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Summary

The computer codes developed in this work provide a self-consistent set of thermodynamic and transport properties for equilibrium air for temperatures from 500 to 30000 K over a pressure range of 10^{-4} to 10^{2} atm. The properties computed include enthalpy, total specific heat, compressibility factor, viscosity, and the total values of thermal conductivity and Prandtl number. These properties are calculated through the use of temperature dependent curve-fits for seven constant values of pressure. A simple method of interpolation is demonstrated for intermediate values of pressure although other methods may be employed. The curve fits are based on mixture values calculated from an 11-species air model. Individual species properties used in the mixture relations are obtained from a recent study by the present authors. A review and discussion of the sources and accuracy of the curve-fitted data used herein are given in NASA RP 1260.

The computer subroutines developed to evaluate the various properties and described in this report are available from the NASA Computer Software Management and Information Center (COSMIC).

Symbols

$\bar{A}$	averaged coefficient of polynomial curve fit in overlap region (eq. (1))
A_h, B_h, C_h, D_h, E_h	curve-fit coefficients for specific heat at constant pressure, h, (eqs. (4) and (5))
A_{C_p}, B_{C_p}, C_{C_p}, D_{C_p}, E_{C_p}	curve-fit coefficients for specific heat at constant pressure, C_p, (eqs. (7) and (8))
A_Z, B_Z, C_Z, D_Z, E_Z	curve-fit coefficients for compressibility factor, Z, (eq. (10))
A_μ, B_μ, C_μ, D_μ, E_μ, F_μ	curve-fit coefficients for viscosity, μ, (eq. (12))
A_K, B_K, C_K, D_K, E_K	curve-fit coefficients for total thermal conductivity, K
A_{Pr}, B_{Pr}, C_{Pr}, D_{Pr}, E_{Pr}, F_{Pr}	curve-fit coefficients for total thermal conductivity, Pr, (eq. (17))
C_p	specific heat at constant pressure, $cal/g-K$
h	enthalpy, $kcal/g$

K	total thermal conductivity, $cal/cm-sec-K$
Pr	total Prandtl number, $C_p \mu/K$
p	pressure, atm
T	temperature, K
Z	compressibility factor
μ	viscosity, $poise$
χ	$= (T/1000)$ in Eqs. (11), (13), and (17)
	$= \ln(T/10{,}000)$ in Eqs. (6), (9), and (16)

Analysis

It is desirable to have curve fits to the various equilibrium air properties as opposed to tabulated values since curve fits generally permit more efficient computation for flow-field analyses. In addition, for accurate calculations, it is preferable that these curve fits be obtained to values which are computed in a self-consistent manner from the same set of data and other physical properties. The present work follows these guidelines closely. In this report, details of the curve-fits and associated computer routines developed to evaluate the equilibrium properties are presented along with a brief physical overview. The reader should consult the companion report (Ref. 1) for a more detailed discussion of the sources and accuracy of the methods employed to calculate the original equilibrium air data. The computer codes developed in this work to evaluate the thermodynamic and transport properties of equilibrium air may be obtained for a fee from:

COSMIC
Computer Services Annex
University of Georgia
Athens, GA 30602
(404) 542-3265

Request the codes by the designation LAR 14760.

These codes were written in the form of FORTRAN subroutines for easy adaption to existing programs. The subroutines are well commented and can be easily modified to suit the user's needs.

The present equilibrium air properties are based on calculations using an 11-species (N_2, O_2, N, O, NO, NO^+, e^-, N^+, O^+, N^{++}, and O^{++}) air model and which includes the single and double ionization effects encountered at high temperatures. The curve fits provided here can only be used for equilibrium air calculations without ablation or injection of foreign products, i.e., with constant elemental composition through the flowfield. Values of 0.24 and 0.76 are employed in this work for the elemental mass composition of oxygen and nitrogen, respectively. In addition, these properties assume charge neutrality for ionized air and, therefore, neglect the associated electric field effects. This assumption can generally be made for an ionized gas mixture in thermochemical equilibrium.

The present equilibrium thermodynamic and transport properties are for temperatures from 500 to 30000 K over a pressure range of 10^{-4} to 10^2 atm. Included in these properties are enthalpy, total specific heat, compressibility factor, viscosity, and the total values of thermal conductivity and Prandtl number. Curve fits of these properties are based on the use of temperature dependent polynomial curve-fits for discrete values of pressure. Seven pressure intervals from 10^{-4} to 10^2 atm in constant steps by factors of ten were considered. A simple linear interpolation in the logarithm of the pressure is employed for intermediate values.

Other interpolation schemes may be developed to cover these intermediate areas.

The order of the curve-fits polynomials and the number of temperature intervals for the curve-fits have been selected so as to achieve an overall 5 percent accuracy of the curve-fit values in relation to the computed values along the constant pressure lines. It was also desirable to employ the minimum number of temperature intervals (or ranges) and the lowest order polynomials possible along the constant pressure lines while achieving this accuracy. In the final result, the entire temperature range of $500 < T < 30000\ K$ is broken down into two or more intervals using these criteria. To ensure a smooth variation of the curve-fitted properties over the complete temperature range, values of the curve-fit coefficients are linearly averaged at the temperature interval boundaries over a specified overlap region. The overlap range is equally spread on the two sides at the temperature boundaries and is $500\ K$ for temperatures less than $20000\ K$ and $1000\ K$ for higher temperatures. The averaging procedure for all coefficients in the overlap region can be written as

$$\bar{A}_{\phi} = (1-a)A_{\phi}^{L} + aA_{\phi}^{U} \tag{1}$$

where

$$a = \left[\frac{T - T_B^L}{T_B^U - T_B^L}\right] \tag{2}$$

Here, T_B^U and T_B^L are the lower and upper temperature limits, respectively, of the overlap region. The quantity A_{ϕ} is one of the curve-fit coefficients for flowfield property "ϕ". The superscripts U and L on A_{ϕ} denote coefficients of the curve fits from the upper and lower sides of the temperature boundaries, respectively. With these definitions, all curve-fit coefficients A_{ϕ} are replaced by $\bar{A}_{\phi}$ from Eq. (1) when the temperature (at which the property is to be evaluated) is within an overlap region.

Since the curve fits are obtained for a range of constant values of pressure $(10^{-4} \le p \le 10^{2})$ in steps of a factor of 10, a logarithmic interpolation procedure was used to obtain values of the flowfield properties at intermediate pressures. That is, a property "ϕ^*" is interpolated at pressure p^* (for a specified temperature) from the following relation:

$$\log \phi^* = \left[\frac{\log \phi_2 - \log \phi_1)}{(\log p_2 - \log p_1}\right] (\log p^* - \log p_1) + \log \phi_1 \tag{3}$$

where ϕ_2 and ϕ_1 are the values of property ϕ evaluated for a specified temperature T at pressures p_2 and p_1, respectively, such that $p_1 \le p^* \le p_2$.

Using these relations and the curve-fits described subsequently, the interpolated values of viscosity (μ), specific heat at constant pressure (C_p), thermal conductivity (K), and Prandtl number (Pr) are within 5 percent of the computed values for temperatures less than 2500 K over the entire pressure range. The error in the interpolated values of μ, C_p, K, and Pr increases at higher temperatures. A maximum error of about 20 percent is obtained in the interpolated values of C_p and Pr at temperatures between 5000 K and 8000 K, whereas this error is about 10 percent or less for K for temperatures between 2500 K and 8000 K. For temperatures greater than 8000 K, the maximum error in the interpolated values is believed to be less than 20 percent for C_p, K, and Pr, and much less for μ. Such errors in the interpolated values of C_p, K, and Pr are compounded by the presence of the reaction component in these properties. The interpolation errors verified in the present study and expected using the logarithmic scheme are summarized in the following table.

Interpolation Errors (for P=0.03, 0.3, and 3.0 atm)

Temperature Range, K	Property	Error
$500 \leq T \leq 15000$	μ	< 8%
$500 \leq T \leq 15000$	h	< 5%
$500 \leq T \leq 15000$	Z	< 5%
$500 \leq T \leq 2500$	C_p	< 5%
$2500 \leq T \leq 5000$	C_p	< 10%
$5000 \leq T \leq 15000$	C_p	< 20%
$500 \leq T \leq 2500$	K	< 5%
$2500 \leq T \leq 15000$	K	< 10%
$500 \leq T \leq 2500$	Pr	< 5%
$2500 \leq T \leq 5000$	Pr	< 10%
$5000 \leq T \leq 15000$	Pr	< 20%

Finer pressure intervals (than those used here) may improve the interpolation accuracies by capturing the initiation of various reactions better. Additionally, a different approach to interpolating for properties at the intermediate pressures may be developed which will improve the accuracy. However, even with the interpolation scheme and pressure intervals employed presently, flowfield quantities of interest such as the skin-friction drag, surface heat transfer, and the aerodynamic coefficients can be computed for cooled surfaces with fair degree of accuracy.

The curve fits provided here are in terms of temperature. These may easily be converted to those in terms of enthalpy by using the relation between temperature and enthalpy provided by the curve fits given in the next section.

Enthalpy

The specific enthalpy for equilibrium air can be computed from following curve-fit expression to obtain enthalpy as a function of temperature at constant pressure

$$h = \exp(A_h \chi^4 + B_h \chi^3 + C_h \chi^2 + D_h \chi + E_h) \tag{4}$$

or,

$$\ln h = A_h \chi^4 + B_h \chi^3 + C_h \chi^2 + D_h \chi + E_h \tag{5}$$

where

$$\chi = \ln (T/10{,}000) \tag{6}$$

The coefficients A_h, B_h, C_h, D_h, and E_h have been evaluated from the computed values by using a least squares curve-fit technique and are given in Table I. These coefficients are given for several temperature ranges at a specified pressure. As stated previously, the number of temperature ranges is established so as to obtain a smooth and accurate curve fit to the computed values and generally, a larger number of ranges is needed at lower pressures. The accuracy of the curve fit expression (4) is good to within 4 percent of the computed values (Ref. 1) for the entire temperature range ($500\ K \leq T \leq 30000\ K$) range along the constant pressure lines.

Total Specific Heat At Constant Pressure

The total specific heat at constant pressure can be computed from the following curve-fit expression

$$C_p = \exp(A_{C_p}\chi^4 + B_{C_p}\chi^3 + C_{C_p}\chi^2 + D_{C_p}\chi + E_{C_p}) \tag{7}$$

or,

$$C_p = A_{C_p}\chi^4 + B_{C_p}\chi^3 + C_{C_p}\chi^2 + D_{C_p}\chi + E_{C_p} \tag{8}$$

where

$$\chi = \ln(T/10{,}000) \tag{9}$$

The tabulated values of coefficients A_{C_p}, B_{C_p}, C_{C_p}, D_{C_p}, E_{C_p} are listed in Table II. The accuracy of the curve-fit values is within 4 percent of the computed values (Ref. 1) along constant pressure lines for the entire temperature range considered here.

Compressibility Factor

The compressibility factor, Z, (which is equal to the ratio of the molecular weight of undissociated air to the mean molecular weight) can be obtained by employing the following curve-fit expression at constant pressure:

$$Z = A_Z + B_Z\chi + C_Z\chi^2 + D_Z\chi^3 + E_Z\chi^4 \tag{10}$$

where

$$\chi = \frac{T}{1000} \tag{11}$$

The coefficients appearing in Eq. (10) are tabulated in Table III. The curve fit values are within 3 percent of the computed values (Ref. 1) for values along the constant pressure lines.

Viscosity

The following expression has been used to curve-fit the viscosity values computed in Ref. 1,

$$\mu = A_\mu + B_\mu\chi + C_\mu\chi^2 + D_\mu\chi^3 + E_\mu\chi^4 + F_\mu\chi^5 \tag{12}$$

where

$$\chi = \frac{T}{1000} \tag{13}$$

The polynomial coefficients of Eq. (12) are given in Table IV. In general, the accuracy of the curve fits along constant pressure lines is good to within 4 percent of the value computed in Ref. 1. The accuracy improves with increasing pressure, similar to the other thermodynamic and transport properties.

Total Thermal Conductivity

The total thermal conductivity, K, for equilibrium air is obtained from the curve-fit expression

$$K = \exp(A_K\chi^4 + B_K\chi^3 + C_K\chi^2 + D_K\chi + E_K) \tag{14}$$

or

$$\ln K = A_K \chi^4 + B_K \chi^3 + C_K \chi^2 + D_K \chi + E_K \tag{15}$$

where

$$\chi = \ln (T/10{,}000) \tag{16}$$

The coefficients appearing in Eqs. (14) and (15) are given in Table V. The accuracy of the curve fit is within 4 percent of the computed values along the constant pressure lines for the entire temperature ranges.

Total Prandtl Number

The computed values of the total Prandtl number have been curve fit by employing the relation

$$Pr = A_{Pr} + B_{Pr}\chi + C_{Pr}\chi^2 + D_{Pr}\chi^3 + E_{Pr}\chi^4 + F_{Pr}\chi^5 \tag{17}$$

with

$$\chi = \frac{T}{1000} \tag{18}$$

The polynomial coefficients of Eq. (17) are provided in Table VI. The accuracy of the curve-fits is within 4 percent of the values computed in Ref. 1 for the constant pressure and variable temperature ranges considered here.

User Instructions

The computer codes developed in this work to evaluate the thermodynamic and transport properties of equilibrium air were written in the form of FORTRAN subroutines for easy adaption to existing programs. The subroutines are commented and can be easily modified to suit the user's needs. In an attempt to maintain generality, a total of six separate subroutines are available for use. These six routines are used for the evaluation of the following properties:

1) specific enthalpy, h, *kcal/g*
2) total specific heat at constant pressure, C_p, *cal/g−K*
3) compressibility factor, Z
4) viscosity, μ, *poise*
5) total thermal conductivity, K, *cal/cm−sec−K*
6) total Prandtl number, Pr

Each routine evaluates one of the curve-fits described above at a given (input) temperature and pressure and returns a dimensional quantity for the associated property. It should be noted that all of the curve-fit coefficients used in the present work are listed in the form of DATA statements in the subroutines where they are used. In this form, it would be a simple task to incorporate the coefficient data into computer codes developed independently of those described in this report. The routines could also be modified to return the properties for arrays of temperatures and pressures for improved efficiency in some applications.

Subroutine Description and Use

The calling syntax of the six subroutines developed in the present work are outlined in the following sections. Each subroutine was named to reflect the property computed as shown in the following list:

1) ENTHLPY - specific enthalpy
2) SPECIFC - total specific heat at constant pressure
3) COMPRES - compressibility factor
4) VISCSTY - viscosity
5) CONDUCT - total thermal conductivity
6) PRANDTL - total Prandtl number

In the following descriptions, parameter lists are described for each subroutine.

Specific Enthalpy

-- ENTHLPY --

Purpose:	Compute specific enthalpy at a given temperature and pressure
Use:	CALL ENTHLPY(P,T,H)
Input:	P = Pressure, atm $(10^{-4} \leq P \leq 10^2)$ T = Temperature, K $(500 \leq T \leq 30000)$
Output:	H = h, specific enthalpy, $kcal/g$

Specific Heat

-- SPECIFC --

Purpose:	Compute the specific heat at constant pressure at a given temperature and pressure
Use:	CALL SPECIFC(P,T,CP)
Input:	P = Pressure, atm $(10^{-4} \leq P \leq 10^2)$ T = Temperature, K $(500 \leq T \leq 30000)$
Output:	CP = C_p, specific heat at constant pressure, $g/cm{-}s$

Compressibility Factor

-- COMPRES --

Purpose:	Compute the compressibility factor at a given temperature and pressure
Use:	CALL COMPRES(P,T,Z)
Input:	P = Pressure, atm $(10^{-4} \leq P \leq 10^2)$ T = Temperature, K $(500 \leq T \leq 30000)$
Output:	Z = Z, compressibility factor

Viscosity

-- VISCSTY ---

Purpose: Compute the viscosity at a given temperature and pressure

Use: CALL VISCSTY(P,T,AMU)

Input: P = Pressure, atm $(10^{-4} \leq P \leq 10^2)$
T = Temperature, K $(500 \leq T \leq 30000)$

Output: AMU = μ, viscosity, *poise*

Thermal Conductivity

-- CONDUCT ---

Purpose: Compute the total thermal conductivity at a given temperature and pressure

Use: CALL CONDUCT(P,T,AK)

Input: P = Pressure, atm $(10^{-4} \leq P \leq 10^2)$
T = Temperature, K $(500 \leq T \leq 30000)$

Output: AK = K, total thermal conductivity, $cal/cm\text{-}sec\text{-}K$

Prandtl Number

-- PRANDTL ---

Purpose: Compute the total Prandtl number at a given temperature and pressure

Use: CALL PRANDTL(P,T,PR)

Input: P = Pressure, atm $(10^{-4} \leq P \leq 10^2)$
T = Temperature, K $(500 \leq T \leq 30000)$

Output: PR = Pr, total Prandtl number

Environmental Characteristics

The computer codes described in this report were developed on a SUN SPARCstation 2 computer running the SunOS 4.0 operating system. The codes are written in standard FORTRAN 77 language and should run without modification on other machines. All routines are written with double precision (64 bit) reals for accuracy in evaluating the relatively high order polynomials employed. The memory sizes of the various routines are tabulated in the following table:

Memory Size of Subroutines

Routine	Size, bytes
ENTHLPY	3853
SPECIFC	1395
COMPRES	1543
VISCSTY	3023
CONDUCT	3039
PRANDTL	3039

The codes were timed on a Sun SPARCstation 2 with global optimization invoked for the FORTRAN compiler (i.e., f77 -O3). Times were monitored for 10^4 calls to each subroutine for an intermediate pressure (3 *atm*), and the average time for a single call was computed as shown in the following table:

CPU Time for Single Subroutine Calls

Routine	Time, s
ENTHLPY	8.7×10^{-5}
SPECIFC	9.5×10^{-5}
COMPRES	7.2×10^{-5}
VISCSTY	7.0×10^{-5}
CONDUCT	9.2×10^{-5}
PRANDTL	7.5×10^{-5}

Implementation Instructions

The compilation command for the FORTRAN compiler on the Sun SPARCstation 2 system for the subroutines described in this guide is

f77 -O3 -c filename.f

where *filename.f* is the specific program name from the list of names described earlier (i.e., ENTHLPY,SPECIFC,...,PRANDTL). The object file from the compilation step above would be linked to a user program by the following command:

f77 -ffpa -O3 -o exec userprogram.o filename.o

where *exec* is the executable file to be created, *userprogram.o* is the object file of the user's program after compilation, and *filename.o* is the object file from the subroutine compilation. In the compilation and linkage steps above, the command line parameter *-O3* is used to invoke global optimization which may be omitted if desired.

A driver program was written along with the subroutines described thus far which is used to exercise each of the subroutines for typical conditions. This driver program is useful for testing the subroutines and could be modified to generate a useful collection of tabulated properties. Output from the driver program is listed in the next section.

The sequence of commands listed below is used to execute the driver program on the Sun SPARCstation 2 system.

f77 -O3 -o DRIVER DRIVER.f ENTHLPY.f SPECIFC.f COMPRES.f
VISCSTY.f CONDUCT.f PRANDTL.f
DRIVER

Sample Input/Output

The driver routine described above is used to exercise each of the subroutines for typical input parameters. This section lists the output from the driver program which is generated directly using the output from the various subroutines. The driver routine calls all six subroutines to evaluate the equilibrium air properties for a range of temperatures (T) from 1000 to 25000 *K* for a constant pressure of 1 *atm*. The output from each subroutine is gathered by the driver program for all temperatures and is then printed in tabular form. The following table represents the output from the driver program.

Output from the DRIVER program

T, K	H, KCAL/G	CP, CAL/G-K	Z	MU, POISE	K, CAL/CM-S-K	PR
1000.0	0.25541	0.27521	0.99354	0.41558E-03	0.16340E-03	0.70378
2000.0	0.54646	0.31575	0.99734	0.65842E-03	0.30859E-03	0.68567
3000.0	0.99546	0.63713	1.0438	0.85660E-03	0.98728E-03	0.58220
4000.0	1.9005	0.77051	1.1258	0.10596E-02	0.14361E-02	0.59570
5000.0	2.4441	0.66248	1.2233	0.12962E-02	0.14556E-02	0.59818
6000.0	3.7070	1.8092	1.3027	0.15742E-02	0.48761E-02	0.56958
7000.0	6.2717	3.2664	1.6070	0.18809E-02	0.82702E-02	0.73562
8000.0	9.2197	1.8646	1.8794	0.21824E-02	0.46497E-02	0.90105
9000.0	10.532	1.0399	1.9864	0.24241E-02	0.28336E-02	0.88022
10000.0	11.497	1.0966	2.0334	0.25305E-02	0.29954E-02	0.93840
11000.0	12.859	1.7093	2.1009	0.24050E-02	0.37364E-02	1.0738
12000.0	15.018	2.5369	2.2240	0.20425E-02	0.46628E-02	1.1410
13000.0	18.161	3.7196	2.4229	0.15550E-02	0.55023E-02	1.0458
14000.0	22.310	4.8176	2.6949	0.10822E-02	0.60073E-02	0.85147
15000.0	27.242	5.1329	3.0149	0.70535E-03	0.61244E-02	0.58859
16000.0	32.374	4.5418	3.3395	0.44773E-03	0.59685E-02	0.34731
17000.0	36.752	3.5076	3.5748	0.29438E-03	0.57214E-02	0.18211
18000.0	39.583	2.5291	3.7358	0.21155E-03	0.55549E-02	0.94596E-01
19000.0	41.775	1.8305	3.8390	0.16621E-03	0.56152E-02	0.53406E-01
20000.0	43.262	1.4279	3.9002	0.14582E-03	0.58621E-02	0.35340E-01
21000.0	44.453	1.2553	3.9350	0.13808E-03	0.62391E-02	0.27895E-01
22000.0	45.666	1.3206	3.9587	0.13708E-03	0.67285E-02	0.26112E-01
23000.0	47.140	1.5895	3.9857	0.13809E-03	0.72978E-02	0.28862E-01
24000.0	49.060	2.0770	4.0277	0.13776E-03	0.79202E-02	0.35793E-01
25000.0	51.579	2.8165	4.0899	0.13405E-03	0.85734E-02	0.44190E-01

References

1. Gupta, R. N.; Lee, K. P.; Thompson, R. A.; and Yos, J. M.: *Calculations ans Curve-Fits of Thermodynamic and Transport Properties for Equilibrium Air to 30000 K.* NASA RP-1260, 1991.

Table I. Curve-fit coefficients for enthalpy* of equilibrium air** (500 K $\leq T \leq$ 30000 K)†

Pressure, atm	A_h	B_h	C_h	D_h	E_h	Temperature Range, K
10^{-4}	$0.128180E+01$	$0.121182E+02$	$0.424907E+02$	$0.665524E+02$	$0.385195E+02$	500– 2250
	$0.125380E+02$	$0.720107E+02$	$0.148949E+03$	$0.133853E+03$	$0.451550E+02$	2250– 4250
	$0.426138E+02$	$0.123001E+03$	$0.121801E+03$	$0.509305E+02$	$0.995964E+01$	4250– 6750
	$0.885088E+01$	$-0.207380E+02$	$-0.134604E+02$	$0.166408E+01$	$0.356570E+01$	6750–10750
	$0.151569E+02$	$-0.713138E+01$	$-0.172524E+00$	$0.643645E+00$	$0.356353E+01$	10750–17750
	$0.101759E+02$	$-0.161956E+02$	$-0.336892E+01$	$0.161274E+02$	$-0.201068E+01$	17750–25000
10^{-3}	$0.902850E+00$	$0.839944E+01$	$0.289458E+02$	$0.448640E+02$	$0.256452E+02$	500– 2250
	$0.237222E+02$	$0.118014E+03$	$0.214780E+03$	$0.171168E+03$	$0.513939E+02$	2250– 4250
	$0.880011E+02$	$0.213329E+03$	$0.181623E+03$	$0.661367E+02$	$0.110476E+02$	4250– 6750
	$-0.333238E+02$	$-0.316397E+02$	$-0.401000E+01$	$0.379639E+01$	$0.325469E+01$	6750–11750
	$0.196866E+02$	$-0.201771E+02$	$0.635249E+01$	$-0.174347E+00$	$0.354258E+01$	11750–18750
	$0.446869E+02$	$-0.141086E+03$	$0.159412E+03$	$-0.738595E+02$	$0.155141E+02$	18750–28000
10^{-2}	$0.653358E+00$	$0.596886E+01$	$0.201689E+02$	$0.309518E+02$	$0.174843E+02$	500– 2750
	$0.431122E+01$	$0.267604E+02$	$0.541203E+02$	$0.462077E+02$	$0.152182E+02$	2750– 5250
	$-0.126229E+01$	$0.113432E+02$	$0.109117E+02$	$0.400303E+01$	$0.284253E+01$	5250– 9750
	$0.209845E+02$	$-0.181381E+02$	$-0.399635E+00$	$0.387388E+01$	$0.283981E+01$	9750–17750
	$0.268647E+02$	$-0.104256E+03$	$0.145439E+03$	$-0.846045E+02$	$0.212051E+02$	17750–30000
10^{-1}	$0.363885E+00$	$0.329839E+01$	$0.110641E+02$	$0.173605E+02$	$0.999025E+01$	500– 3250
	$-0.865884E+01$	$-0.208034E+02$	$-0.132700E+02$	$0.242899E+01$	$0.417259E+01$	3250– 6250
	$-0.164319E+02$	$-0.285858E+00$	$0.447878E+01$	$0.196275E+01$	$0.256061E+01$	6250–15250
	$-0.207249E+02$	$0.633182E+02$	$-0.678713E+02$	$0.312942E+02$	$-0.158288E+01$	15250–30000

Table I. Concluded

Pressure, atm	A_h	B_h	C_h	D_h	E_h	Temperature Range, K
1	$0.209284E+00$	$0.187458E+01$	$0.622153E+01$	$0.101561E+02$	$0.603650E+01$	500– 3750
	$-0.171560E+02$	$-0.416138E+02$	$-0.332532E+02$	$-0.747816E+01$	$0.178858E+01$	3750– 8250
	$-0.134978E+02$	$0.801118E+01$	$0.192371E+01$	$0.930272E+00$	$0.244209E+01$	8250–17750
	$-0.564265E+01$	$0.262889E+02$	$-0.396119E+02$	$0.251297E+02$	$-0.207198E+01$	17750–30000
10	$0.124937E+00$	$0.109286E+01$	$0.355163E+01$	$0.617946E+01$	$0.386028E+01$	500– 4250
	$-0.120314E+02$	$-0.229170E+02$	$-0.129249E+02$	$0.262066E+00$	$0.235363E+01$	4250– 9250
	$-0.913636E+01$	$0.113996E+02$	$-0.259796E+01$	$0.114665E+01$	$0.236890E+01$	9250–18750
	$0.639208E+01$	$-0.149544E+02$	$0.882252E+01$	$0.258596E+01$	$0.107086E+01$	18750–30000
100	$-0.755123E-02$	$0.164258E-01$	$0.366590E+00$	$0.210603E+01$	$0.195195E+01$	500– 6250
	$-0.117469E+01$	$-0.592622E+01$	$-0.214181E+01$	$0.251111E+01$	$0.212013E+01$	6250–12750
	$-0.245329E+01$	$0.371340E+01$	$-0.288683E+00$	$0.421200E+00$	$0.239842E+01$	12750–30000

* Enthalpy is obtained in kcal/g.

** These curve fits have been obtained from the individual species enthalpy values referenced to a temperature of 0 K.

† For temperatures less than 500 K, enthalpy for air may be obtained from the relation:

$$h = 0.24 \mathrm{x} 10^{-3}\ \mathrm{T}$$

Table II. Curve-fit coefficients for specific heat* of equilibrium air (500 K $\leq T \leq$ 30000 K)**

Pressure, atm	A_{C_p}	B_{C_p}	C_{C_p}	D_{C_p}	E_{C_p}	Temperature Range, K
10^{-4}	$0.349023E+00$	$0.344158E+01$	$0.126715E+02$	$0.208154E+02$	$0.116592E+02$	500– 1250
	$0.152264E+02$	$0.129277E+03$	$0.411057E+03$	$0.580300E+03$	$0.305728E+03$	1250– 1750
	$-0.159675E+02$	$-0.136508E+03$	$-0.411657E+03$	$-0.525250E+03$	$-0.241298E+03$	1750– 2750
	$-0.108293E+03$	$-0.515276E+03$	$-0.882748E+03$	$-0.642505E+03$	$-0.166628E+03$	2750– 4750
	$-0.116246E+04$	$-0.266973E+04$	$-0.221802E+04$	$-0.791376E+03$	$-0.102433E+03$	4750– 6250
	$-0.238707E+02$	$-0.104336E+03$	$-0.890658E+02$	$-0.182697E+02$	$0.138792E+01$	6250– 9750
	$-0.209557E+02$	$0.253228E+02$	$0.212355E+02$	$-0.128857E+02$	$0.135712E+01$	9750–14250
	$0.762671E+03$	$-0.167407E+04$	$0.130713E+04$	$-0.422349E+03$	$0.482128E+02$	14250–19750
	$-0.789820E+03$	$0.263864E+04$	$-0.326378E+04$	$0.176381E+04$	$-0.348874E+03$	19750–25000
10^{-3}	$0.199532E+00$	$0.192597E+01$	$0.694347E+01$	$0.112521E+02$	$0.570825E+01$	500– 1250
	$0.345376E+01$	$0.315624E+02$	$0.107177E+03$	$0.160585E+03$	$0.884544E+02$	1250– 2250
	$-0.369572E+02$	$-0.128366E+03$	$-0.129698E+03$	$-0.169299E+02$	$0.207647E+02$	2250– 3750
	$-0.146237E+03$	$-0.581296E+03$	$-0.848597E+03$	$-0.532403E+03$	$-0.119389E+03$	3750– 5250
	$-0.758521E+03$	$-0.139794E+04$	$-0.900003E+03$	$-0.238528E+03$	$-0.216169E+02$	5250– 7250
	$-0.330240E+02$	$-0.866157E+02$	$-0.489572E+02$	$-0.182071E+01$	$0.229104E+01$	7250–10750
	$-0.618098E+02$	$0.103127E+03$	$-0.262275E+02$	$-0.850086E+01$	$0.253250E+01$	10750–17250
	$0.125063E+03$	$-0.298121E+03$	$0.210795E+03$	$-0.295269E+02$	$-0.792067E+01$	17250–28000
10^{-2}	$0.669436E+00$	$0.644478E+01$	$0.230631E+02$	$0.365225E+02$	$0.203928E+02$	500– 1750
	$-0.453138E+02$	$-0.292666E+03$	$-0.699603E+03$	$-0.730849E+03$	$-0.281133E+03$	1750– 2750
	$-0.151035E+03$	$-0.591051E+03$	$-0.835692E+03$	$-0.502696E+03$	$-0.107793E+03$	2750– 4750
	$0.539167E+03$	$0.126894E+04$	$0.106221E+04$	$0.370582E+03$	$0.457650E+02$	4750– 6750
	$0.217707E+02$	$-0.450370E+02$	$-0.192634E+02$	$0.517928E+01$	$0.180195E+01$	6750–12750
	$-0.122810E+03$	$0.240030E+03$	$-0.138486E+03$	$0.225676E+02$	$0.100733E+01$	12750–19750
	$0.162348E+03$	$-0.497482E+03$	$0.525270E+03$	$-0.216688E+03$	$0.277132E+02$	19750–30000

Table II. Continued

Pressure, atm	A_{C_p}	B_{C_p}	C_{C_p}	D_{C_p}	E_{C_p}	Temperature Range, K
10^{-1}	$0.291577E+00$	$0.278787E+01$	$0.992221E+01$	$0.157475E+02$	$0.820277E+01$	500- 1750
	$-0.662937E+01$	$-0.382984E+02$	$-0.779456E+02$	$-0.627915E+02$	$-0.154364E+02$	1750- 2750
	$0.128388E+03$	$0.596922E+03$	$0.101945E+04$	$0.757047E+03$	$0.205793E+03$	2750- 4250
	$-0.296048E+02$	$-0.133243E+03$	$-0.187832E+03$	$-0.100614E+03$	$-0.168003E+02$	4250- 6750
	$-0.308894E+03$	$-0.267701E+03$	$-0.478605E+02$	$0.326629E+01$	$0.838365E+00$	6750- 9750
	$0.104767E+03$	$-0.105447E+03$	$0.127166E+02$	$0.595868E+01$	$0.821623E+00$	9750-15750
	$-0.188079E+03$	$0.472158E+03$	$-0.407311E+03$	$0.141182E+03$	$-0.156018E+02$	15750-21500
	$0.232697E+03$	$-0.869061E+03$	$0.117775E+04$	$-0.682883E+03$	$0.143551E+03$	21500-30000
1	$0.164992E+00$	$0.156336E+01$	$0.552429E+01$	$0.879873E+01$	$0.412806E+01$	500- 1750
	$-0.830572E+01$	$-0.483112E+02$	$-0.101598E+03$	$-0.897230E+02$	$-0.280651E+02$	1750- 3250
	$0.848335E+02$	$0.361629E+03$	$0.561712E+03$	$0.376565E+03$	$0.915792E+02$	3250- 4750
	$-0.945467E+01$	$-0.640807E+02$	$-0.893740E+02$	$-0.403342E+02$	$-0.458728E+01$	4750- 7750
	$-0.153176E+03$	$-0.476111E+02$	$0.217674E+02$	$0.314736E+01$	$0.922570E-01$	7750-11750
	$0.975058E+02$	$-0.158721E+03$	$0.753693E+02$	$-0.936668E+01$	$0.987515E+00$	11750-20500
	$-0.473648E+02$	$0.818135E+02$	$0.169726E+02$	$-0.836769E+02$	$0.339060E+02$	20500-30000
10	$0.111751E+00$	$0.105018E+01$	$0.368846E+01$	$0.591074E+01$	$0.244269E+01$	500- 1750
	$0.252675E+00$	$0.341131E+01$	$0.131529E+02$	$0.203259E+02$	$0.100197E+02$	1750- 3250
	$0.450386E+02$	$0.167261E+03$	$0.224425E+03$	$0.128924E+03$	$0.263694E+02$	3250- 5750
	$0.231376E+02$	$-0.104484E+01$	$-0.271807E+02$	$-0.102436E+02$	$-0.333185E-01$	5750- 9250
	$-0.799940E+02$	$0.170114E+02$	$0.187072E+02$	$-0.350311E+01$	$0.184168E+00$	9250-13750
	$0.491689E+02$	$-0.116351E+03$	$0.889977E+02$	$-0.242638E+02$	$0.263659E+01$	13750-22500
	$-0.253231E+03$	$0.955890E+03$	$-0.132457E+04$	$0.798459E+03$	$-0.175990E+03$	22500-30000

Table II. Concluded

Pressure, atm	A_{C_p}	B_{C_p}	C_{C_p}	D_{C_p}	E_{C_p}	Temperature Range, K
100	$0.986591E-01$	$0.923581E+00$	$0.323392E+01$	$0.519284E+01$	$0.202191E+01$	500–1750
	$0.974261E-01$	$0.146776E+01$	$0.575473E+01$	$0.896935E+01$	$0.384233E+01$	1750–3750
	$0.210207E+02$	$0.677318E+02$	$0.778089E+02$	$0.381171E+02$	$0.628850E+01$	3750–6750
	$0.143729E+02$	$-0.128820E+02$	$-0.173603E+02$	$-0.137585E+01$	$0.743313E+00$	6750–10750
	$-0.347606E+02$	$0.320177E+02$	$0.148249E+01$	$-0.510951E+01$	$0.877002E+00$	10750–17750
	$0.450529E+02$	$-0.143364E+03$	$0.161302E+03$	$-0.752038E+02$	$0.129598E+02$	17750–30000

* Specific heat is obtained in cal/g-K.

** For temperatures less than 500 K, a value of 0.24 cal/g-K for the specific heat of air may be used.

Table III. Curve-fit coefficients for compressibility of equilibrium air (500 K $\leq T \leq$ 30000 K)*

Pressure, atm	A_Z	B_Z	C_Z	D_Z	E_Z	Temperature Range, K
10^{-4}	0.710750E + 00	0.107229E + 01	−0.125673E + 01	0.564944E + 00	−0.822333E − 01	500– 2750
	−0.614415E + 01	0.861656E + 01	−0.370256E + 01	0.681208E + 00	−0.443045E − 01	2750– 5750
	−0.632086E + 02	0.370722E + 02	−0.776456E + 01	0.706484E + 00	−0.233636E − 01	5750– 8750
	−0.467833E + 02	0.139011E + 02	−0.138693E + 01	0.592861E − 01	−0.903887E − 03	8750–17750
	0.556705E + 02	−0.135009E + 02	0.118386E + 01	−0.427210E − 01	0.551468E − 03	17750–25000
10^{-3}	0.824286E + 00	0.625098E + 00	−0.689867E + 00	0.286982E + 00	−0.376727E − 01	500– 3250
	0.746758E + 01	−0.460729E + 01	0.109594E + 01	−0.898428E − 01	0.162238E − 02	3250– 6750
	−0.385889E + 02	0.209649E + 02	−0.398276E + 01	0.327436E + 00	−0.970559E − 02	6750– 9750
	−0.455262E + 02	0.121138E + 02	−0.108251E + 01	0.415356E − 01	−0.569596E − 03	9750–19750
	0.809623E + 02	−0.162146E + 02	0.120105E + 01	−0.375039E − 01	0.424122E − 03	19750–28000
10^{-2}	0.873086E + 00	0.434929E + 00	−0.454400E + 00	0.176448E + 00	−0.212727E − 01	500– 3250
	−0.195828E + 01	0.324383E + 01	−0.123210E + 01	0.198816E + 00	−0.110471E − 01	3250– 7250
	−0.417508E + 02	0.199010E + 02	−0.334091E + 01	0.243749E + 00	−0.644569E − 02	7250–11750
	−0.431463E + 02	0.101757E + 02	−0.804882E + 00	0.274096E − 01	−0.334336E − 03	11750–21500
	0.208036E + 03	−0.342626E + 02	0.210825E + 01	−0.563525E − 01	0.555405E − 03	21500–30000
10^{-1}	0.904213E + 00	0.311295E + 00	−0.302086E + 00	0.107468E + 00	−0.116924E − 01	500– 3750
	0.124751E + 01	0.485004E + 00	−0.321087E + 00	0.632573E − 01	−0.364522E − 02	3750– 8250
	−0.325326E + 02	0.137742E + 02	−0.203163E + 01	0.130377E + 00	−0.302863E − 02	8250–13750
	−0.428667E + 02	0.888031E + 01	−0.620696E + 00	0.188157E − 01	−0.206237E − 03	13750–23500
	0.217096E + 03	−0.309522E + 02	0.165245E + 01	−0.384201E − 01	0.330019E − 03	23500–30000

Table III. Concluded

Pressure, atm	A_Z	B_Z	C_Z	D_Z	E_Z	Temperature Range, K
1	$0.102671E+01$	$-0.465274E-01$	$0.972123E-02$	$0.417402E-02$	$-0.536830E-03$	500–5750
	$0.387376E+02$	$-0.204439E+02$	$0.404607E+01$	$-0.344141E+00$	$0.107287E-01$	5750–9250
	$-0.161621E+02$	$0.637080E+01$	$-0.827695E+00$	$0.466769E-01$	$-0.941988E-03$	9250–15750
	$-0.255245E+02$	$0.419968E+01$	$-0.208573E+00$	$0.395832E-02$	$-0.175392E-04$	15750–23500
	$-0.784807E+02$	$0.129796E+02$	$-0.758996E+00$	$0.194343E-01$	$-0.182292E-03$	23500–30000
10	$0.970875E+00$	$0.869030E-01$	$-0.737745E-01$	$0.218303E-01$	$-0.179762E-02$	500–5750
	$-0.100200E+01$	$0.186655E+01$	$-0.540958E+00$	$0.639254E-01$	$-0.255478E-02$	5750–9750
	$-0.993188E+01$	$0.353080E+01$	$-0.389667E+00$	$0.187431E-01$	$-0.320898E-03$	9750–17250
	$0.398457E-01$	$-0.612253E+00$	$0.997312E-01$	$-0.411847E-02$	$0.542207E-04$	17250–30000
100	$0.103304E+01$	$-0.585872E-01$	$0.237877E-01$	$-0.281715E-02$	$0.168221E-03$	500–8750
	$-0.555015E+01$	$0.157079E+01$	$-0.115055E+00$	$0.324023E-02$	$-0.188832E-04$	8750–17750
	$0.202955E+02$	$-0.323532E+01$	$0.203092E+00$	$-0.525620E-02$	$0.489857E-04$	17750–30000

* For temperatures less than 500 K, a compressibility factor of unity may be used for air.

Table IV. Curve-fit coefficients for viscosity* of equilibrium air (500 K $\leq T \leq$ 30000 K)**

Pressure, atm	A_μ	B_μ	C_μ	D_μ	E_μ	F_μ	Temperature Range, K
10^{-4}	−0.1160076E − 04	0.6656010E − 03	−0.2933969E − 03	0.7427050E − 04	−0.6456605E − 05	0.8752161E − 07	500– 7750
	−0.9105422E + 00	0.4949794E + 00	−0.1060568E + 00	0.1123425E − 01	−0.5896774E − 03	0.1229026E − 04	7750–10750
	0.1463029E − 01	−0.5019958E − 02	0.6886543E − 03	−0.4723839E − 04	0.1623374E − 05	−0.2239581E − 07	10750–16750
	−0.2140374E − 02	0.6529285E − 03	−0.7290226E − 04	0.3865996E − 05	−0.9908122E − 07	0.9916638E − 09	16750–25000
10^{-3}	0.2397194E − 04	0.5564725E − 03	−0.1970968E − 03	0.4272210E − 04	−0.2690853E − 05	−0.3009241E − 07	500– 8250
	−0.5784272E + 00	0.2816531E + 00	−0.5377449E − 01	0.5058384E − 02	−0.2352317E − 03	0.4336410E − 05	8250–12250
	0.1658118E − 01	−0.5027652E − 02	0.6106363E − 03	−0.3715711E − 04	0.1135683E − 05	−0.1397984E − 07	12250–18750
	0.6903134E − 02	−0.1345295E − 02	0.1061916E − 03	−0.4234384E − 05	0.8514686E − 07	−0.6893227E − 09	18750–28000
10^{-2}	0.5085043E − 04	0.4774840E − 03	−0.1322133E − 03	0.2362256E − 04	−0.8014978E − 06	−0.6458338E − 07	500– 8750
	−0.3414870E + 00	0.1473594E + 00	−0.2471167E − 01	0.2030404E − 02	−0.8216415E − 04	0.1314540E − 05	8750–14250
	0.2450600E − 01	−0.6697224E − 02	0.7362709E − 03	−0.4070960E − 04	0.1134307E − 05	−0.1276018E − 07	14250–19750
	−0.3561146E − 01	0.7255623E − 02	−0.5837678E − 03	0.2324839E − 04	−0.4590857E − 06	0.3600777E − 08	19750–30000
10^{-1}	0.6394112E − 04	0.4385020E − 03	−0.1024141E − 03	0.1654305E − 04	−0.5014106E − 06	−0.3710875E − 07	500– 9750
	−0.2376368E + 00	0.9006170E − 01	−0.1315352E − 01	0.9370344E − 03	−0.3279124E − 04	0.4529650E − 06	9750–16750
	0.6309492E − 03	0.6108099E − 03	−0.1286661E − 03	0.9381977E − 05	−0.2960969E − 06	0.3444222E − 08	16750–24500
	−0.1622687E + 01	0.3035173E + 00	−0.2266401E − 01	0.8445985E − 03	−0.1570909E − 04	0.1166667E − 06	24500–30000
1	0.5781887E − 04	0.4438221E − 03	−0.1020840E − 03	0.1688754E − 04	−0.8622324E − 06	−0.2239193E − 09	500–11250
	−0.1844238E + 00	0.6040101E − 01	−0.7566737E − 02	0.4609058E − 03	−0.1377229E − 04	0.1623637E − 06	11250–19750
	0.2606784E − 01	−0.4562535E − 02	0.3111533E − 03	−0.1018512E − 04	0.1576999E − 06	−0.9011456E − 09	19750–30000
10	0.7256455E − 04	0.4050530E − 03	−0.7626766E − 04	0.1114437E − 04	−0.5020411E − 06	0.7074486E − 10	500–12750
	−0.9524274E − 01	0.2589951E − 01	−0.2593217E − 02	0.1227975E − 03	−0.2772500E − 05	0.2383398E − 07	12750–21500
	0.5037513E − 01	−0.8081647E − 02	0.5209350E − 03	−0.1682098E − 04	0.2731352E − 06	−0.1794872E − 08	21500–30000

Table IV. Concluded

Pressure, atm	A_μ	B_μ	C_μ	D_μ	E_μ	F_μ	Temperature Range, K
100	$0.7609039E-04$	$0.3891948E-03$	$-0.6458779E-04$	$0.8791566E-05$	$-0.4216496E-06$	$0.4509800E-08$	500–15250
	$-0.7868582E-01$	$0.1820922E-01$	$-0.1543467E-02$	$0.6257766E-04$	$-0.1234998E-05$	$0.9579999E-08$	15250–30000

* Viscosity is obtained in poise or g/cm-sec.

** For temperatures less than 500 K, Sutherland's viscosity law may be used:

$$\mu_S = 1.4584\text{x}10^{-5} \frac{T^{3/2}}{(T + 110.33)}$$

Table V. Curve-fit coefficients for thermal conductivity* of equilibrium air (500 K $\leq T \leq$ 30000 K)**

Pressure, atm	A_K	B_K	C_K	D_K	E_K	Temperature Range, K
10^{-4}	$0.395299E+01$	$0.386816E+02$	$0.140687E+03$	$0.226110E+03$	$0.127138E+03$	500–1750
	$0.119879E+02$	$0.412181E+02$	$0.717156E+01$	$-0.911924E+02$	$-0.810415E+02$	1750–2750
	$-0.832682E+02$	$-0.419438E+03$	$-0.751764E+03$	$-0.566912E+03$	$-0.157470E+03$	2750–4750
	$-0.103603E+04$	$-0.242470E+04$	$-0.206135E+04$	$-0.757541E+03$	$-0.108281E+03$	4750–6250
	$0.261125E+02$	$0.411940E+01$	$-0.186054E+02$	$-0.645054E+01$	$-0.621476E+01$	6250–10250
	$0.246095E+02$	$-0.507490E+02$	$0.369131E+02$	$-0.897288E+01$	$-0.623025E+01$	10250–17750
	$-0.571805E+02$	$0.168628E+03$	$-0.181577E+03$	$0.859388E+02$	$-0.213335E+02$	17750–25000
10^{-3}	$0.199665E+01$	$0.194822E+02$	$0.706404E+02$	$0.113538E+03$	$0.599079E+02$	500–1750
	$-0.831120E+02$	$-0.560438E+03$	$-0.140314E+04$	$-0.154128E+04$	$-0.632398E+03$	1750–2750
	$-0.110139E+03$	$-0.481050E+03$	$-0.757873E+03$	$-0.505860E+03$	$-0.125800E+03$	2750–4750
	$0.299875E+03$	$0.923042E+03$	$0.992814E+03$	$0.442621E+03$	$0.634709E+02$	4750–6250
	$0.434485E+02$	$0.464790E+01$	$-0.155778E+02$	$-0.220224E+01$	$-0.558790E+01$	6250–11250
	$0.895136E+01$	$-0.322183E+02$	$0.350726E+02$	$-0.129798E+02$	$-0.498154E+01$	11250–18250
	$-0.422029E+02$	$0.144838E+03$	$-0.182586E+03$	$0.101698E+03$	$-0.270417E+02$	18250–28000
10^{-2}	$0.198558E+01$	$0.189164E+02$	$0.668384E+02$	$0.104546E+03$	$0.527822E+02$	500–2250
	$0.595832E+02$	$0.288748E+03$	$0.500756E+03$	$0.363789E+03$	$0.844428E+02$	2250–3250
	$-0.442143E+02$	$-0.206207E+03$	$-0.324643E+03$	$-0.204871E+03$	$-0.494556E+02$	3250–5750
	$-0.584437E+03$	$-0.873106E+03$	$-0.445088E+03$	$-0.927269E+02$	$-0.128529E+02$	5750–7750
	$0.373716E+02$	$-0.115449E+02$	$-0.113653E+02$	$0.135799E+01$	$-0.542822E+01$	7750–12750
	$-0.143675E+02$	$0.801073E+01$	$0.146420E+02$	$-0.117248E+02$	$-0.389761E+01$	12750–18750
	$0.502985E+01$	$-0.960227E+01$	$0.196818E+01$	$0.643952E+01$	$-0.896353E+01$	18750–30000

Table V. Continued

Pressure, atm	A_K	B_K	C_K	D_K	E_K	Temperature Range, K
10^{-1}	$0.105928E+01$	$0.100924E+02$	$0.356709E+02$	$0.561818E+02$	$0.249670E+02$	500- 2250
	$0.101351E+03$	$0.490653E+03$	$0.868620E+03$	$0.666792E+03$	$0.180596E+03$	2250- 4250
	$0.830640E+01$	$-0.324274E+02$	$-0.942568E+02$	$-0.647282E+02$	$-0.180857E+02$	4250- 6750
	$-0.318301E+03$	$-0.306306E+03$	$-0.782124E+02$	$-0.466313E+01$	$-0.585083E+01$	6750- 9250
	$0.469099E+02$	$-0.330961E+02$	$-0.146607E+01$	$0.306898E+01$	$-0.562490E+01$	9250-16750
	$0.154279E+02$	$-0.541310E+02$	$0.693640E+02$	$-0.366810E+02$	$0.115271E+01$	16750-30000
1	$0.334316E+00$	$0.328202E+01$	$0.119939E+02$	$0.200944E+02$	$0.462882E+01$	500- 2250
	$0.109992E+02$	$0.387106E+02$	$0.387282E+02$	$0.548304E+01$	$-0.120106E+02$	2250- 4250
	$0.124072E+02$	$-0.147438E+02$	$-0.530293E+02$	$-0.299886E+02$	$-0.961485E+01$	4250- 7750
	$-0.189644E+03$	$-0.828711E+02$	$0.998789E+01$	$0.227739E+01$	$-0.581069E+01$	7750-10750
	$0.298795E+02$	$-0.381078E+02$	$0.117041E+02$	$0.122011E+01$	$-0.578171E+01$	10750-19250
	$0.844897E+01$	$-0.358117E+02$	$0.553921E+02$	$-0.353787E+02$	$0.274595E+01$	19250-30000
10	$0.413573E+00$	$0.383393E+01$	$0.131885E+02$	$0.207305E+02$	$0.427728E+01$	500- 3250
	$0.821184E+02$	$0.308927E+03$	$0.423174E+03$	$0.250668E+03$	$0.475889E+02$	3250- 5250
	$0.113875E+02$	$-0.133907E+02$	$-0.337860E+02$	$-0.122339E+02$	$-0.610064E+01$	5250- 8750
	$-0.723261E+02$	$0.143656E+02$	$0.135247E+02$	$-0.233991E+01$	$-0.556444E+01$	8750-13750
	$-0.382696E+01$	$0.146502E+02$	$-0.187337E+02$	$0.107119E+02$	$-0.717162E+01$	13750-30000

Table V. Concluded

Pressure, atm	A_K	B_K	C_K	D_K	E_K	Temperature Range, K
100	$0.208749E+00$	$0.192122E+01$	$0.658813E+01$	$0.107630E+02$	$-0.127699E+01$	500– 3750
	$0.378677E+02$	$0.123284E+03$	$0.144224E+03$	$0.728083E+02$	$0.684807E+01$	3750– 6250
	$0.223116E+02$	$0.336369E+00$	$-0.142705E+02$	$-0.134534E+01$	$-0.498832E+01$	6250–10750
	$0.792550E+01$	$-0.216552E+02$	$0.204578E+02$	$-0.597164E+01$	$-0.485454E+01$	10750–30000

* Thermal conductivity is obtained in cal/cm-sec-K.

** For temperatures less than 500 K, Sutherland's thermal conductivity law may be used:

$$K_S = 5.9776\text{x}10^{-6} \frac{T^{3/2}}{(T + 194.4)}$$

Table VI. Curve-fit coefficients for Prandtl number of equilibrium air (500 K $\leq T \leq$ 30000 K)*

Pressure, atm	A_{Pr}	B_{Pr}	C_{Pr}	D_{Pr}	E_{Pr}	F_{Pr}	Temperature Range, K
10^{-4}	0.7695318E + 00	−0.2487156E + 00	−0.3371200E − 02	0.5237761E + 00	−0.4272376E + 00	0.9284843E − 01	500– 2250
	0.4081926E + 02	−0.6945482E + 02	0.4642510E + 02	−0.1500926E + 02	0.2350767E + 01	−0.1430131E + 00	2250– 3750
	−0.5060907E + 03	0.5765441E + 03	−0.2594581E + 03	0.5768434E + 02	−0.6333573E + 01	0.2747920E + 00	3750– 5750
	0.3172744E + 02	−0.1923593E + 02	0.6031312E + 01	−0.1191714E + 01	0.1301576E + 00	−0.5625333E − 02	5750– 8250
	−0.7624622E + 04	0.3908646E + 04	−0.7963915E + 03	0.8069517E + 02	−0.4069244E + 01	0.8174707E − 01	8250–10750
	0.1034825E + 03	−0.3861297E + 02	0.5742599E + 01	−0.4251452E + 00	0.1565525E − 01	−0.2291528E − 03	10750–14750
	−0.3414530E + 03	0.1193445E + 03	−0.1639670E + 02	0.1109347E + 01	−0.3701973E − 01	0.4881128E − 03	14750–18250
	0.1398841E + 02	−0.2209182E + 01	0.1254939E + 00	−0.2782377E − 02	0.6736752E − 05	0.3740205E − 06	18250–25000
10^{-3}	0.7483071E + 00	−0.1659050E + 00	−0.3548542E − 01	0.3843113E + 00	−0.2847560E + 00	0.5734562E − 01	500– 2250
	0.4355608E + 02	−0.6751147E + 02	0.4101816E + 02	−0.1204527E + 02	0.1712608E + 01	−0.9453467E − 01	2250– 4750
	0.6877578E + 03	−0.5984367E + 03	0.2059622E + 03	−0.3502408E + 02	0.2943975E + 01	−0.9787067E − 01	4750– 7250
	−0.7024989E + 03	0.4515788E + 03	−0.1153420E + 03	0.1460894E + 02	−0.9148849E + 00	0.2261774E − 01	7250–10250
	−0.3107328E + 03	0.1863582E + 03	−0.3984823E + 02	0.4000552E + 01	−0.1930037E + 00	0.3624133E − 02	10250–12750
	0.9153227E + 02	−0.3041980E + 02	0.4035104E + 01	−0.2667702E + 00	0.8781471E − 02	−0.1150000E − 03	12750–17250
	0.2304245E + 04	−0.6078459E + 03	0.6397478E + 02	−0.3358410E + 01	0.8795057E − 01	−0.9193691E − 03	17250–20500
	−0.1424413E + 02	0.3715427E + 01	−0.3586053E + 00	0.1651461E − 01	−0.3685522E − 03	0.3216955E − 05	20500–28000
10^{-2}	0.7406012E + 00	−0.1629686E + 00	0.8014385E − 01	0.1480977E + 00	−0.1294933E + 00	0.2544039E − 01	500– 2750
	0.3206825E + 02	−0.4531855E + 02	0.2519178E + 02	−0.6755087E + 01	0.8752933E + 00	−0.4395200E − 01	2750– 5250
	0.4409105E + 03	−0.3447078E + 03	0.1064873E + 03	−0.1623127E + 02	0.1221500E + 01	−0.3631877E − 01	5250– 8250
	0.2474049E + 02	0.2323747E + 01	−0.4089151E + 01	0.8375614E + 00	−0.6543669E − 01	0.1793128E − 02	8250–11750
	−0.9639789E + 03	0.3960004E + 03	−0.6388451E + 02	0.5082427E + 01	−0.2000122E + 00	0.3121600E − 02	11750–14250
	0.9436717E + 02	−0.2761116E + 02	0.3229296E + 01	−0.1885223E + 00	0.5488061E − 02	−0.6365539E − 04	14250–18250
	−0.7123564E + 02	0.2178196E + 02	−0.2554952E + 01	0.1451363E + 00	−0.4016437E − 02	0.4349632E − 04	18250–23500
	−0.7846718E + 02	0.1520447E + 02	−0.1165686E + 01	0.4430242E − 01	−0.8360113E − 03	0.6273942E − 05	23500–30000

Table VI. Continued

Pressure, atm	A_{Pr}	B_{Pr}	C_{Pr}	D_{Pr}	E_{Pr}	F_{Pr}	Temperature Range, K
10^{-1}	$0.7548377E+00$	$-0.2611566E+00$	$0.3168480E+00$	$-0.1019887E+00$	$-0.1326718E-01$	$0.6541023E-02$	500– 2750
	$0.6190687E+02$	$-0.8052889E+02$	$0.4117452E+02$	$-0.1025306E+02$	$0.1246034E+01$	$-0.5926933E-01$	2750– 5250
	$-0.2641868E+03$	$0.2214640E+03$	$-0.7330522E+02$	$0.1198777E+02$	$-0.9677752E+00$	$0.3085867E-01$	5250– 7750
	$0.7451996E+02$	$-0.2929220E+02$	$0.4227110E+01$	$-0.2590555E+00$	$0.5423023E-02$	$0.1836850E-04$	7750–13750
	$0.1034771E+03$	$-0.2138868E+02$	$0.1519602E+01$	$-0.3418909E-01$	$-0.5284942E-03$	$0.2331795E-04$	13750–18250
	$-0.1252168E+03$	$0.2959573E+02$	$-0.2775372E+01$	$0.1290359E+00$	$-0.2973274E-02$	$0.2716070E-04$	18250–25500
	$-0.5022975E+04$	$0.9203587E+03$	$-0.6737887E+02$	$0.2463703E+01$	$-0.4499464E-01$	$0.3283492E-03$	25500–30000
1	$0.8037721E+00$	$-0.5531739E+00$	$0.9090234E+00$	$-0.6243393E+00$	$0.1903222E+00$	$-0.2182155E-01$	500– 2750
	$0.9173178E+02$	$-0.1294114E+03$	$0.7264736E+02$	$-0.2015462E+02$	$0.2763213E+01$	$-0.1497413E+00$	2750– 4750
	$0.1874806E+02$	$-0.1571672E+02$	$0.5656501E+01$	$-0.1040290E+01$	$0.9598832E-01$	$-0.3499282E-02$	4750– 7750
	$-0.1974460E+03$	$0.9815976E+02$	$-0.1915726E+02$	$0.1841274E+01$	$-0.8709938E-01$	$0.1622326E-02$	7750–13250
	$0.5713095E+02$	$-0.2693925E+02$	$0.4625149E+01$	$-0.3686820E+00$	$0.1391085E-01$	$-0.2015436E-03$	13250–17750
	$0.1619271E+03$	$-0.3657252E+02$	$0.3311637E+01$	$-0.1501584E+00$	$0.3407133E-02$	$-0.3092820E-04$	17750–23500
	$-0.1396134E+03$	$0.2786187E+02$	$-0.2213081E+01$	$0.8742029E-01$	$-0.1716422E-02$	$0.1339615E-04$	23500–30000
10	$0.8167207E+00$	$-0.6186780E+00$	$0.1015263E+01$	$-0.6989158E+00$	$0.2151091E+00$	$-0.2479595E-01$	500– 2750
	$-0.1857130E+02$	$0.2610712E+02$	$-0.1366805E+02$	$0.3448930E+01$	$-0.4205156E+00$	$0.1987815E-01$	2750–5750
	$-0.4287169E+02$	$0.3082544E+02$	$-0.8483934E+01$	$0.1132069E+01$	$-0.7326105E-01$	$0.1844057E-02$	5750–10750
	$0.6447596E+02$	$-0.2113068E+02$	$0.2725852E+01$	$-0.1705427E+00$	$0.5177594E-02$	$-0.6127611E-04$	10750–20500
	$0.7384318E+02$	$-0.1345184E+02$	$0.9862360E+00$	$-0.3633532E-01$	$0.6720911E-03$	$-0.4987500E-05$	20500–30000

Table VI. Concluded

Pressure, atm	A_{Pr}	B_{Pr}	C_{Pr}	D_{Pr}	E_{Pr}	F_{Pr}	Temperature Range, K
100	$0.8147770E+00$	$-0.6129922E+00$	$0.1017670E+01$	$-0.7111724E+00$	$0.2215290E+00$	$-0.2557178E-01$	500– 2750
	$-0.6650000E+01$	$0.9087650E+01$	$-0.4283159E+01$	$0.9588901E+00$	$-0.1026406E+00$	$0.4226421E-02$	2750– 6750
	$-0.2736096E+02$	$0.1729215E+02$	$-0.4132288E+01$	$0.4767165E+00$	$-0.2655841E-01$	$0.5732041E-03$	6750–12750
	$0.4889586E+02$	$-0.1351549E+02$	$0.1493734E+01$	$-0.8122753E-01$	$0.2173037E-02$	$-0.2296542E-04$	12750–20500
	$-0.5525036E+02$	$0.1123889E+02$	$-0.8807574E+00$	$0.3371865E-01$	$-0.6355462E-03$	$0.4740705E-05$	20500–30000

* For temperatures less than 500 K, the following relation (employing the Sutherland'values for the viscosity and thermal conductivity) may be used to obtain Prandtl number for air:

$$Pr = 0.24 \mu_S/K_S$$

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16. Abstract

The computer codes developed in this work provide self-consistent thermodynamic and transport properties for equilibrium air for temperatures from 500 to 30000 K over a pressure range of 10^{-4} to 10^{2} atm. These properties are computed through the use of temperature dependent curve-fits for discrete values of pressure. Interpolation is employed for intermediate values of pressure. The curve fits are based on mixture values calculated from an 11-species air model. Individual species properties used in the mixture relations are obtained from a recent study by the present authors. A review and discussion of the sources and accuracy of the curve-fitted data used herein are given in NASA RP 1260.

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