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THERMODYNAMIC PROPERTIES OF AIR FROM 300 TO 6000°K AND FROM 1 TO 1000 AMAGATS

Martin Grabau and H. S. Brahinsky

ARO, Inc.

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*Deceased

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FOREWORD

The work reported herein was done at the request of Headquarters, Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 65402234.

The results of the research presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of AEDC, AFSC, Arnold Air Force Station, Tennessee, under contract AF40(600)-1200. The work was performed under ARO Project No. VT8002, and the manuscript was submitted for publication on November 8, 1966.

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This technical report has been reviewed and is approved.

Terry L. Hershey
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Colonel, USAF
Director of Plans and Technology

ABSTRACT

Tables for the thermodynamic properties of equilibrium air are presented at intervals of log ρ = 0.2, the density ρ in amagats extending from 1 to 1000 amagats and at temperature intervals of 100 deg from 300 to 6000°K. In accordance with full discussion in the text of the report, the compressibility factor Z at 300 and 400°K is extrapolated to 1000 amagats by linear extrapolation of log (Z - 1) against log ρ at constant temperature. At 5000 and 6000°K the values of Z were obtained from unpublished virial corrections furnished by Joseph Hilsenrath of the National Bureau of Standards. Interpolations between these extremes of temperature are based on an empirical equation for the pressure-temperature lines at constant density, the form of which fits known data at medium densities and also predicts data at temperatures below 300°K. The values of the dimensionless thermal functions E/RT (internal energy) and S/R (entropy) are based on numerical integrations of Z and its derivative $(\partial Z/\partial T)_\rho$, using known values of these functions at 1 amagat as constants of integration.

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NOMENCLATURE

a, b, c, e	Parameters (as functions of density) in an empirical equation for pressure-temperature lines at constant density
B	Second virial coefficient in reciprocal amagats
C	Third virial coefficient in reciprocal amagats squared
D	Fourth virial coefficient in reciprocal amagats cubed
E	Internal energy in dimensionless function E/RT
H	Enthalpy in dimensionless function H/RT
k	Exponent in empirical formula for solidification pressure
ln	Natural logarithm
log	Common logarithm to base 10
m	Subscript relating to effects of intermolecular forces
p	Pressure in atmospheres
R	Gas constant in dimensionless functions, such as E/RT
S	Entropy in dimensionless function S/R
T	Temperature in degrees Kelvin
t	Subscript relating to thermally perfect gas
y	Generic symbol for ordinate of logarithmic plot
Z	Dimensionless compressibility factor in gas law $p = ZRT\rho$
ρ	Density in amagat units
G&B	Symbol for tables given in Appendix III

H&K	Symbol for tables of Hilsenrath and Klein (Ref. 3)
H&N	Symbol for tables of Humphrey and Neel (Ref. 2)

SUBSCRIPT

°	Reference conditions at one atmosphere pressure and 273.15°K

REFERENCE AND USEFUL QUANTITIES FOR AIR

T_o = 273.15°K

Gravitational Constant = 32.174 ft/sec^2

1 Btu = 778.158 ft-lbs

1 gm-cal = 42,692.8 gm-cm

1 lb/ft^3 = 62.4283 gm/cm^3

p_o = pressure at one atmosphere

P_o = 1.03323 x 10^3 gm/cm^2

P_o = 14.6959 psi

P_o = 2116.22 psf

P_o = 760 mm Hg

P_o = 1.013246 x 10^5 newtons/m^2

Molecular Weight = 28.967

R = Gas constant

R = 1.98726 gm-cal/gm-mole °K or Btu/lb-mole °R

R = 6.860427 x 10^{-2} gm-cal/gm °K or Btu/lb °R

R = 3091.694 ft^2/sec^2 °K

R = 1717.608 ft^2/sec^2 °R

R = 3.66099 x 10^{-3} atm/amagat °K

ρ_o = Density at one amagat

ρ_o = 4.45848 x 10^{-5} gm-mole/cm^3

ρ_o = 1.29149 x 10^{-3} gm/cm^3

ρ_o = 8.06254 x 10^{-2} lb/ft^3

ρ_o = 2.50592 x 10^{-3} slugs/ft^3

SECTION I
INTRODUCTION

The need for tables of thermodynamic properties of air to high densities arose in the von Kármán Facility, of AEDC, in connection with the gradual extension of the range of operation of arc-driven (hotshot) wind tunnels and, more especially, in the design of proposed new wind tunnels and other apparatus. A similar requirement for nitrogen tables was recently met by the present authors in Ref. 1. The general method of generating the air tables given herewith in Appendix III is substantially the same as the one used in constructing the above referenced nitrogen tables.

For the range of moderately high densities, the three most recently issued sets of air tables are those of Humphrey and Neel (Ref. 2), Hilsenrath and Klein (Ref. 3), and Vasiliu (Ref. 4). The tables of Humphrey and Neel cover the temperature range from 90 to 1500°K up to various density limits, the highest being 400 amagats at ambient temperatures. They are a compilation of the tables of Din (Ref. 5) and of Hilsenrath, Beckett, et al. (Ref. 6). The tables of Hilsenrath and Klein represent theoretically calculated effects of dissociation and ionization, as well as second virial corrections. They extend from 1500 to 15,000°K, their upper density limits being 250 amagats at the lower temperatures and 160 amagats at the higher ones. The tables of Vasiliu range from 200 to 6000°K, and from 400°K upwards they represent a first attempt to extrapolate to high densities on a broad scale, in this instance to 630 amagats ($\log \rho = 2.8$). These tables were based on the earlier 1959 tables of Hilsenrath, Klein, and Woolley (Ref. 7) which do not go beyond 100 amagats and do not include any virial corrections. Vasiliu began with algebraic extrapolation of entries in Ref. 7 to account for the progressive diminution of dissociation, and then added to the entries of Ref. 7 and their extrapolations the increments which were attributable to second and third virial corrections calculated from the Lennard-Jones potential, as set forth by Hirschfelder et al. (Ref. 8). The issuance of these tables was timely and also underscored the growing need for such information at high densities. Prior to their publication, the needs for high-density air data were served in part by the table of Gilmore (Ref. 9) which cites computed thermodynamic properties of air up to 316 amagats ($\log \rho = 2.5$) at intervals of 1000 deg from 2000 to 10,000°K. Figure 1 (Appendix I) shows the areas covered by the above described tables within the thermodynamic domain from 100 to 6000°K and up to 1000 amagats.

SECTION II
DISCUSSION AND PROCEDURE

In broad outline, the tables given in Appendix III are based on (1) graphical extrapolation of the compressibility factor Z to 1000 amagats at 300 and 400°K, (2) the assumption that the virial corrections of Friedman, as supplied by Hilsenrath, suffice to determine the thermodynamic states to 1000 amagats from 3000 to 6000°K, and (3) the use of a discreetly chosen empirical equation whenever necessary to fill in a gap between 400 and 3000°K. The dimensionless thermal quantities E/RT and S/R are developed by numerical differentiation and integration of a carefully prepared array of values of Z, using the known values of E/RT and S/R at one amagat as constants of integration.

2.1 A USEFUL GRAPHICAL DOMAIN

The compressibility factor of a real gas is often computed by means of the equation

$$Z \simeq 1 + B\rho + C\rho^2 + D\rho^3 + \text{etc.}$$

in which the parameters B, C, D, etc., are the virial coefficients which are assumed to be functions only of the temperature. As usually tabulated in the literature, these parameters are merely coefficients in a finite series expansion in integral powers of the density, as determined from experimental data by a numerical curve fitting procedure. In the range of interest of the present work, the number of virial coefficients required generally decreases as the temperature increases.

Below the Boyle temperature (about 347°K for air) the second virial coefficient B is negative, because the numerical value of Z is less than unity, being approximately 0.3 at the critical point. In theoretical determinations of Z, the coefficient B generally represents interactions between pairs of entities (molecules, atoms, or ions). In like manner, the coefficient C pertains to three-particle interactions, and so on. Above the Boyle temperature, the occasional appearance of negative empirically determined virials is probably fortuitous, it having been found that a change of one percent or less in a given datum point will occasionally change the sign of a higher virial coefficient in a curve fitting procedure. The literature does not appear to disclose any negative theoretical virials above the Boyle temperature, and through the remainder of this section it is assumed that all virials are positive above the Boyle temperature.

For the sake of convenience in notation, the virial equation is written in the form

$$Z = 1 + \Delta Z_2 + \Delta Z_3 + \text{etc.}$$

where the ΔZ's are the contributions to Z of the successive virial coefficients beyond the first. In this equation ΔZ_2 is equal to $B\rho$, so we can write

$$y = \log \Delta Z_2 = \log B - \log \rho$$

a plot of which with respect to log ρ is a straight line of unit slope whose intercept on the line $y = 0$ is equal to log (1/B). In the same way, $\Delta Z_3 = C\rho^2$ so that

$$y = \log \Delta Z_3 = \log C + 2 \log \rho$$

which is a straight line of slope 2 intersecting the $y = 0$ axis at the point (1/2) log (1/C). The generalization to the nth virial is obvious.

Before considering the interaction of these straight lines on a logarithmic plot, it is worthwhile briefly to see the case of a bivirial gas in which the effects of dissociation are decreasing with increasing density. On completion of recombination, the bivirial gas is represented by the relation

$$Z - 1 = B\rho$$

and

$$\log (Z - 1) = \log B + \log \rho$$

Figure 2 shows a plot of (Z - 1) on a log scale versus log ρ for air at 7000°K, the data being taken from Ref. 3. It is shown that the curve joins the bivirial line as the effects of dissociation disappear, showing how easily in many instances the effects of dissociation can be distinguished from the virial effects. However, in the present work it is not necessary to resort to this method, because the tables of Ref. 3 list the quantity Z*, which is the value of Z without the virial effects.

The presence of several positive virial lines on the logarithmic plot is illustrated in Fig. 3. Here the straight lines represent the contributions to Z of the second and third virials given by Friedman (Ref. 10) for air at 3000°K. In addition, there is also a plot of (Z - 1) computed from the corresponding virial equation. It can be seen that the locus of (Z - 1) on the log scale eventually converges very slowly on the straight line representing the highest virial contribution, and this is also shown in another way in Section 2.2. It is also worth noting in passing that the locus of (Z - 1) can easily be found graphically when positive virial lines

are drawn on logarithmic graph paper. At any given density, (Z - 1) is merely the sum of the ΔZ's read off the graph.

2.2 A GENERALIZATION OF THIS DOMAIN

Inasmuch as the tables given in Appendix III begin at 300°K, which is below the Boyle temperature, it is important to examine a generalization of the domain to accommodate numerical values of the compressibility factor less than unity. Such values of Z arise by virtue of negative values of the second virial, and under certain conditions the third may also be negative. When Z is equal to unity, log (Z - 1) is equal to minus infinity, and when it is less than unity log (Z - 1) is complex.

This suggests plotting the logarithm of the absolute value of (Z - 1), rather than the logarithm of (Z - 1) itself. Everything is real in this generalized domain, and the equation for the slope of the curve is unchanged on crossing the singularity. At high densities

$$Z - 1 = B\rho + C\rho^2 + D\rho^3 + \text{etc.}$$

and

$$[\partial(Z-1)/\partial\rho]_T = B + 2C\rho^2 + 3D\rho^2 + \text{etc.}$$

and by changing the variables on the left-hand side from ρ to log ρ and from (Z - 1) to log (Z - 1) there follows

$$\left[\frac{\partial \log (Z-1)}{\partial \log \rho}\right]_T = \left[\frac{B + 2C\rho + 3D\rho^2 + \text{etc.}}{B + C\rho + D\rho^2 + \text{etc.}}\right]$$

On the other hand, at sufficiently low densities and below the Boyle temperature

$$1 - Z = -(B\rho + C\rho^2 + D\rho^3 + \text{etc.})$$

and by differentiating and changing the variables as before

$$\left[\frac{\partial \log (1-Z)}{\partial \log \rho}\right]_T = 1 + \rho \left[\frac{C + D\rho + \text{etc.}}{B + C\rho + D\rho^2 + \text{etc.}}\right]$$

in which the minus signs in the numerator and denominator cancel each other. These two derivatives can be combined in the statement

$$\left[\frac{\partial \log |Z-1|}{\partial \log \rho}\right]_T = 1 + \rho \left[\frac{C + 2D\rho + \text{etc.}}{B + C\rho + D\rho^2 + \text{etc.}}\right]$$

It is seen by inspection that, as the density is allowed to increase indefinitely, the derivative approaches the exponent of the highest virial contribution.

Figure 4 shows a plot of log $|Z - 1|$ against log ρ for air at 25°C, the points being computed from the array of virials given by Michels et al. (Ref. 11). Also shown are the negative bivirial line and the lines for the positive third and fourth virials. Since the slope of the curve to the left of the singularity does not exceed unity, it follows that only the second virial is negative, the third being positive.

The main purpose of Fig. 4 is to set forth the arm of the curve to the right of the singularity. It rises steeply from minus infinity at the singularity and bends over to the right with negative curvature. If the third virial were the highest, the curve would join the third virial line. But by virtue of the still higher virials, it traverses a point of inflection and its curvature becomes positive. Since the curvatures in this region are small, and because of scatter and rounding-off errors, a fairly long segment of the curve in this region can be approximated by a straight line, especially with an expanded scale for log ρ.

Consideration of Fig. 4 also shows why in this study the domain of log (Z - 1) was chosen in preference to log Z. The domain of Fig. 4 is not only more sensitive to rounding-off errors in the tables, but also shows more clearly the effects of the successive virials.

By differentiating the general gas law, $Z = P/RT\rho$, the derivative of log (Z - 1) may also be written in the form

$$\left[\frac{\partial \log (Z-1)}{\partial \log \rho}\right]_T = \frac{Z}{Z-1}\left[\left(\frac{\partial \log P}{\partial \log \rho}\right)_T - 1\right]$$

As the density and the compressibility factor increase, the ratio $Z/(Z - 1)$ decreases slowly as it approaches unity. On the other hand, the isothermal derivative of log P with respect to log ρ must increase at a fair rate, because of the steadily increasing relative difficulty of compressing a gas at high densities.

2.3 EXTRAPOLATION TO 1000 AMAGATS AT 300 AND 400°K

The application of the loci of log (Z - 1) to the isothermal extrapolation of Z to 1000 amagats is shown in Fig. 5 with a plot of data for air at 300°K given in Table 2 of Humphrey and Neel (Ref. 2). The highest points

from log ρ = 2.6 to 2.707 lie clustered about a straight line. Now, a detailed examination of the air data in Fig. 4 shows that their locus of log (Z - 1) goes through a point of inflection in the vicinity of log ρ = 2.6. So, it is fair to conclude that the data of Fig. 5 lie beyond their region of negative curvature and that a straight-line extrapolation is conservative. Prolongation of the straight line in Fig. 5 yields a value of Z = 12.32 at log ρ = 3.0. Using the similarity between the nitrogen data of Ref. 1 and the air data of this report as a guide, extrapolation of the data at 400°K also defines a straight line whose prolongation suggests the value of Z = 11.04 at 1000 amagats.

2.4 THE ISOMETRIC DOMAIN

Beattie and Bridgeman (Ref. 12), Obert (Ref. 13), and other authors observe that the pressure-temperature lines at constant density, the so-called isometrics, of a real gas have negative curvature (except for effects identified with the critical point) and approach linearity at high temperatures. This is illustrated in Fig. 6, showing the air isometric at log ρ = 2.0 (100 amagats). Below 700°K the data are taken from Ref. 2 and from 1500°K upwards from Ref. 3. The small terminal curvature of this isometric at its high-temperature end is revealed by drawing a straight line from the 1500 to the 6000°K point, noting that its maximum relative deviation from the isometric is of the order of one percent. The fact that the isometric approaches a straight line immediately suggests an empirical equation in the form

$$P = a + bT - c \exp(eT)$$

in which the parameters a, b, c, and e are functions of the density. At a given density, the constants a and b are determined by a straight line through the points at 5000 and 6000°K and, in the exponential correction, the constants c and e are determined by the points at 300 and 400°K.

As would be expected, the insufficiency of Friedman's virial corrections at moderately high temperatures increases with density. This can be seen in Fig. 7 which is mainly devoted to the isometric for the case of log ρ = 3.0. The solid line at the low-temperature end represents the extrapolated data at 300 and 400°K described in Section 2.3, whereas the solid line from 1000°K upwards is based on the virial corrections of Friedman (Ref. 10). These two parts of the curve obviously cannot be joined without incurring a point of inflection, and this would be thermodynamically inadmissible. The empirical equation for this case joins the two solid-line portions of the curve with the dotted line in Fig. 7. The data for log ρ = 2.8 are also shown.

2.5 COMPUTATIONAL PROCEDURE

The first step in generating the accompanying tables given in Appendix III was obviously the one of tabulating the numerical values of the compressibility factor Z. This was done at intervals of 100 deg from 300 to 1000°K, then at intervals of 200 deg from 1000 to 3000°K, than at intervals of 200 deg from 1000 to 3000°K, and finally at intervals of 500 deg from 3000 to 6000°K. The density range extends from log ρ = 0 (1 amagat) to log ρ = 3.0 (1000 amagats), entries being made at intervals of 0.2 in log ρ. At all densities from log ρ = 1 (10 amagats) upward, the values of Z were computed by means of the empirical formulas for the isometric pressure, in which the parameters were determined from pressure data at 300 and 400°K in Ref. 2 (extrapolated to 1000 amagats as described in Section 2.3) and from the virial corrections of Ref. 10 at 5000 and 6000°K. This procedure not only took care of the instances at high densities in which the virial corrections of Ref. 10 would have to be augmented to bring the isometrics into thermodynamic conformity with the low-temperature data, but it also smoothed out a few situations at medium and low densities at which the pressures predicted by the virials had to be changed slightly to satisfy the low-temperature conditions. In only a few instances at the highest temperatures and at the lower densities, it was necessary to add to the values of Z corrections for the effects of dissociation. These small increments were determined from the values of Z* in Ref. 3.

The input of thermal data to the computing machine consisted of the numerical values of the dimensionless functions E/RT and S/R at log ρ = 0 and at all temperatures at intervals of 100 deg from 300 to 6000°K. These data were taken from Ref. 2 up to 1000°K, then from Ref. 3 to 6000°K. Very little smoothing was required. The computing machine was instructed to compute the pressure from the relation

$$P = ZRT\rho$$

and then to integrate the differential equations

$$[\partial(E/RT)/\partial(ln\rho)]_T = -T\,(\partial Z/\partial T)_\rho$$

$$[\partial(S/R)/\partial(ln\rho)]_T = -T\,(\partial Z/\partial T)_\rho - Z$$

using the values of E/RT and S/R at log ρ = 0 as initial values. Finally, the dimensionless enthalpy H/RT followed from the relation

$$H/RT = E/RT + Z$$

For the performance of interpolations and differentiations, the computer program applied the method of spline fit described by Landis and

Nilson (Ref. 14) as applied by Lewis and Neel (Ref. 15). In this method the computer represents a column of entries in terms of a set of local cubics, each of which is determined by two neighboring entries, subject to the condition that the first and second derivatives of two neighboring cubics are continuous at the junction point. The computations were made on an IBM 7074 computer.

Beyond computing the values of Z, no further use was made of the fact that analytical expressions were available for isometrics. For instance, if the pressure is given by the equation

$$P = a + bT - c \exp(eT)$$

where the parameters a, b, c, and e are known functions of density, then

$$[\partial(S/R)/\partial(ln\rho)]_T = -(1/R\rho)[b - ce \exp(et)]$$

with a corresponding expression for the isothermal derivative of E/RT, which could be integrated numerically. Inasmuch as the spline fit and its accessories were already available as subroutines for the computer, it was felt that no great benefit would accrue from programming the indicated numerical integrations. Verification of the method for determining the thermal quantities E/RT and S/R is given in Ref. 1. The ability of this method to reproduce a given set of data is excellent, the largest error being 2.5 parts in 10,000.

2.6 INTERCOMPARISONS OF TABLES

Table I (Appendix II) shows spot comparisons of entries for Z, E/RT, and S/R given in the tables of Appendix III (G&B) with the corresponding entries in the tables of Humphrey and Neel (H&N) and Hilsenrath and Klein (H&K). It should also be kept in mind that the sets of entries for the pressure, H/RT, and S/R in Ref. 2 were determined by separate interpolations among entries in the source tables, and the authors of Ref. 2 reported finding internal thermodynamic inconsistencies as great as 0.2 percent. In other respects the entries in Table I speak for themselves.

Although there is no claim to absolute accuracy in the tables of Appendix III, nevertheless it is felt that the extrapolations and interpolations are reasonable from an engineering point of view and that they are thermodynamically consistent among one another.

REFERENCES

1. Grabau, M. and Brahinsky, H. S. "Thermodynamic Properties of Nitrogen from 300 to 5000°K and from 1 to 1000 Amagats." AEDC-TR-66-69 (AD636730), August 1966.

2. Humphrey, R. L. and Neel, C. A. "Tables of Thermodynamic Properties of Air from 90 to 1500°K." AEDC-TN-61-103 (AD262692), August 1961.

3. Hilsenrath, J. and Klein, M. "Tables of Thermodynamic Properties of Air in Chemical Equilibrium Including Second Virial Corrections from 1500°K to 15,000°K." AEDC-TDR-63-161 (AD416040), August 1963.

4. Vasiliu, J. "Approximations to the Thermodynamic Properties of High-Density Air, Including Second and Third Virial Corrections." Republic Aviation RAC 1883, November 1963.

5. Din, F. Thermodynamic Functions of Gases, Vol. 2, Butterworths Scientific Publications, London 1956.

6. Hilsenrath, J., Beckett, C. W., et al. "Tables of Thermal Properties of Gases." National Bureau of Standards Circular 564, November 1955.

7. Hilsenrath, J., Klein, M., and Woolley, H. W. "Tables of Thermodynamic Properties of Air Including Dissociation and Ionization from 1500°K to 15,00°K." AEDC-TR-59-20 (AD229962), December 1959.

8. Hirschfelder, J. O., Curtiss, C. F., and Bird, R. B. Molecular Theory of Gases and Liquids, John Wiley & Sons, New York, 1954.

9. Gilmore, F. R. "Additional Values for the Equilibrium Composition and Thermodynamic Properties of Air." Rand Corporation RM-2328, December 1959.

10. Friedman, A. S. "Intermolecular Forces in Air." Journal of Research of the National Bureau of Standards, Vol. 58, No. 2, February 1957.

11. Michels, A., Wassenaar, T., and Van Seventer, W. "Isotherms of Air Between 0°C and 75°C and at Pressures up to 2200 Atmospheres." Applied Scientific Research, Vol. (A)4, 1953, p 52.

12. Beattie, J. A. and Bridgeman, O. C. "A New Equation of State of Air." Proceedings of the American Academy of Arts and Sciences, Vol. 63, 1928, pp 229-308.

13. Obert, E. F. Concepts of Thermodynamics, McGraw-Hill, New York, 1960.

14. Landis, F. and Nilson, E. N. "Thermodynamic Properties of Ionized and Dissociated Air from 1500°K to 15,000°K." Pratt & Whitney Report No. 1921, January 1961.

15. Lewis, C. H. and Neel, C. A. "Specific Heat and Speed of Sound Data for Imperfect Air." AEDC-TDR-64-36 (AD600469), May 1964.

APPENDIX I
ILLUSTRATIONS

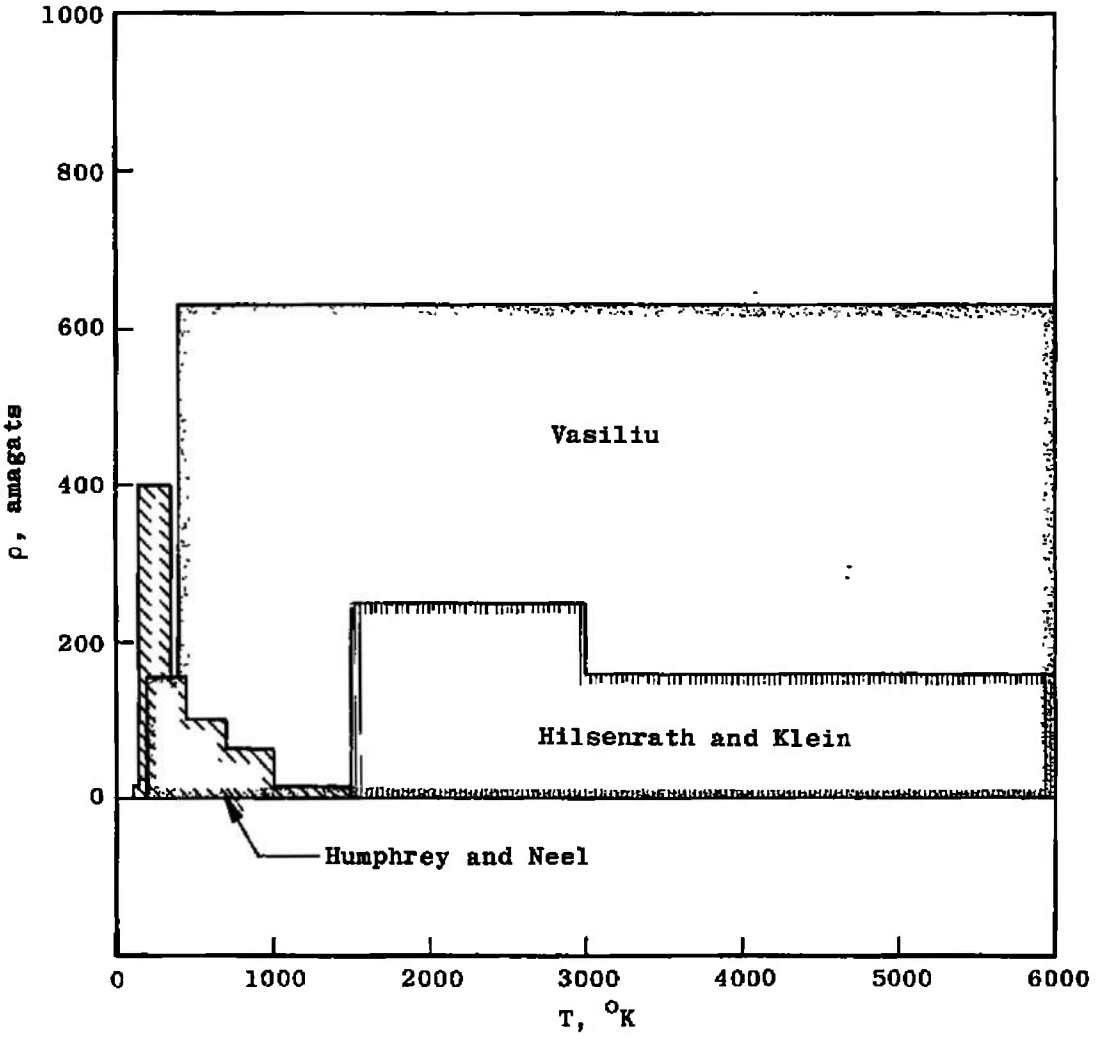

Fig. 1 The Thermodynamic Domain, with Density and Temperature as Variables, Showing Area Covered by Previously Published Tables

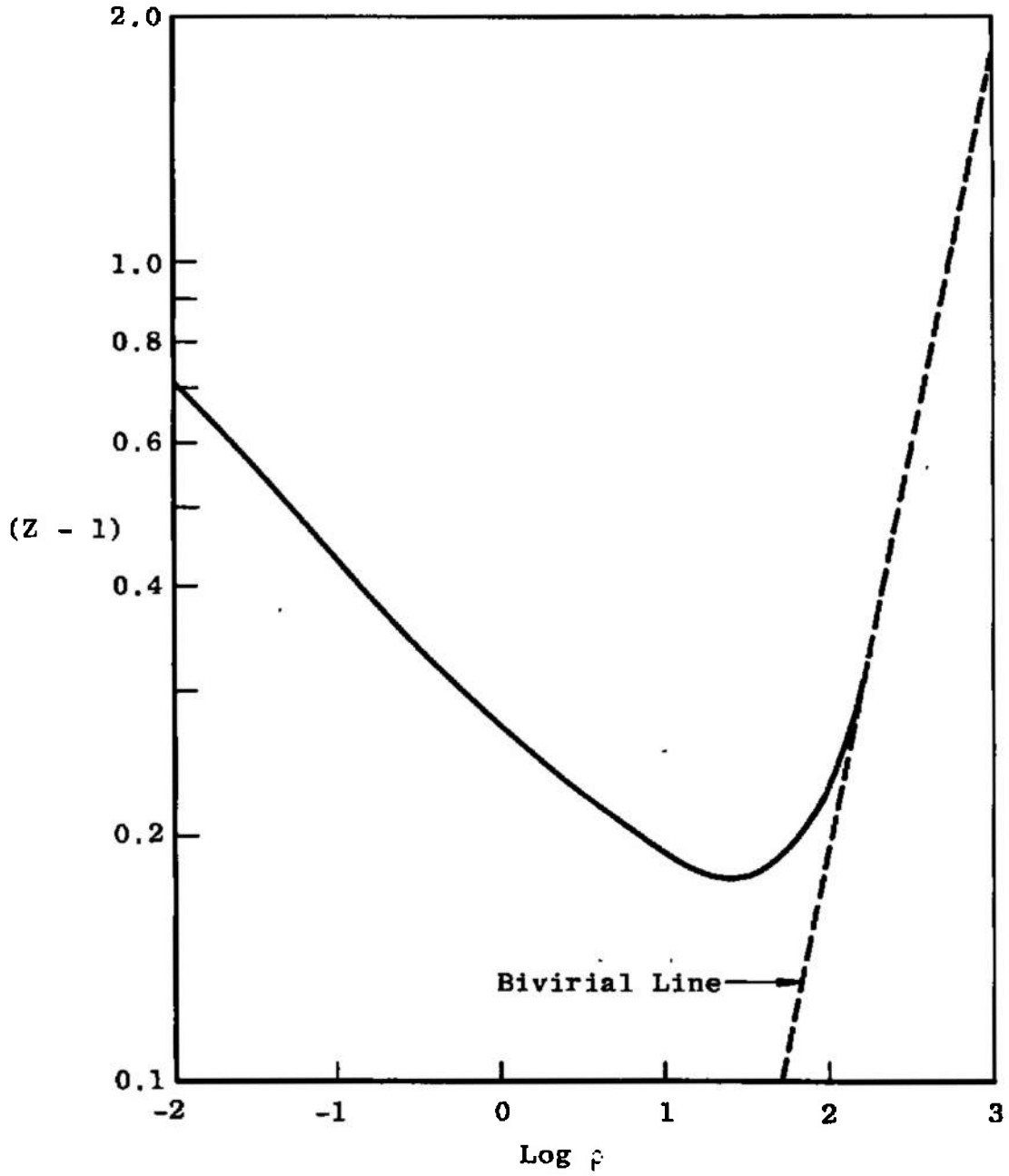

Fig. 2 Plot of (Z – 1) for Air at 7000°K

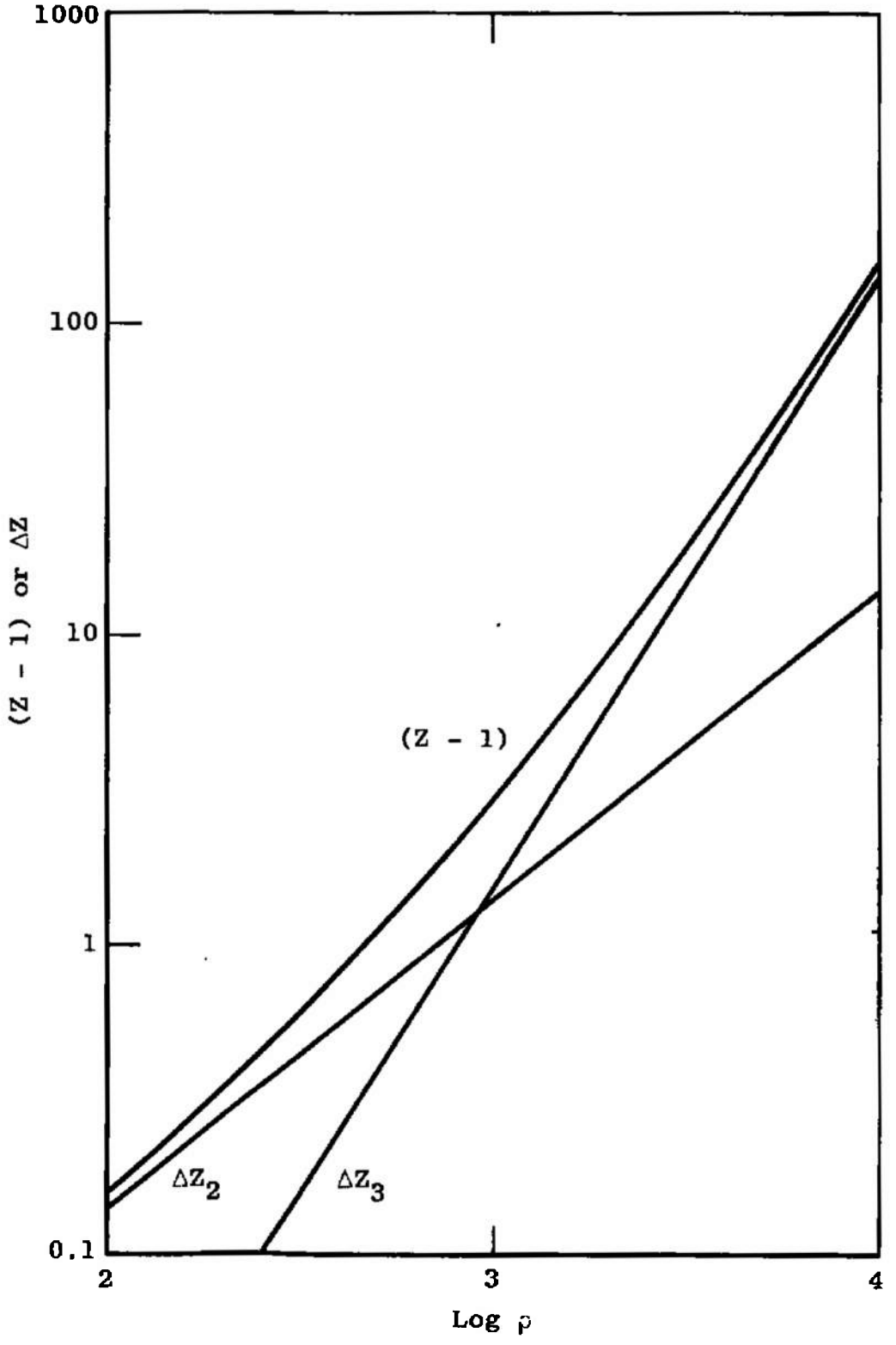

Fig. 3 Plot of Second and Third Virial Lines for Air at 3000°K – Data from Ref. 10

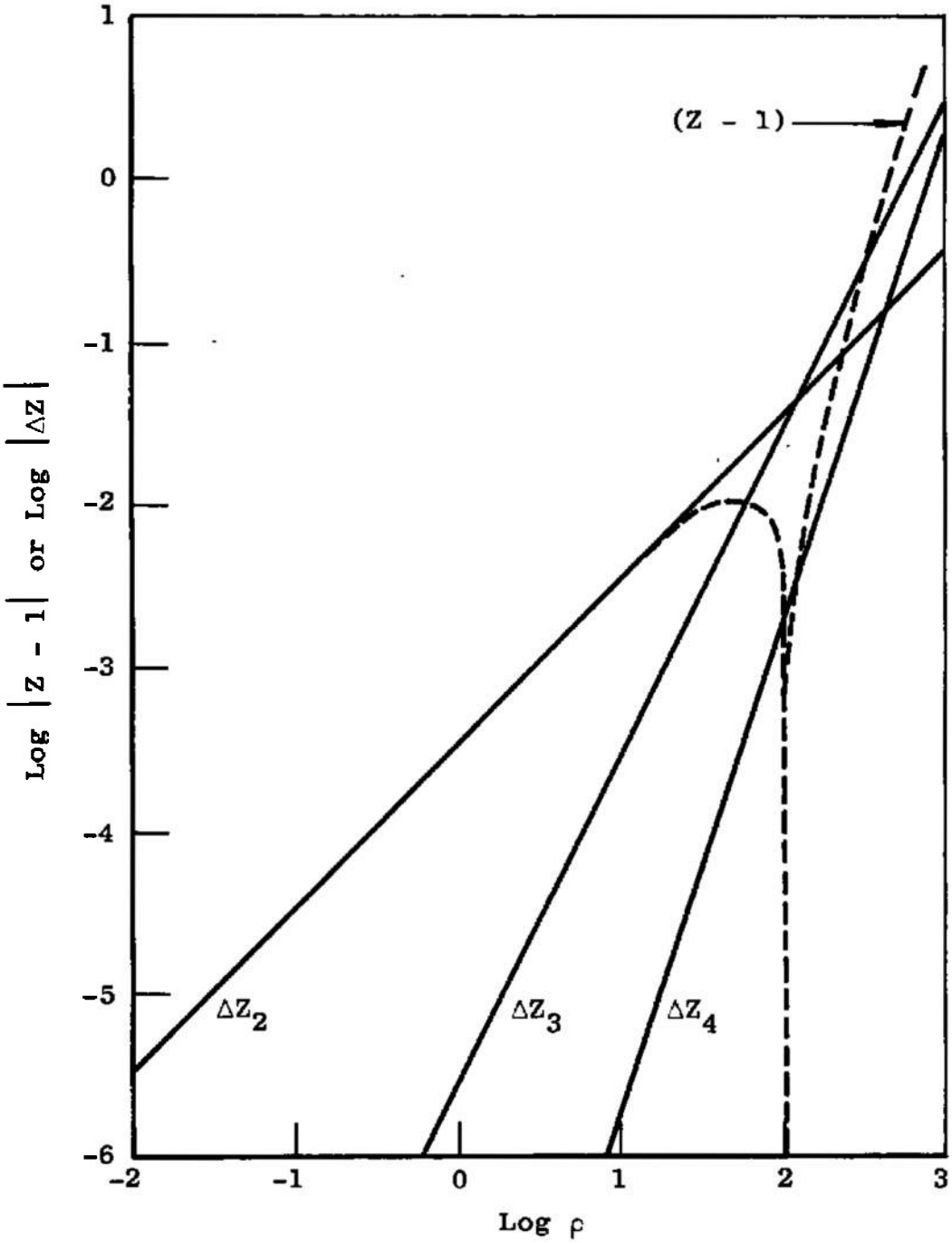

Fig. 4 Plot of Log |Z – 1| and Second, Third, and Fourth Virial Lines for Air at 25°C – Data from Ref. 11

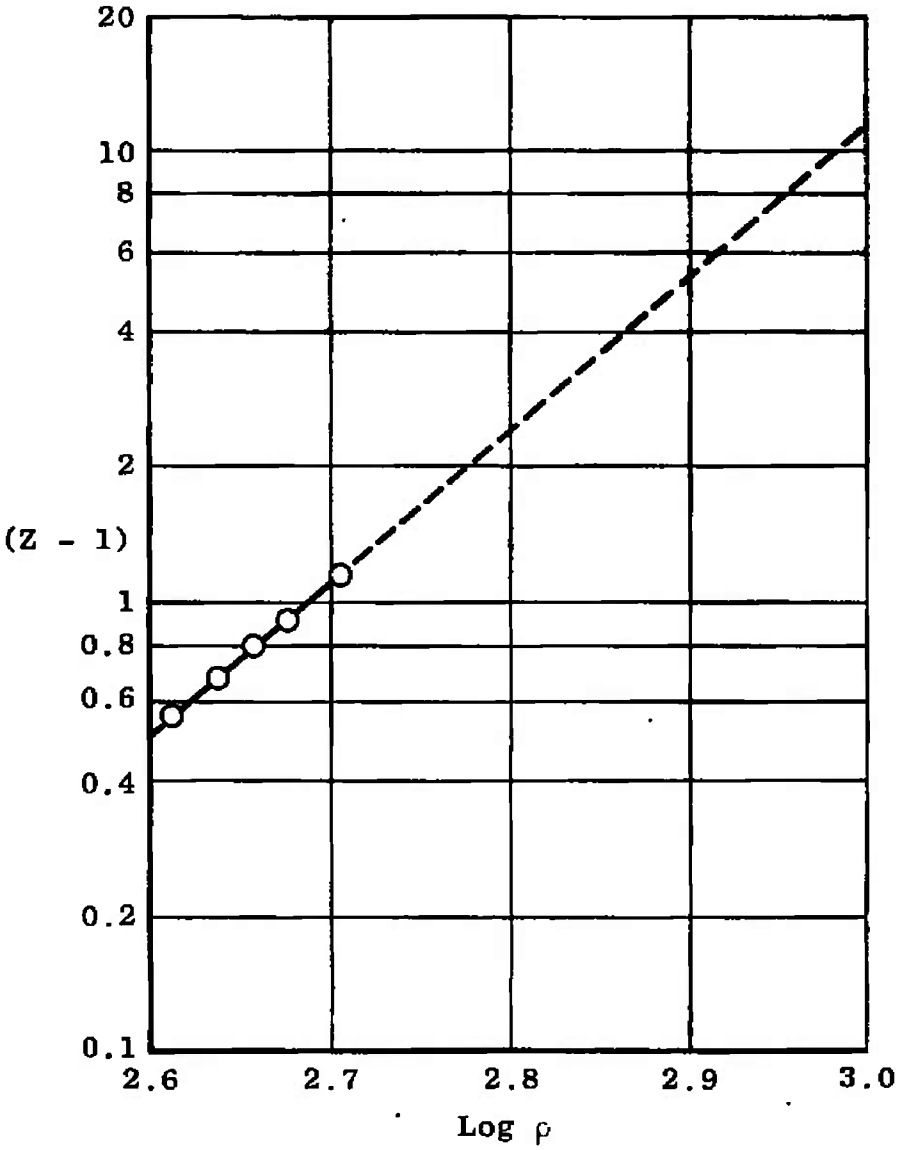

Fig. 5 Plot of (Z – 1) for Air at 300°K – Data from Ref. 2

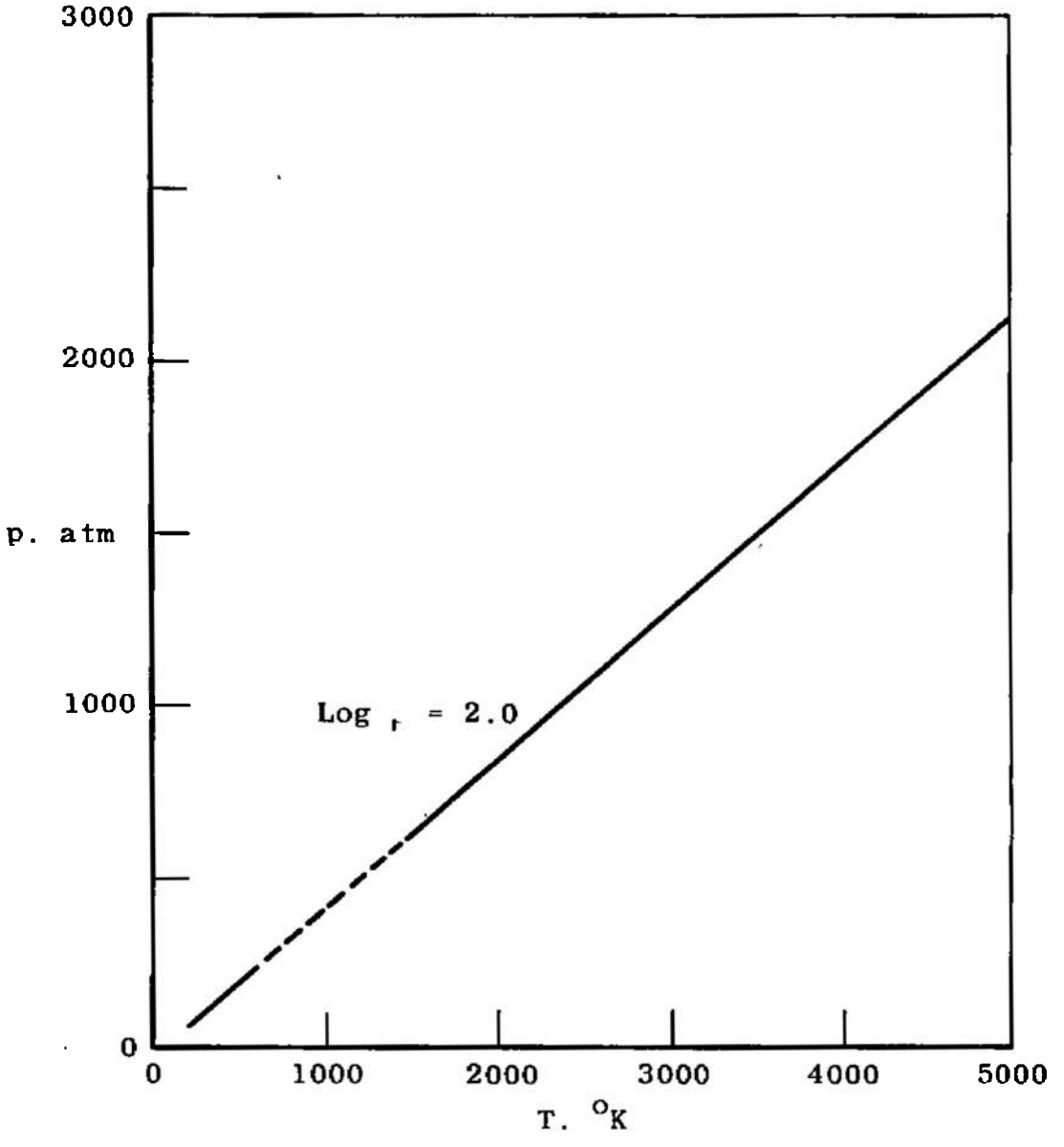

Fig. 6 Pressure-Temperature Line for Air at Log ρ = 2.0 – Data from Refs. 2 and 3

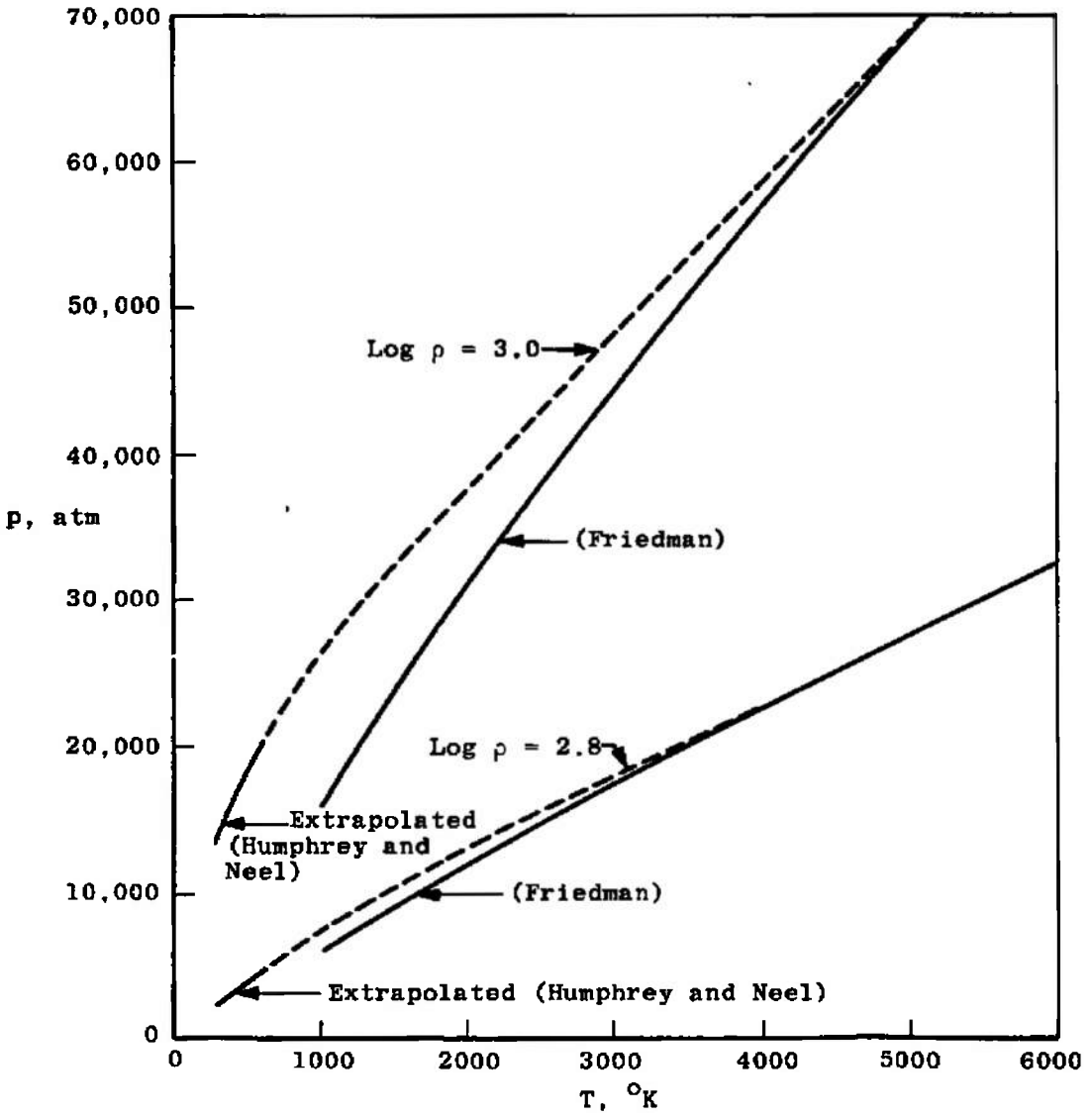

Fig. 7 Pressure-Temperature Lines for Air at Log ρ = 3.0 and 2.8 as Corrected by Empirical Formula (Sources of Data as Indicated)

APPENDIX II
TABLE

APPENDIX II

TABLE I
SPOT COMPARISONS OF ENTRIES IN THE THERMODYNAMIC TABLES GIVEN IN APPENDIX III (G&B) WITH THE CORRESPONDING ENTRIES IN THE TABLES OF HUMPHREY AND NEEL (H&N), AND HILSENRATH AND KLEIN (H&K)

T = 300°K				T = 1000°K			
log ρ = 1.2				log ρ = 1.2			
	Z	E/RT	S/R		Z	E/RT	S/R
G&B	.99588	2.4496	21.029	G&B	1.0203	2.6375	24.240
H&N	.99588	2.4527	21.031	H&N	1.0197	2.6382	24.235
log ρ = 1.4				log ρ = 1.4			
G&B	.99395	2.4283	20.549	G&B	1.0327	2.6319	23.762
H&N	.99395	2.4310	20.552	H&N	1.0316	2.6343	23.764
log ρ = 2.4							
G&B	1.1248	1.9700	17.767				
H&N	1.1250	1.8785	17.673				
log ρ = 2.6							
G&B	1.5150	1.7315	16.941				
H&N	1.5161	1.5589	16.769				
T = 3000°K				T = 6000°K			
log ρ = 1.2				log ρ = 1.2			
	Z	E/RT	S/R		Z	E/RT	S/R
G&B	1.02486	3.30183	28.1022	G&B	1.13479	4.70568	32.2194
H&K	1.02445	3.30249	28.1030	H&K	1.13447	4.67497	32.1889
log ρ = 1.8				log ρ = 1.8			
G&B	1.09754	3.28731	26.6337	G&B	1.16372	4.33039	30.2688
H&K	1.09108	3.28715	26.6368	H&K	1.15861	4.30382	30.2449
log ρ = 2.4				log ρ = 2.2			
G&B	1.45689	3.30399	24.9528	G&B	1.29973	4.14289	28.9589
H&K	1.35596	3.28891	24.9883	H&K	1.26752	4.11482	28.9479

APPENDIX III
TABLES OF THERMODYNAMIC PROPERTIES OF AIR

APPENDIX III
TABLES OF THERMODYNAMIC PROPERTIES FOR AIR

T= 300 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	.99979	2.48670	3.48649	23.82500	.04061	1.09802+00
.20	.99979	2.48619	3.48598	23.36393	.24061	1.74024+00
.40	.99790	2.48226	3.48016	22.90008	.43979	2.75290+00
.60	.99924	2.47692	3.47617	22.43492	.64037	4.36888+00
.80	.99865	2.47180	3.47045	21.96968	.84012	6.92022+00
1.00	.99746	2.46307	3.46053	21.50133	1.03960	1.09547+01
1.20	.99588	2.44955	3.44543	21.02881	1.23891	1.73344+01
1.40	.99395	2.42834	3.42229	20.54941	1.43807	2.74202+01
1.60	.99203	2.39587	3.38790	20.05966	1.63723	4.33741+01
1.80	.99125	2.34465	3.33590	19.55188	1.83689	6.86894+01
2.00	.99672	2.26533	3.26205	19.01523	2.03928	1.09466+02
2.20	1.02330	2.14475	3.16805	18.43093	2.25071	1.78119+02
2.40	1.12481	1.96996	3.09478	17.76658	2.49178	3.10299+02
2.60	1.51500	1.73150	3.24650	16.94060	2.82112	6.62400+02
2.80	3.33517	1.44398	4.77914	15.64243	3.36382	2.31111+03
3.00	12.31588	1.98881	14.30468	13.11151	4.13117	1.35260+04

T= 400 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00040	2.49230	3.49270	24.54600	.16582	1.46494+00
.20	1.00058	2.49155	3.49213	24.08451	.36590	2.32220+00
.40	1.00092	2.48937	3.49029	23.62148	.56604	3.68163+00
.60	1.00160	2.48633	3.48793	23.15736	.76634	5.83902+00
.80	1.00240	2.48263	3.48503	22.69222	.96668	9.26147+00
1.00	1.00350	2.47646	3.47996	22.22419	1.16716	1.46947+01
1.20	1.00550	2.46623	3.47173	21.75142	1.36803	2.33362+01
1.40	1.00910	2.44968	3.45878	21.27107	1.56958	3.71176+01
1.60	1.01560	2.42334	3.43894	20.77870	1.77237	5.92066+01
1.80	1.02870	2.38179	3.41049	20.26675	1.97793	9.50452+01
2.00	1.05450	2.31709	3.37159	19.72314	2.18869	1.54415+02
2.20	1.11270	2.21443	3.32713	19.12324	2.41202	2.58238+02
2.40	1.25206	2.05922	3.31128	18.42876	2.66327	4.60543+02
2.60	1.68498	1.84519	3.53017	17.55888	2.99224	9.82291+02
2.80	3.45036	1.62247	5.07283	16.24796	3.50351	3.18794+03
3.00	11.03911	2.23587	13.27498	13.95167	4.20858	1.61652+04

T= 500 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00070	2.50590	3.50660	25.10900	.26286	1.83172+00
.20	1.00110	2.50503	3.50613	24.64721	.46303	2.90422+00
.40	1.00170	2.50405	3.50575	24.18508	.66329	4.60564+00
.60	1.00272	2.50264	3.50536	23.72214	.86373	7.30685+00
.80	1.00420	2.50007	3.50427	23.25749	1.06437	1.15977+01
1.00	1.00650	2.49587	3.50237	22.79036	1.26537	1.84234+01
1.20	1.01060	2.48898	3.49958	22.31910	1.46713	2.93177+01
1.40	1.01730	2.47764	3.49494	21.84094	1.67000	4.67735+01
1.60	1.02880	2.45939	3.48819	21.35180	1.87488	7.49687+01
1.80	1.04900	2.43075	3.47975	20.84517	2.08333	1.21152+02
2.00	1.08620	2.38623	3.47243	20.30999	2.29846	1.98820+02
2.20	1.16250	2.31888	3.48138	19.72688	2.52795	3.37248+02
2.40	1.32499	2.21572	3.54071	19.05630	2.78477	6.09214+02
2.60	1.77873	2.07175	3.85048	18.21767	3.11266	1.29616+03
2.80	3.47128	1.95994	5.43122	16.98177	3.60304	4.00904+03
3.00	10.07273	2.64012	12.71285	14.89655	4.26570	1.84374+04

T= 600 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00090	2.52570	3.52660	25.58700	.34213	2.19852+00
.20	1.00150	2.52503	3.52653	25.12526	.54239	3.48650+00
.40	1.00220	2.52392	3.52612	24.66279	.74269	5.52955+00
.60	1.00350	2.52240	3.52590	24.19947	.94325	8.77506+00
.80	1.00550	2.52003	3.52553	23.73454	1.14412	1.39354+01
1.00	1.00860	2.51610	3.52470	23.26690	1.34545	2.21539+01
1.20	1.01380	2.51011	3.52391	22.79535	1.54769	3.52931+01
1.40	1.02260	2.50054	3.52314	22.31703	1.75144	5.64209+01
1.60	1.03690	2.48599	3.52289	21.82858	1.95747	9.06713+01
1.80	1.06250	2.46122	3.52372	21.32093	2.16806	1.47252+02
2.00	1.10640	2.42179	3.52820	20.78311	2.38565	2.43024+02
2.20	1.19160	2.36677	3.55837	20.20120	2.61786	4.14820+02
2.40	1.37094	2.28275	3.65369	19.53266	2.87875	7.56397+02
2.60	1.83485	2.16480	3.99965	18.69582	3.20533	1.60446+03
2.80	3.45080	2.10336	5.55416	17.49418	3.67965	4.78245+03
3.00	9.29930	2.83373	12.13303	15.58784	4.31018	2.04258+04

T= 700 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00110	2.55110	3.55220	26.00400	.40916	2.56543+00
.20	1.00170	2.55073	3.55243	25.54248	.60942	4.06837+00
.40	1.00260	2.55003	3.55263	25.08029	.80981	6.45372+00
.60	1.00400	2.54883	3.55283	24.61708	1.01041	1.02426+01
.80	1.00640	2.54707	3.55347	24.15244	1.21145	1.62723+01
1.00	1.01000	2.54408	3.55408	23.68523	1.41300	2.58821+01
1.20	1.01610	2.53902	3.55512	23.21377	1.61562	4.12686+01
1.40	1.02610	2.53140	3.55750	22.73609	1.81987	6.60496+01
1.60	1.04250	2.51830	3.56080	22.24703	2.02676	1.06356+02
1.80	1.07150	2.50218	3.57368	21.74473	2.23867	1.73249+02
2.00	1.12050	2.47545	3.59595	21.21434	2.45809	2.87138+02
2.20	1.21230	2.42687	3.63917	20.63096	2.69229	4.92368+02
2.40	1.40161	2.35742	3.75903	19.96523	2.95531	9.02215+02
2.60	1.86984	2.26864	4.13848	19.14176	3.28049	1.90761+03
2.80	3.41086	2.25388	5.66475	17.98110	3.74155	5.51506+03
3.00	8.66138	3.01636	11.67774	16.22213	4.34627	2.21958+04

T= 800 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00120	2.58050	3.58170	26.37300	.46719	2.93218+00
.20	1.00180	2.58024	3.58204	25.91155	.66745	4.64997+00
.40	1.00286	2.57963	3.58249	25.44937	.86791	7.37751+00
.60	1.00440	2.57860	3.58300	24.98617	1.06858	1.17106+01
.80	1.00700	2.57698	3.58398	24.52146	1.26970	1.86080+01
1.00	1.01113	2.57403	3.58516	24.05390	1.47148	2.96128+01
1.20	1.01780	2.56932	3.58713	23.58213	1.67434	4.72433+01
1.40	1.02880	2.56237	3.59117	23.10416	1.87900	7.56833+01
1.60	1.04700	2.55078	3.59778	22.61488	2.08662	1.22073+02
1.80	1.07550	2.53344	3.60894	22.10949	2.29828	1.98738+02
2.00	1.13080	2.50716	3.63796	21.57645	2.52006	3.31177+02
2.20	1.22840	2.46503	3.69343	20.99336	2.75601	5.70177+02
2.40	1.42286	2.40651	3.82936	20.32997	3.01983	1.04672+03
2.60	1.89193	2.33711	4.22904	19.51531	3.34358	2.20587+03
2.80	3.36192	2.35478	5.71670	18.38729	3.79326	6.21241+03
3.00	8.12493	3.13407	11.25900	16.74815	4.37649	2.37952+04

T= 900 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00120	2.61220	3.61340	26.71500	.51835	3.29875+00
.20	1.00192	2.61199	3.61391	26.25357	.71866	5.23191+00
.40	1.00305	2.61151	3.61456	25.79145	.91915	8.30137+00
.60	1.00470	2.61064	3.61534	25.32831	1.11986	1.31783+01
.80	1.00756	2.60903	3.61659	24.86341	1.32110	2.09459+01
1.00	1.01205	2.60646	3.61851	24.39588	1.52303	3.33449+01
1.20	1.01920	2.60235	3.62155	23.92420	1.72608	5.32206+01
1.40	1.03090	2.59570	3.62660	23.44571	1.93104	8.53179+01
1.60	1.05040	2.58643	3.63683	22.95759	2.13918	1.37778+02
1.80	1.08300	2.56643	3.64943	22.44701	2.35245	2.25139+02
2.00	1.13900	2.53683	3.67583	21.90699	2.57435	3.75275+02
2.20	1.24050	2.49889	3.73939	21.32352	2.81142	6.47769+02
2.40	1.43791	2.44912	3.88703	20.66256	3.07556	1.19004+03
2.60	1.90568	2.39643	4.30211	19.85743	3.39788	2.49965+03
2.80	3.30940	2.44041	5.74980	18.75937	3.83757	6.87971+03
3.00	7.66795	3.22533	10.89328	17.21811	4.40250	2.52639+04

T= 1000 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00120	2.64540	3.64660	27.03000	.56410	3.66522+00
.20	1.00198	2.64522	3.64720	26.56858	.76444	5.81353+00
.40	1.00315	2.64500	3.64815	26.10668	.96495	9.22465+00
.60	1.00500	2.64417	3.64917	25.64349	1.16575	1.46470+01
.80	1.00795	2.64277	3.65072	25.17865	1.36702	2.32820+01
1.00	1.01269	2.64089	3.65358	24.71158	1.56906	3.70732+01
1.20	1.02030	2.63753	3.65783	24.24025	1.77231	5.91984+01
1.40	1.03267	2.63185	3.66452	23.76209	1.97754	9.49598+01
1.60	1.05301	2.62279	3.67580	23.27318	2.18602	1.53469+02
1.80	1.08711	2.61186	3.69897	22.77015	2.39986	2.51108+02
2.00	1.14586	2.59260	3.73846	22.23801	2.62271	4.19479+02
2.20	1.25075	2.55687	3.80762	21.65275	2.86075	7.25688+02
2.40	1.44871	2.51420	3.96291	20.99398	3.12457	1.33220+03
2.60	1.91381	2.47461	4.38842	20.19712	3.44548	2.78920+03
2.80	3.25619	2.53960	5.79580	19.12583	3.87629	7.52125+03
3.00	7.27463	3.31966	10.59429	17.66222	4.42539	2.66312+04

T= 1100 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00130	2.67890	3.68020	27.32500	.60554	4.03218+00
.20	1.00203	2.67863	3.68066	26.86347	.80585	6.39514+00
.40	1.00323	2.67835	3.68158	26.40148	1.00638	1.01480+01
.60	1.00523	2.67767	3.68290	25.93838	1.20724	1.61154+01
.80	1.00824	2.67656	3.68479	25.47370	1.40854	2.56177+01
1.00	1.01316	2.67494	3.68810	25.00673	1.61065	4.07990+01
1.20	1.02111	2.67221	3.69333	24.53574	1.81405	6.51703+01
1.40	1.03400	2.66775	3.70175	24.05831	2.01950	1.04592+02
1.60	1.05497	2.66071	3.71567	23.57065	2.22821	1.69126+02
1.80	1.08959	2.65110	3.74069	23.06796	2.44224	2.76847+02
2.00	1.15094	2.63529	3.78623	22.53760	2.66603	4.63479+02
2.20	1.25839	2.60835	3.86674	21.95813	2.90479	8.03138+02
2.40	1.45652	2.57521	4.03173	21.30528	3.16829	1.47330+03
2.60	1.91805	2.54628	4.46434	20.51581	3.48784	3.07496+03
2.80	3.20399	2.62836	5.83235	19.46863	3.91067	8.14085+03
3.00	6.93337	3.39779	10.33116	18.06826	4.44592	2.79203+04

T= 1200 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00130	2.71210	3.71340	27.58800	.64333	4.39876+00
.20	1.00208	2.71189	3.71397	27.12651	.84366	6.97686+00
.40	1.00331	2.71156	3.71486	26.66445	1.04420	1.10713+01
.60	1.00538	2.71104	3.71642	26.20144	1.24510	1.75833+01
.80	1.00846	2.71019	3.71865	25.73694	1.44642	2.79525+01
1.00	1.01351	2.70883	3.72235	25.27011	1.64859	4.45236+01
1.20	1.02169	2.70672	3.72841	24.79952	1.85208	7.11345+01
1.40	1.03492	2.70341	3.73832	24.32290	2.05767	1.14201+02
1.60	1.05637	2.69824	3.75460	23.83658	2.26658	1.84748+02
1.80	1.09163	2.69005	3.78168	23.33454	2.48084	3.02580+02
2.00	1.15436	2.67764	3.83200	22.80634	2.70511	5.07119+02
2.20	1.26348	2.65908	3.92257	22.23329	2.94433	8.79691+02
2.40	1.46208	2.63464	4.09672	21.58663	3.20773	1.61336+03
2.60	1.91946	2.61465	4.53411	20.80398	3.52594	3.35691+03
2.80	3.15360	2.71048	5.86408	19.77831	3.94157	8.74118+03
3.00	6.63517	3.46501	10.10018	18.42939	4.46462	2.91488+04

T= 1300 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00130	2.74510	3.74640	27.82800	.67809	4.76530+00
.20	1.00212	2.74498	3.74710	27.36659	.87845	7.55875+00
.40	1.00338	2.74462	3.74800	26.90447	1.07899	1.19947+01
.60	1.00547	2.74423	3.74971	26.44156	1.27990	1.90502+01
.80	1.00863	2.74361	3.75224	25.97723	1.48126	3.02873+01
1.00	1.01377	2.74251	3.75629	25.51055	1.68347	4.82470+01
1.20	1.02208	2.74093	3.76301	25.04034	1.88701	7.70921+01
1.40	1.03552	2.73858	3.77410	24.56447	2.09268	1.23788+02
1.60	1.05734	2.73498	3.79232	24.07937	2.30174	2.00327+02
1.80	1.09327	2.72820	3.82147	23.57814	2.51625	3.28284+02
2.00	1.15651	2.71883	3.87534	23.05211	2.74068	5.50402+02
2.20	1.26659	2.70734	3.97393	22.48493	2.98016	9.55344+02
2.40	1.46601	2.69023	4.15624	21.84394	3.24366	1.75251+03
2.60	1.91890	2.67771	4.59660	21.06746	3.56058	3.63563+03
2.80	3.10557	2.78432	5.88989	20.06068	3.96967	9.32545+03
3.00	6.37298	3.52099	9.89397	18.75360	4.48187	3.03298+04

T= 1400 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00130	2.77760	3.77890	28.06400	.71028	5.13192+00
.20	1.00217	2.77741	3.77958	27.60251	.91065	8.14048+00
.40	1.00344	2.77708	3.78052	27.14040	1.11120	1.29181+01
.60	1.00553	2.77679	3.78232	26.67756	1.31210	2.05163+01
.80	1.00876	2.77634	3.78510	26.21336	1.51350	3.26212+01
1.00	1.01396	2.77546	3.78942	25.74683	1.71573	5.19673+01
1.20	1.02234	2.77427	3.79662	25.27691	1.91931	8.30443+01
1.40	1.03590	2.77261	3.80850	24.80157	2.12503	1.33361+02
1.60	1.05799	2.77010	3.82810	24.31735	2.33419	2.15869+02
1.80	1.09455	2.76461	3.85916	23.81695	2.54895	3.53957+02
2.00	1.15779	2.75762	3.91541	23.29270	2.77334	5.93390+02
2.20	1.26833	2.75096	4.01929	22.72969	3.01294	1.03024+03
2.40	1.46870	2.73952	4.20821	22.09332	3.27664	1.89078+03
2.60	1.91687	2.73378	4.65065	21.32294	3.59230	3.91111+03
2.80	3.06009	2.84904	5.90913	20.33305	3.99545	9.89578+03
3.00	6.14115	3.56606	9.70721	19.06021	4.49796	3.14746+04

T= 1500 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00140	2.80940	3.81080	28.29970	.74028	5.49895+00
.20	1.00220	2.80913	3.81133	27.83811	.94063	8.72228+00
.40	1.00349	2.80888	3.81237	27.37606	1.14119	1.38417+01
.60	1.00556	2.80864	3.81420	26.91325	1.34208	2.19826+01
.80	1.00885	2.80828	3.81712	26.44911	1.54350	3.49543+01
1.00	1.01410	2.80756	3.82166	25.98269	1.74576	5.56878+01
1.20	1.02253	2.80658	3.82911	25.51292	1.94935	8.89918+01
1.40	1.03616	2.80521	3.84137	25.03776	2.15510	1.42922+02
1.60	1.05846	2.80315	3.86161	24.55382	2.36435	2.31393+02
1.80	1.09553	2.79872	3.89425	24.05415	2.57930	3.79577+02
2.00	1.15859	2.79319	3.95178	23.53094	2.80360	6.36209+02
2.20	1.26933	2.78826	4.05759	22.96927	3.04325	1.10471+03
2.40	1.47043	2.78029	4.25072	22.33572	3.30712	2.02824+03
2.60	1.91378	2.78075	4.69453	21.57136	3.62157	4.18379+03
2.80	3.01722	2.90269	5.91991	20.59633	4.01928	1.04539+04
3.00	5.93513	3.59900	9.53413	19.35155	4.51310	3.25912+04

T= 1600 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00140	2.84178	3.84318	28.51410	.76831	5.86557+00
.20	1.00222	2.84160	3.84382	28.05258	.96867	9.30401+00
.40	1.00353	2.84142	3.84494	27.59059	1.16923	1.47649+01
.60	1.00559	2.84120	3.84679	27.12779	1.37012	2.34488+01
.80	1.00892	2.84087	3.84979	26.66366	1.57156	3.72872+01
1.00	1.01421	2.84028	3.85449	26.19732	1.77383	5.94060+01
1.20	1.02268	2.83941	3.86209	25.72759	1.97744	9.49380+01
1.40	1.03639	2.83811	3.87449	25.25243	2.18322	1.52483+02
1.60	1.05884	2.83613	3.89497	24.76844	2.39253	2.46905+02
1.80	1.09624	2.83262	3.92886	24.26942	2.60761	4.05145+02
2.00	1.15926	2.82799	3.98725	23.74678	2.83188	6.79016+02
2.20	1.27012	2.82310	4.09321	23.18484	3.07155	1.17910+03
2.40	1.47141	2.81733	4.28874	22.55304	3.33544	2.16491+03
2.60	1.90989	2.82341	4.73331	21.79453	3.64871	4.45359+03
2.80	2.97693	2.95049	5.92743	20.83268	4.04147	1.10020+04
3.00	5.75116	3.62555	9.37670	19.61090	4.52746	3.36868+04

T= 1700 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00141	2.87521	3.87662	28.71910	.79464	6.23218+00
.20	1.00224	2.87514	3.87738	28.25768	.99500	9.88553+00
.40	1.00355	2.87500	3.87855	27.79572	1.19557	1.56881+01
.60	1.00562	2.87479	3.88042	27.33292	1.39647	2.49155+01
.80	1.00898	2.87449	3.88347	26.86880	1.59791	3.96196+01
1.00	1.01430	2.87402	3.88831	26.40255	1.80020	6.31248+01
1.20	1.02282	2.87325	3.89607	25.93287	2.00383	1.00886+02
1.40	1.03659	2.87205	3.90864	25.45774	2.20964	1.62047+02
1.60	1.05915	2.87021	3.92937	24.97377	2.41899	2.62416+02
1.80	1.09674	2.86755	3.96429	24.47542	2.63414	4.30665+02
2.00	1.15985	2.86383	4.02368	23.95343	2.85843	7.21822+02
2.20	1.27078	2.85931	4.13008	23.39157	3.09810	1.25343+03
2.40	1.47182	2.85565	4.32747	22.76160	3.36189	2.30086+03
2.60	1.90545	2.86662	4.77207	22.00849	3.67403	4.72096+03
2.80	2.93915	2.99761	5.93676	21.05837	4.06225	1.15412+04
3.00	5.58615	3.65110	9.23725	19.85531	4.54114	3.47648+04

T= 1800 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00142	2.90517	3.90659	28.91610	.81947	6.59888+00
.20	1.00225	2.90508	3.90734	28.45467	1.01983	1.04672+01
.40	1.00357	2.90496	3.90853	27.99271	1.22040	1.66112+01
.60	1.00566	2.90475	3.91040	27.52990	1.42130	2.63815+01
.80	1.00902	2.90446	3.91348	27.06578	1.62275	4.19517+01
1.00	1.01436	2.90408	3.91844	26.59959	1.82505	6.68421+01
1.20	1.02293	2.90342	3.92635	26.12998	2.02870	1.06832+02
1.40	1.03676	2.90236	3.93912	25.65491	2.23453	1.71605+02
1.60	1.05941	2.90072	3.96013	25.17105	2.44392	2.77920+02
1.80	1.09706	2.89880	3.99586	24.67331	2.65909	4.56131+02
2.00	1.16034	2.89598	4.05632	24.15203	2.88344	7.64610+02
2.20	1.27128	2.89218	4.16346	23.59066	3.12310	1.32770+03
2.40	1.47177	2.89064	4.36240	22.96265	3.38669	2.43607+03
2.60	1.90060	2.90591	4.80651	22.21459	3.69775	4.98597+03
2.80	2.90374	3.03982	5.94357	21.27498	4.08181	1.20729+04
3.00	5.43750	3.67181	9.10931	20.08715	4.55426	3.58311+04

T= 1900 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00144	2.93725	3.93869	29.10600	.84296	6.96562+00
.20	1.00227	2.93707	3.93933	28.64446	1.04332	1.10489+01
.40	1.00359	2.93691	3.94050	28.18247	1.24389	1.75344+01
.60	1.00569	2.93668	3.94237	27.71962	1.44480	2.78484+01
.80	1.00905	2.93641	3.94546	27.25550	1.64625	4.42843+01
1.00	1.01442	2.93608	3.95050	26.78935	1.84855	7.05586+01
1.20	1.02302	2.93553	3.95855	26.31981	2.05222	1.12777+02
1.40	1.03691	2.93463	3.97153	25.84485	2.25808	1.81167+02
1.60	1.05961	2.93326	3.99286	25.36118	2.46748	2.93413+02
1.80	1.09726	2.93194	4.02920	24.86396	2.68265	4.81560+02
2.00	1.16072	2.92998	4.09069	24.34341	2.90706	8.07347+02
2.20	1.27161	2.92730	4.19890	23.78297	3.14669	1.40181+03
2.40	1.47135	2.92789	4.39924	23.15707	3.41005	2.57069+03
2.60	1.89547	2.94692	4.84238	22.41370	3.72005	5.24868+03
2.80	2.87060	3.08292	5.95352	21.48348	4.10031	1.25982+04
3.00	5.30305	3.69371	8.99676	20.30805	4.56686	3.68859+04

T= 2000 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00147	2.96972	3.97119	29.28970	.86525	7.33247+00
.20	1.00229	2.96941	3.97170	28.82802	1.06561	1.16308+01
.40	1.00361	2.96917	3.97278	28.36593	1.26618	1.84578+01
.60	1.00572	2.96890	3.97462	27.90304	1.46709	2.93150+01
.80	1.00908	2.96862	3.97770	27.43889	1.66854	4.66165+01
1.00	1.01446	2.96832	3.98278	26.97275	1.87085	7.42763+01
1.20	1.02309	2.96786	3.99095	26.50329	2.07453	1.18722+02
1.40	1.03702	2.96716	4.00418	26.02848	2.28040	1.90722+02
1.60	1.05975	2.96613	4.02588	25.54509	2.48982	3.08901+02
1.80	1.09737	2.96524	4.06261	25.04824	2.70497	5.06956+02
2.00	1.16096	2.96406	4.12502	24.52840	2.92943	8.50022+02
2.20	1.27173	2.96293	4.23466	23.96941	3.16901	1.47574+03
2.40	1.47066	2.96573	4.43639	23.34580	3.43212	2.70471+03
2.60	1.89014	2.98804	4.87818	22.60677	3.74111	5.50947+03
2.80	2.83957	3.12547	5.96504	21.68498	4.11787	1.31181+04
3.00	5.18097	3.71559	8.89656	20.51970	4.57902	3.79332+04

T= 2100 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00153	3.00222	4.00375	29.46820	.88647	7.69963+00
.20	1.00233	3.00163	4.00396	29.00622	1.08681	1.22127+01
.40	1.00364	3.00118	4.00482	28.54390	1.28738	1.93812+01
.60	1.00575	3.00077	4.00652	28.08085	1.48829	3.07815+01
.80	1.00911	3.00040	4.00952	27.61661	1.68974	4.89486+01
1.00	1.01450	3.00005	4.01455	27.15040	1.89205	7.79920+01
1.20	1.02314	2.99964	4.02278	26.68096	2.09574	1.24664+02
1.40	1.03710	2.99910	4.03620	26.20629	2.30162	2.00272+02
1.60	1.05984	2.99841	4.05825	25.72319	2.51104	3.24369+02
1.80	1.09744	2.99781	4.09525	25.22660	2.72618	5.32329+02
2.00	1.16106	2.99734	4.15840	24.70742	2.95066	8.92606+02
2.20	1.27163	2.99789	4.26953	24.15010	3.19016	1.54939+03
2.40	1.46974	3.00282	4.47256	23.52882	3.45304	2.83818+03
2.60	1.88470	3.02800	4.91270	22.79381	3.76105	5.76833+03
2.80	2.81052	3.16625	5.97676	21.87957	4.13459	1.36330+04
3.00	5.06974	3.73633	8.80607	20.72255	4.59079	3.89753+04

T= 2200 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00163	3.03652	4.03815	29.64230	.90671	8.06696+00
.20	1.00240	3.03538	4.03778	29.17974	1.10705	1.27953+01
.40	1.00371	3.03447	4.03817	28.71692	1.30761	2.03053+01
.60	1.00580	3.03373	4.03953	28.25351	1.50852	3.22493+01
.80	1.00916	3.03312	4.04227	27.78900	1.70996	5.12814+01
1.00	1.01454	3.03259	4.04713	27.32260	1.91228	8.17109+01
1.20	1.02319	3.03211	4.05530	26.85307	2.11596	1.30605+02
1.40	1.03715	3.03164	4.06879	26.37844	2.32185	2.09822+02
1.60	1.05990	3.03118	4.09108	25.89555	2.53127	3.39836+02
1.80	1.09747	3.03082	4.12830	25.39918	2.74640	5.57699+02
2.00	1.16104	3.03097	4.19201	24.88061	2.97085	9.35083+02
2.20	1.27135	3.03296	4.30431	24.32479	3.21027	1.62282+03
2.40	1.46864	3.03976	4.50839	23.70565	3.47292	2.97112+03
2.60	1.87921	3.06748	4.94669	22.97442	3.77998	6.02532+03
2.80	2.78330	3.20605	5.98935	22.06695	4.15057	1.41439+04
3.00	4.96806	3.75678	8.72484	20.91664	4.60219	4.00120+04

T= 2300 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00179	3.07099	4.07278	25.81300	.92609	8.43510+00
.20	1.00253	3.06897	4.07150	29.34948	1.12641	1.33786+01
.40	1.00381	3.06732	4.07114	28.88589	1.32696	2.12305+01
.60	1.00589	3.06603	4.07192	28.42188	1.52786	3.37179+01
.80	1.00923	3.06500	4.07422	27.95691	1.72930	5.36167+01
1.00	1.01460	3.06415	4.07875	27.49016	1.93161	8.54299+01
1.20	1.02324	3.06348	4.08673	27.02042	2.13529	1.36549+02
1.40	1.03719	3.06296	4.10015	26.54572	2.34117	2.19366+02
1.60	1.05993	3.06261	4.12254	26.06292	2.55059	3.55296+02
1.80	1.09748	3.06243	4.15991	25.56670	2.76571	5.83056+02
2.00	1.16093	3.06307	4.22400	25.04865	2.99012	9.77507+02
2.20	1.27093	3.06622	4.33714	24.49410	3.22943	1.69602+03
2.40	1.46740	3.07460	4.54200	23.87689	3.49186	3.10356+03
2.60	1.87370	3.10460	4.97830	23.14921	3.79801	6.28073+03
2.80	2.75779	3.24306	6.00085	22.24779	4.16587	1.46511+04
3.00	4.87479	3.77518	8.64996	21.10294	4.61327	4.10459+04

T= 2400 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00206	3.10745	4.10951	29.98110	.94469	8.80420+00
.20	1.00275	3.10415	4.10690	29.51620	1.14499	1.39634+01
.40	1.00399	3.10148	4.10547	29.05148	1.34552	2.21575+01
.60	1.00603	3.09938	4.10541	28.58660	1.54640	3.51884+01
.80	1.00934	3.09773	4.10707	28.12095	1.74783	5.59539+01
1.00	1.01469	3.09642	4.11110	27.65369	1.95013	8.91518+01
1.20	1.02331	3.09542	4.11873	27.18358	2.15380	1.42495+02
1.40	1.03724	3.09470	4.13194	26.70867	2.35967	2.28913+02
1.60	1.05996	3.09432	4.15427	26.22581	2.56908	3.70749+02
1.80	1.09747	3.09424	4.19171	25.72969	2.78419	6.08401+02
2.00	1.16075	3.09523	4.25599	25.21203	3.00853	1.01984+03
2.20	1.27041	3.09918	4.36959	24.65844	3.24774	1.76905+03
2.40	1.46606	3.10887	4.57492	24.04291	3.50995	3.23556+03
2.60	1.86821	3.14092	5.00913	23.31861	3.81522	6.53461+03
2.80	2.73387	3.27894	6.01281	22.42264	4.18057	1.51555+04
3.00	4.78897	3.79320	8.58217	21.28219	4.62404	4.20765+04

T= 2500 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00246	3.14690	4.14936	30.14780	.96259	9.17466+00
.20	1.00308	3.14184	4.14492	29.68097	1.16286	1.45499+01
.40	1.00425	3.13782	4.14207	29.21477	1.36336	2.30866+01
.60	1.00623	3.13465	4.14088	28.74870	1.56422	3.66623+01
.80	1.00950	3.13215	4.14165	28.28212	1.76563	5.82948+01
1.00	1.01481	3.13020	4.14501	27.81416	1.96791	9.28774+01
1.20	1.02340	3.12871	4.15211	27.34352	2.17157	1.48447+02
1.40	1.03730	3.12766	4.16496	26.86822	2.37743	2.38468+02
1.60	1.05998	3.12707	4.18705	26.38515	2.58682	3.86207+02
1.80	1.09745	3.12700	4.22445	25.88904	2.80191	6.33738+02
2.00	1.16055	3.12819	4.28874	25.37162	3.02619	1.06216+03
2.20	1.26984	3.13253	4.40237	24.81858	3.26527	1.84192+03
2.40	1.46463	3.14319	4.60782	24.20445	3.52725	3.36705+03
2.60	1.86277	3.17711	5.03988	23.48336	3.83168	6.78703+03
2.80	2.71142	3.31439	6.02581	22.59226	4.19472	1.56574+04
3.00	4.70979	3.81159	8.52138	21.45540	4.63452	4.31042+04

T= 2600 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00306	3.18893	4.19199	30.31400	.97988	9.54729+00
.20	1.00355	3.18140	4.18494	29.84445	1.18010	1.51391+01
.40	1.00462	3.17548	4.18010	29.37615	1.38056	2.40193+01
.60	1.00652	3.17078	4.17730	28.90841	1.58138	3.81399+01
.80	1.00973	3.16707	4.17680	28.44051	1.78276	6.06401+01
1.00	1.01499	3.16420	4.17918	27.97153	1.98502	9.66095+01
1.20	1.02353	3.16199	4.18552	27.50009	2.18866	1.54405+02
1.40	1.03739	3.16038	4.19777	27.02419	2.39450	2.48028+02
1.60	1.06002	3.15941	4.21943	26.54071	2.60387	4.01671+02
1.80	1.09742	3.15920	4.25663	26.04446	2.81893	6.59068+02
2.00	1.16034	3.16043	4.32078	25.52712	3.04314	1.10443+03
2.20	1.26926	3.16489	4.43414	24.97438	3.28211	1.91474+03
2.40	1.46315	3.17630	4.63945	24.36142	3.54384	3.49816+03
2.60	1.85739	3.21186	5.06925	23.64334	3.84746	7.03817+03
2.80	2.69033	3.34815	6.03847	22.75662	4.20836	1.61570+04
3.00	4.63652	3.82913	8.46565	21.62272	4.64475	4.41316+04

T= 2700 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00390	3.23417	4.23807	30.48100	.99664	9.92293+00
.20	1.00421	3.22322	4.22743	30.00769	1.19677	1.57315+01
.40	1.00514	3.21459	4.21973	29.53641	1.39718	2.49563+01
.60	1.00694	3.20772	4.21466	29.06628	1.59795	3.96232+01
.80	1.01006	3.20229	4.21235	28.59649	1.79929	6.29927+01
1.00	1.01524	3.19807	4.21331	28.12602	2.00152	1.00351+02
1.20	1.02373	3.19480	4.21852	27.65342	2.20513	1.60373+02
1.40	1.03752	3.19237	4.22989	27.17663	2.41094	2.57597+02
1.60	1.06009	3.19079	4.25088	26.69249	2.62029	4.17148+02
1.80	1.09740	3.19026	4.28767	26.19590	2.83531	6.84400+02
2.00	1.16015	3.19137	4.35152	25.67849	3.05946	1.14673+03
2.20	1.26868	3.19584	4.46452	25.12593	3.29830	1.98747+03
2.40	1.46162	3.20789	4.66951	24.51406	3.55978	3.62894+03
2.60	1.85210	3.24490	5.09700	23.79879	3.86261	7.28803+03
2.80	2.67049	3.38000	6.05049	22.91600	4.22154	1.66548+04
3.00	4.56855	3.84551	8.41406	21.78449	4.65473	4.51575+04

T= 2800 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00506	3.28499	4.29005	30.64990	1.01293	1.03022+01
.20	1.00513	3.26958	4.27471	30.17165	1.21296	1.63290+01
.40	1.00587	3.25733	4.26320	29.69638	1.41328	2.58988+01
.60	1.00752	3.24759	4.25511	29.22308	1.61399	4.11140+01
.80	1.01051	3.23987	4.25038	28.75076	1.81528	6.53552+01
1.00	1.01559	3.23383	4.24942	28.27829	2.01746	1.04102+02
1.20	1.02400	3.22913	4.25312	27.80411	2.22104	1.66357+02
1.40	1.03772	3.22559	4.26331	27.32610	2.42682	2.67190+02
1.60	1.06020	3.22317	4.28337	26.84105	2.63613	4.32643+02
1.80	1.09741	3.22210	4.31951	26.34390	2.85111	7.09758+02
2.00	1.15997	3.22291	4.38288	25.82622	3.07519	1.18902+03
2.20	1.26810	3.22728	4.49539	25.27372	3.31390	2.06016+03
2.40	1.46006	3.23986	4.69992	24.66283	3.57511	3.75933+03
2.60	1.84691	3.27817	5.12508	23.95023	3.87719	7.53685+03
2.80	2.65182	3.41194	6.06376	23.07100	4.23429	1.71510+04
3.00	4.50534	3.86264	8.36798	21.94135	4.66447	4.61817+04

T= 2900 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00660	3.34057	4.34717	30.82170	1.02884	1.06866+01
.20	1.00636	3.31949	4.32585	30.33715	1.22873	1.69328+01
.40	1.00685	3.30266	4.30951	29.85678	1.42895	2.68504+01
.60	1.00830	3.28926	4.29756	29.37942	1.62957	4.26157+01
.80	1.01112	3.27862	4.28975	28.90386	1.83079	6.77314+01
1.00	1.01608	3.27026	4.28633	28.42882	2.03291	1.07872+02
1.20	1.02437	3.26373	4.28810	27.95262	2.23644	1.72361+02
1.40	1.03799	3.25875	4.29675	27.47303	2.44218	2.76809+02
1.60	1.06037	3.25524	4.31561	26.98678	2.65144	4.48167+02
1.80	1.09745	3.25339	4.35084	26.48879	2.86636	7.35123+02
2.00	1.15982	3.25372	4.41354	25.97066	3.09037	1.23132+03
2.20	1.26755	3.25786	4.52541	25.41808	3.32895	2.13280+03
2.40	1.45848	3.27085	4.72933	24.80804	3.58988	3.88938+03
2.60	1.84182	3.31030	5.15212	24.09796	3.89123	7.78449+03
2.80	2.63424	3.44262	6.07685	23.22194	4.24664	1.76457+04
3.00	4.44641	3.87922	8.32563	22.09375	4.67399	4.72052+04

T= 3000 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.00860	3.40461	4.41321	31.00020	1.04442	1.10769+01
.20	1.00797	3.37648	4.38445	30.50777	1.24415	1.75449+01
.40	1.00813	3.35400	4.36213	30.02109	1.44422	2.78112+01
.60	1.00932	3.33609	4.34541	29.53870	1.64473	4.41296+01
.80	1.01193	3.32187	4.33380	29.05913	1.84585	7.01213+01
1.00	1.01671	3.31063	4.32734	28.58089	2.04790	1.11661+02
1.20	1.02486	3.30183	4.32669	28.10216	2.25137	1.78390+02
1.40	1.03836	3.29508	4.33344	27.62059	2.45705	2.86451+02
1.60	1.06062	3.29018	4.35080	27.13281	2.66626	4.63724+02
1.80	1.09754	3.28731	4.38484	26.63372	2.88112	7.60536+02
2.00	1.15971	3.28694	4.44665	26.11489	3.10505	1.27365+03
2.20	1.26702	3.29071	4.55773	25.56207	3.34349	2.20541+03
2.40	1.45689	3.30399	4.76088	24.95277	3.60413	4.01911+03
2.60	1.83684	3.34443	5.18127	24.24503	3.90478	8.03119+03
2.80	2.61765	3.47517	6.09282	23.37190	4.25862	1.81393+04
3.00	4.39136	3.89843	8.28979	22.24495	4.68330	4.82281+04

T= 3100 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.01113	3.47301	4.48414	31.18100	1.05975	1.14749+01
.20	1.01002	3.43656	4.44658	30.67920	1.25927	1.81664+01
.40	1.00976	3.40738	4.41714	30.18498	1.45916	2.87846+01
.60	1.01062	3.38410	4.39472	29.69654	1.65953	4.56594+01
.80	1.01296	3.36557	4.37853	29.21212	1.86054	7.25337+01
1.00	1.01752	3.35087	4.36839	28.72999	2.06249	1.15476+02
1.20	1.02549	3.33932	4.36481	28.24818	2.26588	1.84451+02
1.40	1.03884	3.33039	4.36923	27.76418	2.47149	2.96135+02
1.60	1.06095	3.32379	4.38475	27.27452	2.68064	4.79336+02
1.80	1.09770	3.31961	4.41731	26.77400	2.89543	7.86013+02
2.00	1.15965	3.31832	4.47797	26.25422	3.11927	1.31604+03
2.20	1.26652	3.32153	4.58805	25.70096	3.35756	2.27803+03
2.40	1.45530	3.33497	4.79027	25.09226	3.61790	4.14859+03
2.60	1.83197	3.37628	5.20825	24.38673	3.91786	8.27675+03
2.80	2.60199	3.50535	6.10734	23.51619	4.27025	1.86316+04
3.00	4.33981	3.91592	8.25573	22.39022	4.69242	4.92516+04

T= 3200 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.01427	3.54756	4.56183	31.36730	1.07489	1.18820+01
.20	1.01255	3.50167	4.51422	30.85475	1.27415	1.87997+01
.40	1.01179	3.46477	4.47655	30.35176	1.47382	2.97728+01
.60	1.01224	3.43522	4.44745	29.85622	1.67402	4.72085+01
.80	1.01425	3.41161	4.42586	29.36607	1.87488	7.49687+01
1.00	1.01854	3.39281	4.41135	28.87930	2.07671	1.19319+02
1.20	1.02629	3.37798	4.40427	28.39380	2.28000	1.90546+02
1.40	1.03945	3.36644	4.40589	27.90686	2.48554	3.05872+02
1.60	1.06139	3.35779	4.41917	27.41490	2.69461	4.95005+02
1.80	1.09794	3.35199	4.44993	26.91261	2.90931	8.11540+02
2.00	1.15964	3.34952	4.50917	26.39160	3.13306	1.35850+03
2.20	1.26607	3.35193	4.61801	25.83763	3.37119	2.35066+03
2.40	1.45372	3.36538	4.81910	25.22936	3.63121	4.27770+03
2.60	1.82723	3.40748	5.23471	24.52594	3.93053	8.52177+03
2.80	2.58719	3.53482	6.12202	23.65775	4.28156	1.91232+04
3.00	4.29146	3.93325	8.22470	22.53246	4.70134	5.02736+04

T= 3300 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.01806	3.62926	4.64732	31.55940	1.08987	1.22990+01
.20	1.01561	3.57269	4.58830	31.03460	1.28882	1.94455+01
.40	1.01425	3.52696	4.54121	30.52151	1.48824	3.07780+01
.60	1.01421	3.49017	4.50438	30.01771	1.68822	4.87776+01
.80	1.01583	3.46067	4.47650	29.52085	1.88892	7.74319+01
1.00	1.01980	3.43708	4.45688	29.02865	2.09061	1.23200+02
1.20	1.02728	3.41840	4.44567	28.53878	2.29379	1.96694+02
1.40	1.04021	3.40378	4.44399	28.04836	2.49922	3.15660+02
1.60	1.06194	3.39268	4.45462	27.55365	2.70820	5.10740+02
1.80	1.09828	3.38494	4.48322	27.04921	2.92281	8.37163+02
2.00	1.15971	3.38103	4.54074	26.52666	3.14645	1.40104+03
2.20	1.26569	3.38238	4.64806	25.97169	3.38442	2.42337+03
2.40	1.45215	3.39566	4.84781	25.36367	3.64411	4.40666+03
2.60	1.82261	3.43847	5.26108	24.66227	3.94279	8.76577+03
2.80	2.57319	3.56404	6.13723	23.79619	4.29257	1.96142+04
3.00	4.24602	3.95089	8.19691	22.67141	4.71008	5.12956+04

T= 3400 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.02256	3.71834	4.74090	31.75770	1.10475	1.27277+01
.20	1.01925	3.64974	4.66899	31.21900	1.30334	2.01067+01
.40	1.01720	3.59397	4.61116	30.69437	1.50247	3.18031+01
.60	1.01658	3.54888	4.56546	30.18105	1.70220	5.03733+01
.80	1.01773	3.51260	4.53033	29.67643	1.90270	7.99282+01
1.00	1.02131	3.48349	4.50480	29.17792	2.10422	1.27122+02
1.20	1.02848	3.46033	4.48881	28.68295	2.30726	2.02890+02
1.40	1.04114	3.44213	4.48327	28.18846	2.51257	3.25514+02
1.60	1.06264	3.42817	4.49080	27.69052	2.72145	5.26563+02
1.80	1.09873	3.41813	4.51687	27.18353	2.93595	8.62879+02
2.00	1.15987	3.41249	4.57236	26.65910	3.15947	1.44368+03
2.20	1.26537	3.41250	4.67787	26.10281	3.39728	2.49620+03
2.40	1.45059	3.42545	4.87604	25.49484	3.65661	4.53534+03
2.60	1.81810	3.46889	5.28699	24.79536	3.95468	9.00907+03
2.80	2.55994	3.59265	6.15258	23.93119	4.30329	2.01043+04
3.00	4.20325	3.96853	8.17178	22.80683	4.71865	5.23179+04

T= 3500 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.02779	3.81276	4.84055	31.96170	1.11956	1.31692+01
.20	1.02352	3.73066	4.75418	31.40732	1.31775	2.07850+01
.40	1.02067	3.66351	4.68418	30.86954	1.51654	3.28504+01
.60	1.01938	3.60899	4.62837	30.34535	1.71599	5.19984+01
.80	1.01999	3.56496	4.58495	29.83181	1.91625	8.24613+01
1.00	1.02312	3.52952	4.55264	29.32605	2.11758	1.31093+02
1.20	1.02991	3.50123	4.53114	28.82519	2.32045	2.09146+02
1.40	1.04226	3.47890	4.52116	28.32599	2.52563	3.35452+02
1.60	1.06348	3.46163	4.52511	27.82430	2.73438	5.42475+02
1.80	1.09931	3.44894	4.54825	27.31431	2.94877	8.88730+02
2.00	1.16012	3.44125	4.60137	26.78765	3.17215	1.48645+03
2.20	1.26514	3.43963	4.70477	26.22970	3.40979	2.56915+03
2.40	1.44905	3.45204	4.90109	25.62157	3.66873	4.66369+03
2.60	1.81372	3.49604	5.30975	24.92391	3.96622	9.25167+03
2.80	2.54737	3.61795	6.16532	24.06146	4.31374	2.05940+04
3.00	4.16290	3.98352	8.14642	22.93753	4.72705	5.33396+04

T= 3600 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.03377	3.91373	4.94750	32.17130	1.13431	1.36242+01
.20	1.02846	3.81752	4.84598	31.60030	1.33207	2.14818+01
.40	1.02471	3.73830	4.76301	31.04839	1.53048	3.39219+01
.60	1.02265	3.67362	4.69627	30.51235	1.72961	5.36550+01
.80	1.02263	3.62114	4.64378	29.98902	1.92961	8.50374+01
1.00	1.02525	3.57876	4.60401	29.47521	2.13071	1.35117+02
1.20	1.03160	3.54478	4.57638	28.96780	2.33340	2.15477+02
1.40	1.04359	3.51785	4.56144	28.46331	2.53841	3.45470+02
1.60	1.06449	3.49688	4.56138	27.95737	2.74703	5.58509+02
1.80	1.10002	3.48119	4.58121	27.44398	2.96129	9.14724+02
2.00	1.16048	3.47115	4.63164	26.91472	3.18452	1.52940+03
2.20	1.26501	3.46761	4.73262	26.35478	3.42198	2.64229+03
2.40	1.44753	3.47933	4.92686	25.74630	3.68051	4.79192+03
2.60	1.80945	3.52381	5.33326	25.05037	3.97743	9.49358+03
2.80	2.53544	3.64386	6.17930	24.18946	4.32394	2.10834+04
3.00	4.12478	3.99963	8.12441	23.06590	4.73529	5.43613+04

T= 3700 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.04045	4.01840	5.05885	32.38500	1.14901	1.40932+01
.20	1.03403	3.90852	4.94256	31.79751	1.34632	2.21983+01
.40	1.02929	3.81725	4.84654	31.23120	1.54432	3.50203+01
.60	1.02640	3.74216	4.76856	30.68285	1.74310	5.53478+01
.80	1.02567	3.68088	4.70655	30.14916	1.94279	8.76577+01
1.00	1.02770	3.63114	4.65884	29.62673	2.14365	1.39203+02
1.20	1.03356	3.59107	4.62463	29.11222	2.34612	2.21881+02
1.40	1.04514	3.55915	4.60428	28.60192	2.55096	3.55599+02
1.60	1.06569	3.53411	4.59980	28.09129	2.75941	5.74659+02
1.80	1.10089	3.51511	4.61600	27.57412	2.97353	9.40871+02
2.00	1.16097	3.50244	4.66341	27.04191	3.19660	1.57253+03
2.20	1.26499	3.49669	4.76168	26.47965	3.43387	2.71563+03
2.40	1.44603	3.50760	4.95363	25.87066	3.69196	4.91994+03
2.60	1.80531	3.55251	5.35782	25.17639	3.98834	9.73509+03
2.80	2.52411	3.67069	6.19480	24.31687	4.33389	2.15720+04
3.00	4.08871	4.01705	8.10575	23.19351	4.74337	5.53822+04

T= 3800 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.04778	4.12730	5.17508	32.60190	1.16364	1.45761+01
.20	1.04020	4.00431	5.04451	31.99819	1.36048	2.29340+01
.40	1.03441	3.90104	4.93545	31.41729	1.55806	3.61460+01
.60	1.03061	3.81532	4.84593	30.85617	1.75646	5.70769+01
.80	1.02911	3.74485	4.77396	30.31153	1.95583	9.03296+01
1.00	1.03049	3.68732	4.71781	29.77989	2.15641	1.43354+02
1.20	1.03580	3.64073	4.67653	29.25769	2.35864	2.28371+02
1.40	1.04691	3.60339	4.65031	28.74107	2.56328	3.65831+02
1.60	1.06707	3.57391	4.64098	28.22526	2.77156	5.90963+02
1.80	1.10190	3.55129	4.65320	27.70392	2.98551	9.67186+02
2.00	1.16158	3.53567	4.69726	27.16839	3.20842	1.61592+03
2.20	1.26508	3.52744	4.79252	26.60345	3.44548	2.78920+03
2.40	1.44456	3.53739	4.98195	25.99379	3.70310	5.04778+03
2.60	1.80128	3.58270	5.38398	25.30111	3.99895	9.97585+03
2.80	2.51333	3.69899	6.21233	24.44284	4.34362	2.20607+04
3.00	4.05453	4.03634	8.09087	23.31959	4.75131	5.64040+04

T= 3900 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.05569	4.23728	5.29297	32.82060	1.17818	1.50723+01
.20	1.04691	4.10187	5.14878	32.20112	1.37456	2.36897+01
.40	1.04004	3.98671	5.02676	31.60550	1.57170	3.72992+01
.60	1.03528	3.89015	4.92543	31.03116	1.76970	5.88437+01
.80	1.03295	3.81009	4.84304	30.47497	1.96873	9.30529+01
1.00	1.03362	3.74431	4.77793	29.93349	2.16901	1.47574+02
1.20	1.03833	3.69075	4.72908	29.40302	2.37098	2.34952+02
1.40	1.04893	3.64755	4.69649	28.87949	2.57540	3.76184+02
1.60	1.06865	3.61323	4.68188	28.35801	2.78349	6.07421+02
1.80	1.10309	3.58665	4.68974	27.83208	2.99726	9.93711+02
2.00	1.16235	3.56776	4.73011	27.29283	3.21998	1.65951+03
2.20	1.26530	3.55672	4.82202	26.72483	3.45684	2.86312+03
2.40	1.44311	3.56559	5.00870	26.11433	3.71395	5.17547+03
2.60	1.79737	3.61124	5.40861	25.42318	4.00928	1.02160+04
2.80	2.50308	3.72566	6.22874	24.56603	4.35312	2.25486+04
3.00	4.02211	4.05444	8.07655	23.44286	4.75910	5.74249+04

T= 4000 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.06407	4.34655	5.41062	33.03900	1.19261	1.55815+01
.20	1.05411	4.19957	5.25368	32.40437	1.38853	2.44641+01
.40	1.04616	4.07270	5.11886	31.79397	1.58524	3.84804+01
.60	1.04040	3.96507	5.00547	31.20599	1.78284	6.06513+01
.80	1.03719	3.87501	4.91220	30.63765	1.98150	9.58297+01
1.00	1.03710	3.80051	4.83761	30.08566	2.18146	1.51866+02
1.20	1.04116	3.73949	4.78065	29.54629	2.38316	2.41635+02
1.40	1.05121	3.68997	4.74118	29.01526	2.58733	3.86661+02
1.60	1.07045	3.65038	4.72082	28.48758	2.79521	6.24037+02
1.80	1.10445	3.61949	4.72394	27.95662	3.00879	1.02045+03
2.00	1.16327	3.59698	4.76025	27.41322	3.23132	1.70341+03
2.20	1.26564	3.58281	4.84845	26.84178	3.46795	2.93731+03
2.40	1.44169	3.59046	5.03215	26.23026	3.72452	5.30298+03
2.60	1.79356	3.63640	5.42996	25.54056	4.01936	1.04559+04
2.80	2.49331	3.74896	6.24227	24.68443	4.36242	2.30367+04
3.00	3.99130	4.06964	8.06094	23.56138	4.76676	5.84467+04

T= 4100 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.07280	4.45451	5.52731	33.25550	1.20689	1.61024+01
.20	1.06174	4.29738	5.35912	32.60696	1.40239	2.52575+01
.40	1.05273	4.15962	5.21235	31.98240	1.59868	3.96899+01
.60	1.04596	4.04132	5.08728	31.38095	1.79588	6.25000+01
.80	1.04184	3.94134	4.98317	30.80035	1.99417	9.86666+01
1.00	1.04094	3.85801	4.89895	30.23759	2.19379	1.56239+02
1.20	1.04430	3.78934	4.83363	29.68896	2.39519	2.48422+02
1.40	1.05375	3.73325	4.78700	29.15007	2.59910	3.97283+02
1.60	1.07246	3.68814	4.76060	28.61582	2.80675	6.40841+02
1.80	1.10599	3.65270	4.75869	28.07948	3.02012	1.04742+03
2.00	1.16436	3.62638	4.79074	27.53168	3.24245	1.74763+03
2.20	1.26612	3.60891	4.87503	26.95654	3.47884	3.01190+03
2.40	1.44030	3.61520	5.05550	26.34384	3.73482	5.43025+03
2.60	1.78987	3.66141	5.45128	25.65555	4.02919	1.06952+04
2.80	2.48400	3.77212	6.25611	24.80031	4.37152	2.35245+04
3.00	3.96199	4.08508	8.04706	23.67737	4.77428	5.94675+04

T= 4200 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.08172	4.55837	5.64009	33.46810	1.22095	1.66322+01
.20	1.06970	4.39320	5.46291	32.80763	1.41610	2.60675+01
.40	1.05968	4.24612	5.30580	32.17033	1.61201	4.09270+01
.60	1.05191	4.11821	5.17012	31.55630	1.80881	6.43888+01
.80	1.04685	4.00898	5.05583	30.96392	2.00672	1.01559+02
1.00	1.04510	3.91717	4.96228	30.39057	2.20599	1.60690+02
1.20	1.04773	3.84097	4.88870	29.83267	2.40708	2.55317+02
1.40	1.05654	3.77834	4.83488	29.28580	2.61072	4.08056+02
1.60	1.07469	3.72766	4.80235	28.74483	2.81812	6.57840+02
1.80	1.10772	3.68753	4.79524	28.20289	3.03126	1.07463+03
2.00	1.16560	3.65739	4.82299	27.65059	3.25338	1.79217+03
2.20	1.26674	3.63661	4.90335	27.07168	3.48952	3.08688+03
2.40	1.43894	3.64143	5.08038	26.45764	3.74488	5.55751+03
2.60	1.78629	3.68789	5.47418	25.77072	4.03878	1.09340+04
2.80	2.47510	3.79675	6.27185	24.91628	4.38043	2.40121+04
3.00	3.93407	4.10230	8.03637	23.79338	4.78167	6.04881+04

T= 4300 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.09068	4.65739	5.74807	33.67500	1.23475	1.71692+01
.20	1.07788	4.48663	5.56451	33.00498	1.42962	2.68918+01
.40	1.06692	4.33207	5.39899	32.35664	1.62518	4.21871+01
.60	1.05818	4.19578	5.25397	31.73113	1.82161	6.63147+01
.80	1.05219	4.07807	5.13026	31.12760	2.01915	1.04508+02
1.00	1.04957	3.97820	5.02777	30.54392	2.21806	1.65219+02
1.20	1.05144	3.89464	4.94608	29.97679	2.41883	2.62319+02
1.40	1.05958	3.82550	4.88508	29.42186	2.62218	4.18967+02
1.60	1.07713	3.76919	4.84633	28.87401	2.82932	6.75025+02
1.80	1.10962	3.72424	4.83386	28.32624	3.04223	1.10212+03
2.00	1.16699	3.69029	4.85728	27.76938	3.26412	1.83705+03
2.20	1.26750	3.66619	4.93369	27.18662	3.50000	3.16228+03
2.40	1.43761	3.66944	5.10705	26.57111	3.75469	5.68447+03
2.60	1.78281	3.71613	5.49894	25.88551	4.04816	1.11727+04
2.80	2.46661	3.82315	6.28976	25.03177	4.38915	2.44991+04
3.00	3.90746	4.12161	8.02907	23.90889	4.78895	6.15106+04

T= 4400 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.09957	4.74890	5.84847	33.87500	1.24826	1.77117+01
.20	1.08614	4.57535	5.66150	33.19824	1.44292	2.77281+01
.40	1.07435	4.41542	5.48977	32.54090	1.63818	4.34690+01
.60	1.06471	4.27219	5.33690	31.90523	1.83427	6.82763+01
.80	1.05781	4.14689	5.20470	31.29132	2.03144	1.07508+02
1.00	1.05432	4.03944	5.09376	30.69768	2.23001	1.69828+02
1.20	1.05540	3.94873	5.00413	30.12139	2.43045	2.69433+02
1.40	1.06285	3.87314	4.93599	29.55835	2.63351	4.30041+02
1.60	1.07978	3.81117	4.89096	29.00348	2.84037	6.92421+02
1.80	1.11171	3.76126	4.87297	28.44967	3.05303	1.12987+03
2.00	1.16851	3.72352	4.89203	27.88818	3.27467	1.88222+03
2.20	1.26839	3.69610	4.96450	27.30151	3.51029	3.23810+03
2.40	1.43630	3.69768	5.13398	26.68438	3.76428	5.81139+03
2.60	1.77943	3.74458	5.52401	26.00008	4.05732	1.14109+04
2.80	2.45849	3.84977	6.30826	25.14695	4.39770	2.49862+04
3.00	3.88205	4.14151	8.02355	24.02412	4.79610	6.25317+04

T= 4500 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.10825	4.83402	5.94227	34.06740	1.26144	1.82574+01
.20	1.09436	4.66088	5.75524	33.38714	1.45596	2.85733+01
.40	1.08188	4.49797	5.57985	32.72320	1.65097	4.47682+01
.60	1.07142	4.34945	5.42087	32.07895	1.84676	7.02684+01
.80	1.06365	4.21759	5.28124	31.45559	2.04359	1.10558+02
1.00	1.05932	4.10311	5.16243	30.85243	2.24182	1.74510+02
1.20	1.05961	4.00550	5.06511	30.26713	2.44194	2.76656+02
1.40	1.06634	3.92356	4.98990	29.69596	2.64469	4.41255+02
1.60	1.08263	3.85591	4.93854	29.13394	2.85128	7.10035+02
1.80	1.11397	3.80091	4.91488	28.57386	3.06367	1.15790+03
2.00	1.17015	3.75938	4.92954	28.00771	3.28504	1.92770+03
2.20	1.26943	3.72867	4.99810	27.41709	3.52040	3.31436+03
2.40	1.43503	3.72844	5.16347	26.79818	3.77366	5.93827+03
2.60	1.77615	3.77556	5.55170	26.11514	4.06627	1.16485+04
2.80	2.45072	3.87894	6.32966	25.26255	4.40609	2.54736+04
3.00	3.85777	4.16432	8.02209	24.13985	4.80313	6.35521+04

T= 4600 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.11661	4.91008	6.02669	34.25080	1.27424	1.88036+01
.20	1.10241	4.73948	5.84189	33.56930	1.46868	2.94225+01
.40	1.08940	4.57544	5.66484	32.90063	1.66353	4.60819+01
.60	1.07824	4.42303	5.50127	32.24918	1.85906	7.22870+01
.80	1.06968	4.28562	5.35530	31.61732	2.05559	1.13655+02
1.00	1.06453	4.16476	5.22929	31.00519	2.25350	1.79267+02
1.20	1.06404	4.06061	5.12465	30.41113	2.45330	2.83988+02
1.40	1.07004	3.97249	5.04253	29.83191	2.65574	4.52627+02
1.60	1.08567	3.89919	4.98486	29.26270	2.86204	7.27847+02
1.80	1.11641	3.83907	4.95547	28.69623	3.07416	1.18621+03
2.00	1.17190	3.79364	4.96555	28.12522	3.29523	1.97347+03
2.20	1.27061	3.75947	5.03007	27.53043	3.53035	3.39117+03
2.40	1.43378	3.75738	5.19117	26.90964	3.78282	6.06485+03
2.60	1.77296	3.80468	5.57764	26.22781	4.07504	1.18861+04
2.80	2.44327	3.90629	6.34956	25.37570	4.41431	2.59603+04
3.00	3.83454	4.18558	8.02012	24.25312	4.81005	6.45729+04

T= 4700 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.12459	4.97822	6.10281	34.42540	1.28668	1.93500+01
.20	1.11024	4.81100	5.92123	33.74364	1.48110	3.02761+01
.40	1.09687	4.64695	5.74382	33.07144	1.67583	4.74056+01
.60	1.08512	4.49179	5.57692	32.41394	1.87116	7.43293+01
.80	1.07584	4.34980	5.42563	31.77447	2.06743	1.16797+02
1.00	1.06993	4.22328	5.29321	31.15403	2.26504	1.84094+02
1.20	1.06866	4.11309	5.18175	30.55161	2.46452	2.91420+02
1.40	1.07393	4.01905	5.09299	29.96453	2.66666	4.64152+02
1.60	1.08890	3.94023	5.02913	29.38816	2.87267	7.45882+02
1.80	1.11901	3.87507	4.99408	28.81531	3.08451	1.21481+03
2.00	1.17378	3.82545	4.99923	28.23907	3.30527	2.01962+03
2.20	1.27192	3.78745	5.05937	27.63969	3.54014	3.46849+03
2.40	1.43256	3.78352	5.21609	27.01698	3.79180	6.19156+03
2.60	1.76987	3.83095	5.60082	26.33632	4.08362	1.21233+04
2.80	2.43613	3.93082	6.36695	25.48462	4.42238	2.64472+04
3.00	3.81230	4.20419	8.01649	24.36207	4.81687	6.55949+04

T= 4800 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.13214	5.03883	6.17097	34.59150	1.29873	1.98944+01
.20	1.11780	4.87586	5.99366	33.91052	1.49319	3.11308+01
.40	1.10421	4.71305	5.81726	33.23611	1.68788	4.87394+01
.60	1.09201	4.55643	5.64843	32.57386	1.88305	7.63924+01
.80	1.08208	4.41092	5.49300	31.92785	2.07909	1.19975+02
1.00	1.07546	4.27957	5.35503	31.29985	2.27642	1.88982+02
1.20	1.07345	4.16390	5.23735	30.68959	2.47561	2.98958+02
1.40	1.07800	4.06427	5.14228	30.09487	2.67744	4.75817+02
1.60	1.09230	3.98008	5.07237	29.51141	2.88316	7.64117+02
1.80	1.12177	3.90996	5.03174	28.93219	3.09473	1.24374+03
2.00	1.17581	3.85585	5.03166	28.35036	3.31516	2.06614+03
2.20	1.27338	3.81365	5.08702	27.74594	3.54978	3.54634+03
2.40	1.43137	3.80789	5.23926	27.12130	3.80058	6.31801+03
2.60	1.76686	3.85541	5.62227	26.44171	4.09203	1.23603+04
2.80	2.42929	3.95356	6.38285	25.59040	4.43030	2.69339+04
3.00	3.79099	4.22121	8.01220	24.46781	4.82358	6.66162+04

T= 4900 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.13925	5.09257	6.23182	34.74940	1.31040	2.04362+01
.20	1.12506	4.93478	6.05984	34.07029	1.50495	3.19853+01
.40	1.11138	4.77456	5.88594	33.39513	1.69964	5.00772+01
.60	1.09884	4.61788	5.71672	32.72960	1.89471	7.84711+01
.80	1.08837	4.47007	5.55844	32.07826	2.09056	1.23186+02
1.00	1.08111	4.33481	5.41592	31.44361	2.28765	1.93932+02
1.20	1.07838	4.21431	5.29270	30.82608	2.48655	3.06584+02
1.40	1.08223	4.10946	5.19169	30.22402	2.68810	4.87641+02
1.60	1.09585	4.02005	5.11591	29.63357	2.89353	7.82582+02
1.80	1.12469	3.94511	5.06980	29.04801	3.10481	1.27295+03
2.00	1.17801	3.88617	5.06418	28.46021	3.32493	2.11315+03
2.20	1.27496	3.83938	5.11434	27.85026	3.55928	3.62477+03
2.40	1.43021	3.83180	5.26202	27.22367	3.80918	6.44436+03
2.60	1.76394	3.87936	5.64330	26.54511	4.10026	1.25968+04
2.80	2.42272	3.97585	6.39857	25.69414	4.43808	2.74208+04
3.00	3.77056	4.23797	8.00853	24.57148	4.83018	6.76363+04

T= 5000 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.14565	5.14745	6.29310	34.90760	1.32160	2.09701+01
.20	1.13197	4.99579	6.12776	34.23150	1.51639	3.28390+01
.40	1.11832	4.83963	5.95795	33.55720	1.71112	5.14186+01
.60	1.10555	4.68446	5.79001	32.89002	1.90613	8.05620+01
.80	1.09465	4.53569	5.63034	32.23472	2.10183	1.26424+02
1.00	1.08681	4.39757	5.48438	31.59444	2.29871	1.98934+02
1.20	1.08343	4.27295	5.35638	30.97032	2.49735	3.14304+02
1.40	1.08660	4.16328	5.24988	30.36128	2.69862	4.99597+02
1.60	1.09956	4.06887	5.16843	29.76396	2.90377	8.01254+02
1.80	1.12775	3.98924	5.11699	29.17215	3.11477	1.30248+03
2.00	1.18039	3.92514	5.10553	28.57795	3.33458	2.16063+03
2.20	1.27668	3.87332	5.15000	27.96199	3.56863	3.70365+03
2.40	1.42908	3.86396	5.29304	27.33344	3.81761	6.57068+03
2.60	1.76111	3.91150	5.67261	26.65582	4.10834	1.28333+04
2.80	2.41640	4.00639	6.42280	25.80518	4.44572	2.79074+04
3.00	3.75094	4.26320	8.01414	24.68245	4.83669	6.86578+04

T= 5100 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.15189	5.18938	6.34127	35.05210	1.33256	2.15060+01
.20	1.13851	5.04383	6.18233	34.37916	1.52749	3.36891+01
.40	1.12498	4.89224	6.01722	33.70639	1.72230	5.27594+01
.60	1.11210	4.73938	5.85148	33.03847	1.91730	8.26609+01
.80	1.10087	4.59051	5.69138	32.38013	2.11289	1.29685+02
1.00	1.09254	4.45031	5.54284	31.73501	2.30959	2.03981+02
1.20	1.08856	4.32221	5.41077	31.10490	2.50801	3.22114+02
1.40	1.09109	4.20817	5.29926	30.48928	2.70901	5.11694+02
1.60	1.10340	4.10905	5.21245	29.88534	2.91389	8.20144+02
1.80	1.13095	4.02492	5.15587	29.28741	3.12460	1.33229+03
2.00	1.18297	3.95571	5.13868	28.68676	3.34413	2.20867+03
2.20	1.27853	3.89883	5.17736	28.06467	3.57786	3.78321+03
2.40	1.42797	3.88769	5.31566	27.43414	3.82587	6.69684+03
2.60	1.75836	3.93519	5.69356	26.75742	4.11626	1.30695+04
2.80	2.41034	4.02853	6.43887	25.90709	4.45323	2.83942+04
3.00	3.73209	4.28025	8.01234	24.78431	4.84311	6.96803+04

T= 5200 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.15778	5.22725	6.38503	35.19100	1.34321	2.20399+01
.20	1.14470	5.08664	6.23134	34.52023	1.53828	3.45366+01
.40	1.13136	4.93904	6.07040	33.84854	1.73319	5.40991+01
.60	1.11847	4.78841	5.90688	33.17991	1.92821	8.47637+01
.80	1.10701	4.63974	5.74675	32.51887	2.12374	1.32966+02
1.00	1.09826	4.49793	5.59620	31.86941	2.32029	2.09069+02
1.20	1.09375	4.36687	5.46062	31.23382	2.51850	3.29989+02
1.40	1.09567	4.24896	5.34464	30.61208	2.71927	5.23926+02
1.60	1.10735	4.14555	5.25290	30.00187	2.92387	8.39209+02
1.80	1.13427	4.05717	5.19144	29.39803	3.13430	1.36239+03
2.00	1.18573	3.98329	5.16902	28.79132	3.35357	2.25720+03
2.20	1.28049	3.92176	5.20225	28.16342	3.58696	3.86331+03
2.40	1.42689	3.90883	5.33572	27.53087	3.83398	6.82307+03
2.60	1.75569	3.95630	5.71199	26.85505	4.12403	1.33055+04
2.80	2.40450	4.04811	6.45262	26.00499	4.46061	2.88809+04
3.00	3.71397	4.29498	8.00895	24.88220	4.84942	7.07001+04

T= 5300 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.16335	5.26226	6.42561	35.32550	1.35357	2.25720+01
.20	1.15060	5.12527	6.27587	34.65570	1.54879	3.53826+01
.40	1.13751	4.98094	6.11845	33.98451	1.74381	5.54383+01
.60	1.12467	4.83242	5.95709	33.31513	1.93888	8.68720+01
.80	1.11306	4.68425	5.79731	32.65178	2.13438	1.36264+02
1.00	1.10397	4.54137	5.64534	31.99853	2.33082	2.14200+02
1.20	1.09897	4.40793	5.50690	31.35804	2.52885	3.37948+02
1.40	1.10034	4.28669	5.38702	30.73068	2.72938	5.36266+02
1.60	1.11140	4.17945	5.29085	30.11464	2.93373	8.58480+02
1.80	1.13770	4.08711	5.22481	29.50512	3.14389	1.39280+03
2.00	1.18864	4.00905	5.19769	28.89279	3.36291	2.30627+03
2.20	1.28257	3.94330	5.22587	28.25946	3.59594	3.94403+03
2.40	1.42584	3.92859	5.35443	27.62486	3.84193	6.94912+03
2.60	1.75309	3.97603	5.72913	26.94991	4.13166	1.35413+04
2.80	2.39888	4.06636	6.46524	26.10010	4.46787	2.93677+04
3.00	3.69652	4.30864	8.00516	24.97738	4.85565	7.17216+04

T= 5400 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.16867	5.29561	6.46428	35.45760	1.36367	2.31031+01
.20	1.15628	5.16073	6.31700	34.78737	1.55904	3.62276+01
.40	1.14343	5.01886	6.16229	34.11597	1.75419	5.67793+01
.60	1.13069	4.87228	6.00297	33.44577	1.94932	8.89857+01
.80	1.11900	4.72494	5.84393	32.78048	2.14481	1.39576+02
1.00	1.10962	4.58155	5.69118	32.12405	2.34115	2.19356+02
1.20	1.10421	4.44635	5.55055	31.47929	2.53903	3.45963+02
1.40	1.10505	4.32239	5.42743	30.84692	2.73936	5.48732+02
1.60	1.11553	4.21182	5.32735	30.22552	2.94346	8.77930+02
1.80	1.14121	4.11585	5.25706	29.61059	3.15334	1.42344+03
2.00	1.19165	4.03416	5.22581	28.99315	3.37212	2.35570+03
2.20	1.28475	3.96467	5.24942	28.35481	3.60480	4.02532+03
2.40	1.42481	3.94817	5.37298	27.71813	3.84973	7.07506+03
2.60	1.75057	3.99560	5.74617	27.04405	4.13916	1.37772+04
2.80	2.39346	4.08448	6.47795	26.19447	4.47500	2.98538+04
3.00	3.67972	4.32244	8.00216	25.07192	4.86179	7.27428+04

T= 5500 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.17381	5.32826	6.50207	35.58740	1.37354	2.36342+01
.20	1.16177	5.19380	6.35557	34.91513	1.56907	3.70740+01
.40	1.14916	5.05346	6.20262	34.24266	1.76433	5.81206+01
.60	1.13655	4.90860	6.04515	33.57151	1.95953	9.11024+01
.80	1.12481	4.76242	5.88723	32.90469	2.15502	1.42896+02
1.00	1.11521	4.61915	5.73436	32.24575	2.35130	2.24543+02
1.20	1.10942	4.48288	5.59230	31.59743	2.54904	3.54030+02
1.40	1.10978	4.35687	5.46665	30.96071	2.74918	5.61281+02
1.60	1.11971	4.24354	5.36325	30.33449	2.95305	8.97532+02
1.80	1.14481	4.14427	5.28908	29.71448	3.16268	1.45439+03
2.00	1.19473	4.05956	5.25429	29.09248	3.38122	2.40558+03
2.20	1.28703	3.98685	5.27388	28.44962	3.61353	4.10705+03
2.40	1.42380	3.96857	5.39237	27.81084	3.85740	7.20112+03
2.60	1.74811	4.01598	5.76410	27.13762	4.14652	1.40126+04
2.80	2.38824	4.10348	6.49171	26.28827	4.48202	3.03403+04
3.00	3.66351	4.33739	8.00091	25.16600	4.86784	7.37632+04

T= 5600 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.17888	5.36156	6.54044	35.71700	1.38324	2.41680+01
.20	1.16714	5.22670	6.39384	35.04190	1.57889	3.79219+01
.40	1.15473	5.08751	6.24224	34.36807	1.77425	5.94634+01
.60	1.14224	4.94440	6.08664	33.69607	1.96953	9.32245+01
.80	1.13048	4.79970	5.93018	33.02811	2.16503	1.46228+02
1.00	1.12070	4.65698	5.77768	32.36713	2.36126	2.29752+02
1.20	1.11459	4.52008	5.63468	31.71573	2.55889	3.62151+02
1.40	1.11452	4.39239	5.50691	31.07505	2.75886	5.73931+02
1.60	1.12393	4.27659	5.40052	30.44429	2.96251	9.17297+02
1.80	1.14847	4.17419	5.32266	29.81933	3.17189	1.48556+03
2.00	1.19786	4.08673	5.28459	29.19303	3.39018	2.45573+03
2.20	1.28939	4.01104	5.30043	28.54585	3.62216	4.18948+03
2.40	1.42282	3.99095	5.41377	27.90492	3.86492	7.32690+03
2.60	1.74573	4.03835	5.78407	27.23253	4.15375	1.42479+04
2.80	2.38319	4.12444	6.50763	26.38335	4.48893	3.08269+04
3.00	3.64787	4.35438	8.00225	25.26129	4.87381	7.47842+04

T= 5700 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.18388	5.39623	6.58011	35.84720	1.39277	2.47042+01
.20	1.17238	5.26112	6.43350	35.16946	1.58853	3.87731+01
.40	1.16013	5.12334	6.28346	34.49458	1.78396	6.08079+01
.60	1.14775	4.98228	6.13003	33.82213	1.97930	9.53455+01
.80	1.13601	4.83936	5.97537	33.15340	2.17484	1.49568+02
1.00	1.12610	4.69741	5.82351	32.49068	2.37103	2.34980+02
1.20	1.11972	4.56003	5.67975	31.83636	2.56857	3.70314+02
1.40	1.11925	4.43071	5.54996	31.19178	2.76839	5.86665+02
1.60	1.12818	4.31243	5.44062	30.55647	2.97184	9.37217+02
1.80	1.15219	4.20683	5.35901	25.92646	3.18098	1.51698+03
2.00	1.20102	4.11656	5.31758	29.29578	3.39901	2.50617+03
2.20	1.29185	4.03780	5.32965	28.64417	3.63067	4.27238+03
2.40	1.42186	4.01585	5.43771	28.00100	3.87232	7.45281+03
2.60	1.74341	4.06320	5.80661	27.32941	4.16086	1.44830+04
2.80	2.37832	4.14782	6.52613	26.48026	4.49573	3.13134+04
3.00	3.63278	4.37363	8.00641	25.35811	4.87970	7.58054+04

T= 5800 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.18892	5.43322	6.62214	35.97810	1.40216	2.52441+01
.20	1.17751	5.29800	6.47551	35.29790	1.59798	3.96260+01
.40	1.16535	5.16189	6.32725	34.62232	1.79347	6.21541+01
.60	1.15308	5.02321	6.17629	33.94980	1.98887	9.74698+01
.80	1.14138	4.88237	6.02374	33.28068	2.18444	1.52911+02
1.00	1.13139	4.74143	5.87282	32.61651	2.38062	2.40226+02
1.20	1.12480	4.60371	5.72850	31.95945	2.57808	3.78512+02
1.40	1.12398	4.47282	5.59680	31.31105	2.77777	5.99474+02
1.60	1.13247	4.35204	5.48452	30.67116	2.98104	9.57282+02
1.80	1.15597	4.24316	5.39913	30.03602	3.18996	1.54867+03
2.00	1.20423	4.15003	5.35426	29.40087	3.40772	2.55694+03
2.20	1.29438	4.06813	5.36251	28.74472	3.63907	4.35582+03
2.40	1.42093	4.04424	5.46517	28.09922	3.87958	7.57844+03
2.60	1.74115	4.09153	5.83269	27.42839	4.16785	1.47180+04
2.80	2.37361	4.17459	6.54821	26.57914	4.50242	3.17995+04
3.00	3.61822	4.39613	8.01435	25.45660	4.88551	7.68263+04

T= 5900 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.19404	5.47350	6.66754	36.11160	1.41146	2.57905+01
.20	1.18251	5.33833	6.52084	35.42914	1.60724	4.04800+01
.40	1.17041	5.20416	6.37457	34.75318	1.80277	6.34995+01
.60	1.15822	5.06816	6.22639	34.08100	1.99823	9.95933+01
.80	1.14659	4.92971	6.07630	33.41188	2.19384	1.56257+02
1.00	1.13658	4.79002	5.92660	32.74657	2.39003	2.45488+02
1.20	1.12982	4.65210	5.78192	32.08696	2.58744	3.86759+02
1.40	1.12871	4.51971	5.64842	31.43479	2.78702	6.12379+02
1.60	1.13680	4.39642	5.53322	30.79031	2.99012	9.77507+02
1.80	1.15981	4.28420	5.44401	30.14993	3.19882	1.58059+03
2.00	1.20747	4.18813	5.39561	29.51024	3.41631	2.60801+03
2.20	1.29701	4.10301	5.40002	28.84944	3.64738	4.43997+03
2.40	1.42002	4.07713	5.49715	28.20152	3.88673	7.70424+03
2.60	1.73896	4.12433	5.86329	27.53141	4.17472	1.49527+04
2.80	2.36909	4.20575	6.57484	26.68193	4.50902	3.22864+04
3.00	3.60419	4.42285	8.02704	25.55870	4.89124	7.78467+04

T= 6000 AIR

LOG RHO	Z	E/RT	H/RT	S/R	LOG P	P
.00	1.19931	5.51750	6.71681	36.24820	1.42067	2.63433+01
.20	1.18737	5.38254	6.56991	35.56368	1.61632	4.13352+01
.40	1.17528	5.25057	6.42585	34.88769	1.81187	6.48440+01
.60	1.16318	5.11759	6.28077	34.21626	2.00738	1.01714+02
.80	1.15164	4.98183	6.13347	33.54753	2.20305	1.59606+02
1.00	1.14165	4.84365	5.98530	32.88138	2.39927	2.50767+02
1.20	1.13479	4.70568	5.84047	32.21941	2.59665	3.95048+02
1.40	1.13343	4.57184	5.70527	31.56356	2.79613	6.25360+02
1.60	1.14116	4.44603	5.58719	30.91446	2.99908	9.97884+02
1.80	1.16372	4.33039	5.49411	30.26875	3.20758	1.61280+03
2.00	1.21076	4.23133	5.44209	29.62443	3.42479	2.65944+03
2.20	1.29973	4.14289	5.44262	28.95885	3.65559	4.52470+03
2.40	1.41913	4.11496	5.53409	28.30842	3.89376	7.82997+03
2.60	1.73683	4.16204	5.89888	27.63899	4.18149	1.51876+04
2.80	2.36473	4.24175	6.60648	26.78915	4.51552	3.27733+04
3.00	3.59066	4.45427	8.04493	25.66495	4.89691	7.88697+04

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13 ABSTRACT Tables for the thermodynamic properties of equilibrium air are presented at intervals of log ρ = 0.2, the density ρ in amagats extending from 1 to 1000 amagats and at temperature intervals of 100 deg from 300 to 6000°K. In accordance with full discussion in the text of the report, the compressibility factor Z at 300 and 400°K is extrapolated to 1000 amagats by linear extrapolation of log (Z - 1) against log ρ at constant temperature. At 5000 and 6000°K the values of Z were obtained from unpublished virial corrections furnished by Joseph Hilsenrath of the National Bureau of Standards. Interpolations between these extremes of temperature are based on an empirical equation for the pressure-temperature lines at constant density, the form of which fits known data at medium densities and also predicts data at temperatures below 300°K. The values of the dimensionless thermal functions E/RT (internal energy) and S/R (entropy) are based on numerical integrations of Z and its derivative $(\partial Z/\partial T)_\rho$, using known values of these functions at 1 amagat as constants of integration.

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