	1.80-10	3.50-15	3177.	6.6-02	.267	.245	1.7+12	4341.	9.3+04	10.29	2.9+08
1.6405	2698.6	1.59-10	3.06-15	3194.	6.6-02	.270	.249	1.5+12	4364.	1.1+05	10.30	3.4+08
1.8045	2704.8	8.79-11	1.64-15	3250.	6.5-02	.284	.268	8.3+11	4441.	1.9+05	10.31	6.3+08
1.9686	2711.0	5.00-11	9.00-16	3305.	6.4-02	.298	.281	4.7+11	4515.	3.4+05	10.32	1.1+09
2.1326	2712.3	2.91-11	5.17-16	3340.	6.3-02	.309	.297	2.7+11	4563.	5.8+05	10.32	2.0+09
2.2967	2713.7	1.73-11	2.96-16	3374.	6.2-02	.319	.307	1.6+11	4610.	9.8+05	10.33	3.5+09
2.4607	2713.7	1.04-11	1.79-16	3377.	6.1-02	.325	.323	9.7+10	4614.	1.6+06	10.33	5.8+09
2.6248	2713.7	6.28-12	1.08-16	3380.	6.0-02	.330	.329	5.9+10	4618.	2.7+06	10.33	9.6+09
2.7888	2713.7	3.83-12	6.59-17	3383.	6.0-02	.335	.334	3.6+10	4622.	4.4+06	10.33	1.6+10
2.9529	2713.7	2.36-12	4.04-17	3386.	5.9-02	.340	.339	2.2+10	4626.	7.1+06	10.33	2.6+10
3.1169	2713.7	1.46-12	2.50-17	3389.	5.8-02	.345	.344	1.4+10	4630.	1.2+07	10.33	4.1+10

COLUMNAR MASS = 65.968 SLUG/SQ FT PLANETARY RADIUS = 3961.0 MILES

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