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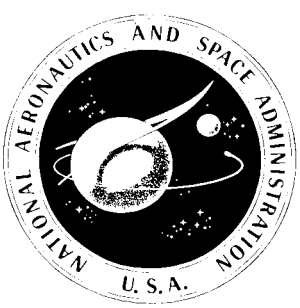
PATCH



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# THERMODYNAMIC PROPERTIES AND THEORETICAL ROCKET PERFORMANCE OF HYDROGEN TO 100000 K and $1.01325 \times 10^8$ N/m$^2$

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# THERMODYNAMIC PROPERTIES AND THEORETICAL ROCKET PERFORMANCE OF HYDROGEN TO 100 000 K AND $1.01325 \times 10^8$ N/m$^2$

by R. W. Patch

Lewis Research Center

## SUMMARY

The composition and thermodynamic properties were calculated for 100 to 110 000 K (180° to 198 000° R) and $1.01325 \times 10^2$ to $1.01325 \times 10^8$ N/m$^2$ (0.001 to 1000 atm) for chemical equilibrium in the Debye-Hückel and ideal-gas approximations. Quantities obtained were the concentrations of hydrogen atoms (H), protons ($H^+$), free electrons ($e^-$), hydrogen molecules ($H_2$), negative hydrogen ions ($H^-$), hydrogen diatomic molecular ions ($H_2^+$), and hydrogen triatomic molecular ions ($H_3^+$), and the enthalpy, entropy, average molecular weight, specific heat at constant pressure, density, and isentropic exponent. Electronically excited states of H and $H_2$ were included.

Choked, isentropic, one-dimensional nozzle flow with shifting chemical equilibrium was calculated to the Debye-Hückel and ideal-gas approximations for stagnation temperatures from 2500 to 100 000 K (4500° to 180 000° R) and stagnation pressures from $1.01325 \times 10^5$ to $1.01325 \times 10^8$ N/m$^2$ (1 to 1000 atm). The mass flow per unit throat area and the sonic flow factor were obtained. The pressure ratio, temperature, velocity, and ideal and vacuum specific impulses at the throat and for pressure ratios as low as $10^{-6}$ downstream were found.

For high temperatures at pressures approaching $1.01325 \times 10^8$ N/m$^2$ (1000 atm), the ideal-gas approximation was found to be inadequate for calculations of composition, precise thermodynamic properties, and precise nozzle flow. For such calculations, the Debye-Hückel approximation is recommended. The greatest discrepancy in nozzle flow occurred in the exit temperature, which was as much as 21 percent higher when the Debye-Hückel approximation was used.

# INTRODUCTION

The need for reliable values for thermodynamic properties for high-temperature hydrogen gas occurs in gaseous-core nuclear rockets (refs. 1 to 3), arcjets, and in high-speed entry into the atmospheres of Jupiter, Saturn, Uranus, and Neptune. Calculated performance of high-temperature hydrogen as a propellant depends on the values of thermodynamic properties and is needed for gaseous-core nuclear rockets.

A prerequisite to interpreting the thermodynamic properties of hydrogen is the distinction between the ortho and para forms of the hydrogen molecule $H_2$. Ortho and para refer to $H_2$ states with triplet and singlet nuclear spin states, respectively. Ortho states only occur with odd values of total angular momentum quantum number, whereas para states only occur with even values of total angular momentum quantum number. It is this fact, coupled with the difference in nuclear spin statistical weights, that effects the thermodynamic properties (refs. 4 and 5). In the absence of paramagnetic catalysts or hydrogen atoms H, there is very slow equilibration between ortho and para hydrogen; therefore, in many low-temperature problems they may be considered as separate substances. At temperatures of several thousand degrees K, the ortho-para ratio rapidly attains an equilibrium value of 3:1 due to the action of catalysts or H atoms. Hydrogen with this ortho-para ratio is called "normal" hydrogen. At lower temperatures, the equilibrium ortho-para ratio is less than 3:1. Hydrogen with the equilibrium ortho-para ratio for its temperature is said to be "spin equilibrated." For engineering purposes, the difference between the thermodynamic properties of normal and spin-equilibrated hydrogen is negligible above room temperature.

There are many previous calculations of the thermodynamic properties of hydrogen. Calculations with a maximum temperature of 5000 K ($9000^{\circ}$ R) or less include those of Woolley, Scott, and Brickwedde (ref. 4), Hilsenrath, et al. (ref. 6), King (ref. 7), Roder, Weber, and Goodwin (ref. 8), Svehla (ref. 9), Farmer (ref. 10), and Johnson (ref. 11). Other investigators have calculated thermodynamic properties for chemical equilibrium at higher temperatures. Rosenbaum and Levitt (ref. 12) considered spinless $H_2$, H, positive hydrogen atomic ions $H^+$, and free electrons $e^-$ for temperatures from 300 to 100 000 K ($540^{\circ}$ to $180\ 000^{\circ}$ R) and pressures from 1.01325 to $1.01325\times10^7$ $N/m^2$ (0.00001 to 100 atm) and included a covolume correction. McGee and Heller (ref. 13) considered H, $H^+$, and $e^-$ for temperatures from 2000 to 50 000 K ($3600^{\circ}$ to $90\ 000^{\circ}$ R) and pressures from $1.01325\times10^1$ to $1.01325\times10^7$ $N/m^2$ (0.0001 to 100 atm) and included Debye-Hückel corrections to the thermodynamic properties. These corrections account for the coulomb interactions between charged particles treated as point charges. McChesney (ref. 14) pointed out that McGee and Heller (ref. 13) were inconsistent because they used the Inglis-Teller cutoff. Krascella (ref. 15) included normal $H_2$, H, $H^+$, and $e^-$ in some thermodynamic functions for temperatures from 1667 to 111 111 K ($3001^{\circ}$ to $200\ 000^{\circ}$ R) and pressures from $1.01325\times10^5$ to $1.01325\times10^8$ $N/m^2$

(1 to 1000 atm). He included lowering of the ionization potential according to Ecker and Weizel (ref. 16) in the composition used to get the thermodynamic functions. However, Ecker and Weizel's work was later retracted (ref. 17). Kubin and Presley (ref. 18) calculated ideal-gas thermodynamic functions including spinless $H_2$, H, $H^+$, and $e^-$ for temperatures from 300 to 20 000 K (540° to 36 000° R) and pressures from $1.01325\times10^1$ to $1.01325\times10^8$ N/m$^2$ (0.0001 to 1000 atm); for their calculations they assumed $H_2$ to be a rigid rotor harmonic oscillator. Roback (ref. 19) computed some ideal-gas thermodynamic functions including normal $H_2$, H, e, $H^+$, and the negative hydrogen ion $H^-$ for temperatures from 300 to 111 111 K (540° to 200 000° R) and pressures from $1.01325\times10^{-1}$ to $1.01325\times10^8$ N/m$^2$ (0.000001 to 1000 atm). Thus, previous to this report there was no complete published set of hydrogen thermodynamic properties (from an engineering viewpoint) for temperatures above 20 000 K (36 000° R) and no reliable Debye-Hückel calculations for hydrogen at any temperature.

There are three previous calculations of choked nozzle flow of hydrogen. King (ref. 7) assumed chemical equilibrium of $H_2$ and H during isentropic expansion from stagnation temperatures of 600 to 5000 K (1080° to 9000° R) and stagnation pressures of $1.01325\times10^3$ to $1.01325\times10^7$ N/m$^2$ (0.01 to 100 atm). Roback (ref. 19) did equilibrium-flow and frozen-flow calculations including $H_2$, H, $e^-$, $H^-$, and $H^+$ for isentropic expansion from stagnation temperatures of 2778 to 111 111 K (5000° to 200 000° R) and stagnation pressures of $1.01325\times10^5$ to $2.0265\times10^8$ N/m$^2$ (1 to 2000 atm). Johnson (ref. 11) did real-gas calculations for stagnation temperatures of 97 to 389 K (175° to 700° R) and stagnation pressures of 0 to $1.01325\times10^7$ N/m$^2$ (100 atm).

The present work was based on the Debye-Hückel and ideal-gas approximations and had three purposes: (1) to provide a complete set of more refined compositions and thermodynamic functions for spin-equilibrated hydrogen in chemical equilibrium up to 110 000 K (198 000° R); (2) to provide more-accurate rocket-design and performance data for hydrogen in chemical equilibrium at high temperatures; and (3) to determine the magnitude of the Debye-Hückel effect on thermodynamic properties and rocket-design and performance data. For compositions and thermodynamic functions, the scope of the present work was 100 to 110 000 K (180° to 198 000° R) and $1.01325\times10^2$ to $1.01325\times10^8$ N/m$^2$ (0.001 to 1000 atm), and no deuterium or tritium were included. For rocket performance, the scope was stagnation temperatures of 2500 to 100 000 K (4500° to 180 000° R), stagnation pressures of $1.01325\times10^5$ to $1.01325\times10^8$ N/m$^2$ (1 to 1000 atm), and nozzle pressure ratios from critical down to $10^{-6}$. (Nozzle pressure ratio is defined as exit static pressure divided by stagnation pressure.) This report thus supplements the reports of King (ref. 7) and Johnson (ref. 11).

# ANALYSIS

## Thermodynamic Properties

The thermodynamic properties were based largely on compositions calculated by Patch (ref. 20). In that work, the species H, $H^+$, $e^-$, $H_2$, $H^-$, $H_2^+$, and $H_3^+$ were included for conditions where each was important.

The first six species are well known, but $H_3^+$ has not previously been included in calculations of thermodynamic properties. It has been observed experimentally for more than 44 years (refs. 21 to 24), but no optical spectrum has been detected. Thus, there was no reliable partition function or dissociation energy before the ab initio calculations of Conroy (ref. 25) and Patch and McBride (refs. 26 and 27). Their $H_3^+$ partition function was estimated to be accurate to within 20 percent from 298 to 8000 K ($536^\circ$ to 14 $400^\circ$ R) and within a factor of 2 from 8000 to 15 000 K (14 $400^\circ$ to 27 $000^\circ$ R). The $H_3^+$ ion is not important above 15 000 K (27 $000^\circ$ R). Since references 26 and 27 were written, Leventhal and Friedman (ref. 28) have experimentally determined the dissociation energy of $D_3^+$. Allowing for differences in vibrational zero point energies of $H_3^+$ and $D_3^+$ and also $H_2$ and $D_2$, their results agree within the experimental error with the dissociation energy of $H_3^+$ calculated by Patch and McBride (refs. 26 and 27) and used by Patch (ref. 20) to calculate composition.

Such a wide range of temperatures was included in reference 20 that Patch had to use different approximations for different temperature ranges, being careful that the results matched at the beginnings and ends of the ranges. Above 2000 K ($3600^\circ$ R) there was appreciable ionization, so the generally accepted Debye-Hückel approximation for charged-particle interactions was used. Other interactions between particles were neglected because these are less important at high temperatures. Above 1300 K ($2340^\circ$ R), electronically excited states of H and $H_2$ were included, necessitating some sort of cutoff. Cox (ref. 29) pointed out that for high degrees of ionization the perturbation of the energy levels is due principally to Coulomb forces, so that one method of cutoff should be used, whereas for low degrees of ionization the perturbation of the energy levels is due principally to neutral particles, so that another method of cutoff should be used. Hence, the cutoff was calculated by the Debye-Hückel method (ref. 30) and a modified Bethe method (ref. 31), and the method which cut off the most states was used. The ground electronic states of $H_2$ and $H_2^+$ were assumed to be spin-equilibrated for all temperatures.

Inclusion of the nuclear spin degeneracy in the partition function of $H_2$ has caused problems in the past (ref. 4) because the resulting entropies and free energies cannot be used directly to calculate chemical equilibria. This is due to the customary neglect of nuclear spin and inclusion of symmetry numbers for other components of a chemical reaction. This inconsistency was eliminated in reference 20 by including symmetry

numbers for $H_2$ and $H_2^+$ and weighting ortho states with a factor of 3/2 and para states with a factor of 1/2.

Certain modifications to the method in reference 20 were necessary to extend the temperature and pressure ranges. For temperatures below 298 K (536° R), it was assumed that the only species was $H_2$. The high-temperature method of reference 20 had a convergence limit because of the small concentrations of $H_2$ and/or $H_3^+$ at very high temperatures. In this report, the temperature limit of convergence was approximated by 7989 $\log_{10} p$ - 6323 (with p in $N/m^2$ and the limit in degrees K). For higher temperatures, equilibrium was calculated for this report by a major-minor Debye-Hückel iteration scheme. The major species were taken to be H, $H^+$, and $e^-$, while the minor species were $H^-$ and $H_2^+$. For pressures below $1.01325 \times 10^5$ $N/m^2$ (1 atm), it was necessary to include additional excited electronic states with principal quantum numbers as high as 65.

The thermodynamic properties for a given pressure and temperature may be calculated from the composition, the partition functions and their derivatives, and two derivatives of the density. The enthalpy, entropy, specific heat at constant pressure, and isentropic exponent were desired. The following paragraphs give the derivations.

As pointed out in reference 20, the Helmholtz free energy, pressure, and Gibbs free energy are each the sum of an ideal gas contribution based on the system volume and number of each kind of particle present and an "excess" contribution due to the Coulomb interactions according to the Debye-Hückel theory. Consider a system of volume V containing the seven chemical species in thermodynamic equilibrium. From reference 20, the excess Helmholtz free energy is

$$\mathcal{A}_{ex} = - \frac{kTV\kappa^3}{12\pi} \tag{1}$$

(Symbols are defined in the appendix.) The reciprocal Debye length is given in SI units by

$$\kappa = \left( \frac{e^2}{\epsilon_0 kTV} \sum_{i=1}^{7} z_i^2 N_i \right)^{1/2} \tag{2}$$

The excess pressure is (ref. 20)

$$p_{ex} = - \frac{kT\kappa^3}{24\pi} \tag{3}$$

The excess Gibbs free energy is then (ref. 20)

$$G_{ex} = -\frac{kTV\kappa^3}{8\pi} \tag{4}$$

The excess internal energy was found from equations (1) and (2) and a thermodynamic identity (ref. 5).

$$E_{ex} = -T^2\left(\frac{\partial \frac{\mathscr{A}_{ex}}{T}}{\partial T}\right)_{V, N_i} = -\frac{kTV\kappa^3}{8\pi} \tag{5}$$

The excess enthalpy was found from equations (3) and (5).

$$H_{ex} = E_{ex} + p_{ex}V = -\frac{kTV\kappa^3}{6\pi} \tag{6}$$

All the excess thermodynamic functions are negative, so the term "excess" is somewhat of a misnomer.

The enthalpy and specific heat were found from the ideal internal energy, ideal pressure, and excess enthalpy. The ideal internal energy of the system with $n_i$ moles of each species i is (ref. 5)

$$E_{id} = \frac{3}{2}nRT + RT^2\sum_{i=1}^{7} n_i\left(\frac{\partial \ln q_i}{\partial T}\right)_V \tag{7}$$

where all partition functions $q_i$ are referenced to the same energy, just as in reference 20. The enthalpy of the system is

$$H = E_{id} + p_{id}V + H_{ex} \tag{8}$$

From equations (6) to (8) and the perfect gas law,

$$H = \frac{5}{2} nRT + RT^2 \sum_{i=1}^{7} n_i \left( \frac{\partial \ln q_i}{\partial T} \right)_V - \frac{kTV\kappa^3}{6\pi} \tag{9}$$

Thus, the enthalpy per unit mass is

$$h = \frac{5}{2} \frac{nRT}{\rho V} + \frac{RT^2}{\rho V} \sum_{i=1}^{7} n_i \left( \frac{\partial \ln q_i}{\partial T} \right)_V - \frac{kT\kappa^3}{6\pi\rho} \tag{10}$$

which is the desired result. In evaluating the seven partial derivatives in equation (10), no simplifying assumptions were made except to neglect the variation of the H and $H_2$ cutoffs with temperature. The specific heat at constant pressure was found by numerical differentiation.

$$c_p = \left( \frac{\partial h}{\partial T} \right)_p \tag{11}$$

In carrying out the differentiation, the equilibrium, of course, shifted when the temperature was changed.

The entropy was found from the enthalpy and the Gibbs free energy. The Gibbs free energy per unit mass is (ref. 20)

$$g = - \frac{RT}{\rho V} \sum_{i=1}^{7} n_i \ln \frac{V q_i}{\Lambda_i N_o n_i} - \frac{kT\kappa^3}{8\pi\rho} \tag{12}$$

where

$$\Lambda_i \equiv \left( \frac{2\pi\hbar^2}{m_i kT} \right)^{3/2} \qquad i = 1, 2, \ldots, 7 \tag{13}$$

The entropy per unit mass is then

$$s = \frac{h - g}{T} \tag{14}$$

The isentropic exponent is useful in calculating sonic velocity, which for low-frequency sound waves is given by

$$a = \sqrt{\left(\frac{\partial p}{\partial \rho}\right)_s} \tag{15}$$

The isentropic exponent $\gamma$ is defined by

$$\gamma \equiv \left(\frac{\partial \ln p}{\partial \ln \rho}\right)_s = \frac{\rho}{p}\left(\frac{\partial p}{\partial \rho}\right)_s \tag{16}$$

so

$$a = \sqrt{\frac{\gamma p}{\rho}} \tag{17}$$

Use of the Bridgman table (ref. 32) gives

$$\gamma = \frac{\rho}{p} \frac{c_p}{c_p\left(\frac{\partial \rho}{\partial p}\right)_T - \frac{T}{\rho^2}\left(\frac{\partial \rho}{\partial T}\right)_p^2} \tag{18}$$

which, due to Debye-Hückel effects, cannot be reduced to a simpler form such as given by King (ref. 7). The two partial derivatives in equation (18) were determined numerically. In carrying out the differentiation, the equilibrium, of course, shifted when the temperature or pressure was changed.

To calculate the thermodynamic properties h, $c_p$, s, and $\gamma$ for a given temperature and pressure, it was thus necessary to do five equilibrium calculations (one at the specified temperature and pressure, and four at other, slightly different, temperatures and pressures) because of the numerically determined partial derivatives in equations (11) and (18).

## Rocket Performance

High-performance rockets always utilize choked nozzles (nozzles with sonic flow at the throat). In evaluating nozzle flow in this report, isentropic, choked, one-dimensional flow with shifting chemical equilibrium was assumed, just as in references 7 and 19. (Shifting chemical equilibrium means chemical equilibrium for the local temperature and pressure.) All necessary quantities were derived from the momentum, energy, and continuity equations. The stagnation conditions (essentially the chamber conditions) were specified.

Conditions at the throat were found by simultaneous solution of the equations

$$h_t = h^* + \frac{1}{2}\frac{\gamma^* p^*}{\rho^*} \tag{19}$$

and

$$s_t = s^* \tag{20}$$

where subscript $t$ indicates stagnation conditions and superscript $*$ indicates throat. The mass flow rate per unit throat area is

$$\frac{\dot{W}}{A^*} = \sqrt{\gamma^* p^* \rho^*} \tag{21}$$

This quantity has a strong dependence on stagnation temperature $T_t$ and stagnation pressure $p_t$ (which are essentially the same as chamber temperature and chamber pressure, respectively). When presenting tables which are to be interpolated to find $\dot{W}/A^*$, a quantity with less $T_t$ and $p_t$ dependence, which can hence be interpolated more accurately than $\dot{W}/A^*$, is the sonic flow factor $\psi$.

$$\psi \equiv \frac{\dot{W}\sqrt{T_t}}{A^* p_t} \tag{22}$$

The throat velocity is given by

$$v^* = \sqrt{\frac{\gamma^* p^*}{\rho^*}} \tag{23}$$

At any point in the nozzle, the velocity is

$$v = \sqrt{2(h_t - h)} \tag{24}$$

The Mach number is

$$M = v\sqrt{\frac{\rho}{\gamma p}} \tag{25}$$

The area ratio is

$$\frac{A}{A^*} = \frac{\rho^*}{\rho}\frac{v^*}{v} \tag{26}$$

Two kinds of specific impulse are usually given. The ideal specific impulse $I_{sp,\,i}$ is the specific impulse for the case where the ambient pressure is the same as the exit pressure.

$$I_{sp,\,i} = \frac{v_e}{B} \tag{27}$$

where subscript e indicates nozzle exit, and B is a conversion factor numerically equal to the standard acceleration of gravity. The vacuum specific impulse $I_{sp,\,v}$ is the specific impulse when the nozzle exhausts to a perfect vacuum.

$$I_{sp,\,v} = I_{sp,\,i} + \frac{p_e}{B}\frac{A_e}{A^*}\frac{A^*}{\dot{W}} \tag{28}$$

Most other common rocket performance parameters can be derived from those already given.

## RESULTS AND DISCUSSION

In this section, numerical results from the Debye-Hückel approximation are presented, their limitations and accuracy are discussed, and they are compared with the results of ideal-gas calculations and with the results of the calculations of other investigators, both for thermodynamic properties and for rocket performance.

## Thermodynamic Properties

Values for concentrations and properties. - Numerical results for the dimensionless concentrations $n_i N_o/VL_o$ of the species H, $H^+$, $e^-$, $H_2$, $H^-$, $H_2^+$, and $H_3^+$ in spin-equilibrated hydrogen in chemical equilibrium in the Debye-Hückel approximation are given in table I for pressures from $1.01325\times10^2$ to $1.01325\times10^8$ N/m$^2$ (0.001 to 1000 atm) and temperatures from 100 to 110 000 K (180° to 198 000° R). The dimensionless concentration of each species may also be thought of as the ratio of the number density of the species to the Loschmidt number $L_o$, where $L_o$ equals $2.68699\times10^{25}$ particles per cubic meter. Graphs of number densities were given in reference 20 for pressures of $1.01325\times10^5$ and $1.01325\times10^8$ N/m$^2$ (1 and 1000 atm). Below 7000 K (12 600° R), $H_3^+$ is the principal positive ion at a pressure of $1.01325\times10^8$ N/m$^2$ (1000 atm) although it was neglected by all previous investigators. Its inclusion greatly increases the concentrations of $e^-$ and $H^-$ at this pressure (ref. 20). However, at lower pressures it is less important.

Values for the thermodynamic properties in spin-equilibrated hydrogen in chemical equilibrium in the Debye-Hückel approximation (eqs. (10) to (14) and (18)) are given in table II for pressures from $1.01325\times10^2$ to $1.01325\times10^8$ N/m$^2$ (0.001 to 1000 atm) and temperatures from 100 to 110 000 K (180° to 198 000° R). Slight irregularities in $c_p$ and $\gamma$ at the higher temperatures are due to the Debye-Hückel gradual cutoff equations used for H (ref. 20). The reference energies for all partition functions are $e^-$ and the ground state of H, so the reference for enthalpy is the H atom at a temperature of 0 K. This makes many of the enthalpy values negative. To change the reference to liquid parahydrogen at 20.268 K (36.482° R) and $1.01325\times10^5$ N/m$^2$ (1 atm), add 214 586 J/g (92 288 Btu/lb) to the tabulated enthalpy values (refs. 4 and 8). The other tabulated thermodynamic properties are independent of the reference energy.

The thermodynamic properties are plotted in figures 1 to 6. In all of these figures, the effects of the dissociation of $H_2$ and the subsequent ionization of H are apparent as the temperature increases. It is also apparent that these two processes occur at higher temperatures as the pressure is increased.

Accuracy and limitations. - The composition and thermodynamic properties were evaluated to four significant figures or better, based on the equations in reference 20 and this report. However, the interactions between neutral particles and between neutral and charged particles were neglected, resulting in appreciable errors at high density. These errors were evaluated for $H_2$ and H concentrations by using the equations and virial coefficients of Fisher (ref. 33). The errors in h, s, $c_p$, $\rho$, and $\gamma - 1$ were estimated from Johnson's program (ref. 11). For all conditions, the error in $\gamma - 1$ was larger than in the other thermodynamic properties. Conditions where the error in $\gamma - 1$, H concentration, or $H_2$ concentration exceeded 20 percent were eliminated from tables I and II and figures 1 to 6.

There is a limit to the charged-particle density at which the Debye-Hückel theory is accurate. The theory is believed valid provided the equivalent concentration does not exceed the critical equivalent concentration (refs. 34, 35, and 20). However, as the equivalent concentration approaches the critical equivalent concentration, the accuracy can be expected to decrease (ref. 36). For the conditions in this report, the equivalent concentration never exceeded 0.6 of the critical equivalent concentration.

Estimated error in the $H_3^+$ partition function had no significant effect on the thermodynamic properties.

Comparisons. - To facilitate an understanding of the Debye-Hückel results, calculations of the composition and thermodynamic properties were repeated with all Debye-Hückel terms omitted but using the same cutoff methods. This gave ideal-gas results. A composition comparison was given in figure 4 of reference 20. At a pressure of $1.01325\times10^8$ N/m$^2$ (1000 atm), the Debye-Hückel approximation gave free-electron concentrations as much as 44 percent higher than those given by the ideal-gas approximation. The differences for other species were smaller.

For the thermodynamic properties, the two sets of results are plotted in figures 7 to 12 and are labeled "this report." In the following paragraphs, these two sets of results are discussed and compared with the results of other investigations.

Because of different enthalpy references used by various investigators, some standard had to be devised for comparison of enthalpies. The standard chosen was the enthalpy difference between the given temperature and 298 K (536$^\circ$ R). Such enthalpy differences for two pressures are given in figures 7 and 8 for the two approximations of this report and for the results of four other investigators.

In figure 7 it can be seen that the ideal-gas enthalpy differences of Svehla (ref. 9), Roback (ref. 19), and this report are all in excellent agreement. Including Debye-Hückel effects did not cause the enthalpy difference to deviate appreciably from the ideal-gas calculations, even at $1.01325\times10^8$ N/m$^2$ (1000 atm), where such deviation should be largest. This is surprising, considering the large concentration deviations. The explanation is that increased ionization due to Debye-Hückel effects increases the first and second terms in equation (10) but makes the third term more negative, so the changes in the terms roughly cancel. On the other hand, Krascella (ref. 15) gets much higher enthalpy differences from 15 000 to 40 000 K (27 000$^\circ$ to 72 000$^\circ$ R) than any other investigator. This is because his enthalpy equation contains charged-particle interactions only indirectly, through changes in composition, and hence the cancellation mentioned previously does not take place. Anyhow, the theory of Ecker and Weizel (ref. 16) used by Krascella was incorrect (ref. 17).

In figure 8, all calculations are in good agreement because at the low pressure of $1.01325\times10^5$ N/m$^2$ (1 atm) the interactions between charged particles have a relatively small effect.

A comparison of entropies calculated by various investigators and those calculated for this report is made in figures 9 and 10 for different pressures. The previous comments on enthalpies also apply to entropies, since a similar cancellation of Debye-Hückel effects takes place.

Specific heats at constant pressure by the two methods of this report are given in figure 11 for a pressure of $1.01325\times10^8$ N/m$^2$ (1000 atm). Including Debye-Hückel effects shifted the second peak to lower temperatures because ionization occurs at lower temperatures. The difference between the two methods varied from +14.9 to -13.6 percent.

A comparison of constant-pressure specific heats at $1.01325\times10^5$ N/m$^2$ (1 atm) showed that the values from King (ref. 7), Svehla (ref. 9), and this report (ideal gas and Debye-Hückel) for 600 to 5000 K (1080° to 9000° R) were too close together to separate graphically.

Isentropic exponents by the two methods of this report are given in figure 12 for $1.01325\times10^8$ N/m$^2$ (1000 atm). The temperatures of the extrema were shifted just as for specific heat at constant pressure. The difference between the two methods varied from -0.051 to +0.030.

A comparison of isentropic exponents at $1.01325\times10^5$ N/m$^2$ (1 atm) showed that the values from King (ref. 7), Svehla (ref. 9), and this report (ideal gas and Debye-Hückel) for 600 to 5000 K (1080° to 9000° R) were too close together to separate graphically.

## Rocket Performance

Numerical results. - Nozzle flow was calculated from equations (19) to (28) for stagnation pressures of $1.01325\times10^5$, $1.01325\times10^6$, $1.01325\times10^7$, $2.0265\times10^7$, $5.06625\times10^7$, and $1.01325\times10^8$ N/m$^2$ (1, 10, 100, 200, 500, and 1000 atm), stagnation temperatures from 2500 to 100 000 K (4500° to 180 000° R), and static- to stagnation-pressure ratios of $10^{-1}$, $10^{-2}$, $10^{-3}$, $10^{-4}$, $3\times10^{-5}$, $10^{-5}$, $3\times10^{-6}$, and $10^{-6}$. There were two restrictions to the calculations: (1) no calculations were made for static pressures below $1.01325\times10^2$ N/m$^2$ (0.001 atm), and (2) no calculations were made for static temperatures below 298.15 K (536.67° R). Both restrictions were due to the spin-equilibrated thermodynamic properties (table II and unpublished tables for intermediate pressures) used. During nozzle expansion from temperatures of 2500 K (4500° R) or higher, nuclear spin of $H_2$ is not equilibrated after most of the H atoms have recombined. This effect is insignificant until the temperature drops below roughly 298 K (536° R). Below 298 K (536° R), thermodynamic properties for normal $H_2$ must be used instead of properties for spin-equilibrated $H_2$ if accurate results are desired for nozzle flow.

Nozzle flow results are given in table III. The line labeled "chamber" gives stagnation conditions. Lines labeled "downstream" are for downstream of the throat. Vacuum specific impulse from table III is plotted in figure 13 for a pressure ratio of $10^{-4}$. For this pressure ratio, the ideal specific impulse was at least 97 percent of the vacuum specific impulse for all conditions in table III. Both specific impulses increased monotonically with stagnation temperature.

Accuracy and limitations. - Nozzle flow was calculated by interpolation and inverse interpolation of thermodynamic property tables, so the results are only accurate to ±1 in the third significant digit. In addition, shifting chemical equilibrium was assumed. This is undoubtedly a good assumption for stagnation conditions where there is negligible dissociation and also for high stagnation pressures combined with high exit pressure ratios. However, the validity of shifting chemical equilibrium for other conditions depends on the nozzle length and is beyond the scope of this report.

Comparisons. - Table III agrees with the ideal-gas calculations of King (ref. 7) and the ideal-gas, shifting-equilibrium flow calculations of Roback (ref. 19) to within ±1 in the third significant digit for stagnation temperatures up to 6000 K (10 800° R). For higher stagnation temperatures, there is reasonable agreement with Roback's shifting-equilibrium flow calculations. For comparison, Roback (ref. 19) also gives frozen-flow calculations. Frozen flow gives lower specific impulse than shifting-equilibrium flow.

The effects of the Debye-Hückel approximation compared with the ideal-gas approximation for nozzle flow were evaluated by means of the two sets of thermodynamic properties (this report) described earlier and are presented in figures 14 to 16 for a stagnation pressure of $1.01325 \times 10^8$ N/m$^2$ (1000 atm).

Figures 14 and 15 are for an exit pressure ratio of $10^{-3}$ and show effects on six parameters. Using the Debye-Hückel approximation gave exit temperature as much as 21 percent higher, exit Mach number as much as 10 percent lower, nozzle area ratio as much as 17 percent higher, exit velocity as much as 3.4 percent higher, ideal specific impulse as much as 3.4 percent higher, and vacuum specific impulse as much as 3.5 percent higher than these quantities according to the ideal-gas approximation. The measurably higher Debye-Hückel exit temperature suggests the use of a choked converging-diverging nozzle to test the validity of the Debye-Hückel approximation for high charged-particle densities.

Figure 16 shows that the Debye-Hückel approximation gave mass rates of flow per unit nozzle throat area of from 1.5 percent lower to 2.1 percent higher than for the ideal-gas approximation.

## SUMMARY OF RESULTS

The composition and thermodynamic properties of hydrogen were calculated for 100 to 110 000 K (180° to 198 000° R) and $1.01325\times10^2$ to $1.01325\times10^8$ N/m$^2$ (0.001 to 1000 atm). At a pressure of $1.01325\times10^8$ N/m$^2$ (1000 atm), the Debye-Hückel approximation gave free-electron concentrations as much as 44 percent higher than given by the ideal-gas approximation. The differences for other species were smaller.

The differences between enthalpies and entropies calculated by the Debye-Hückel and ideal-gas approximations were slight. However, the specific heats differed by -13.6 to +14.9 percent at $1.01325\times10^8$ N/m$^2$ (1000 atm). The isentropic exponents differed by -0.051 to +0.030 at the same pressure.

Choked, isentropic, one-dimensional nozzle flow with shifting chemical equilibrium was calculated to the Debye-Hückel and ideal-gas approximations for stagnation temperatures from 2500 to 100 000 K (4500° to 180 000° R) and stagnation pressures from $1.01325\times10^5$ to $1.01325\times10^8$ N/m$^2$ (1 to 1000 atm). For a stagnation pressure of $1.01325\times10^8$ N/m$^2$ (1000 atm) and an exit pressure ratio of $10^{-3}$, the Debye-Hückel approximation gave exit temperatures as much as 21 percent higher, exit Mach numbers as much as 10 percent lower, nozzle area ratios as much as 17 percent higher, exit velocities as much as 3.4 percent higher, ideal specific impulses as much as 3.4 percent higher, and vacuum specific impulses as much as 3.5 percent higher than these quantities according to the ideal-gas approximation. For the same stagnation pressure, the Debye-Hückel approximation gave mass rates of flow of from 1.5 percent lower to 2.1 percent higher than for the ideal-gas approximation.

## CONCLUSIONS

An analytic investigation was made of the composition, thermodynamic properties, and nozzle flow of spin-equilibrated hydrogen gas in chemical equilibrium in the Debye-Hückel and ideal-gas approximations. The following conclusions are based on the results of this investigation:

1. For hydrogen at temperatures from about 10 000 to 100 000 K (18 000° to 180 000° R) at pressures approaching $1.01325\times10^8$ N/m$^2$ (1000 atm), the ideal-gas approximation is inadequate even for crude (±40 percent) calculations of composition. For thermodynamic properties and nozzle flow, the Debye-Hückel approximation is necessary for precise calculations, but the ideal-gas approximation suffices for crude calculations.

2. The Debye-Hückel approximation gave nozzle exit temperatures as much as 21 percent higher than those obtained with the ideal-gas approximation for the same

stagnation conditions, which suggests the use of a choked converging-diverging nozzle to test the validity of the Debye-Hückel approximation for high charged-particle densities.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, June 16, 1971,
122-28.

# APPENDIX - SYMBOLS

| | |
|---|---|
| $A$ | cross-sectional area of nozzle |
| $\mathscr{A}$ | Helmholtz free energy of system referenced to H atoms at 0 K |
| $a$ | sonic velocity |
| $B$ | conversion factor numerically equal to the standard acceleration of gravity |
| $c_p$ | specific heat at constant pressure per unit mass |
| $E$ | internal energy of system referenced to H atoms at 0 K |
| $e$ | charge of electron |
| $G$ | Gibbs free energy of system referenced to H atoms at 0 K |
| $g$ | Gibbs free energy per unit mass referenced to H atoms at 0 K |
| $H$ | enthalpy of system referenced to H atoms at 0 K |
| $h$ | enthalpy per unit mass referenced to H atoms at 0 K |
| $\hbar$ | Planck constant divided by $2\pi$ |
| $I_{sp,i}$ | ideal specific impulse |
| $I_{sp,v}$ | vacuum specific impulse |
| $k$ | Boltzmann constant |
| $L_o$ | Loschmidt number |
| $M$ | Mach number |
| $m_i$ | mass of species i |
| $N_i$ | number of particles of species i |
| $N_o$ | Avogadro's number |
| $n$ | moles of all species |
| $n_i$ | moles of species i |
| $p$ | pressure |
| $q_i$ | ideal-gas internal partition function of species i relative to internal energy of $e^-$ and ground electronic state of H |
| $R$ | universal gas constant |
| $s$ | entropy per unit mass |
| $T$ | absolute temperature |
| $V$ | volume of system |

$v$ velocity of gas relative to nozzle

$\dot{W}$ mass rate of flow

$z_i$ net number of elementary charges e on species i (1, 0, or -1)

$\gamma$ isentropic exponent

$\epsilon_o$ electric permittivity of free space

$\kappa$ reciprocal Debye length

$\Lambda_i$ characteristic volume for translation for species i

$\rho$ density

$\psi$ sonic flow factor

Subscripts:

DH Debye-Hückel approximation

e nozzle exit

ex excess

id ideal-gas approximation

t stagnation

1 hydrogen atom H

2 proton, $H^+$

3 free electron, $e^-$

4 hydrogen molecule, $H_2$

5 negative hydrogen ion, $H^-$

6 hydrogen diatomic molecular ion, $H_2^+$

7 hydrogen triatomic molecular ion, $H_3^+$

298 temperature of 298 K ($536^o$ R)

Superscript:

* nozzle throat

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TABLE I. - CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(a) Pressure, $1.01325 \times 10^{2}$ N/m$^2$ (0.001 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | °R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 100.00 | 180.00 | | | | 2.732E-03 | | | |
| 150.00 | 270.00 | | | | 1.821E-03 | | | |
| 200.00 | 360.00 | | | | 1.366E-03 | | | |
| 250.00 | 450.00 | | | | 1.093E-03 | | | |
| 298.15 | 536.67 | 7.095E-38 | | | 9.162E-04 | | | |
| 400.00 | 720.00 | 2.882E-28 | | | 6.829E-04 | | | |
| 500.00 | 900.00 | 1.201E-22 | | | 5.463E-04 | | | |
| 600.00 | 1080.00 | 6.645E-19 | | | 4.553E-04 | | | |
| 700.00 | 1260.00 | 3.114E-16 | | | 3.902E-04 | | | |
| 800.00 | 1440.00 | 3.120E-14 | | | 3.414E-04 | | | |
| 900.00 | 1620.00 | 1.119E-12 | | | 3.035E-04 | | | |
| 1000.00 | 1800.00 | 1.955E-11 | | | 2.732E-04 | | | |
| 1100.00 | 1980.00 | 2.024E-10 | | | 2.483E-04 | | | |
| 1200.00 | 2160.00 | 1.416E-09 | | | 2.276E-04 | | | |
| 1300.00 | 2340.00 | 7.325E-09 | | | 2.101E-04 | | | |
| 1400.00 | 2520.00 | 2.990E-08 | | 1.436E-24 | 1.951E-04 | 1.347E-30 | | 1.436E-24 |
| 1500.00 | 2700.00 | 1.010E-07 | | 3.213E-23 | 1.820E-04 | 6.033E-29 | | 3.213E-23 |
| 1600.00 | 2880.00 | 2.922E-07 | | 4.873E-22 | 1.704E-04 | 1.655E-27 | | 4.873E-22 |
| 1700.00 | 3060.00 | 7.443E-07 | | 5.364E-21 | 1.599E-04 | 3.057E-26 | | 5.364E-21 |
| 1800.00 | 3240.00 | 1.703E-06 | | 4.512E-20 | 1.500E-04 | 4.031E-25 | | 4.512E-20 |
| 1900.00 | 3420.00 | 3.550E-06 | | 3.018E-19 | 1.402E-04 | 3.991E-24 | | 3.018E-19 |
| 2000.00 | 3600.00 | 6.822E-06 | 1.792E-21 | 1.654E-18 | 1.298E-04 | 3.079E-23 | 8.652E-24 | 1.652E-18 |
| 2100.00 | 3780.00 | 1.216E-05 | 3.207E-20 | 7.588E-18 | 1.179E-04 | 1.891E-22 | 1.330E-22 | 7.555E-18 |
| 2200.00 | 3960.00 | 2.017E-05 | 4.445E-19 | 2.964E-17 | 1.040E-04 | 9.414E-22 | 1.577E-21 | 2.919E-17 |
| 2300.00 | 4140.00 | 3.111E-05 | 4.911E-18 | 1.001E-16 | 8.765E-05 | 3.843E-21 | 1.471E-20 | 9.513E-17 |
| 2400.00 | 4320.00 | 4.451E-05 | 4.365E-17 | 2.994E-16 | 6.930E-05 | 1.313E-20 | 1.077E-19 | 2.557E-16 |
| 2500.00 | 4500.00 | 5.881E-05 | 3.035E-16 | 8.394E-16 | 5.045E-05 | 3.940E-20 | 5.966E-19 | 5.353E-16 |
| 2600.00 | 4680.00 | 7.164E-05 | 1.567E-15 | 2.381E-15 | 3.341E-05 | 1.118E-19 | 2.355E-18 | 8.117E-16 |
| 2700.00 | 4860.00 | 8.095E-05 | 6.063E-15 | 6.965E-15 | 2.022E-05 | 3.076E-19 | 6.699E-18 | 8.963E-16 |
| 2800.00 | 5040.00 | 8.611E-05 | 1.916E-14 | 1.997E-14 | 1.144E-05 | 7.891E-19 | 1.512E-17 | 7.987E-16 |
| 2900.00 | 5220.00 | 8.793E-05 | 5.329E-14 | 5.395E-14 | 6.263E-06 | 1.850E-18 | 2.969E-17 | 6.366E-16 |
| 3000.00 | 5400.00 | 8.764E-05 | 1.357E-13 | 1.363E-13 | 3.411E-06 | 3.993E-18 | 5.347E-17 | 4.834E-16 |
| 3100.00 | 5580.00 | 8.623E-05 | 3.227E-13 | 3.232E-13 | 1.883E-06 | 8.057E-18 | 9.081E-17 | 3.615E-16 |
| 3200.00 | 5760.00 | 8.430E-05 | 7.242E-13 | 7.246E-13 | 1.063E-06 | 1.539E-17 | 1.477E-16 | 2.706E-16 |
| 3400.00 | 6120.00 | 7.997E-05 | 3.149E-12 | 3.149E-12 | 3.671E-07 | 4.915E-17 | 3.542E-16 | 1.562E-16 |
| 3600.00 | 6480.00 | 7.573E-05 | 1.161E-11 | 1.161E-11 | 1.408E-07 | 1.361E-16 | 7.668E-16 | 9.481E-17 |
| 3800.00 | 6840.00 | 7.182E-05 | 3.732E-11 | 3.732E-11 | 5.929E-08 | 3.356E-16 | 1.529E-15 | 6.048E-17 |
| 4000.00 | 7200.00 | 6.826E-05 | 1.068E-10 | 1.068E-10 | 2.710E-08 | 7.511E-16 | 2.847E-15 | 4.035E-17 |
| 4200.00 | 7560.00 | 6.502E-05 | 2.766E-10 | 2.766E-10 | 1.330E-08 | 1.548E-15 | 5.001E-15 | 2.799E-17 |
| 4400.00 | 7920.00 | 6.207E-05 | 6.573E-10 | 6.573E-10 | 6.946E-09 | 2.973E-15 | 8.353E-15 | 2.010E-17 |
| 4600.00 | 8280.00 | 5.937E-05 | 1.449E-09 | 1.449E-09 | 3.828E-09 | 5.371E-15 | 1.335E-14 | 1.487E-17 |
| 4800.00 | 8640.00 | 5.690E-05 | 2.994E-09 | 2.994E-09 | 2.212E-09 | 9.197E-15 | 2.055E-14 | 1.130E-17 |
| 5000.00 | 9000.00 | 5.462E-05 | 5.837E-09 | 5.837E-09 | 1.333E-09 | 1.503E-14 | 3.055E-14 | 8.787E-18 |
| 5200.00 | 9360.00 | 5.251E-05 | 1.082E-08 | 1.082E-08 | 8.335E-10 | 2.356E-14 | 4.408E-14 | 6.977E-18 |
| 5400.00 | 9720.00 | 5.054E-05 | 1.915E-08 | 1.915E-08 | 5.387E-10 | 3.560E-14 | 6.190E-14 | 5.641E-18 |
| 5600.00 | 10080.00 | 4.871E-05 | 3.256E-08 | 3.256E-08 | 3.585E-10 | 5.207E-14 | 8.482E-14 | 4.636E-18 |
| 5800.00 | 10440.00 | 4.699E-05 | 5.337E-08 | 5.337E-08 | 2.449E-10 | 7.392E-14 | 1.137E-13 | 3.864E-18 |
| 6000.00 | 10800.00 | 4.536E-05 | 8.465E-08 | 8.465E-08 | 1.712E-10 | 1.022E-13 | 1.492E-13 | 3.262E-18 |
| 6300.00 | 11340.00 | 4.304E-05 | 1.600E-07 | 1.600E-07 | 1.039E-10 | 1.587E-13 | 2.168E-13 | 2.577E-18 |
| 6600.00 | 11880.00 | 4.082E-05 | 2.852E-07 | 2.852E-07 | 6.540E-11 | 2.345E-13 | 3.028E-13 | 2.073E-18 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(a) Concluded. Pressure, $1.01325\times10^{2}$ N/m$^2$ (0.001 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o/VL_o$ | | | | | | |
| 7000.00 | 12600.00 | 3.788E-05 | 5.687E-07 | 5.687E-07 | 3.685E-11 | 3.677E-13 | 4.462E-13 | 1.574E-18 |
| 7300.00 | 13140.00 | 3.561E-05 | 9.045E-07 | 9.045E-07 | 2.447E-11 | 4.897E-13 | 5.718E-13 | 1.282E-18 |
| 7600.00 | 13680.00 | 3.318E-05 | 1.379E-06 | 1.379E-06 | 1.636E-11 | 6.241E-13 | 7.050E-13 | 1.033E-18 |
| 8000.00 | 14400.00 | 2.960E-05 | 2.275E-06 | 2.275E-06 | 9.493E-12 | 8.016E-13 | 8.728E-13 | 7.485E-19 |
| 8300.00 | 14940.00 | 2.658E-05 | 3.166E-06 | 3.166E-06 | 6.175E-12 | 9.106E-13 | 9.687E-13 | 5.622E-19 |
| 8600.00 | 15480.00 | 2.329E-05 | 4.241E-06 | 4.241E-06 | 3.884E-12 | 9.755E-13 | 1.017E-12 | 3.996E-19 |
| 9000.00 | 16200.00 | 1.857E-05 | 5.893E-06 | 5.893E-06 | 1.938E-12 | 9.641E-13 | 9.829E-13 | 2.260E-19 |
| 9300.00 | 16740.00 | 1.499E-05 | 7.198E-06 | 7.198E-06 | 1.067E-12 | 8.757E-13 | 8.801E-13 | 1.325E-19 |
| 9600.00 | 17280.00 | 1.158E-05 | 8.445E-06 | 8.445E-06 | 5.446E-13 | 7.340E-13 | 7.286E-13 | 6.993E-20 |
| 10000.00 | 18000.00 | 7.664E-06 | 9.835E-06 | 9.835E-06 | | 5.119E-13 | 5.010E-13 | |
| 10500.00 | 18900.00 | 4.168E-06 | 1.093E-05 | 1.093E-05 | | 2.747E-13 | 2.650E-13 | |
| 11000.00 | 19800.00 | 2.134E-06 | 1.136E-05 | 1.136E-05 | | 1.302E-13 | 1.242E-13 | |
| 11500.00 | 20700.00 | 1.081E-06 | 1.134E-05 | 1.134E-05 | | 5.874E-14 | 5.553E-14 | |
| 12000.00 | 21600.00 | 5.608E-07 | 1.111E-05 | 1.111E-05 | | 2.654E-14 | 2.491E-14 | |
| 12500.00 | 22500.00 | 3.035E-07 | 1.078E-05 | 1.078E-05 | | 1.232E-14 | 1.150E-14 | |
| 13000.00 | 23400.00 | 1.730E-07 | 1.043E-05 | 1.043E-05 | | 5.929E-15 | 5.510E-15 | |
| 13500.00 | 24300.00 | 1.043E-07 | 1.007E-05 | 1.007E-05 | | 2.968E-15 | 2.748E-15 | |
| 14000.00 | 25200.00 | 6.670E-08 | 9.727E-06 | 9.727E-06 | | 1.543E-15 | 1.425E-15 | |
| 15000.00 | 27000.00 | 3.228E-08 | 9.093E-06 | 9.093E-06 | | 4.635E-16 | 4.266E-16 | |
| 16000.00 | 28800.00 | 1.901E-08 | 8.530E-06 | 8.530E-06 | | 1.574E-15 | 1.447E-16 | |
| 17000.00 | 30600.00 | 1.292E-08 | 8.030E-06 | 8.030E-06 | | 5.933E-17 | 5.451E-17 | |
| 18000.00 | 32400.00 | 9.653E-09 | 7.585E-06 | 7.585E-06 | | 2.443E-17 | 2.246E-17 | |
| 19000.00 | 34200.00 | 7.646E-09 | 7.187E-06 | 7.187E-06 | | 1.085E-17 | 9.987E-18 | |
| 20000.00 | 36000.00 | 6.280E-09 | 6.827E-06 | 6.827E-06 | | 5.145E-18 | 4.743E-18 | |
| 21000.00 | 37800.00 | 5.283E-09 | 6.503E-06 | 6.503E-06 | | 2.582E-18 | 2.384E-18 | |
| 22000.00 | 39600.00 | 4.518E-09 | 6.207E-06 | 6.207E-06 | | 1.362E-18 | 1.260E-18 | |
| 23000.00 | 41400.00 | 3.908E-09 | 5.937E-06 | 5.937E-06 | | 7.501E-19 | 6.956E-19 | |
| 24000.00 | 43200.00 | 3.414E-09 | 5.690E-06 | 5.690E-06 | | 4.296E-19 | 3.992E-19 | |
| 25000.00 | 45000.00 | 3.004E-09 | 5.462E-06 | 5.462E-06 | | 2.547E-19 | 2.372E-19 | |
| 26000.00 | 46800.00 | 2.660E-09 | 5.252E-06 | 5.252E-06 | | 1.558E-19 | 1.454E-19 | |
| 27000.00 | 48600.00 | 2.369E-09 | 5.058E-06 | 5.058E-06 | | 9.796E-20 | 9.162E-20 | |
| 28000.00 | 50400.00 | 2.119E-09 | 4.877E-06 | 4.877E-06 | | 6.317E-20 | 5.921E-20 | |
| 29000.00 | 52200.00 | 1.904E-09 | 4.709E-06 | 4.709E-06 | | 4.168E-20 | 3.914E-20 | |
| 30000.00 | 54000.00 | 1.718E-09 | 4.552E-06 | 4.552E-06 | | 2.808E-20 | 2.642E-20 | |
| 32000.00 | 57600.00 | 1.413E-09 | 4.268E-06 | 4.268E-06 | | 1.347E-20 | 1.272E-20 | |
| 34000.00 | 61200.00 | 1.175E-09 | 4.017E-06 | 4.017E-06 | | 6.892E-21 | 6.533E-21 | |
| 36000.00 | 64800.00 | 9.899E-10 | 3.794E-06 | 3.794E-06 | | 3.725E-21 | 3.543E-21 | |
| 38000.00 | 68400.00 | 8.409E-10 | 3.594E-06 | 3.594E-06 | | 2.110E-21 | 2.014E-21 | |
| 40000.00 | 72000.00 | 7.207E-10 | 3.414E-06 | 3.414E-06 | | 1.246E-21 | 1.192E-21 | |
| 43000.00 | 77400.00 | 5.795E-10 | 3.176E-06 | 3.176E-06 | | 6.035E-22 | 5.799E-22 | |
| 46000.00 | 82800.00 | 4.733E-10 | 2.969E-06 | 2.969E-06 | | 3.127E-22 | 3.016E-22 | |
| 50000.00 | 90000.00 | 3.684E-10 | 2.731E-06 | 2.731E-06 | | 1.419E-22 | 1.374E-22 | |
| 55000.00 | 99000.00 | 2.766E-10 | 2.483E-06 | 2.483E-06 | | 5.915E-23 | 5.757E-23 | |
| 60000.00 | 108000.00 | 2.130E-10 | 2.276E-06 | 2.276E-06 | | 2.726E-23 | 2.664E-23 | |
| 65000.00 | 117000.00 | 1.675E-10 | 2.101E-06 | 2.101E-06 | | 1.362E-23 | 1.336E-23 | |
| 70000.00 | 126000.00 | 1.341E-10 | 1.951E-06 | 1.951E-06 | | 7.258E-24 | 7.151E-24 | |
| 80000.00 | 144000.00 | 8.977E-11 | 1.707E-06 | 1.707E-06 | | 2.422E-24 | 2.395E-24 | |
| 90000.00 | 162000.00 | 6.303E-11 | 1.517E-06 | 1.517E-06 | | 9.477E-25 | 9.412E-25 | |
| 100000.00 | 180000.00 | 4.594E-11 | 1.366E-06 | 1.365E-06 | | 4.185E-25 | 4.170E-25 | |
| 110000.00 | 198000.00 | 3.451E-11 | 1.242E-06 | 1.242E-06 | | 2.030E-25 | 2.029E-25 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(b) Pressure, $3.03975 \times 10^{2}$ N/m$^2$ (0.003 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 100.00 | 180.00 | | | | 8.195E-03 | | | |
| 150.00 | 270.00 | | | | 5.463E-03 | | | |
| 200.00 | 360.00 | | | | 4.097E-03 | | | |
| 250.00 | 450.00 | | | | 3.278E-03 | | | |
| 298.15 | 536.67 | 1.229E-37 | | | 2.748E-03 | | | |
| 400.00 | 720.00 | 4.991E-28 | | | 2.049E-03 | | | |
| 500.00 | 900.00 | 2.081E-22 | | | 1.639E-03 | | | |
| 600.00 | 1080.00 | 1.151E-18 | | | 1.366E-03 | | | |
| 700.00 | 1260.00 | 5.393E-16 | | | 1.171E-03 | | | |
| 800.00 | 1440.00 | 5.405E-14 | | | 1.024E-03 | | | |
| 900.00 | 1620.00 | 1.938E-12 | | | 9.105E-04 | | | |
| 1000.00 | 1800.00 | 3.385E-11 | | | 8.195E-04 | | | |
| 1100.00 | 1980.00 | 3.505E-10 | | | 7.450E-04 | | | |
| 1200.00 | 2160.00 | 2.452E-09 | | | 6.829E-04 | | | |
| 1300.00 | 2340.00 | 1.269E-08 | | | 6.303E-04 | | | |
| 1400.00 | 2520.00 | 5.180E-08 | | 3.274E-24 | 5.853E-04 | 5.348E-30 | | 3.274E-24 |
| 1500.00 | 2700.00 | 1.749E-07 | | 7.325E-23 | 5.461E-04 | 2.385E-28 | | 7.325E-23 |
| 1600.00 | 2880.00 | 5.064E-07 | | 1.111E-21 | 5.116E-04 | 6.559E-27 | | 1.111E-21 |
| 1700.00 | 3060.00 | 1.290E-06 | | 1.224E-20 | 4.807E-04 | 1.211E-25 | | 1.225E-20 |
| 1800.00 | 3240.00 | 2.956E-06 | | 1.032E-19 | 4.523E-04 | 1.603E-24 | | 1.032E-19 |
| 1900.00 | 3420.00 | 6.182E-06 | | 6.934E-19 | 4.251E-04 | 1.597E-23 | | 6.934E-19 |
| 2000.00 | 3600.00 | 1.194E-05 | 1.355E-21 | 3.830E-18 | 3.978E-04 | 1.248E-22 | 1.145E-23 | 3.829E-18 |
| 2100.00 | 3780.00 | 2.150E-05 | 2.416E-20 | 1.782E-17 | 3.687E-04 | 7.853E-22 | 1.771E-22 | 1.779E-17 |
| 2200.00 | 3960.00 | 3.626E-05 | 3.332E-19 | 7.109E-17 | 3.362E-04 | 4.060E-21 | 2.126E-21 | 7.076E-17 |
| 2300.00 | 4140.00 | 5.745E-05 | 3.679E-18 | 2.466E-16 | 2.988E-04 | 1.749E-20 | 2.034E-20 | 2.429E-16 |
| 2400.00 | 4320.00 | 8.553E-05 | 3.331E-17 | 7.539E-16 | 2.559E-04 | 6.352E-20 | 1.580E-19 | 7.205E-16 |
| 2500.00 | 4500.00 | 1.195E-04 | 2.499E-16 | 2.071E-15 | 2.083E-04 | 1.975E-19 | 9.983E-19 | 1.820E-15 |
| 2600.00 | 4680.00 | 1.562E-04 | 1.532E-15 | 5.311E-15 | 1.589E-04 | 5.441E-19 | 5.022E-18 | 3.774E-15 |
| 2700.00 | 4860.00 | 1.910E-04 | 7.388E-15 | 1.348E-14 | 1.125E-04 | 1.405E-18 | 1.926E-17 | 6.079E-15 |
| 2800.00 | 5040.00 | 2.188E-04 | 2.765E-14 | 3.515E-14 | 7.387E-05 | 3.529E-18 | 5.547E-17 | 7.443E-15 |
| 2900.00 | 5220.00 | 2.370E-04 | 8.439E-14 | 9.184E-14 | 4.552E-05 | 8.489E-18 | 1.268E-16 | 7.329E-15 |
| 3000.00 | 5400.00 | 2.462E-04 | 2.247E-13 | 2.312E-13 | 2.693E-05 | 1.904E-17 | 2.487E-16 | 6.317E-15 |
| 3100.00 | 5580.00 | 2.487E-04 | 5.457E-13 | 5.512E-13 | 1.566E-05 | 3.963E-17 | 4.428E-16 | 5.083E-15 |
| 3200.00 | 5760.00 | 2.470E-04 | 1.238E-12 | 1.242E-12 | 9.125E-06 | 7.728E-17 | 7.395E-16 | 3.969E-15 |
| 3400.00 | 6120.00 | 2.378E-04 | 5.428E-12 | 5.432E-12 | 3.245E-06 | 2.520E-16 | 1.816E-15 | 2.380E-15 |
| 3600.00 | 6480.00 | 2.264E-04 | 2.007E-11 | 2.008E-11 | 1.257E-06 | 7.033E-16 | 3.962E-15 | 1.464E-15 |
| 3800.00 | 6840.00 | 2.151E-04 | 6.459E-11 | 6.460E-11 | 5.318E-07 | 1.740E-15 | 7.925E-15 | 9.390E-16 |
| 4000.00 | 7200.00 | 2.046E-04 | 1.849E-10 | 1.849E-10 | 2.435E-07 | 3.899E-15 | 1.478E-14 | 6.277E-16 |
| 4200.00 | 7560.00 | 1.950E-04 | 4.790E-10 | 4.790E-10 | 1.196E-07 | 8.041E-15 | 2.597E-14 | 4.359E-16 |
| 4400.00 | 7920.00 | 1.862E-04 | 1.138E-09 | 1.138E-09 | 6.249E-08 | 1.545E-14 | 4.339E-14 | 3.132E-16 |
| 4600.00 | 8280.00 | 1.781E-04 | 2.510E-09 | 2.511E-09 | 3.444E-08 | 2.791E-14 | 6.938E-14 | 2.318E-16 |
| 4800.00 | 8640.00 | 1.707E-04 | 5.186E-09 | 5.186E-09 | 1.991E-08 | 4.779E-14 | 1.068E-13 | 1.761E-16 |
| 5000.00 | 9000.00 | 1.639E-04 | 1.011E-08 | 1.011E-08 | 1.200E-08 | 7.810E-14 | 1.588E-13 | 1.370E-16 |
| 5200.00 | 9360.00 | 1.575E-04 | 1.874E-08 | 1.874E-08 | 7.504E-09 | 1.225E-13 | 2.291E-13 | 1.088E-16 |
| 5400.00 | 9720.00 | 1.517E-04 | 3.318E-08 | 3.318E-08 | 4.851E-09 | 1.851E-13 | 3.218E-13 | 8.801E-17 |
| 5600.00 | 10080.00 | 1.462E-04 | 5.641E-08 | 5.641E-08 | 3.230E-09 | 2.708E-13 | 4.411E-13 | 7.238E-17 |
| 5800.00 | 10440.00 | 1.411E-04 | 9.250E-08 | 9.250E-08 | 2.208E-09 | 3.847E-13 | 5.915E-13 | 6.039E-17 |
| 6000.00 | 10800.00 | 1.363E-04 | 1.468E-07 | 1.468E-07 | 1.545E-09 | 5.322E-13 | 7.774E-13 | 5.105E-17 |
| 6300.00 | 11340.00 | 1.295E-04 | 2.777E-07 | 2.777E-07 | 9.406E-10 | 8.284E-13 | 1.132E-12 | 4.050E-17 |
| 6600.00 | 11880.00 | 1.232E-04 | 4.955E-07 | 4.955E-07 | 5.956E-10 | 1.229E-12 | 1.588E-12 | 3.280E-17 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(b) Concluded. Pressure, $3.03975 \times 10^{2}$ N/m$^2$ (0.003 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | °R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 7000.00 | 12600.00 | 1.151E-04 | 9.916E-07 | 9.916E-07 | 3.401E-10 | 1.947E-12 | 2.363E-12 | 2.533E-17 |
| 7300.00 | 13140.00 | 1.091E-04 | 1.584E-06 | 1.584E-06 | 2.297E-10 | 2.627E-12 | 3.067E-12 | 2.105E-17 |
| 7600.00 | 13680.00 | 1.030E-04 | 2.430E-06 | 2.430E-06 | 1.575E-10 | 3.413E-12 | 3.855E-12 | 1.754E-17 |
| 8000.00 | 14400.00 | 9.431E-05 | 4.064E-06 | 4.064E-06 | 9.640E-11 | 4.563E-12 | 4.968E-12 | 1.358E-17 |
| 8300.00 | 14940.00 | 8.725E-05 | 5.741E-06 | 5.741E-06 | 6.654E-11 | 5.420E-12 | 5.766E-12 | 1.099E-17 |
| 8600.00 | 15480.00 | 7.960E-05 | 7.848E-06 | 7.848E-06 | 4.539E-11 | 6.172E-12 | 6.436E-12 | 8.644E-18 |
| 9000.00 | 16200.00 | 6.843E-05 | 1.132E-05 | 1.132E-05 | 2.630E-11 | 6.826E-12 | 6.959E-12 | 5.897E-18 |
| 9300.00 | 16740.00 | 5.944E-05 | 1.435E-05 | 1.435E-05 | 1.678E-11 | 6.928E-12 | 6.963E-12 | 4.158E-18 |
| 9600.00 | 17280.00 | 5.019E-05 | 1.761E-05 | 1.761E-05 | 1.023E-11 | 6.638E-12 | 6.589E-12 | 2.743E-18 |
| 10000.00 | 18000.00 | 3.808E-05 | 2.196E-05 | 2.196E-05 | 4.857E-12 | 5.688E-12 | 5.567E-12 | 1.395E-18 |
| 10500.00 | 18900.00 | 2.471E-05 | 2.670E-05 | 2.670E-05 | 1.644E-12 | 3.989E-12 | 3.849E-12 | 4.841E-19 |
| 11000.00 | 19800.00 | 1.470E-05 | 2.994E-05 | 2.994E-05 | 4.772E-13 | 2.377E-12 | 2.268E-12 | 1.353E-19 |
| 11500.00 | 20700.00 | 8.242E-06 | 3.155E-05 | 3.155E-05 | 1.257E-13 | 1.259E-12 | 1.191E-12 | 3.257E-20 |
| 12000.00 | 21600.00 | 4.526E-06 | 3.192E-05 | 3.192E-05 | 3.231E-14 | 6.277E-13 | 5.892E-13 | 7.372E-21 |
| 12500.00 | 22500.00 | 2.509E-06 | 3.156E-05 | 3.156E-05 | 8.621E-15 | 3.080E-13 | 2.875E-13 | 1.682E-21 |
| 13000.00 | 23400.00 | 1.433E-06 | 3.084E-05 | 3.084E-05 | 2.481E-15 | 1.530E-13 | 1.421E-13 | 4.034E-22 |
| 13500.00 | 24300.00 | 8.514E-07 | 2.996E-05 | 2.996E-05 | 7.861E-16 | 7.790E-14 | 7.215E-14 | 1.035E-22 |
| 14000.00 | 25200.00 | 5.298E-07 | 2.903E-05 | 2.903E-05 | | 4.091E-14 | 3.779E-14 | |
| 15000.00 | 27000.00 | 2.372E-07 | 2.722E-05 | 2.722E-05 | | 1.240E-14 | 1.142E-14 | |
| 16000.00 | 28800.00 | 1.278E-07 | 2.556E-05 | 2.556E-05 | | 4.228E-15 | 3.886E-15 | |
| 17000.00 | 30600.00 | 8.045E-08 | 2.408E-05 | 2.408E-05 | | 1.596E-15 | 1.467E-15 | |
| 18000.00 | 32400.00 | 5.676E-08 | 2.275E-05 | 2.275E-05 | | 6.579E-16 | 6.049E-16 | |
| 19000.00 | 34200.00 | 4.321E-08 | 2.155E-05 | 2.155E-05 | | 2.924E-16 | 2.691E-16 | |
| 20000.00 | 36000.00 | 3.460E-08 | 2.048E-05 | 2.048E-05 | | 1.387E-16 | 1.278E-16 | |
| 21000.00 | 37800.00 | 2.862E-08 | 1.950E-05 | 1.950E-05 | | 6.960E-17 | 6.428E-17 | |
| 22000.00 | 39600.00 | 2.419E-08 | 1.862E-05 | 1.862E-05 | | 3.671E-17 | 3.397E-17 | |
| 23000.00 | 41400.00 | 2.078E-08 | 1.781E-05 | 1.781E-05 | | 2.023E-17 | 1.876E-17 | |
| 24000.00 | 43200.00 | 1.806E-08 | 1.707E-05 | 1.707E-05 | | 1.159E-17 | 1.077E-17 | |
| 25000.00 | 45000.00 | 1.583E-08 | 1.639E-05 | 1.639E-05 | | 6.871E-18 | 6.399E-18 | |
| 26000.00 | 46800.00 | 1.398E-08 | 1.576E-05 | 1.576E-05 | | 4.202E-18 | 3.922E-18 | |
| 27000.00 | 48600.00 | 1.242E-08 | 1.517E-05 | 1.517E-05 | | 2.643E-18 | 2.472E-18 | |
| 28000.00 | 50400.00 | 1.110E-08 | 1.463E-05 | 1.463E-05 | | 1.704E-18 | 1.597E-18 | |
| 29000.00 | 52200.00 | 9.962E-09 | 1.413E-05 | 1.413E-05 | | 1.125E-18 | 1.056E-18 | |
| 30000.00 | 54000.00 | 8.976E-09 | 1.366E-05 | 1.366E-05 | | 7.576E-19 | 7.129E-19 | |
| 32000.00 | 57600.00 | 7.375E-09 | 1.280E-05 | 1.280E-05 | | 3.635E-19 | 3.434E-19 | |
| 34000.00 | 61200.00 | 6.134E-09 | 1.205E-05 | 1.205E-05 | | 1.860E-19 | 1.763E-19 | |
| 36000.00 | 64800.00 | 5.160E-09 | 1.138E-05 | 1.138E-05 | | 1.005E-19 | 9.561E-20 | |
| 38000.00 | 68400.00 | 4.383E-09 | 1.078E-05 | 1.078E-05 | | 5.695E-20 | 5.435E-20 | |
| 40000.00 | 72000.00 | 3.753E-09 | 1.024E-05 | 1.024E-05 | | 3.362E-20 | 3.218E-20 | |
| 43000.00 | 77400.00 | 3.019E-09 | 9.528E-06 | 9.528E-06 | | 1.629E-20 | 1.565E-20 | |
| 46000.00 | 82800.00 | 2.463E-09 | 8.907E-06 | 8.907E-06 | | 8.441E-21 | 8.141E-21 | |
| 50000.00 | 90000.00 | 1.917E-09 | 8.194E-06 | 8.194E-06 | | 3.830E-21 | 3.710E-21 | |
| 55000.00 | 99000.00 | 1.439E-09 | 7.449E-06 | 7.449E-06 | | 1.597E-21 | 1.554E-21 | |
| 60000.00 | 108000.00 | 1.108E-09 | 6.829E-06 | 6.829E-06 | | 7.359E-22 | 7.192E-22 | |
| 65000.00 | 117000.00 | 8.712E-10 | 6.303E-06 | 6.303E-06 | | 3.676E-22 | 3.606E-22 | |
| 70000.00 | 126000.00 | 6.971E-10 | 5.853E-06 | 5.853E-06 | | 1.962E-22 | 1.930E-22 | |
| 80000.00 | 144000.00 | 4.668E-10 | 5.121E-06 | 5.121E-06 | | 6.539E-23 | 6.467E-23 | |
| 90000.00 | 162000.00 | 3.277E-10 | 4.552E-06 | 4.552E-06 | | 2.559E-23 | 2.541E-23 | |
| 100000.00 | 180000.00 | 2.388E-10 | 4.097E-06 | 4.097E-06 | | 1.130E-23 | 1.126E-23 | |
| 110000.00 | 198000.00 | 1.794E-10 | 3.725E-06 | 3.725E-06 | | 5.481E-24 | 5.477E-24 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(c) Pressure, $1.01325\times10^{3}$ N/m$^2$ (0.01 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_iN_o/VL_o$ | | | | | | |
| 100.00 | 180.00 | | | | 2.732E-02 | | | |
| 150.00 | 270.00 | | | | 1.821E-02 | | | |
| 200.00 | 360.00 | | | | 1.366E-02 | | | |
| 250.00 | 450.00 | | | | 1.093E-02 | | | |
| 298.15 | 536.67 | 2.244E-37 | | | 9.162E-03 | | | |
| 400.00 | 720.00 | 9.113E-28 | | | 6.829E-03 | | | |
| 500.00 | 900.00 | 3.799E-22 | | | 5.463E-03 | | | |
| 600.00 | 1080.00 | 2.101E-18 | | | 4.553E-03 | | | |
| 700.00 | 1260.00 | 9.846E-16 | | | 3.902E-03 | | | |
| 800.00 | 1440.00 | 9.868E-14 | | | 3.414E-03 | | | |
| 900.00 | 1620.00 | 3.538E-12 | | | 3.035E-03 | | | |
| 1000.00 | 1800.00 | 6.181E-11 | | | 2.732E-03 | | | |
| 1100.00 | 1980.00 | 6.400E-10 | | | 2.483E-03 | | | |
| 1200.00 | 2160.00 | 4.477E-09 | | | 2.276E-03 | | | |
| 1300.00 | 2340.00 | 2.316E-08 | | | 2.101E-03 | | | |
| 1400.00 | 2520.00 | 9.457E-08 | | 8.077E-24 | 1.951E-03 | 2.416E-29 | | 8.077E-24 |
| 1500.00 | 2700.00 | 3.194E-07 | | 1.807E-22 | 1.821E-03 | 1.078E-27 | | 1.807E-22 |
| 1600.00 | 2880.00 | 9.247E-07 | | 2.743E-21 | 1.706E-03 | 2.958E-26 | | 2.743E-21 |
| 1700.00 | 3060.00 | 2.358E-06 | | 3.023E-20 | 1.604E-03 | 5.464E-25 | | 3.024E-20 |
| 1800.00 | 3240.00 | 5.405E-06 | | 2.552E-19 | 1.512E-03 | 7.245E-24 | | 2.552E-19 |
| 1900.00 | 3420.00 | 1.132E-05 | | 1.719E-18 | 1.426E-03 | 7.257E-23 | | 1.719E-18 |
| 2000.00 | 3600.00 | 2.195E-05 | 9.994E-22 | 9.542E-18 | 1.344E-03 | 5.717E-22 | 1.553E-23 | 9.541E-18 |
| 2100.00 | 3780.00 | 3.975E-05 | 1.777E-20 | 4.479E-17 | 1.261E-03 | 3.650E-21 | 2.410E-22 | 4.477E-17 |
| 2200.00 | 3960.00 | 6.775E-05 | 2.442E-19 | 1.813E-16 | 1.174E-03 | 1.934E-20 | 2.910E-21 | 1.810E-16 |
| 2300.00 | 4140.00 | 1.091E-04 | 2.684E-18 | 6.422E-16 | 1.078E-03 | 8.653E-20 | 2.819E-20 | 6.395E-15 |
| 2400.00 | 4320.00 | 1.666E-04 | 2.426E-17 | 2.017E-15 | 9.715E-04 | 3.310E-19 | 2.242E-19 | 1.992E-15 |
| 2500.00 | 4500.00 | 2.415E-04 | 1.844E-16 | 5.673E-15 | 8.511E-04 | 1.094E-18 | 1.489E-18 | 5.488E-15 |
| 2600.00 | 4680.00 | 3.322E-04 | 1.193E-15 | 1.449E-14 | 7.184E-04 | 3.157E-18 | 8.319E-18 | 1.329E-14 |
| 2700.00 | 4860.00 | 4.330E-04 | 6.569E-15 | 3.439E-14 | 5.786E-04 | 8.124E-18 | 3.883E-17 | 2.779E-14 |
| 2800.00 | 5040.00 | 5.346E-04 | 3.016E-14 | 7.874E-14 | 4.410E-04 | 1.932E-17 | 1.478E-16 | 4.845E-14 |
| 2900.00 | 5220.00 | 6.252E-04 | 1.128E-13 | 1.813E-13 | 3.167E-04 | 4.420E-17 | 4.468E-16 | 6.812E-14 |
| 3000.00 | 5400.00 | 6.956E-04 | 3.458E-13 | 4.244E-13 | 2.149E-04 | 9.872E-17 | 1.081E-15 | 7.760E-14 |
| 3100.00 | 5580.00 | 7.418E-04 | 9.093E-13 | 9.867E-13 | 1.393E-04 | 2.116E-16 | 2.201E-15 | 7.537E-14 |
| 3200.00 | 5760.00 | 7.658E-04 | 2.149E-12 | 2.219E-12 | 8.776E-05 | 4.280E-16 | 3.982E-15 | 6.628E-14 |
| 3400.00 | 6120.00 | 7.694E-04 | 9.741E-12 | 9.795E-12 | 3.398E-05 | 1.471E-15 | 1.054E-14 | 4.472E-14 |
| 3600.00 | 6480.00 | 7.451E-04 | 3.640E-11 | 3.645E-11 | 1.362E-05 | 4.202E-15 | 2.365E-14 | 2.877E-14 |
| 3800.00 | 6840.00 | 7.130E-04 | 1.176E-10 | 1.176E-10 | 5.842E-06 | 1.050E-14 | 4.781E-14 | 1.878E-14 |
| 4000.00 | 7200.00 | 6.802E-04 | 3.371E-10 | 3.372E-10 | 2.691E-06 | 2.353E-14 | 8.955E-14 | 1.265E-14 |
| 4200.00 | 7560.00 | 6.490E-04 | 8.738E-10 | 8.739E-10 | 1.325E-06 | 4.883E-14 | 1.577E-13 | 8.812E-15 |
| 4400.00 | 7920.00 | 6.201E-04 | 2.078E-09 | 2.078E-09 | 6.932E-07 | 9.390E-14 | 2.638E-13 | 6.341E-15 |
| 4600.00 | 8280.00 | 5.934E-04 | 4.583E-09 | 4.583E-09 | 3.824E-07 | 1.697E-13 | 4.220E-13 | 4.697E-15 |
| 4800.00 | 8640.00 | 5.688E-04 | 9.467E-09 | 9.467E-09 | 2.211E-07 | 2.908E-13 | 6.495E-13 | 3.571E-15 |
| 5000.00 | 9000.00 | 5.461E-04 | 1.846E-08 | 1.846E-08 | 1.333E-07 | 4.753E-13 | 9.662E-13 | 2.779E-15 |
| 5200.00 | 9360.00 | 5.251E-04 | 3.421E-08 | 3.421E-08 | 8.337E-08 | 7.453E-13 | 1.394E-12 | 2.207E-15 |
| 5400.00 | 9720.00 | 5.057E-04 | 6.058E-08 | 6.058E-08 | 5.391E-08 | 1.127E-12 | 1.959E-12 | 1.785E-15 |
| 5600.00 | 10080.00 | 4.875E-04 | 1.030E-07 | 1.030E-07 | 3.591E-08 | 1.649E-12 | 2.686E-12 | 1.470E-15 |
| 5800.00 | 10440.00 | 4.706E-04 | 1.690E-07 | 1.690E-07 | 2.456E-08 | 2.344E-12 | 3.604E-12 | 1.227E-15 |
| 6000.00 | 10800.00 | 4.547E-04 | 2.681E-07 | 2.681E-07 | 1.720E-08 | 3.245E-12 | 4.739E-12 | 1.038E-15 |
| 6300.00 | 11340.00 | 4.325E-04 | 5.076E-07 | 5.076E-07 | 1.049E-08 | 5.058E-12 | 6.911E-12 | 8.259E-16 |
| 6600.00 | 11880.00 | 4.120E-04 | 9.067E-07 | 9.067E-07 | 6.666E-09 | 7.525E-12 | 9.718E-12 | 6.717E-16 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(c) Concluded. Pressure, $1.01325\times10^{3}$ N/m$^2$ (0.01 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | °R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o/VL_o$ | | | | | | |
| 7000.00 | 12600.00 | 3.866E-04 | 1.818E-06 | 1.818E-06 | 3.837E-09 | 1.200E-11 | 1.456E-11 | 5.241E-16 |
| 7300.00 | 13140.00 | 3.684E-04 | 2.912E-06 | 2.912E-06 | 2.619E-09 | 1.631E-11 | 1.904E-11 | 4.416E-16 |
| 7600.00 | 13680.00 | 3.504E-04 | 4.487E-06 | 4.487E-06 | 1.825E-09 | 2.144E-11 | 2.422E-11 | 3.750E-16 |
| 8000.00 | 14400.00 | 3.263E-04 | 7.566E-06 | 7.566E-06 | 1.154E-09 | 2.939E-11 | 3.200E-11 | 3.025E-16 |
| 8300.00 | 14940.00 | 3.075E-04 | 1.079E-05 | 1.079E-05 | 8.266E-10 | 3.590E-11 | 3.819E-11 | 2.565E-16 |
| 8600.00 | 15480.00 | 2.878E-04 | 1.494E-05 | 1.494E-05 | 5.932E-10 | 4.247E-11 | 4.429E-11 | 2.151E-16 |
| 9000.00 | 16200.00 | 2.594E-04 | 2.208E-05 | 2.208E-05 | 3.780E-10 | 5.046E-11 | 5.144E-11 | 1.653E-16 |
| 9300.00 | 16740.00 | 2.365E-04 | 2.867E-05 | 2.867E-05 | 2.656E-10 | 5.507E-11 | 5.535E-11 | 1.315E-16 |
| 9600.00 | 17280.00 | 2.121E-04 | 3.627E-05 | 3.627E-05 | 1.828E-10 | 5.781E-11 | 5.738E-11 | 1.010E-16 |
| 10000.00 | 18000.00 | 1.781E-04 | 4.762E-05 | 4.762E-05 | 1.063E-10 | 5.772E-11 | 5.649E-11 | 6.625E-17 |
| 10500.00 | 18900.00 | 1.351E-04 | 6.264E-05 | 6.264E-05 | 4.916E-11 | 5.126E-11 | 4.946E-11 | 3.407E-17 |
| 11000.00 | 19800.00 | 9.542E-05 | 7.662E-05 | 7.662E-05 | 2.011E-11 | 3.963E-11 | 3.781E-11 | 1.470E-17 |
| 11500.00 | 20700.00 | 6.275E-05 | 8.758E-05 | 8.758E-05 | 7.273E-12 | 2.680E-11 | 2.534E-11 | 5.312E-18 |
| 12000.00 | 21600.00 | 3.898E-05 | 9.453E-05 | 9.453E-05 | 2.389E-12 | 1.621E-11 | 1.522E-11 | 1.660E-18 |
| 12500.00 | 22500.00 | 2.344E-05 | 9.775E-05 | 9.775E-05 | 7.468E-13 | 9.101E-12 | 8.495E-12 | 4.741E-19 |
| 13000.00 | 23400.00 | 1.399E-05 | 9.826E-05 | 9.826E-05 | 2.337E-13 | 4.924E-12 | 4.575E-12 | 1.312E-19 |
| 13500.00 | 24300.00 | 8.453E-06 | 9.712E-05 | 9.712E-05 | 7.619E-14 | 2.642E-12 | 2.447E-12 | 3.673E-20 |
| 14000.00 | 25200.00 | 5.242E-06 | 9.510E-05 | 9.510E-05 | 2.652E-14 | 1.432E-12 | 1.322E-12 | 1.069E-20 |
| 15000.00 | 27000.00 | 2.237E-06 | 9.007E-05 | 9.007E-05 | 4.077E-15 | 4.476E-13 | 4.120E-13 | 1.064E-21 |
| 16000.00 | 28800.00 | 1.115E-06 | 8.492E-05 | 8.492E-05 | 8.558E-16 | 1.544E-13 | 1.419E-13 | 1.325E-22 |
| 17000.00 | 30600.00 | 6.451E-07 | 8.011E-05 | 8.011E-05 | 2.310E-16 | 5.862E-14 | 5.386E-14 | 2.025E-23 |
| 18000.00 | 32400.00 | 4.223E-07 | 7.574E-05 | 7.574E-05 | | 2.422E-14 | 2.227E-14 | |
| 19000.00 | 34200.00 | 3.037E-07 | 7.180E-05 | 7.180E-05 | | 1.078E-14 | 9.921E-15 | |
| 20000.00 | 36000.00 | 2.334E-07 | 6.823E-05 | 6.823E-05 | | 5.116E-15 | 4.717E-15 | |
| 21000.00 | 37800.00 | 1.877E-07 | 6.499E-05 | 6.499E-05 | | 2.570E-15 | 2.373E-15 | |
| 22000.00 | 39600.00 | 1.555E-07 | 6.205E-05 | 6.205E-05 | | 1.356E-15 | 1.255E-15 | |
| 23000.00 | 41400.00 | 1.318E-07 | 5.935E-05 | 5.935E-05 | | 7.474E-16 | 6.930E-16 | |
| 24000.00 | 43200.00 | 1.135E-07 | 5.688E-05 | 5.688E-05 | | 4.282E-16 | 3.979E-16 | |
| 25000.00 | 45000.00 | 9.883E-08 | 5.461E-05 | 5.461E-05 | | 2.540E-16 | 2.365E-16 | |
| 26000.00 | 46800.00 | 8.683E-08 | 5.251E-05 | 5.251E-05 | | 1.553E-15 | 1.450E-16 | |
| 27000.00 | 48600.00 | 7.686E-08 | 5.057E-05 | 5.057E-05 | | 9.771E-17 | 9.138E-17 | |
| 28000.00 | 50400.00 | 6.850E-08 | 4.876E-05 | 4.876E-05 | | 6.302E-17 | 5.907E-17 | |
| 29000.00 | 52200.00 | 6.136E-08 | 4.708E-05 | 4.708E-05 | | 4.159E-17 | 3.906E-17 | |
| 30000.00 | 54000.00 | 5.522E-08 | 4.552E-05 | 4.552E-05 | | 2.802E-17 | 2.637E-17 | |
| 32000.00 | 57600.00 | 4.522E-08 | 4.267E-05 | 4.267E-05 | | 1.345E-17 | 1.270E-17 | |
| 34000.00 | 61200.00 | 3.758E-08 | 4.016E-05 | 4.016E-05 | | 6.881E-18 | 6.523E-18 | |
| 36000.00 | 64800.00 | 3.158E-08 | 3.793E-05 | 3.793E-05 | | 3.719E-18 | 3.538E-18 | |
| 38000.00 | 68400.00 | 2.679E-08 | 3.594E-05 | 3.594E-05 | | 2.108E-18 | 2.011E-18 | |
| 40000.00 | 72000.00 | 2.294E-08 | 3.414E-05 | 3.414E-05 | | 1.244E-18 | 1.191E-18 | |
| 43000.00 | 77400.00 | 1.844E-08 | 3.176E-05 | 3.176E-05 | | 6.029E-19 | 5.794E-19 | |
| 46000.00 | 82800.00 | 1.503E-08 | 2.969E-05 | 2.969E-05 | | 3.124E-19 | 3.013E-19 | |
| 50000.00 | 90000.00 | 1.170E-08 | 2.731E-05 | 2.731E-05 | | 1.418E-19 | 1.373E-19 | |
| 55000.00 | 99000.00 | 8.777E-09 | 2.483E-05 | 2.483E-05 | | 5.911E-20 | 5.753E-20 | |
| 60000.00 | 108000.00 | 6.757E-09 | 2.276E-05 | 2.276E-05 | | 2.725E-20 | 2.663E-20 | |
| 65000.00 | 117000.00 | 5.310E-09 | 2.101E-05 | 2.101E-05 | | 1.361E-20 | 1.335E-20 | |
| 70000.00 | 126000.00 | 4.250E-09 | 1.951E-05 | 1.951E-05 | | 7.266E-21 | 7.148E-21 | |
| 80000.00 | 144000.00 | 2.845E-09 | 1.707E-05 | 1.707E-05 | | 2.421E-21 | 2.395E-21 | |
| 90000.00 | 162000.00 | 1.997E-09 | 1.517E-05 | 1.517E-05 | | 9.475E-22 | 9.410E-22 | |
| 100000.00 | 180000.00 | 1.455E-09 | 1.366E-05 | 1.366E-05 | | 4.184E-22 | 4.170E-22 | |
| 110000.00 | 198000.00 | 1.093E-09 | 1.242E-05 | 1.242E-05 | | 2.030E-22 | 2.028E-22 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(d) Pressure, $3.03975 \times 10^{3}$ N/m$^2$ (0.03 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | °R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 100.00 | 180.00 | | | | 8.195E-02 | | | |
| 150.00 | 270.00 | | | | 5.463E-02 | | | |
| 200.00 | 360.00 | | | | 4.097E-02 | | | |
| 250.00 | 450.00 | | | | 3.278E-02 | | | |
| 298.15 | 536.67 | 3.886E-37 | | | 2.748E-02 | | | |
| 400.00 | 720.00 | 1.578E-27 | | | 2.049E-02 | | | |
| 500.00 | 900.00 | 6.580E-22 | | | 1.639E-02 | | | |
| 600.00 | 1080.00 | 3.640E-18 | | | 1.366E-02 | | | |
| 700.00 | 1260.00 | 1.705E-15 | | | 1.171E-02 | | | |
| 800.00 | 1440.00 | 1.709E-13 | | | 1.024E-02 | | | |
| 900.00 | 1620.00 | 6.129E-12 | | | 9.105E-03 | | | |
| 1000.00 | 1800.00 | 1.071E-10 | | | 8.195E-03 | | | |
| 1100.00 | 1980.00 | 1.108E-09 | | | 7.450E-03 | | | |
| 1200.00 | 2160.00 | 7.754E-09 | | | 6.829E-03 | | | |
| 1300.00 | 2340.00 | 4.012E-08 | | | 6.303E-03 | | | |
| 1400.00 | 2520.00 | 1.638E-07 | | 1.841E-23 | 5.853E-03 | 9.558E-29 | | 1.841E-23 |
| 1500.00 | 2700.00 | 5.532E-07 | | 4.120E-22 | 5.462E-03 | 4.252E-27 | | 4.120E-22 |
| 1600.00 | 2880.00 | 1.602E-06 | | 6.253E-21 | 5.120E-03 | 1.168E-25 | | 6.253E-21 |
| 1700.00 | 3060.00 | 4.085E-06 | | 6.895E-20 | 4.816E-03 | 2.160E-24 | | 6.895E-20 |
| 1800.00 | 3240.00 | 9.369E-06 | | 5.824E-19 | 4.543E-03 | 2.866E-23 | | 5.824E-19 |
| 1900.00 | 3420.00 | 1.965E-05 | | 3.928E-18 | 4.293E-03 | 2.878E-22 | | 3.929E-18 |
| 2000.00 | 3600.00 | 3.816E-05 | 7.581E-22 | 2.186E-17 | 4.059E-03 | 2.276E-21 | 2.047E-23 | 2.186E-17 |
| 2100.00 | 3780.00 | 6.932E-05 | 1.346E-20 | 1.031E-16 | 3.833E-03 | 1.465E-20 | 3.183E-22 | 1.031E-16 |
| 2200.00 | 3960.00 | 1.187E-04 | 1.845E-19 | 4.204E-16 | 3.606E-03 | 7.863E-20 | 3.855E-21 | 4.203E-16 |
| 2300.00 | 4140.00 | 1.929E-04 | 2.022E-18 | 1.507E-15 | 3.370E-03 | 3.590E-19 | 3.753E-20 | 1.505E-15 |
| 2400.00 | 4320.00 | 2.985E-04 | 1.821E-17 | 4.813E-15 | 3.116E-03 | 1.415E-18 | 3.013E-19 | 4.796E-15 |
| 2500.00 | 4500.00 | 4.410E-04 | 1.381E-16 | 1.383E-14 | 2.837E-03 | 4.858E-18 | 2.036E-18 | 1.370E-14 |
| 2600.00 | 4680.00 | 6.232E-04 | 8.984E-16 | 3.612E-14 | 2.529E-03 | 1.476E-17 | 1.175E-17 | 3.522E-14 |
| 2700.00 | 4860.00 | 8.429E-04 | 5.081E-15 | 8.654E-14 | 2.192E-03 | 3.979E-17 | 5.846E-17 | 8.144E-14 |
| 2800.00 | 5040.00 | 1.091E-03 | 2.509E-14 | 1.931E-13 | 1.836E-03 | 9.665E-17 | 2.509E-16 | 1.679E-13 |
| 2900.00 | 5220.00 | 1.350E-03 | 1.075E-13 | 4.107E-13 | 1.476E-03 | 2.152E-16 | 9.192E-16 | 3.025E-13 |
| 3000.00 | 5400.00 | 1.598E-03 | 3.924E-13 | 8.592E-13 | 1.134E-03 | 4.591E-16 | 2.818E-15 | 4.645E-13 |
| 3100.00 | 5580.00 | 1.812E-03 | 1.209E-12 | 1.813E-12 | 8.314E-04 | 9.498E-16 | 7.148E-15 | 5.979E-13 |
| 3200.00 | 5760.00 | 1.975E-03 | 3.189E-12 | 3.858E-12 | 5.844E-04 | 1.921E-15 | 1.525E-14 | 6.551E-13 |
| 3400.00 | 6120.00 | 2.146E-03 | 1.601E-11 | 1.662E-11 | 2.643E-04 | 6.960E-15 | 4.832E-14 | 5.717E-13 |
| 3600.00 | 6480.00 | 2.162E-03 | 6.179E-11 | 6.229E-11 | 1.147E-04 | 2.084E-14 | 1.165E-13 | 4.110E-13 |
| 3800.00 | 6840.00 | 2.105E-03 | 2.019E-10 | 2.023E-10 | 5.095E-05 | 5.333E-14 | 2.424E-13 | 2.811E-13 |
| 4000.00 | 7200.00 | 2.025E-03 | 5.814E-10 | 5.819E-10 | 2.385E-05 | 1.214E-13 | 4.598E-13 | 1.933E-13 |
| 4200.00 | 7560.00 | 1.939E-03 | 1.510E-09 | 1.511E-09 | 1.183E-05 | 2.523E-13 | 8.144E-13 | 1.360E-13 |
| 4400.00 | 7920.00 | 1.856E-03 | 3.594E-09 | 3.595E-09 | 6.211E-06 | 4.854E-13 | 1.366E-12 | 9.829E-14 |
| 4600.00 | 8280.00 | 1.778E-03 | 7.932E-09 | 7.934E-09 | 3.433E-06 | 8.803E-13 | 2.189E-12 | 7.299E-14 |
| 4800.00 | 8640.00 | 1.705E-03 | 1.639E-08 | 1.639E-08 | 1.987E-06 | 1.509E-12 | 3.371E-12 | 5.555E-14 |
| 5000.00 | 9000.00 | 1.639E-03 | 3.197E-08 | 3.197E-08 | 1.198E-06 | 2.468E-12 | 5.017E-12 | 4.327E-14 |
| 5200.00 | 9360.00 | 1.575E-03 | 5.925E-08 | 5.926E-08 | 7.500E-07 | 3.872E-12 | 7.244E-12 | 3.439E-14 |
| 5400.00 | 9720.00 | 1.517E-03 | 1.049E-07 | 1.049E-07 | 4.851E-07 | 5.856E-12 | 1.018E-11 | 2.784E-14 |
| 5600.00 | 10080.00 | 1.463E-03 | 1.785E-07 | 1.785E-07 | 3.232E-07 | 8.571E-12 | 1.396E-11 | 2.292E-14 |
| 5800.00 | 10440.00 | 1.412E-03 | 2.927E-07 | 2.928E-07 | 2.211E-07 | 1.219E-11 | 1.874E-11 | 1.914E-14 |
| 6000.00 | 10800.00 | 1.365E-03 | 4.647E-07 | 4.647E-07 | 1.550E-07 | 1.688E-11 | 2.465E-11 | 1.621E-14 |
| 6300.00 | 11340.00 | 1.299E-03 | 8.799E-07 | 8.799E-07 | 9.460E-08 | 2.633E-11 | 3.597E-11 | 1.291E-14 |
| 6600.00 | 11880.00 | 1.238E-03 | 1.573E-06 | 1.573E-06 | 6.021E-08 | 3.923E-11 | 5.066E-11 | 1.052E-14 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(d) Concluded. Pressure, $3.03975 \times 10^{3}$ N/m$^2$ (0.03 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| K | $^{o}$R | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 7000.00 | 12600.00 | 1.164E-03 | 3.158E-06 | 3.158E-06 | 3.481E-08 | 6.274E-11 | 7.614E-11 | 8.255E-15 |
| 7300.00 | 13140.00 | 1.112E-03 | 5.064E-06 | 5.065E-06 | 2.388E-08 | 8.566E-11 | 1.000E-10 | 7.004E-15 |
| 7600.00 | 13680.00 | 1.063E-03 | 7.821E-06 | 7.821E-06 | 1.678E-08 | 1.133E-10 | 1.280E-10 | 6.009E-15 |
| 8000.00 | 14400.00 | 9.979E-04 | 1.325E-05 | 1.325E-05 | 1.079E-08 | 1.574E-10 | 1.713E-10 | 4.954E-15 |
| 8300.00 | 14940.00 | 9.494E-04 | 1.898E-05 | 1.898E-05 | 7.877E-09 | 1.950E-10 | 2.074E-10 | 4.300E-15 |
| 8600.00 | 15480.00 | 9.000E-04 | 2.646E-05 | 2.646E-05 | 5.802E-09 | 2.353E-10 | 2.453E-10 | 3.726E-15 |
| 9000.00 | 16200.00 | 8.315E-04 | 3.959E-05 | 3.959E-05 | 3.884E-09 | 2.901E-10 | 2.957E-10 | 3.045E-15 |
| 9300.00 | 16740.00 | 7.772E-04 | 5.208E-05 | 5.208E-05 | 2.870E-09 | 3.288E-10 | 3.305E-10 | 2.581E-15 |
| 9600.00 | 17280.00 | 7.200E-04 | 6.696E-05 | 6.696E-05 | 2.107E-09 | 3.623E-10 | 3.596E-10 | 2.149E-15 |
| 10000.00 | 18000.00 | 6.391E-04 | 9.042E-05 | 9.042E-05 | 1.369E-09 | 3.934E-10 | 3.851E-10 | 1.621E-15 |
| 10500.00 | 18900.00 | 5.319E-04 | 1.246E-04 | 1.246E-04 | 7.616E-10 | 4.018E-10 | 3.877E-10 | 1.052E-15 |
| 11000.00 | 19800.00 | 4.223E-04 | 1.618E-04 | 1.618E-04 | 3.940E-10 | 3.712E-10 | 3.541E-10 | 6.105E-16 |
| 11500.00 | 20700.00 | 3.177E-04 | 1.981E-04 | 1.981E-04 | 1.864E-10 | 3.080E-10 | 2.912E-10 | 3.102E-16 |
| 12000.00 | 21600.00 | 2.261E-04 | 2.292E-04 | 2.292E-04 | 8.017E-11 | 2.294E-10 | 2.153E-10 | 1.371E-16 |
| 12500.00 | 22500.00 | 1.530E-04 | 2.521E-04 | 2.521E-04 | 3.171E-11 | 1.550E-10 | 1.446E-10 | 5.330E-17 |
| 13000.00 | 23400.00 | 9.995E-05 | 2.661E-04 | 2.661E-04 | 1.184E-11 | 9.701E-11 | 9.014E-11 | 1.880E-17 |
| 13500.00 | 24300.00 | 6.411E-05 | 2.723E-04 | 2.723E-04 | 4.327E-12 | 5.779E-11 | 5.352E-11 | 6.267E-18 |
| 14000.00 | 25200.00 | 4.109E-05 | 2.729E-04 | 2.729E-04 | 1.601E-12 | 3.360E-11 | 3.103E-11 | 2.051E-18 |
| 15000.00 | 27000.00 | 1.769E-05 | 2.650E-04 | 2.650E-04 | 2.497E-13 | 1.132E-11 | 1.042E-11 | 2.314E-19 |
| 16000.00 | 28800.00 | 8.485E-06 | 2.524E-04 | 2.524E-04 | 4.971E-14 | 4.033E-12 | 3.707E-12 | 3.039E-20 |
| 17000.00 | 30600.00 | 4.613E-06 | 2.392E-04 | 2.392E-04 | 1.260E-14 | 1.552E-12 | 1.426E-12 | 4.756E-21 |
| 18000.00 | 32400.00 | 2.824E-06 | 2.266E-04 | 2.266E-04 | 3.891E-15 | 6.457E-13 | 5.937E-13 | 8.781E-22 |
| 19000.00 | 34200.00 | 1.912E-06 | 2.150E-04 | 2.150E-04 | 1.395E-15 | 2.884E-13 | 2.654E-13 | 1.876E-22 |
| 20000.00 | 36000.00 | 1.400E-06 | 2.045E-04 | 2.045E-04 | 5.595E-16 | 1.372E-13 | 1.265E-13 | 4.545E-23 |
| 21000.00 | 37800.00 | 1.085E-06 | 1.948E-04 | 1.948E-04 | 2.445E-16 | 6.898E-14 | 6.371E-14 | 1.229E-23 |
| 22000.00 | 39600.00 | 8.766E-07 | 1.860E-04 | 1.860E-04 | | 3.643E-14 | 3.371E-14 | |
| 23000.00 | 41400.00 | 7.285E-07 | 1.780E-04 | 1.780E-04 | | 2.009E-14 | 1.863E-14 | |
| 24000.00 | 43200.00 | 6.182E-07 | 1.706E-04 | 1.706E-04 | | 1.152E-14 | 1.070E-14 | |
| 25000.00 | 45000.00 | 5.333E-07 | 1.638E-04 | 1.638E-04 | | 6.834E-15 | 6.364E-15 | |
| 26000.00 | 46800.00 | 4.653E-07 | 1.575E-04 | 1.575E-04 | | 4.182E-15 | 3.903E-15 | |
| 27000.00 | 48600.00 | 4.098E-07 | 1.517E-04 | 1.517E-04 | | 2.631E-15 | 2.460E-15 | |
| 28000.00 | 50400.00 | 3.635E-07 | 1.463E-04 | 1.463E-04 | | 1.697E-15 | 1.591E-15 | |
| 29000.00 | 52200.00 | 3.244E-07 | 1.412E-04 | 1.412E-04 | | 1.120E-15 | 1.052E-15 | |
| 30000.00 | 54000.00 | 2.911E-07 | 1.365E-04 | 1.365E-04 | | 7.549E-16 | 7.104E-16 | |
| 32000.00 | 57600.00 | 2.379E-07 | 1.280E-04 | 1.280E-04 | | 3.624E-16 | 3.423E-16 | |
| 34000.00 | 61200.00 | 1.971E-07 | 1.205E-04 | 1.205E-04 | | 1.855E-16 | 1.758E-16 | |
| 36000.00 | 64800.00 | 1.653E-07 | 1.138E-04 | 1.138E-04 | | 1.003E-16 | 9.538E-17 | |
| 38000.00 | 68400.00 | 1.401E-07 | 1.078E-04 | 1.078E-04 | | 5.683E-17 | 5.423E-17 | |
| 40000.00 | 72000.00 | 1.199E-07 | 1.024E-04 | 1.024E-04 | | 3.356E-17 | 3.211E-17 | |
| 43000.00 | 77400.00 | 9.623E-08 | 9.527E-05 | 9.527E-05 | | 1.626E-17 | 1.563E-17 | |
| 46000.00 | 82800.00 | 7.844E-08 | 8.906E-05 | 8.906E-05 | | 8.428E-18 | 8.129E-18 | |
| 50000.00 | 90000.00 | 6.100E-08 | 8.193E-05 | 8.193E-05 | | 3.825E-18 | 3.705E-18 | |
| 55000.00 | 99000.00 | 4.572E-08 | 7.449E-05 | 7.449E-05 | | 1.595E-18 | 1.552E-18 | |
| 60000.00 | 108000.00 | 3.520E-08 | 6.828E-05 | 6.828E-05 | | 7.352E-19 | 7.185E-19 | |
| 65000.00 | 117000.00 | 2.765E-08 | 6.303E-05 | 6.303E-05 | | 3.674E-19 | 3.603E-19 | |
| 70000.00 | 126000.00 | 2.212E-08 | 5.853E-05 | 5.853E-05 | | 1.961E-19 | 1.929E-19 | |
| 80000.00 | 144000.00 | 1.480E-08 | 5.121E-05 | 5.121E-05 | | 6.536E-20 | 6.464E-20 | |
| 90000.00 | 162000.00 | 1.039E-08 | 4.552E-05 | 4.552E-05 | | 2.558E-20 | 2.540E-20 | |
| 100000.00 | 180000.00 | 7.569E-09 | 4.097E-05 | 4.097E-05 | | 1.130E-20 | 1.126E-20 | |
| 110000.00 | 198000.00 | 5.685E-09 | 3.725E-05 | 3.725E-05 | | 5.479E-21 | 5.476E-21 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(e) Pressure, $1.01325\times10^{4}$ N/m$^2$ (0.1 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_iN_o/VL_o$ | | | | | | |
| 100.00 | 180.00 | | | | 2.732E-01 | | | |
| 150.00 | 270.00 | | | | 1.821E-01 | | | |
| 200.00 | 360.00 | | | | 1.366E-01 | | | |
| 250.00 | 450.00 | | | | 1.093E-01 | | | |
| 298.15 | 536.67 | 7.095E-37 | | | 9.162E-02 | | | |
| 400.00 | 720.00 | 2.882E-27 | | | 6.829E-02 | | | |
| 500.00 | 900.00 | 1.201E-21 | | | 5.463E-02 | | | |
| 600.00 | 1080.00 | 6.645E-18 | | | 4.553E-02 | | | |
| 700.00 | 1260.00 | 3.114E-15 | | | 3.902E-02 | | | |
| 800.00 | 1440.00 | 3.120E-13 | | | 3.414E-02 | | | |
| 900.00 | 1620.00 | 1.119E-11 | | | 3.035E-02 | | | |
| 1000.00 | 1800.00 | 1.955E-10 | | | 2.732E-02 | | | |
| 1100.00 | 1980.00 | 2.024E-09 | | | 2.483E-02 | | | |
| 1200.00 | 2160.00 | 1.416E-08 | | | 2.276E-02 | | | |
| 1300.00 | 2340.00 | 7.325E-08 | | | 2.101E-02 | | | |
| 1400.00 | 2520.00 | 2.991E-07 | | 4.542E-23 | 1.951E-02 | 4.303E-28 | | 4.542E-23 |
| 1500.00 | 2700.00 | 1.010E-06 | | 1.016E-21 | 1.821E-02 | 1.915E-26 | | 1.016E-21 |
| 1600.00 | 2880.00 | 2.925E-06 | | 1.543E-20 | 1.707E-02 | 5.264E-25 | | 1.543E-20 |
| 1700.00 | 3060.00 | 7.459E-06 | | 1.701E-19 | 1.606E-02 | 9.729E-24 | | 1.702E-19 |
| 1800.00 | 3240.00 | 1.711E-05 | | 1.438E-18 | 1.516E-02 | 1.293E-22 | | 1.438E-18 |
| 1900.00 | 3420.00 | 3.591E-05 | | 9.705E-18 | 1.434E-02 | 1.300E-21 | | 9.707E-18 |
| 2000.00 | 3600.00 | 6.981E-05 | 5.605E-22 | 5.410E-17 | 1.359E-02 | 1.031E-20 | 2.769E-23 | 5.411E-17 |
| 2100.00 | 3780.00 | 1.271E-04 | 9.944E-21 | 2.558E-16 | 1.288E-02 | 6.654E-20 | 4.310E-22 | 2.559E-16 |
| 2200.00 | 3960.00 | 2.184E-04 | 1.361E-19 | 1.048E-15 | 1.220E-02 | 3.606E-19 | 5.229E-21 | 1.048E-15 |
| 2300.00 | 4140.00 | 3.567E-04 | 1.488E-18 | 3.787E-15 | 1.152E-02 | 1.667E-18 | 5.106E-20 | 3.787E-15 |
| 2400.00 | 4320.00 | 5.563E-04 | 1.336E-17 | 1.223E-14 | 1.083E-02 | 6.700E-18 | 4.120E-19 | 1.222E-14 |
| 2500.00 | 4500.00 | 8.318E-04 | 1.009E-16 | 3.570E-14 | 1.009E-02 | 2.370E-17 | 2.806E-18 | 3.562E-14 |
| 2600.00 | 4680.00 | 1.195E-03 | 6.547E-16 | 9.510E-14 | 9.310E-03 | 7.458E-17 | 1.643E-17 | 9.450E-14 |
| 2700.00 | 4860.00 | 1.656E-03 | 3.708E-15 | 2.330E-13 | 8.461E-03 | 2.104E-16 | 8.382E-17 | 2.294E-13 |
| 2800.00 | 5040.00 | 2.211E-03 | 1.857E-14 | 5.289E-13 | 7.544E-03 | 5.366E-16 | 3.765E-16 | 5.105E-13 |
| 2900.00 | 5220.00 | 2.848E-03 | 8.294E-14 | 1.123E-12 | 6.571E-03 | 1.247E-15 | 1.497E-15 | 1.040E-12 |
| 3000.00 | 5400.00 | 3.540E-03 | 3.310E-13 | 2.257E-12 | 5.565E-03 | 2.671E-15 | 5.267E-15 | 1.923E-12 |
| 3100.00 | 5580.00 | 4.246E-03 | 1.174E-12 | 4.374E-12 | 4.565E-03 | 5.369E-15 | 1.627E-14 | 3.189E-12 |
| 3200.00 | 5760.00 | 4.918E-03 | 3.664E-12 | 8.356E-12 | 3.618E-03 | 1.035E-14 | 4.359E-14 | 4.659E-12 |
| 3400.00 | 6120.00 | 5.981E-03 | 2.403E-11 | 3.086E-11 | 2.053E-03 | 3.602E-14 | 2.022E-13 | 6.665E-12 |
| 3600.00 | 6480.00 | 6.538E-03 | 1.045E-10 | 1.114E-10 | 1.049E-03 | 1.127E-13 | 5.959E-13 | 6.361E-12 |
| 3800.00 | 6840.00 | 6.675E-03 | 3.569E-10 | 3.629E-10 | 5.122E-04 | 3.033E-13 | 1.359E-12 | 4.995E-12 |
| 4000.00 | 7200.00 | 6.577E-03 | 1.046E-09 | 1.051E-09 | 2.516E-04 | 7.124E-13 | 2.686E-12 | 3.663E-12 |
| 4200.00 | 7560.00 | 6.375E-03 | 2.736E-09 | 2.742E-09 | 1.279E-04 | 1.505E-12 | 4.851E-12 | 2.663E-12 |
| 4400.00 | 7920.00 | 6.140E-03 | 6.535E-09 | 6.542E-09 | 6.796E-05 | 2.927E-12 | 8.215E-12 | 1.955E-12 |
| 4600.00 | 8280.00 | 5.900E-03 | 1.445E-08 | 1.446E-08 | 3.780E-05 | 5.324E-12 | 1.323E-11 | 1.464E-12 |
| 4800.00 | 8640.00 | 5.669E-03 | 2.989E-08 | 2.990E-08 | 2.196E-05 | 9.151E-12 | 2.043E-11 | 1.120E-12 |
| 5000.00 | 9000.00 | 5.450E-03 | 5.832E-08 | 5.834E-08 | 1.327E-05 | 1.499E-11 | 3.046E-11 | 8.741E-13 |
| 5200.00 | 9360.00 | 5.244E-03 | 1.081E-07 | 1.082E-07 | 8.315E-06 | 2.353E-11 | 4.402E-11 | 6.959E-13 |
| 5400.00 | 9720.00 | 5.053E-03 | 1.916E-07 | 1.916E-07 | 5.383E-06 | 3.561E-11 | 6.190E-11 | 5.639E-13 |
| 5600.00 | 10080.00 | 4.873E-03 | 3.259E-07 | 3.259E-07 | 3.588E-06 | 5.215E-11 | 8.494E-11 | 4.645E-13 |
| 5800.00 | 10440.00 | 4.705E-03 | 5.346E-07 | 5.347E-07 | 2.455E-06 | 7.417E-11 | 1.140E-10 | 3.883E-13 |
| 6000.00 | 10800.00 | 4.549E-03 | 8.488E-07 | 8.488E-07 | 1.722E-06 | 1.028E-10 | 1.501E-10 | 3.290E-13 |
| 6300.00 | 11340.00 | 4.331E-03 | 1.608E-06 | 1.608E-06 | 1.052E-06 | 1.604E-10 | 2.192E-10 | 2.623E-13 |
| 6600.00 | 11880.00 | 4.132E-03 | 2.875E-06 | 2.875E-06 | 6.704E-07 | 2.393E-10 | 3.090E-10 | 2.142E-13 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(e) Concluded. Pressure, $1.01325 \times 10^{4}$ N/m$^2$ (0.1 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 7000.00 | 12600.00 | 3.890E-03 | 5.777E-06 | 5.778E-06 | 3.886E-07 | 3.836E-10 | 4.655E-10 | 1.686E-13 |
| 7300.00 | 13140.00 | 3.723E-03 | 9.276E-06 | 9.276E-06 | 2.675E-07 | 5.251E-10 | 6.131E-10 | 1.437E-13 |
| 7600.00 | 13680.00 | 3.565E-03 | 1.434E-05 | 1.434E-05 | 1.889E-07 | 6.974E-10 | 7.878E-10 | 1.241E-13 |
| 8000.00 | 14400.00 | 3.366E-03 | 2.436E-05 | 2.437E-05 | 1.228E-07 | 9.763E-10 | 1.063E-09 | 1.037E-13 |
| 8300.00 | 14940.00 | 3.221E-03 | 3.503E-05 | 3.503E-05 | 9.067E-08 | 1.221E-09 | 1.299E-09 | 9.133E-14 |
| 8600.00 | 15480.00 | 3.078E-03 | 4.903E-05 | 4.903E-05 | 6.788E-08 | 1.491E-09 | 1.555E-09 | 8.077E-14 |
| 9000.00 | 16200.00 | 2.887E-03 | 7.396E-05 | 7.396E-05 | 4.684E-08 | 1.882E-09 | 1.918E-09 | 6.861E-14 |
| 9300.00 | 16740.00 | 2.742E-03 | 9.809E-05 | 9.809E-05 | 3.571E-08 | 2.184E-09 | 2.195E-09 | 6.049E-14 |
| 9600.00 | 17280.00 | 2.591E-03 | 1.274E-04 | 1.274E-04 | 2.729E-08 | 2.481E-09 | 2.463E-09 | 5.297E-14 |
| 10000.00 | 18000.00 | 2.382E-03 | 1.752E-04 | 1.752E-04 | 1.902E-08 | 2.842E-09 | 2.782E-09 | 4.366E-14 |
| 10500.00 | 18900.00 | 2.106E-03 | 2.490E-04 | 2.490E-04 | 1.193E-08 | 3.179E-09 | 3.067E-09 | 3.295E-14 |
| 11000.00 | 19800.00 | 1.813E-03 | 3.369E-04 | 3.369E-04 | 7.256E-09 | 3.319E-09 | 3.167E-09 | 2.345E-14 |
| 11500.00 | 20700.00 | 1.511E-03 | 4.345E-04 | 4.345E-04 | 4.211E-09 | 3.218E-09 | 3.042E-09 | 1.544E-14 |
| 12000.00 | 21600.00 | 1.212E-03 | 5.347E-04 | 5.347E-04 | 2.304E-09 | 2.881E-09 | 2.704E-09 | 9.270E-15 |
| 12500.00 | 22500.00 | 9.345E-04 | 6.287E-04 | 6.287E-04 | 1.179E-09 | 2.376E-09 | 2.217E-09 | 5.022E-15 |
| 13000.00 | 23400.00 | 6.920E-04 | 7.084E-04 | 7.084E-04 | 5.644E-10 | 1.808E-09 | 1.680E-09 | 2.454E-15 |
| 13500.00 | 24300.00 | 4.949E-04 | 7.682E-04 | 7.682E-04 | 2.553E-10 | 1.281E-09 | 1.187E-09 | 1.092E-15 |
| 14000.00 | 25200.00 | 3.451E-04 | 8.071E-04 | 8.071E-04 | 1.113E-10 | 8.578E-10 | 7.923E-10 | 4.523E-16 |
| 15000.00 | 27000.00 | 1.627E-04 | 8.330E-04 | 8.330E-04 | 2.062E-11 | 3.475E-10 | 3.199E-10 | 6.934E-17 |
| 16000.00 | 28800.00 | 7.905E-05 | 8.175E-04 | 8.175E-04 | 4.236E-12 | 1.355E-10 | 1.245E-10 | 1.059E-17 |
| 17000.00 | 30600.00 | 4.177E-05 | 7.854E-04 | 7.854E-04 | 1.041E-12 | 5.440E-11 | 4.999E-11 | 1.779E-18 |
| 18000.00 | 32400.00 | 2.425E-05 | 7.491E-04 | 7.491E-04 | 3.062E-13 | 2.311E-11 | 2.125E-11 | 3.403E-19 |
| 19000.00 | 34200.00 | 1.544E-05 | 7.133E-04 | 7.133E-04 | 1.052E-13 | 1.044E-11 | 9.607E-12 | 7.407E-20 |
| 20000.00 | 36000.00 | 1.066E-05 | 6.794E-04 | 6.794E-04 | 4.086E-14 | 4.995E-12 | 4.605E-12 | 1.814E-20 |
| 21000.00 | 37800.00 | 7.870E-06 | 6.480E-04 | 6.480E-04 | 1.745E-14 | 2.521E-12 | 2.329E-12 | 4.936E-21 |
| 22000.00 | 39600.00 | 6.109E-06 | 6.191E-04 | 6.191E-04 | 8.039E-15 | 1.335E-12 | 1.235E-12 | 1.471E-21 |
| 23000.00 | 41400.00 | 4.928E-06 | 5.926E-04 | 5.926E-04 | 3.943E-15 | 7.375E-13 | 6.838E-13 | 4.752E-22 |
| 24000.00 | 43200.00 | 4.092E-06 | 5.681E-04 | 5.681E-04 | 2.036E-15 | 4.232E-13 | 3.933E-13 | 1.645E-22 |
| 25000.00 | 45000.00 | 3.470E-06 | 5.455E-04 | 5.455E-04 | 1.098E-15 | 2.513E-13 | 2.341E-13 | 6.059E-23 |
| 26000.00 | 46800.00 | 2.989E-06 | 5.246E-04 | 5.246E-04 | | 1.539E-13 | 1.436E-13 | |
| 27000.00 | 48600.00 | 2.607E-06 | 5.053E-04 | 5.053E-04 | | 9.688E-14 | 9.061E-14 | |
| 28000.00 | 50400.00 | 2.295E-06 | 4.873E-04 | 4.873E-04 | | 6.253E-14 | 5.861E-14 | |
| 29000.00 | 52200.00 | 2.036E-06 | 4.705E-04 | 4.705E-04 | | 4.129E-14 | 3.878E-14 | |
| 30000.00 | 54000.00 | 1.819E-06 | 4.549E-04 | 4.549E-04 | | 2.784E-14 | 2.619E-14 | |
| 32000.00 | 57600.00 | 1.477E-06 | 4.265E-04 | 4.265E-04 | | 1.337E-14 | 1.263E-14 | |
| 34000.00 | 61200.00 | 1.219E-06 | 4.015E-04 | 4.015E-04 | | 6.846E-15 | 6.490E-15 | |
| 36000.00 | 64800.00 | 1.019E-06 | 3.792E-04 | 3.792E-04 | | 3.703E-15 | 3.522E-15 | |
| 38000.00 | 68400.00 | 8.615E-07 | 3.593E-04 | 3.593E-04 | | 2.099E-15 | 2.003E-15 | |
| 40000.00 | 72000.00 | 7.361E-07 | 3.413E-04 | 3.413E-04 | | 1.240E-15 | 1.187E-15 | |
| 43000.00 | 77400.00 | 5.904E-07 | 3.175E-04 | 3.175E-04 | | 6.010E-16 | 5.776E-16 | |
| 46000.00 | 82800.00 | 4.807E-07 | 2.968E-04 | 2.968E-04 | | 3.116E-16 | 3.005E-16 | |
| 50000.00 | 90000.00 | 3.729E-07 | 2.731E-04 | 2.731E-04 | | 1.415E-16 | 1.370E-16 | |
| 55000.00 | 99000.00 | 2.798E-07 | 2.483E-04 | 2.483E-04 | | 5.900E-17 | 5.743E-17 | |
| 60000.00 | 108000.00 | 2.150E-07 | 2.276E-04 | 2.276E-04 | | 2.720E-17 | 2.658E-17 | |
| 65000.00 | 117000.00 | 1.689E-07 | 2.101E-04 | 2.101E-04 | | 1.359E-17 | 1.333E-17 | |
| 70000.00 | 126000.00 | 1.351E-07 | 1.951E-04 | 1.951E-04 | | 7.257E-18 | 7.140E-18 | |
| 80000.00 | 144000.00 | 9.029E-08 | 1.707E-04 | 1.707E-04 | | 2.419E-18 | 2.393E-18 | |
| 90000.00 | 162000.00 | 6.339E-08 | 1.517E-04 | 1.517E-04 | | 9.469E-19 | 9.404E-19 | |
| 100000.00 | 180000.00 | 4.614E-08 | 1.366E-04 | 1.366E-04 | | 4.182E-19 | 4.167E-19 | |
| 110000.00 | 198000.00 | 3.466E-08 | 1.242E-04 | 1.242E-04 | | 2.029E-19 | 2.027E-19 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(f) Pressure, $3.03975 \times 10^{4}$ N/m$^2$ (0.3 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 100.00 | 180.00 | | | | 8.195E-01 | | | |
| 150.00 | 270.00 | | | | 5.463E-01 | | | |
| 200.00 | 360.00 | | | | 4.097E-01 | | | |
| 250.00 | 450.00 | | | | 3.278E-01 | | | |
| 298.15 | 536.67 | 1.229E-36 | | | 2.748E-01 | | | |
| 400.00 | 720.00 | 4.991E-27 | | | 2.049E-01 | | | |
| 500.00 | 900.00 | 2.081E-21 | | | 1.639E-01 | | | |
| 600.00 | 1080.00 | 1.151E-17 | | | 1.366E-01 | | | |
| 700.00 | 1260.00 | 5.393E-15 | | | 1.171E-01 | | | |
| 800.00 | 1440.00 | 5.405E-13 | | | 1.024E-01 | | | |
| 900.00 | 1620.00 | 1.938E-11 | | | 9.105E-02 | | | |
| 1000.00 | 1800.00 | 3.385E-10 | | | 8.195E-02 | | | |
| 1100.00 | 1980.00 | 3.505E-09 | | | 7.450E-02 | | | |
| 1200.00 | 2160.00 | 2.452E-08 | | | 6.829E-02 | | | |
| 1300.00 | 2340.00 | 1.269E-07 | | | 6.303E-02 | | | |
| 1400.00 | 2520.00 | 5.180E-07 | | 1.035E-22 | 5.853E-02 | 1.698E-27 | | 1.035E-22 |
| 1500.00 | 2700.00 | 1.750E-06 | | 2.317E-21 | 5.463E-02 | 7.561E-26 | | 2.317E-21 |
| 1600.00 | 2880.00 | 5.066E-06 | | 3.517E-20 | 5.121E-02 | 2.079E-24 | | 3.517E-20 |
| 1700.00 | 3060.00 | 1.292E-05 | | 3.879E-19 | 4.819E-02 | 3.844E-23 | | 3.879E-19 |
| 1800.00 | 3240.00 | 2.965E-05 | | 3.278E-18 | 4.550E-02 | 5.107E-22 | | 3.279E-18 |
| 1900.00 | 3420.00 | 6.222E-05 | | 2.214E-17 | 4.307E-02 | 5.138E-21 | | 2.215E-17 |
| 2000.00 | 3600.00 | 1.210E-04 | 4.257E-22 | 1.235E-16 | 4.085E-02 | 4.080E-20 | 3.647E-23 | 1.236E-16 |
| 2100.00 | 3780.00 | 2.206E-04 | 7.548E-21 | 5.849E-16 | 3.880E-02 | 2.644E-19 | 5.679E-22 | 5.852E-16 |
| 2200.00 | 3960.00 | 3.797E-04 | 1.032E-19 | 2.403E-15 | 3.687E-02 | 1.437E-18 | 6.896E-21 | 2.404E-15 |
| 2300.00 | 4140.00 | 6.217E-04 | 1.127E-18 | 8.713E-15 | 3.501E-02 | 6.688E-18 | 6.744E-20 | 8.719E-15 |
| 2400.00 | 4320.00 | 9.738E-04 | 1.010E-17 | 2.831E-14 | 3.317E-02 | 2.715E-17 | 5.454E-19 | 2.832E-14 |
| 2500.00 | 4500.00 | 1.465E-03 | 7.614E-17 | 8.335E-14 | 3.131E-02 | 9.746E-17 | 3.729E-18 | 8.336E-14 |
| 2600.00 | 4680.00 | 2.125E-03 | 4.925E-16 | 2.246E-13 | 2.939E-02 | 3.130E-16 | 2.196E-17 | 2.244E-13 |
| 2700.00 | 4860.00 | 2.978E-03 | 2.781E-15 | 5.586E-13 | 2.737E-02 | 9.077E-16 | 1.131E-16 | 5.567E-13 |
| 2800.00 | 5040.00 | 4.043E-03 | 1.391E-14 | 1.291E-12 | 2.522E-02 | 2.395E-15 | 5.157E-16 | 1.279E-12 |
| 2900.00 | 5220.00 | 5.321E-03 | 6.239E-14 | 2.788E-12 | 2.294E-02 | 5.786E-15 | 2.104E-15 | 2.730E-12 |
| 3000.00 | 5400.00 | 6.797E-03 | 2.530E-13 | 5.668E-12 | 2.052E-02 | 1.288E-14 | 7.731E-15 | 5.421E-12 |
| 3100.00 | 5580.00 | 8.431E-03 | 9.333E-13 | 1.093E-11 | 1.800E-02 | 2.664E-14 | 2.568E-14 | 9.995E-12 |
| 3200.00 | 5760.00 | 1.016E-02 | 3.135E-12 | 2.018E-11 | 1.545E-02 | 5.165E-14 | 7.706E-14 | 1.702E-11 |
| 3400.00 | 6120.00 | 1.355E-02 | 2.626E-11 | 6.401E-11 | 1.055E-02 | 1.693E-13 | 5.007E-13 | 3.742E-11 |
| 3600.00 | 6480.00 | 1.627E-02 | 1.445E-10 | 2.005E-10 | 6.494E-03 | 5.046E-13 | 2.050E-12 | 5.444E-11 |
| 3800.00 | 6840.00 | 1.789E-02 | 5.596E-10 | 6.201E-10 | 3.677E-03 | 1.389E-12 | 5.709E-12 | 5.624E-11 |
| 4000.00 | 7200.00 | 1.850E-02 | 1.730E-09 | 1.787E-09 | 1.990E-03 | 3.406E-12 | 1.250E-11 | 4.799E-11 |
| 4200.00 | 7560.00 | 1.844E-02 | 4.632E-09 | 4.686E-09 | 1.070E-03 | 7.439E-12 | 2.375E-11 | 3.771E-11 |
| 4400.00 | 7920.00 | 1.804E-02 | 1.118E-08 | 1.124E-08 | 5.865E-04 | 1.477E-11 | 4.129E-11 | 2.887E-11 |
| 4600.00 | 8280.00 | 1.748E-02 | 2.485E-08 | 2.491E-08 | 3.319E-04 | 2.718E-11 | 6.741E-11 | 2.211E-11 |
| 4800.00 | 8640.00 | 1.688E-02 | 5.155E-08 | 5.162E-08 | 1.945E-04 | 4.704E-11 | 1.049E-10 | 1.712E-11 |
| 5000.00 | 9000.00 | 1.627E-02 | 1.008E-07 | 1.009E-07 | 1.183E-04 | 7.735E-11 | 1.571E-10 | 1.346E-11 |
| 5200.00 | 9360.00 | 1.568E-02 | 1.870E-07 | 1.871E-07 | 7.437E-05 | 1.218E-10 | 2.277E-10 | 1.076E-11 |
| 5400.00 | 9720.00 | 1.513E-02 | 3.315E-07 | 3.317E-07 | 4.824E-05 | 1.845E-10 | 3.207E-10 | 8.746E-12 |
| 5600.00 | 10080.00 | 1.460E-02 | 5.642E-07 | 5.644E-07 | 3.220E-05 | 2.705E-10 | 4.406E-10 | 7.218E-12 |
| 5800.00 | 10440.00 | 1.410E-02 | 9.259E-07 | 9.261E-07 | 2.206E-05 | 3.850E-10 | 5.919E-10 | 6.041E-12 |
| 6000.00 | 10800.00 | 1.364E-02 | 1.470E-06 | 1.471E-06 | 1.548E-05 | 5.338E-10 | 7.796E-10 | 5.123E-12 |
| 6300.00 | 11340.00 | 1.299E-02 | 2.786E-06 | 2.787E-06 | 9.465E-06 | 8.341E-10 | 1.140E-09 | 4.090E-12 |
| 6600.00 | 11880.00 | 1.240E-02 | 4.985E-06 | 4.985E-06 | 6.036E-06 | 1.245E-09 | 1.608E-09 | 3.344E-12 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(f) Concluded. Pressure, $3.03975 \times 10^{4}$ N/m$^2$ (0.3 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | °R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 7000.00 | 12600.00 | 1.168E-02 | 1.002E-05 | 1.002E-05 | 3.505E-06 | 1.999E-09 | 2.425E-09 | 2.639E-12 |
| 7300.00 | 13140.00 | 1.119E-02 | 1.610E-05 | 1.610E-05 | 2.417E-06 | 2.740E-09 | 3.199E-09 | 2.254E-12 |
| 7600.00 | 13680.00 | 1.073E-02 | 2.493E-05 | 2.493E-05 | 1.711E-06 | 3.648E-09 | 4.120E-09 | 1.953E-12 |
| 8000.00 | 14400.00 | 1.016E-02 | 4.241E-05 | 4.241E-05 | 1.118E-06 | 5.129E-09 | 5.584E-09 | 1.644E-12 |
| 8300.00 | 14940.00 | 9.750E-03 | 6.108E-05 | 6.108E-05 | 8.309E-07 | 6.443E-09 | 6.854E-09 | 1.459E-12 |
| 8600.00 | 15480.00 | 9.357E-03 | 8.571E-05 | 8.571E-05 | 6.272E-07 | 7.923E-09 | 8.262E-09 | 1.304E-12 |
| 9000.00 | 16200.00 | 8.846E-03 | 1.298E-04 | 1.298E-04 | 4.396E-07 | 1.012E-08 | 1.032E-08 | 1.130E-12 |
| 9300.00 | 16740.00 | 8.467E-03 | 1.729E-04 | 1.729E-04 | 3.406E-07 | 1.189E-08 | 1.195E-08 | 1.017E-12 |
| 9600.00 | 17280.00 | 8.086E-03 | 2.259E-04 | 2.259E-04 | 2.657E-07 | 1.373E-08 | 1.363E-08 | 9.145E-13 |
| 10000.00 | 18000.00 | 7.571E-03 | 3.135E-04 | 3.135E-04 | 1.921E-07 | 1.616E-08 | 1.582E-08 | 7.891E-13 |
| 10500.00 | 18900.00 | 6.904E-03 | 4.530E-04 | 4.530E-04 | 1.283E-07 | 1.896E-08 | 1.830E-08 | 6.448E-13 |
| 11000.00 | 19800.00 | 6.204E-03 | 6.267E-04 | 6.267E-04 | 8.501E-08 | 2.114E-08 | 2.017E-08 | 5.115E-13 |
| 11500.00 | 20700.00 | 5.473E-03 | 8.322E-04 | 8.322E-04 | 5.526E-08 | 2.235E-08 | 2.113E-08 | 3.889E-13 |
| 12000.00 | 21600.00 | 4.719E-03 | 1.063E-03 | 1.063E-03 | 3.488E-08 | 2.232E-08 | 2.095E-08 | 2.801E-13 |
| 12500.00 | 22500.00 | 3.963E-03 | 1.306E-03 | 1.306E-03 | 2.118E-08 | 2.100E-08 | 1.960E-08 | 1.889E-13 |
| 13000.00 | 23400.00 | 3.233E-03 | 1.547E-03 | 1.547E-03 | 1.229E-08 | 1.855E-08 | 1.724E-08 | 1.183E-13 |
| 13500.00 | 24300.00 | 2.559E-03 | 1.769E-03 | 1.769E-03 | 6.792E-09 | 1.540E-08 | 1.426E-08 | 6.851E-14 |
| 14000.00 | 25200.00 | 1.968E-03 | 1.958E-03 | 1.958E-03 | 3.586E-09 | 1.205E-08 | 1.113E-08 | 3.676E-14 |
| 15000.00 | 27000.00 | 1.084E-03 | 2.206E-03 | 2.206E-03 | 8.934E-10 | 6.343E-09 | 5.839E-09 | 8.722E-15 |
| 16000.00 | 28800.00 | 5.707E-04 | 2.291E-03 | 2.291E-03 | 2.116E-10 | 2.934E-09 | 2.696E-09 | 1.771E-15 |
| 17000.00 | 30600.00 | 3.045E-04 | 2.272E-03 | 2.272E-03 | 5.339E-11 | 1.297E-09 | 1.192E-09 | 3.494E-16 |
| 18000.00 | 32400.00 | 1.716E-04 | 2.203E-03 | 2.203E-03 | 1.537E-11 | 5.795E-10 | 5.328E-10 | 7.274E-17 |
| 19000.00 | 34200.00 | 1.043E-04 | 2.115E-03 | 2.115E-03 | 5.137E-12 | 2.687E-10 | 2.473E-10 | 1.655E-17 |
| 20000.00 | 36000.00 | 6.873E-05 | 2.024E-03 | 2.024E-03 | 1.964E-12 | 1.305E-10 | 1.203E-10 | 4.155E-18 |
| 21000.00 | 37800.00 | 4.879E-05 | 1.935E-03 | 1.935E-03 | 8.377E-13 | 6.640E-11 | 6.132E-11 | 1.147E-18 |
| 22000.00 | 39600.00 | 3.695E-05 | 1.851E-03 | 1.851E-03 | 3.898E-13 | 3.533E-11 | 3.269E-11 | 3.445E-19 |
| 23000.00 | 41400.00 | 2.950E-05 | 1.773E-03 | 1.773E-03 | 1.912E-13 | 1.958E-11 | 1.815E-11 | 1.119E-19 |
| 24000.00 | 43200.00 | 2.389E-05 | 1.701E-03 | 1.701E-03 | 9.773E-14 | 1.126E-11 | 1.047E-11 | 3.892E-20 |
| 25000.00 | 45000.00 | 1.981E-05 | 1.634E-03 | 1.634E-03 | 5.232E-14 | 6.702E-12 | 6.241E-12 | 1.438E-20 |
| 26000.00 | 46800.00 | 1.677E-05 | 1.572E-03 | 1.572E-03 | 2.914E-14 | 4.110E-12 | 3.836E-12 | 5.602E-21 |
| 27000.00 | 48600.00 | 1.442E-05 | 1.514E-03 | 1.514E-03 | 1.681E-14 | 2.590E-12 | 2.423E-12 | 2.279E-21 |
| 28000.00 | 50400.00 | 1.257E-05 | 1.461E-03 | 1.461E-03 | 1.001E-14 | 1.673E-12 | 1.568E-12 | 9.718E-22 |
| 29000.00 | 52200.00 | 1.107E-05 | 1.410E-03 | 1.410E-03 | 6.123E-15 | 1.106E-12 | 1.039E-12 | 4.342E-22 |
| 30000.00 | 54000.00 | 9.831E-06 | 1.364E-03 | 1.364E-03 | | 7.460E-13 | 7.020E-13 | |
| 32000.00 | 57600.00 | 7.904E-06 | 1.279E-03 | 1.279E-03 | | 3.586E-13 | 3.388E-13 | |
| 34000.00 | 61200.00 | 6.479E-06 | 1.204E-03 | 1.204E-03 | | 1.838E-13 | 1.743E-13 | |
| 36000.00 | 64800.00 | 5.392E-06 | 1.137E-03 | 1.137E-03 | | 9.948E-14 | 9.463E-14 | |
| 38000.00 | 68400.00 | 4.544E-06 | 1.077E-03 | 1.077E-03 | | 5.643E-14 | 5.385E-14 | |
| 40000.00 | 72000.00 | 3.875E-06 | 1.024E-03 | 1.024E-03 | | 3.334E-14 | 3.191E-14 | |
| 43000.00 | 77400.00 | 3.101E-06 | 9.523E-04 | 9.523E-04 | | 1.617E-14 | 1.554E-14 | |
| 46000.00 | 82800.00 | 2.521E-06 | 8.902E-04 | 8.902E-04 | | 8.388E-15 | 8.090E-15 | |
| 50000.00 | 90000.00 | 1.952E-06 | 8.191E-04 | 8.191E-04 | | 3.810E-15 | 3.691E-15 | |
| 55000.00 | 99000.00 | 1.462E-06 | 7.447E-04 | 7.447E-04 | | 1.590E-15 | 1.547E-15 | |
| 60000.00 | 108000.00 | 1.124E-06 | 6.827E-04 | 6.827E-04 | | 7.332E-16 | 7.165E-16 | |
| 65000.00 | 117000.00 | 8.811E-07 | 6.302E-04 | 6.302E-04 | | 3.665E-16 | 3.594E-16 | |
| 70000.00 | 126000.00 | 7.043E-07 | 5.852E-04 | 5.852E-04 | | 1.957E-16 | 1.925E-16 | |
| 80000.00 | 144000.00 | 4.711E-07 | 5.121E-04 | 5.121E-04 | | 6.525E-17 | 6.454E-17 | |
| 90000.00 | 162000.00 | 3.300E-07 | 4.552E-04 | 4.552E-04 | | 2.555E-17 | 2.537E-17 | |
| 100000.00 | 180000.00 | 2.405E-07 | 4.097E-04 | 4.097E-04 | | 1.128E-17 | 1.124E-17 | |
| 110000.00 | 198000.00 | 1.804E-07 | 3.724E-04 | 3.724E-04 | | 5.475E-18 | 5.471E-18 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(g) Pressure, $1.01325 \times 10^5$ N/m$^2$ (1 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | °R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 100.00 | 180.00 | | | | 2.732E+00 | | | |
| 150.00 | 270.00 | | | | 1.821E+00 | | | |
| 200.00 | 360.00 | | | | 1.366E+00 | | | |
| 250.00 | 450.00 | | | | 1.093E+00 | | | |
| 298.15 | 536.67 | 2.244E-36 | | | 9.162E-01 | | | |
| 400.00 | 720.00 | 9.113E-27 | | | 6.829E-01 | | | |
| 500.00 | 900.00 | 3.799E-21 | | | 5.463E-01 | | | |
| 600.00 | 1080.00 | 2.101E-17 | | | 4.553E-01 | | | |
| 700.00 | 1260.00 | 9.846E-15 | | | 3.902E-01 | | | |
| 800.00 | 1440.00 | 9.868E-13 | | | 3.414E-01 | | | |
| 900.00 | 1620.00 | 3.538E-11 | | | 3.035E-01 | | | |
| 1000.00 | 1800.00 | 6.181E-10 | | | 2.732E-01 | | | |
| 1100.00 | 1980.00 | 6.400E-09 | | | 2.483E-01 | | | |
| 1200.00 | 2160.00 | 4.477E-08 | | | 2.276E-01 | | | |
| 1300.00 | 2340.00 | 2.316E-07 | | | 2.101E-01 | | | |
| 1400.00 | 2520.00 | 9.457E-07 | | 2.554E-22 | 1.951E-01 | 7.651E-27 | | 2.554E-22 |
| 1500.00 | 2700.00 | 3.194E-06 | | 5.715E-21 | 1.821E-01 | 3.406E-25 | | 5.715E-21 |
| 1600.00 | 2880.00 | 9.249E-06 | | 8.676E-20 | 1.707E-01 | 9.365E-24 | | 8.677E-20 |
| 1700.00 | 3060.00 | 2.359E-05 | | 9.570E-19 | 1.607E-01 | 1.731E-22 | | 9.572E-19 |
| 1800.00 | 3240.00 | 5.414E-05 | | 8.089E-18 | 1.517E-01 | 2.301E-21 | | 8.091E-18 |
| 1900.00 | 3420.00 | 1.136E-04 | | 5.464E-17 | 1.436E-01 | 2.316E-20 | | 5.466E-17 |
| 2000.00 | 3600.00 | 2.211E-04 | 3.150E-22 | 3.050E-16 | 1.364E-01 | 1.840E-19 | 4.930E-23 | 3.051E-16 |
| 2100.00 | 3780.00 | 4.032E-04 | 5.584E-21 | 1.445E-15 | 1.297E-01 | 1.195E-18 | 7.679E-22 | 1.447E-15 |
| 2200.00 | 3960.00 | 6.948E-04 | 7.634E-20 | 5.946E-15 | 1.235E-01 | 6.507E-18 | 9.331E-21 | 5.953E-15 |
| 2300.00 | 4140.00 | 1.140E-03 | 8.328E-19 | 2.162E-14 | 1.176E-01 | 3.042E-17 | 9.134E-20 | 2.165E-14 |
| 2400.00 | 4320.00 | 1.790E-03 | 7.456E-18 | 7.048E-14 | 1.120E-01 | 1.242E-16 | 7.397E-19 | 7.059E-14 |
| 2500.00 | 4500.00 | 2.703E-03 | 5.610E-17 | 2.087E-13 | 1.066E-01 | 4.501E-16 | 5.069E-18 | 2.090E-13 |
| 2600.00 | 4680.00 | 3.941E-03 | 3.621E-16 | 5.666E-13 | 1.011E-01 | 1.464E-15 | 2.995E-17 | 5.677E-13 |
| 2700.00 | 4860.00 | 5.566E-03 | 2.040E-15 | 1.424E-12 | 9.560E-02 | 4.323E-15 | 1.550E-16 | 1.426E-12 |
| 2800.00 | 5040.00 | 7.633E-03 | 1.017E-14 | 3.333E-12 | 8.992E-02 | 1.167E-14 | 7.121E-16 | 3.334E-12 |
| 2900.00 | 5220.00 | 1.018E-02 | 4.552E-14 | 7.314E-12 | 8.401E-02 | 2.904E-14 | 2.938E-15 | 7.295E-12 |
| 3000.00 | 5400.00 | 1.324E-02 | 1.846E-13 | 1.513E-11 | 7.781E-02 | 6.696E-14 | 1.099E-14 | 1.500E-11 |
| 3100.00 | 5580.00 | 1.678E-02 | 6.849E-13 | 2.964E-11 | 7.133E-02 | 1.438E-13 | 3.751E-14 | 2.906E-11 |
| 3200.00 | 5760.00 | 2.078E-02 | 2.340E-12 | 5.528E-11 | 6.458E-02 | 2.893E-13 | 1.176E-13 | 5.311E-11 |
| 3400.00 | 6120.00 | 2.970E-02 | 2.168E-11 | 1.699E-10 | 5.064E-02 | 9.848E-13 | 9.057E-13 | 1.483E-10 |
| 3600.00 | 6480.00 | 3.885E-02 | 1.479E-10 | 4.677E-10 | 3.703E-02 | 2.812E-12 | 5.009E-12 | 3.177E-10 |
| 3800.00 | 6840.00 | 4.675E-02 | 7.297E-10 | 1.243E-09 | 2.513E-02 | 7.275E-12 | 1.946E-11 | 5.012E-10 |
| 4000.00 | 7200.00 | 5.235E-02 | 2.661E-09 | 3.288E-09 | 1.594E-02 | 1.774E-11 | 5.440E-11 | 5.912E-10 |
| 4200.00 | 7560.00 | 5.538E-02 | 7.756E-09 | 8.405E-09 | 9.652E-03 | 4.008E-11 | 1.195E-10 | 5.696E-10 |
| 4400.00 | 7920.00 | 5.635E-02 | 1.950E-08 | 2.013E-08 | 5.725E-03 | 8.268E-11 | 2.250E-10 | 4.915E-10 |
| 4600.00 | 8280.00 | 5.598E-02 | 4.421E-08 | 4.484E-08 | 3.403E-03 | 1.567E-10 | 3.841E-10 | 4.033E-10 |
| 4800.00 | 8640.00 | 5.485E-02 | 9.269E-08 | 9.335E-08 | 2.056E-03 | 2.765E-10 | 6.132E-10 | 3.251E-10 |
| 5000.00 | 9000.00 | 5.335E-02 | 1.822E-07 | 1.830E-07 | 1.272E-03 | 4.602E-10 | 9.319E-10 | 2.618E-10 |
| 5200.00 | 9360.00 | 5.172E-02 | 3.394E-07 | 3.403E-07 | 8.087E-04 | 7.301E-10 | 1.363E-09 | 2.124E-10 |
| 5400.00 | 9720.00 | 5.005E-02 | 6.030E-07 | 6.040E-07 | 5.283E-04 | 1.112E-09 | 1.930E-09 | 1.742E-10 |
| 5600.00 | 10080.00 | 4.842E-02 | 1.028E-06 | 1.029E-06 | 3.542E-04 | 1.636E-09 | 2.661E-09 | 1.445E-10 |
| 5800.00 | 10440.00 | 4.685E-02 | 1.688E-06 | 1.690E-06 | 2.434E-04 | 2.333E-09 | 3.585E-09 | 1.215E-10 |
| 6000.00 | 10800.00 | 4.535E-02 | 2.683E-06 | 2.684E-06 | 1.711E-04 | 3.240E-09 | 4.729E-09 | 1.033E-10 |
| 6300.00 | 11340.00 | 4.324E-02 | 5.088E-06 | 5.090E-06 | 1.049E-04 | 5.071E-09 | 6.925E-09 | 8.274E-11 |
| 6600.00 | 11880.00 | 4.130E-02 | 9.108E-06 | 9.110E-06 | 6.597E-05 | 7.579E-09 | 9.785E-09 | 6.779E-11 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(g) Concluded. Pressure, $1.01325\times10^{5}$ N/m$^2$ (1 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_iN_o/VL_o$ | | | | | | |
| 7000.00 | 12600.00 | 3.895E-02 | 1.833E-05 | 1.833E-05 | 3.895E-05 | 1.219E-08 | 1.479E-08 | 5.363E-11 |
| 7300.00 | 13140.00 | 3.733E-02 | 2.947E-05 | 2.947E-05 | 2.690E-05 | 1.673E-08 | 1.953E-08 | 4.590E-11 |
| 7600.00 | 13680.00 | 3.583E-02 | 4.565E-05 | 4.566E-05 | 1.908E-05 | 2.231E-08 | 2.520E-08 | 3.989E-11 |
| 8000.00 | 14400.00 | 3.398E-02 | 7.779E-05 | 7.779E-05 | 1.251E-05 | 3.147E-08 | 3.426E-08 | 3.373E-11 |
| 8300.00 | 14940.00 | 3.268E-02 | 1.122E-04 | 1.122E-04 | 9.332E-06 | 3.966E-08 | 4.219E-08 | 3.010E-11 |
| 8600.00 | 15480.00 | 3.144E-02 | 1.577E-04 | 1.577E-04 | 7.081E-06 | 4.898E-08 | 5.107E-08 | 2.710E-11 |
| 9000.00 | 16200.00 | 2.987E-02 | 2.396E-04 | 2.396E-04 | 5.012E-06 | 6.305E-08 | 6.428E-08 | 2.378E-11 |
| 9300.00 | 15740.00 | 2.873E-02 | 3.201E-04 | 3.201E-04 | 3.922E-06 | 7.470E-08 | 7.507E-08 | 2.168E-11 |
| 9600.00 | 17280.00 | 2.762E-02 | 4.196E-04 | 4.196E-04 | 3.099E-06 | 8.709E-08 | 8.645E-08 | 1.982E-11 |
| 10000.00 | 18000.00 | 2.615E-02 | 5.861E-04 | 5.861E-04 | 2.291E-06 | 1.044E-07 | 1.022E-07 | 1.760E-11 |
| 10500.00 | 18900.00 | 2.431E-02 | 8.558E-04 | 8.558E-04 | 1.592E-06 | 1.262E-07 | 1.218E-07 | 1.512E-11 |
| 11000.00 | 19800.00 | 2.245E-02 | 1.201E-03 | 1.201E-03 | 1.113E-06 | 1.467E-07 | 1.399E-07 | 1.285E-11 |
| 11500.00 | 20700.00 | 2.053E-02 | 1.626E-03 | 1.626E-03 | 7.776E-07 | 1.639E-07 | 1.549E-07 | 1.070E-11 |
| 12000.00 | 21600.00 | 1.855E-02 | 2.127E-03 | 2.127E-03 | 5.387E-07 | 1.759E-07 | 1.651E-07 | 8.683E-12 |
| 12500.00 | 22500.00 | 1.652E-02 | 2.696E-03 | 2.696E-03 | 3.675E-07 | 1.810E-07 | 1.689E-07 | 6.798E-12 |
| 13000.00 | 23400.00 | 1.446E-02 | 3.313E-03 | 3.313E-03 | 2.453E-07 | 1.783E-07 | 1.657E-07 | 5.101E-12 |
| 13500.00 | 24300.00 | 1.242E-02 | 3.954E-03 | 3.954E-03 | 1.593E-07 | 1.679E-07 | 1.555E-07 | 3.643E-12 |
| 14000.00 | 25200.00 | 1.045E-02 | 4.587E-03 | 4.587E-03 | 1.004E-07 | 1.510E-07 | 1.394E-07 | 2.465E-12 |
| 15000.00 | 27000.00 | 6.937E-03 | 5.706E-03 | 5.706E-03 | 3.602E-08 | 1.067E-07 | 9.826E-08 | 9.550E-13 |
| 16000.00 | 28800.00 | 4.278E-03 | 6.473E-03 | 6.473E-03 | 1.152E-08 | 6.426E-08 | 5.907E-08 | 3.009E-13 |
| 17000.00 | 30600.00 | 2.524E-03 | 6.848E-03 | 6.848E-03 | 3.484E-09 | 3.450E-08 | 3.171E-08 | 8.209E-14 |
| 18000.00 | 32400.00 | 1.479E-03 | 6.919E-03 | 6.919E-03 | 1.071E-09 | 1.747E-08 | 1.607E-08 | 2.106E-14 |
| 19000.00 | 34200.00 | 8.895E-04 | 6.807E-03 | 6.807E-03 | 3.536E-10 | 8.735E-09 | 8.040E-09 | 5.436E-15 |
| 20000.00 | 36000.00 | 5.600E-04 | 6.605E-03 | 6.605E-03 | 1.292E-10 | 4.434E-09 | 4.087E-09 | 1.470E-15 |
| 21000.00 | 37800.00 | 3.727E-04 | 6.367E-03 | 6.367E-03 | 5.224E-11 | 2.316E-09 | 2.139E-09 | 4.241E-16 |
| 22000.00 | 39600.00 | 2.621E-04 | 6.120E-03 | 6.120E-03 | 2.326E-11 | 1.253E-09 | 1.159E-09 | 1.310E-16 |
| 23000.00 | 41400.00 | 1.949E-04 | 5.879E-03 | 5.879E-03 | 1.120E-11 | 7.012E-10 | 6.502E-10 | 4.330E-17 |
| 24000.00 | 43200.00 | 1.517E-04 | 5.649E-03 | 5.649E-03 | 5.768E-12 | 4.060E-10 | 3.773E-10 | 1.522E-17 |
| 25000.00 | 45000.00 | 1.228E-04 | 5.432E-03 | 5.432E-03 | 3.128E-12 | 2.425E-10 | 2.259E-10 | 5.667E-18 |
| 26000.00 | 46800.00 | 1.026E-04 | 5.228E-03 | 5.228E-03 | 1.782E-12 | 1.492E-10 | 1.392E-10 | 2.218E-18 |
| 27000.00 | 48600.00 | 8.812E-05 | 5.038E-03 | 5.038E-03 | 1.053E-12 | 9.419E-11 | 8.809E-11 | 9.058E-19 |
| 28000.00 | 50400.00 | 7.715E-05 | 4.861E-03 | 4.861E-03 | 6.424E-13 | 6.094E-11 | 5.712E-11 | 3.873E-19 |
| 29000.00 | 52200.00 | 6.856E-05 | 4.694E-03 | 4.694E-03 | 4.037E-13 | 4.032E-11 | 3.787E-11 | 1.734E-19 |
| 30000.00 | 54000.00 | 6.173E-05 | 4.539E-03 | 4.539E-03 | 2.602E-13 | 2.722E-11 | 2.562E-11 | 8.089E-20 |
| 32000.00 | 57600.00 | 5.039E-05 | 4.257E-03 | 4.257E-03 | 1.087E-13 | 1.311E-11 | 1.239E-11 | 1.963E-20 |
| 34000.00 | 61200.00 | 4.093E-05 | 4.008E-03 | 4.008E-03 | | 6.731E-12 | 6.381E-12 | |
| 36000.00 | 64800.00 | 3.385E-05 | 3.787E-03 | 3.787E-03 | | 3.648E-12 | 3.470E-12 | |
| 38000.00 | 68400.00 | 2.841E-05 | 3.588E-03 | 3.588E-03 | | 2.072E-12 | 1.977E-12 | |
| 40000.00 | 72000.00 | 2.411E-05 | 3.410E-03 | 3.410E-03 | | 1.225E-12 | 1.173E-12 | |
| 43000.00 | 77400.00 | 1.918E-05 | 3.173E-03 | 3.173E-03 | | 5.950E-13 | 5.717E-13 | |
| 46000.00 | 82800.00 | 1.553E-05 | 2.966E-03 | 2.966E-03 | | 3.089E-13 | 2.979E-13 | |
| 50000.00 | 90000.00 | 1.203E-05 | 2.729E-03 | 2.729E-03 | | 1.404E-13 | 1.360E-13 | |
| 55000.00 | 99000.00 | 8.990E-06 | 2.482E-03 | 2.482E-03 | | 5.854E-14 | 5.708E-14 | |
| 60000.00 | 108000.00 | 6.891E-06 | 2.275E-03 | 2.275E-03 | | 2.706E-14 | 2.645E-14 | |
| 65000.00 | 117000.00 | 5.395E-06 | 2.100E-03 | 2.100E-03 | | 1.353E-14 | 1.327E-14 | |
| 70000.00 | 126000.00 | 4.314E-06 | 1.950E-03 | 1.950E-03 | | 7.230E-15 | 7.113E-15 | |
| 80000.00 | 144000.00 | 2.882E-06 | 1.707E-03 | 1.707E-03 | | 2.412E-15 | 2.386E-15 | |
| 90000.00 | 162000.00 | 2.016E-06 | 1.517E-03 | 1.517E-03 | | 9.447E-16 | 9.383E-16 | |
| 100000.00 | 180000.00 | 1.469E-06 | 1.365E-03 | 1.365E-03 | | 4.174E-16 | 4.160E-16 | |
| 110000.00 | 198000.00 | 1.103E-06 | 1.241E-03 | 1.241E-03 | | 2.026E-16 | 2.024E-16 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(h) Pressure, $3.03975 \times 10^5$ N/m$^2$ (3 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 100.00 | 180.00 | | | | 8.195E+00 | | | |
| 150.00 | 270.00 | | | | 5.463E+00 | | | |
| 200.00 | 360.00 | | | | 4.097E+00 | | | |
| 250.00 | 450.00 | | | | 3.278E+00 | | | |
| 298.15 | 536.67 | 3.886E-36 | | | 2.748E+00 | | | |
| 400.00 | 720.00 | 1.578E-26 | | | 2.049E+00 | | | |
| 500.00 | 900.00 | 6.580E-21 | | | 1.639E+00 | | | |
| 600.00 | 1080.00 | 3.640E-17 | | | 1.366E+00 | | | |
| 700.00 | 1260.00 | 1.705E-14 | | | 1.171E+00 | | | |
| 800.00 | 1440.00 | 1.709E-12 | | | 1.024E+00 | | | |
| 900.00 | 1620.00 | 6.129E-11 | | | 9.105E-01 | | | |
| 1000.00 | 1800.00 | 1.071E-09 | | | 8.195E-01 | | | |
| 1100.00 | 1980.00 | 1.108E-08 | | | 7.450E-01 | | | |
| 1200.00 | 2160.00 | 7.754E-08 | | | 6.829E-01 | | | |
| 1300.00 | 2340.00 | 4.012E-07 | | | 6.303E-01 | | | |
| 1400.00 | 2520.00 | 1.638E-06 | | 5.822E-22 | 5.853E-01 | 3.023E-26 | | 5.822E-22 |
| 1500.00 | 2700.00 | 5.533E-06 | | 1.303E-20 | 5.463E-01 | 1.345E-24 | | 1.303E-20 |
| 1600.00 | 2880.00 | 1.602E-05 | | 1.978E-19 | 5.121E-01 | 3.698E-23 | | 1.978E-19 |
| 1700.00 | 3060.00 | 4.086E-05 | | 2.181E-18 | 4.820E-01 | 6.836E-22 | | 2.182E-18 |
| 1800.00 | 3240.00 | 9.377E-05 | | 1.844E-17 | 4.552E-01 | 9.085E-21 | | 1.845E-17 |
| 1900.00 | 3420.00 | 1.969E-04 | | 1.246E-16 | 4.311E-01 | 9.146E-20 | | 1.247E-16 |
| 2000.00 | 3600.00 | 3.832E-04 | 2.394E-22 | 6.954E-16 | 4.093E-01 | 7.271E-19 | 6.491E-23 | 6.961E-16 |
| 2100.00 | 3780.00 | 6.988E-04 | 4.243E-21 | 3.297E-15 | 3.895E-01 | 4.723E-18 | 1.011E-21 | 3.302E-15 |
| 2200.00 | 3960.00 | 1.205E-03 | 5.800E-20 | 1.357E-14 | 3.713E-01 | 2.576E-17 | 1.229E-20 | 1.360E-14 |
| 2300.00 | 4140.00 | 1.978E-03 | 6.325E-19 | 4.940E-14 | 3.543E-01 | 1.206E-16 | 1.204E-19 | 4.952E-14 |
| 2400.00 | 4320.00 | 3.110E-03 | 5.659E-18 | 1.614E-13 | 3.383E-01 | 4.943E-16 | 9.759E-19 | 1.618E-13 |
| 2500.00 | 4500.00 | 4.706E-03 | 4.256E-17 | 4.790E-13 | 3.231E-01 | 1.799E-15 | 6.695E-18 | 4.807E-13 |
| 2600.00 | 4680.00 | 6.882E-03 | 2.744E-16 | 1.306E-12 | 3.083E-01 | 5.893E-15 | 3.962E-17 | 1.311E-12 |
| 2700.00 | 4860.00 | 9.757E-03 | 1.543E-15 | 3.299E-12 | 2.937E-01 | 1.756E-14 | 2.055E-16 | 3.314E-12 |
| 2800.00 | 5040.00 | 1.345E-02 | 7.683E-15 | 7.777E-12 | 2.792E-01 | 4.800E-14 | 9.475E-16 | 7.817E-12 |
| 2900.00 | 5220.00 | 1.807E-02 | 3.430E-14 | 1.722E-11 | 2.645E-01 | 1.214E-13 | 3.928E-15 | 1.731E-11 |
| 3000.00 | 5400.00 | 2.370E-02 | 1.388E-13 | 3.603E-11 | 2.495E-01 | 2.855E-13 | 1.479E-14 | 3.615E-11 |
| 3100.00 | 5580.00 | 3.039E-02 | 5.142E-13 | 7.150E-11 | 2.339E-01 | 6.283E-13 | 5.100E-14 | 7.156E-11 |
| 3200.00 | 5760.00 | 3.816E-02 | 1.757E-12 | 1.352E-10 | 2.179E-01 | 1.300E-12 | 1.623E-13 | 1.345E-10 |
| 3400.00 | 6120.00 | 5.667E-02 | 1.654E-11 | 4.250E-10 | 1.843E-01 | 4.700E-12 | 1.318E-12 | 4.119E-10 |
| 3600.00 | 6480.00 | 7.807E-02 | 1.202E-10 | 1.157E-09 | 1.496E-01 | 1.398E-11 | 8.180E-12 | 1.043E-09 |
| 3800.00 | 6840.00 | 1.002E-01 | 6.837E-10 | 2.844E-09 | 1.154E-01 | 3.568E-11 | 3.908E-11 | 2.157E-09 |
| 4000.00 | 7200.00 | 1.205E-01 | 3.028E-09 | 6.650E-09 | 8.440E-02 | 8.255E-11 | 1.424E-10 | 3.563E-09 |
| 4200.00 | 7560.00 | 1.365E-01 | 1.047E-08 | 1.535E-08 | 5.862E-02 | 1.804E-10 | 3.973E-10 | 4.668E-09 |
| 4400.00 | 7920.00 | 1.472E-01 | 2.936E-08 | 3.492E-08 | 3.905E-02 | 3.746E-10 | 8.849E-10 | 5.049E-09 |
| 4600.00 | 8280.00 | 1.528E-01 | 7.076E-08 | 7.651E-08 | 2.535E-02 | 7.295E-10 | 1.678E-09 | 4.808E-09 |
| 4800.00 | 8640.00 | 1.544E-01 | 1.532E-07 | 1.590E-07 | 1.629E-02 | 1.326E-09 | 2.854E-09 | 4.260E-09 |
| 5000.00 | 9000.00 | 1.534E-01 | 3.068E-07 | 3.127E-07 | 1.051E-02 | 2.261E-09 | 4.509E-09 | 3.642E-09 |
| 5200.00 | 9360.00 | 1.507E-01 | 5.773E-07 | 5.835E-07 | 6.868E-03 | 3.648E-09 | 6.754E-09 | 3.068E-09 |
| 5400.00 | 9720.00 | 1.472E-01 | 1.032E-06 | 1.039E-06 | 4.568E-03 | 5.624E-09 | 9.714E-09 | 2.578E-09 |
| 5600.00 | 10080.00 | 1.432E-01 | 1.766E-06 | 1.773E-06 | 3.099E-03 | 8.339E-09 | 1.353E-08 | 2.174E-09 |
| 5800.00 | 10440.00 | 1.391E-01 | 2.909E-06 | 2.917E-06 | 2.147E-03 | 1.196E-08 | 1.834E-08 | 1.845E-09 |
| 6000.00 | 10800.00 | 1.350E-01 | 4.631E-06 | 4.640E-06 | 1.518E-03 | 1.668E-08 | 2.431E-08 | 1.582E-09 |
| 6300.00 | 11340.00 | 1.291E-01 | 8.799E-06 | 8.810E-06 | 9.349E-04 | 2.621E-08 | 3.576E-08 | 1.276E-09 |
| 6600.00 | 11880.00 | 1.235E-01 | 1.577E-05 | 1.578E-05 | 5.991E-04 | 3.927E-08 | 5.068E-08 | 1.050E-09 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(h) Concluded. Pressure, $3.03975\times10^{5}$ N/m$^2$ (3 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o/VL_o$ | | | | | | |
| 7000.00 | 12600.00 | 1.167E-01 | 3.179E-05 | 3.180E-05 | 3.494E-04 | 6.331E-08 | 7.679E-08 | 8.342E-10 |
| 7300.00 | 13140.00 | 1.119E-01 | 5.115E-05 | 5.116E-05 | 2.417E-04 | 8.705E-08 | 1.016E-07 | 7.159E-10 |
| 7600.00 | 13680.00 | 1.075E-01 | 7.930E-05 | 7.931E-05 | 1.717E-04 | 1.153E-07 | 1.313E-07 | 5.235E-10 |
| 8000.00 | 14400.00 | 1.020E-01 | 1.353E-04 | 1.353E-04 | 1.129E-04 | 1.644E-07 | 1.789E-07 | 5.292E-10 |
| 8300.00 | 14940.00 | 9.826E-02 | 1.953E-04 | 1.953E-04 | 8.438E-05 | 2.076E-07 | 2.209E-07 | 4.739E-10 |
| 8600.00 | 15480.00 | 9.467E-02 | 2.748E-04 | 2.749E-04 | 6.420E-05 | 2.571E-07 | 2.681E-07 | 4.283E-10 |
| 9000.00 | 16200.00 | 9.017E-02 | 4.184E-04 | 4.185E-04 | 4.568E-05 | 3.325E-07 | 3.390E-07 | 3.786E-10 |
| 9300.00 | 16740.00 | 8.697E-02 | 5.600E-04 | 5.600E-04 | 3.593E-05 | 3.956E-07 | 3.976E-07 | 3.476E-10 |
| 9600.00 | 17280.00 | 8.387E-02 | 7.358E-04 | 7.358E-04 | 2.859E-05 | 4.638E-07 | 4.604E-07 | 3.205E-10 |
| 10000.00 | 18000.00 | 7.988E-02 | 1.032E-03 | 1.032E-03 | 2.138E-05 | 5.612E-07 | 5.493E-07 | 2.891E-10 |
| 10500.00 | 18900.00 | 7.503E-02 | 1.515E-03 | 1.515E-03 | 1.515E-05 | 6.896E-07 | 6.654E-07 | 2.549E-10 |
| 11000.00 | 19800.00 | 7.025E-02 | 2.144E-03 | 2.144E-03 | 1.090E-05 | 8.194E-07 | 7.817E-07 | 2.245E-10 |
| 11500.00 | 20700.00 | 6.545E-02 | 2.932E-03 | 2.932E-03 | 7.904E-06 | 9.427E-07 | 8.913E-07 | 1.964E-10 |
| 12000.00 | 21600.00 | 6.061E-02 | 3.888E-03 | 3.888E-03 | 5.750E-06 | 1.051E-06 | 9.865E-07 | 1.695E-10 |
| 12500.00 | 22500.00 | 5.568E-02 | 5.011E-03 | 5.011E-03 | 4.173E-06 | 1.135E-06 | 1.059E-06 | 1.438E-10 |
| 13000.00 | 23400.00 | 5.065E-02 | 6.287E-03 | 6.287E-03 | 3.007E-06 | 1.187E-06 | 1.103E-06 | 1.192E-10 |
| 13500.00 | 24300.00 | 4.557E-02 | 7.691E-03 | 7.691E-03 | 2.142E-06 | 1.201E-06 | 1.113E-06 | 9.590E-11 |
| 14000.00 | 25200.00 | 4.048E-02 | 9.183E-03 | 9.183E-03 | 1.502E-06 | 1.176E-06 | 1.086E-06 | 7.464E-11 |
| 15000.00 | 27000.00 | 3.060E-02 | 1.223E-02 | 1.223E-02 | 6.958E-07 | 1.017E-06 | 9.360E-07 | 4.042E-11 |
| 16000.00 | 28800.00 | 2.179E-02 | 1.498E-02 | 1.498E-02 | 2.945E-07 | 7.683E-07 | 7.061E-07 | 1.858E-11 |
| 17000.00 | 30600.00 | 1.468E-02 | 1.706E-02 | 1.706E-02 | 1.148E-07 | 5.134E-07 | 4.717E-07 | 7.295E-12 |
| 18000.00 | 32400.00 | 9.518E-03 | 1.831E-02 | 1.831E-02 | 4.248E-08 | 3.116E-07 | 2.864E-07 | 2.531E-12 |
| 19000.00 | 34200.00 | 6.075E-03 | 1.882E-02 | 1.882E-02 | 1.559E-08 | 1.779E-07 | 1.637E-07 | 8.152E-13 |
| 20000.00 | 36000.00 | 3.906E-03 | 1.880E-02 | 1.880E-02 | 5.911E-09 | 9.876E-08 | 9.105E-08 | 2.562E-13 |
| 21000.00 | 37800.00 | 2.573E-03 | 1.847E-02 | 1.847E-02 | 2.377E-09 | 5.472E-08 | 5.054E-08 | 8.158E-14 |
| 22000.00 | 39600.00 | 1.754E-03 | 1.797E-02 | 1.797E-02 | 1.028E-09 | 3.073E-08 | 2.844E-08 | 2.687E-14 |
| 23000.00 | 41400.00 | 1.245E-03 | 1.739E-02 | 1.739E-02 | 4.789E-10 | 1.763E-08 | 1.635E-08 | 9.261E-15 |
| 24000.00 | 43200.00 | 9.210E-04 | 1.678E-02 | 1.678E-02 | 2.379E-10 | 1.038E-08 | 9.644E-09 | 3.348E-15 |
| 25000.00 | 45000.00 | 7.072E-04 | 1.619E-02 | 1.619E-02 | 1.257E-10 | 6.270E-09 | 5.839E-09 | 1.271E-15 |
| 26000.00 | 46800.00 | 5.623E-04 | 1.562E-02 | 1.562E-02 | 6.957E-11 | 3.886E-09 | 3.627E-09 | 5.042E-16 |
| 27000.00 | 48600.00 | 4.605E-04 | 1.507E-02 | 1.507E-02 | 4.028E-11 | 2.458E-09 | 2.308E-09 | 2.080E-16 |
| 28000.00 | 50400.00 | 3.873E-04 | 1.455E-02 | 1.455E-02 | 2.426E-11 | 1.604E-09 | 1.503E-09 | 8.958E-17 |
| 29000.00 | 52200.00 | 3.332E-04 | 1.406E-02 | 1.406E-02 | 1.503E-11 | 1.064E-09 | 9.995E-10 | 4.034E-17 |
| 30000.00 | 54000.00 | 2.911E-04 | 1.360E-02 | 1.360E-02 | 9.608E-12 | 7.204E-10 | 6.779E-10 | 1.890E-17 |
| 32000.00 | 57600.00 | 2.321E-04 | 1.276E-02 | 1.276E-02 | 4.185E-12 | 3.481E-10 | 3.288E-10 | 4.615E-18 |
| 34000.00 | 61200.00 | 1.926E-04 | 1.202E-02 | 1.202E-02 | 1.983E-12 | 1.790E-10 | 1.697E-10 | 1.276E-18 |
| 36000.00 | 64800.00 | 1.642E-04 | 1.135E-02 | 1.135E-02 | 1.001E-12 | 9.712E-11 | 9.238E-11 | 3.924E-19 |
| 38000.00 | 68400.00 | 1.425E-04 | 1.076E-02 | 1.076E-02 | | 5.520E-11 | 5.267E-11 | |
| 40000.00 | 72000.00 | 1.258E-04 | 1.022E-02 | 1.022E-02 | | 3.267E-11 | 3.126E-11 | |
| 43000.00 | 77400.00 | 1.018E-04 | 9.508E-03 | 9.508E-03 | | 1.589E-11 | 1.527E-11 | |
| 46000.00 | 82800.00 | 8.236E-05 | 8.891E-03 | 8.891E-03 | | 8.260E-12 | 7.966E-12 | |
| 50000.00 | 90000.00 | 6.352E-05 | 8.182E-03 | 8.182E-03 | | 3.761E-12 | 3.643E-12 | |
| 55000.00 | 99000.00 | 4.728E-05 | 7.441E-03 | 7.441E-03 | | 1.573E-12 | 1.531E-12 | |
| 60000.00 | 108000.00 | 3.614E-05 | 6.822E-03 | 6.822E-03 | | 7.267E-13 | 7.102E-13 | |
| 65000.00 | 117000.00 | 2.827E-05 | 6.298E-03 | 6.298E-03 | | 3.637E-13 | 3.567E-13 | |
| 70000.00 | 126000.00 | 2.260E-05 | 5.849E-03 | 5.849E-03 | | 1.944E-13 | 1.913E-13 | |
| 80000.00 | 144000.00 | 1.508E-05 | 5.119E-03 | 5.119E-03 | | 6.493E-14 | 6.422E-14 | |
| 90000.00 | 162000.00 | 1.054E-05 | 4.551E-03 | 4.551E-03 | | 2.545E-14 | 2.527E-14 | |
| 100000.00 | 180000.00 | 7.663E-06 | 4.096E-03 | 4.096E-03 | | 1.125E-14 | 1.121E-14 | |
| 110000.00 | 198000.00 | 5.754E-06 | 3.724E-03 | 3.724E-03 | | 5.461E-15 | 5.457E-15 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(i) Pressure, $1.01325\times10^{6}$ N/m$^2$ (10 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | H$^{+}$ | $e^{-}$ | $H_2$ | $H^{-}$ | $H_2^{+}$ | $H_3^{+}$ |
| | | Dimensionless concentration, $n_iN_o/VL_o$ | | | | | | |
| 100.00 | 180.00 | | | | 2.732E+01 | | | |
| 150.00 | 270.00 | | | | 1.821E+01 | | | |
| 200.00 | 360.00 | | | | 1.366E+01 | | | |
| 250.00 | 450.00 | | | | 1.093E+01 | | | |
| 298.15 | 536.67 | 7.095E-36 | | | 9.162E+00 | | | |
| 400.00 | 720.00 | 2.882E-26 | | | 6.829E+00 | | | |
| 500.00 | 900.00 | 1.201E-20 | | | 5.463E+00 | | | |
| 600.00 | 1080.00 | 6.645E-17 | | | 4.553E+00 | | | |
| 700.00 | 1260.00 | 3.114E-14 | | | 3.902E+00 | | | |
| 800.00 | 1440.00 | 3.120E-12 | | | 3.414E+00 | | | |
| 900.00 | 1620.00 | 1.119E-10 | | | 3.035E+00 | | | |
| 1000.00 | 1800.00 | 1.955E-09 | | | 2.732E+00 | | | |
| 1100.00 | 1980.00 | 2.024E-08 | | | 2.483E+00 | | | |
| 1200.00 | 2160.00 | 1.415E-07 | | | 2.276E+00 | | | |
| 1300.00 | 2340.00 | 7.325E-07 | | | 2.101E+00 | | | |
| 1400.00 | 2520.00 | 2.991E-06 | | 1.436E-21 | 1.951E+00 | 1.361E-25 | | 1.436E-21 |
| 1500.00 | 2700.00 | 1.010E-05 | | 3.214E-20 | 1.821E+00 | 6.059E-24 | | 3.214E-20 |
| 1600.00 | 2880.00 | 2.925E-05 | | 4.879E-19 | 1.707E+00 | 1.655E-22 | | 4.880E-19 |
| 1700.00 | 3060.00 | 7.461E-05 | | 5.381E-18 | 1.607E+00 | 3.079E-21 | | 5.384E-18 |
| 1800.00 | 3240.00 | 1.712E-04 | | 4.548E-17 | 1.517E+00 | 4.092E-20 | | 4.552E-17 |
| 1900.00 | 3420.00 | 3.595E-04 | | 3.072E-16 | 1.437E+00 | 4.119E-19 | | 3.077E-16 |
| 2000.00 | 3600.00 | 6.997E-04 | 1.772E-22 | 1.715E-15 | 1.365E+00 | 3.275E-18 | 8.775E-23 | 1.719E-15 |
| 2100.00 | 3780.00 | 1.275E-03 | 3.141E-21 | 8.134E-15 | 1.299E+00 | 2.128E-17 | 1.368E-21 | 8.155E-15 |
| 2200.00 | 3960.00 | 2.201E-03 | 4.294E-20 | 3.349E-14 | 1.239E+00 | 1.161E-16 | 1.663E-20 | 3.361E-14 |
| 2300.00 | 4140.00 | 3.616E-03 | 4.683E-19 | 1.220E-13 | 1.184E+00 | 5.445E-16 | 1.629E-19 | 1.225E-13 |
| 2400.00 | 4320.00 | 5.690E-03 | 4.189E-18 | 3.988E-13 | 1.132E+00 | 2.235E-15 | 1.322E-18 | 4.010E-13 |
| 2500.00 | 4500.00 | 8.620E-03 | 3.149E-17 | 1.186E-12 | 1.084E+00 | 8.157E-15 | 9.075E-18 | 1.194E-12 |
| 2600.00 | 4680.00 | 1.263E-02 | 2.029E-16 | 3.239E-12 | 1.038E+00 | 2.682E-14 | 5.377E-17 | 3.266E-12 |
| 2700.00 | 4860.00 | 1.795E-02 | 1.141E-15 | 8.208E-12 | 9.937E-01 | 8.036E-14 | 2.794E-16 | 8.287E-12 |
| 2800.00 | 5040.00 | 2.482E-02 | 5.673E-15 | 1.944E-11 | 9.507E-01 | 2.214E-13 | 1.291E-15 | 1.965E-11 |
| 2900.00 | 5220.00 | 3.349E-02 | 2.529E-14 | 4.329E-11 | 9.084E-01 | 5.653E-13 | 5.367E-15 | 4.383E-11 |
| 3000.00 | 5400.00 | 4.417E-02 | 1.022E-13 | 9.121E-11 | 8.663E-01 | 1.347E-12 | 2.029E-14 | 9.243E-11 |
| 3100.00 | 5580.00 | 5.705E-02 | 3.778E-13 | 1.826E-10 | 8.241E-01 | 3.013E-12 | 7.033E-14 | 1.852E-10 |
| 3200.00 | 5760.00 | 7.225E-02 | 1.289E-12 | 3.491E-10 | 7.813E-01 | 6.355E-12 | 2.253E-13 | 3.539E-10 |
| 3400.00 | 6120.00 | 1.099E-01 | 1.212E-11 | 1.125E-09 | 6.935E-01 | 2.413E-11 | 1.873E-12 | 1.135E-09 |
| 3600.00 | 6480.00 | 1.565E-01 | 8.902E-11 | 3.134E-09 | 6.021E-01 | 7.597E-11 | 1.216E-11 | 3.109E-09 |
| 3800.00 | 6840.00 | 2.103E-01 | 5.282E-10 | 7.729E-09 | 5.085E-01 | 2.035E-10 | 6.337E-11 | 7.341E-09 |
| 4000.00 | 7200.00 | 2.673E-01 | 2.580E-09 | 1.732E-08 | 4.156E-01 | 4.771E-10 | 2.694E-10 | 1.495E-08 |
| 4200.00 | 7560.00 | 3.227E-01 | 1.044E-08 | 3.640E-08 | 3.277E-01 | 1.011E-09 | 9.370E-10 | 2.603E-08 |
| 4400.00 | 7920.00 | 3.717E-01 | 3.500E-08 | 7.404E-08 | 2.491E-01 | 2.006E-09 | 2.663E-09 | 3.838E-08 |
| 4600.00 | 8280.00 | 4.107E-01 | 9.801E-08 | 1.486E-07 | 1.831E-01 | 3.808E-09 | 6.246E-09 | 4.811E-08 |
| 4800.00 | 8640.00 | 4.380E-01 | 2.355E-07 | 2.937E-07 | 1.311E-01 | 6.946E-09 | 1.244E-08 | 5.267E-08 |
| 5000.00 | 9000.00 | 4.541E-01 | 5.030E-07 | 5.652E-07 | 9.216E-02 | 1.210E-08 | 2.189E-08 | 5.235E-08 |
| 5200.00 | 9360.00 | 4.610E-01 | 9.841E-07 | 1.048E-06 | 6.426E-02 | 2.005E-08 | 3.522E-08 | 4.894E-08 |
| 5400.00 | 9720.00 | 4.610E-01 | 1.801E-06 | 1.867E-06 | 4.481E-02 | 3.166E-08 | 5.311E-08 | 4.415E-08 |
| 5600.00 | 10080.00 | 4.563E-01 | 3.128E-06 | 3.196E-06 | 3.146E-02 | 4.788E-08 | 7.634E-08 | 3.909E-08 |
| 5800.00 | 10440.00 | 4.485E-01 | 5.202E-06 | 5.272E-06 | 2.232E-02 | 6.972E-08 | 1.058E-07 | 3.433E-08 |
| 6000.00 | 10800.00 | 4.392E-01 | 8.335E-06 | 8.409E-06 | 1.605E-02 | 9.828E-08 | 1.423E-07 | 3.011E-08 |
| 6300.00 | 11340.00 | 4.235E-01 | 1.593E-05 | 1.602E-05 | 1.005E-02 | 1.563E-07 | 2.124E-07 | 2.495E-08 |
| 6600.00 | 11880.00 | 4.073E-01 | 2.867E-05 | 2.876E-05 | 6.513E-03 | 2.350E-07 | 3.038E-07 | 2.075E-08 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(i) Concluded. Pressure, $1.01325 \times 10^{6}$ N/m$^2$ (10 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 7000.00 | 12600.00 | 3.863E-01 | 5.798E-05 | 5.808E-05 | 3.831E-03 | 3.828E-07 | 4.638E-07 | 1.669E-08 |
| 7300.00 | 13140.00 | 3.713E-01 | 9.347E-05 | 9.357E-05 | 2.661E-03 | 5.283E-07 | 6.161E-07 | 1.440E-08 |
| 7600.00 | 13680.00 | 3.572E-01 | 1.451E-04 | 1.452E-04 | 1.896E-03 | 7.075E-07 | 7.987E-07 | 1.260E-08 |
| 8000.00 | 14400.00 | 3.397E-01 | 2.480E-04 | 2.481E-04 | 1.251E-03 | 1.004E-05 | 1.092E-06 | 1.075E-08 |
| 8300.00 | 14940.00 | 3.274E-01 | 3.586E-04 | 3.587E-04 | 9.371E-04 | 1.271E-05 | 1.351E-06 | 9.663E-09 |
| 8600.00 | 15480.00 | 3.159E-01 | 5.053E-04 | 5.054E-04 | 7.148E-04 | 1.577E-05 | 1.645E-06 | 8.767E-09 |
| 9000.00 | 16200.00 | 3.015E-01 | 7.709E-04 | 7.710E-04 | 5.105E-04 | 2.048E-05 | 2.088E-06 | 7.795E-09 |
| 9300.00 | 16740.00 | 2.913E-01 | 1.034E-03 | 1.034E-03 | 4.030E-04 | 2.445E-05 | 2.458E-06 | 7.195E-09 |
| 9600.00 | 17280.00 | 2.815E-01 | 1.361E-03 | 1.361E-03 | 3.221E-04 | 2.879E-06 | 2.858E-06 | 6.677E-09 |
| 10000.00 | 18000.00 | 2.691E-01 | 1.913E-03 | 1.913E-03 | 2.427E-04 | 3.507E-06 | 3.433E-06 | 6.086E-09 |
| 10500.00 | 18900.00 | 2.544E-01 | 2.823E-03 | 2.823E-03 | 1.742E-04 | 4.357E-05 | 4.204E-06 | 5.461E-09 |
| 11000.00 | 19800.00 | 2.403E-01 | 4.018E-03 | 4.018E-03 | 1.275E-04 | 5.253E-05 | 5.011E-06 | 4.925E-09 |
| 11500.00 | 20700.00 | 2.265E-01 | 5.536E-03 | 5.535E-03 | 9.467E-05 | 6.160E-05 | 5.824E-06 | 4.442E-09 |
| 12000.00 | 21600.00 | 2.130E-01 | 7.409E-03 | 7.408E-03 | 7.100E-05 | 7.039E-05 | 6.607E-06 | 3.994E-09 |
| 12500.00 | 22500.00 | 1.995E-01 | 9.657E-03 | 9.656E-03 | 5.358E-05 | 7.843E-05 | 7.321E-06 | 3.564E-09 |
| 13000.00 | 23400.00 | 1.860E-01 | 1.229E-02 | 1.228E-02 | 4.053E-05 | 8.526E-06 | 7.924E-06 | 3.147E-09 |
| 13500.00 | 24300.00 | 1.724E-01 | 1.528E-02 | 1.528E-02 | 3.063E-05 | 9.046E-05 | 8.378E-06 | 2.737E-09 |
| 14000.00 | 25200.00 | 1.588E-01 | 1.861E-02 | 1.861E-02 | 2.306E-05 | 9.366E-05 | 8.652E-06 | 2.339E-09 |
| 15000.00 | 27000.00 | 1.314E-01 | 2.603E-02 | 2.603E-02 | 1.277E-05 | 9.328E-06 | 8.587E-06 | 1.599E-09 |
| 16000.00 | 28800.00 | 1.047E-01 | 3.389E-02 | 3.389E-02 | 6.748E-06 | 8.421E-06 | 7.740E-06 | 9.869E-10 |
| 17000.00 | 30600.00 | 8.022E-02 | 4.134E-02 | 4.134E-02 | 3.373E-06 | 6.894E-05 | 6.335E-06 | 5.429E-10 |
| 18000.00 | 32400.00 | 5.910E-02 | 4.759E-02 | 4.759E-02 | 1.594E-06 | 5.150E-06 | 4.735E-06 | 2.660E-10 |
| 19000.00 | 34200.00 | 4.217E-02 | 5.214E-02 | 5.214E-02 | 7.203E-07 | 3.556E-05 | 3.273E-06 | 1.176E-10 |
| 20000.00 | 36000.00 | 2.947E-02 | 5.490E-02 | 5.490E-02 | 3.179E-07 | 2.312E-05 | 2.132E-06 | 4.812E-11 |
| 21000.00 | 37800.00 | 2.044E-02 | 5.610E-02 | 5.610E-02 | 1.405E-07 | 1.446E-05 | 1.336E-06 | 1.875E-11 |
| 22000.00 | 39600.00 | 1.426E-02 | 5.615E-02 | 5.615E-02 | 6.357E-08 | 8.874E-07 | 8.212E-07 | 7.168E-12 |
| 23000.00 | 41400.00 | 1.011E-02 | 5.543E-02 | 5.543E-02 | 2.986E-08 | 5.422E-07 | 5.028E-07 | 2.745E-12 |
| 24000.00 | 43200.00 | 7.326E-03 | 5.425E-02 | 5.425E-02 | 1.467E-08 | 3.335E-07 | 3.099E-07 | 1.070E-12 |
| 25000.00 | 45000.00 | 5.444E-03 | 5.282E-02 | 5.282E-02 | 7.552E-09 | 2.079E-07 | 1.936E-07 | 4.282E-13 |
| 26000.00 | 46800.00 | 4.152E-03 | 5.127E-02 | 5.127E-02 | 4.096E-09 | 1.318E-07 | 1.230E-07 | 1.766E-13 |
| 27000.00 | 48600.00 | 3.260E-03 | 4.969E-02 | 4.969E-02 | 2.321E-09 | 8.505E-08 | 7.954E-08 | 7.488E-14 |
| 28000.00 | 50400.00 | 2.626E-03 | 4.813E-02 | 4.813E-02 | 1.364E-09 | 5.591E-08 | 5.240E-08 | 3.292E-14 |
| 29000.00 | 52200.00 | 2.162E-03 | 4.662E-02 | 4.662E-02 | 8.304E-10 | 3.744E-08 | 3.516E-08 | 1.506E-14 |
| 30000.00 | 54000.00 | 1.818E-03 | 4.516E-02 | 4.516E-02 | 5.220E-10 | 2.552E-08 | 2.401E-08 | 7.143E-15 |
| 32000.00 | 57600.00 | 1.354E-03 | 4.245E-02 | 4.245E-02 | 2.212E-10 | 1.245E-08 | 1.176E-08 | 1.775E-15 |
| 34000.00 | 61200.00 | 1.061E-03 | 4.002E-02 | 4.002E-02 | 1.031E-10 | 6.443E-09 | 6.108E-09 | 4.965E-16 |
| 36000.00 | 64800.00 | 8.711E-04 | 3.782E-02 | 3.782E-02 | 5.128E-11 | 3.511E-09 | 3.340E-09 | 1.539E-16 |
| 38000.00 | 68400.00 | 7.343E-04 | 3.584E-02 | 3.584E-02 | 2.713E-11 | 2.002E-09 | 1.910E-09 | 5.220E-17 |
| 40000.00 | 72000.00 | 6.320E-04 | 3.406E-02 | 3.406E-02 | 1.494E-11 | 1.188E-09 | 1.137E-09 | 1.915E-17 |
| 43000.00 | 77400.00 | 5.199E-04 | 3.169E-02 | 3.169E-02 | | 5.788E-10 | 5.562E-10 | |
| 46000.00 | 82800.00 | 4.392E-04 | 2.962E-02 | 2.962E-02 | | 3.013E-10 | 2.905E-10 | |
| 50000.00 | 90000.00 | 3.592E-04 | 2.725E-02 | 2.725E-02 | | 1.373E-10 | 1.330E-10 | |
| 55000.00 | 99000.00 | 2.905E-04 | 2.478E-02 | 2.478E-02 | | 5.751E-11 | 5.597E-11 | |
| 60000.00 | 108000.00 | 2.236E-04 | 2.272E-02 | 2.272E-02 | | 2.652E-11 | 2.602E-11 | |
| 65000.00 | 117000.00 | 1.749E-04 | 2.098E-02 | 2.098E-02 | | 1.335E-11 | 1.309E-11 | |
| 70000.00 | 126000.00 | 1.393E-04 | 1.948E-02 | 1.948E-02 | | 7.144E-12 | 7.029E-12 | |
| 80000.00 | 144000.00 | 9.250E-05 | 1.705E-02 | 1.705E-02 | | 2.390E-12 | 2.364E-12 | |
| 90000.00 | 162000.00 | 6.456E-05 | 1.516E-02 | 1.516E-02 | | 9.380E-13 | 9.316E-13 | |
| 100000.00 | 180000.00 | 4.702E-05 | 1.365E-02 | 1.365E-02 | | 4.150E-13 | 4.136E-13 | |
| 110000.00 | 198000.00 | 3.526E-05 | 1.241E-02 | 1.241E-02 | | 2.016E-13 | 2.015E-13 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(j) Pressure, $3.03975 \times 10^{6}$ N/m$^2$ (30 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | °R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 150.00 | 270.00 | | | | 5.463E+01 | | | |
| 200.00 | 360.00 | | | | 4.097E+01 | | | |
| 250.00 | 450.00 | | | | 3.278E+01 | | | |
| 298.15 | 536.67 | 1.229E-35 | | | 2.748E+01 | | | |
| 400.00 | 720.00 | 4.991E-26 | | | 2.049E+01 | | | |
| 500.00 | 900.00 | 2.081E-20 | | | 1.639E+01 | | | |
| 600.00 | 1080.00 | 1.151E-16 | | | 1.366E+01 | | | |
| 700.00 | 1260.00 | 5.393E-14 | | | 1.171E+01 | | | |
| 800.00 | 1440.00 | 5.405E-12 | | | 1.024E+01 | | | |
| 900.00 | 1620.00 | 1.938E-10 | | | 9.105E+00 | | | |
| 1000.00 | 1800.00 | 3.385E-09 | | | 8.195E+00 | | | |
| 1100.00 | 1980.00 | 3.505E-08 | | | 7.450E+00 | | | |
| 1200.00 | 2160.00 | 2.452E-07 | | | 6.829E+00 | | | |
| 1300.00 | 2340.00 | 1.269E-06 | | | 6.303E+00 | | | |
| 1400.00 | 2520.00 | 5.180E-06 | | 3.274E-21 | 5.853E+00 | 5.375E-25 | | 3.274E-21 |
| 1500.00 | 2700.00 | 1.750E-05 | | 7.325E-20 | 5.463E+00 | 2.392E-23 | | 7.328E-20 |
| 1600.00 | 2880.00 | 5.066E-05 | | 1.112E-18 | 5.122E+00 | 6.575E-22 | | 1.113E-18 |
| 1700.00 | 3060.00 | 1.292E-04 | | 1.226E-17 | 4.820E+00 | 1.215E-20 | | 1.228E-17 |
| 1800.00 | 3240.00 | 2.966E-04 | | 1.036E-16 | 4.552E+00 | 1.615E-19 | | 1.038E-16 |
| 1900.00 | 3420.00 | 6.226E-04 | | 7.001E-16 | 4.312E+00 | 1.626E-18 | | 7.017E-16 |
| 2000.00 | 3600.00 | 1.212E-03 | 1.347E-22 | 3.908E-15 | 4.096E+00 | 1.293E-17 | 1.156E-22 | 3.921E-15 |
| 2100.00 | 3780.00 | 2.211E-03 | 2.389E-21 | 1.853E-14 | 3.900E+00 | 8.399E-17 | 1.802E-21 | 1.861E-14 |
| 2200.00 | 3960.00 | 3.814E-03 | 3.266E-20 | 7.630E-14 | 3.721E+00 | 4.584E-16 | 2.192E-20 | 7.675E-14 |
| 2300.00 | 4140.00 | 6.267E-03 | 3.563E-19 | 2.778E-13 | 3.557E+00 | 2.150E-15 | 2.149E-19 | 2.800E-13 |
| 2400.00 | 4320.00 | 9.865E-03 | 3.188E-18 | 9.086E-13 | 3.405E+00 | 8.829E-15 | 1.744E-18 | 9.174E-13 |
| 2500.00 | 4500.00 | 1.496E-02 | 2.397E-17 | 2.703E-12 | 3.263E+00 | 3.226E-14 | 1.198E-17 | 2.735E-12 |
| 2600.00 | 4680.00 | 2.193E-02 | 1.545E-16 | 7.390E-12 | 3.130E+00 | 1.063E-13 | 7.107E-17 | 7.496E-12 |
| 2700.00 | 4860.00 | 3.120E-02 | 8.681E-16 | 1.875E-11 | 3.004E+00 | 3.191E-13 | 3.698E-16 | 1.907E-11 |
| 2800.00 | 5040.00 | 4.322E-02 | 4.317E-15 | 4.448E-11 | 2.883E+00 | 8.823E-13 | 1.711E-15 | 4.536E-11 |
| 2900.00 | 5220.00 | 5.845E-02 | 1.924E-14 | 9.933E-11 | 2.767E+00 | 2.264E-12 | 7.127E-15 | 1.015E-10 |
| 3000.00 | 5400.00 | 7.731E-02 | 7.770E-14 | 2.100E-10 | 2.654E+00 | 5.428E-12 | 2.700E-14 | 2.153E-10 |
| 3100.00 | 5580.00 | 1.002E-01 | 2.870E-13 | 4.224E-10 | 2.543E+00 | 1.224E-11 | 9.386E-14 | 4.342E-10 |
| 3200.00 | 5760.00 | 1.275E-01 | 9.782E-13 | 8.118E-10 | 2.433E+00 | 2.608E-11 | 3.018E-13 | 8.365E-10 |
| 3400.00 | 6120.00 | 1.964E-01 | 9.177E-12 | 2.655E-09 | 2.214E+00 | 1.017E-10 | 2.535E-12 | 2.745E-09 |
| 3600.00 | 6480.00 | 2.849E-01 | 6.737E-11 | 7.534E-09 | 1.991E+00 | 3.321E-10 | 1.673E-11 | 7.782E-09 |
| 3800.00 | 6840.00 | 3.918E-01 | 4.017E-10 | 1.894E-08 | 1.765E+00 | 9.290E-10 | 8.978E-11 | 1.938E-08 |
| 4000.00 | 7200.00 | 5.137E-01 | 2.001E-09 | 4.295E-08 | 1.535E+00 | 2.273E-09 | 4.015E-10 | 4.282E-08 |
| 4200.00 | 7560.00 | 6.444E-01 | 8.491E-09 | 8.946E-08 | 1.307E+00 | 4.963E-09 | 1.522E-09 | 8.441E-08 |
| 4400.00 | 7920.00 | 7.762E-01 | 3.104E-08 | 1.745E-07 | 1.086E+00 | 9.872E-09 | 4.932E-09 | 1.484E-07 |
| 4600.00 | 8280.00 | 9.006E-01 | 9.821E-08 | 3.255E-07 | 8.808E-01 | 1.830E-08 | 1.373E-08 | 2.319E-07 |
| 4800.00 | 8640.00 | 1.010E+00 | 2.700E-07 | 5.917E-07 | 6.971E-01 | 3.227E-08 | 3.289E-08 | 3.211E-07 |
| 5000.00 | 9000.00 | 1.099E+00 | 6.501E-07 | 1.060E-06 | 5.398E-01 | 5.492E-08 | 6.847E-08 | 3.963E-07 |
| 5200.00 | 9360.00 | 1.165E+00 | 1.394E-06 | 1.873E-06 | 4.106E-01 | 9.056E-08 | 1.251E-07 | 4.431E-07 |
| 5400.00 | 9720.00 | 1.209E+00 | 2.722E-06 | 3.247E-06 | 3.083E-01 | 1.444E-07 | 2.105E-07 | 4.590E-07 |
| 5600.00 | 10080.00 | 1.233E+00 | 4.935E-06 | 5.489E-06 | 2.299E-01 | 2.223E-07 | 3.256E-07 | 4.506E-07 |
| 5800.00 | 10440.00 | 1.242E+00 | 8.446E-06 | 9.016E-06 | 1.710E-01 | 3.300E-07 | 4.753E-07 | 4.270E-07 |
| 6000.00 | 10800.00 | 1.239E+00 | 1.379E-05 | 1.438E-05 | 1.276E-01 | 4.737E-07 | 6.638E-07 | 3.960E-07 |
| 6300.00 | 11340.00 | 1.218E+00 | 2.685E-05 | 2.745E-05 | 8.313E-02 | 7.701E-07 | 1.029E-06 | 3.461E-07 |
| 6600.00 | 11880.00 | 1.186E+00 | 4.884E-05 | 4.945E-05 | 5.525E-02 | 1.182E-06 | 1.507E-06 | 2.999E-07 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(j) Concluded. Pressure, $3.03975 \times 10^{6}$ N/m$^2$ (30 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 7000.00 | 12600.00 | 1.137E+00 | 9.962E-05 | 1.003E-04 | 3.321E-02 | 1.946E-06 | 2.346E-06 | 2.485E-07 |
| 7300.00 | 13140.00 | 1.099E+00 | 1.613E-04 | 1.619E-04 | 2.330E-02 | 2.705E-06 | 3.146E-06 | 2.175E-07 |
| 7600.00 | 13680.00 | 1.061E+00 | 2.512E-04 | 2.519E-04 | 1.673E-02 | 3.644E-06 | 4.106E-06 | 1.924E-07 |
| 8000.00 | 14400.00 | 1.012E+00 | 4.307E-04 | 4.313E-04 | 1.111E-02 | 5.198E-06 | 5.652E-06 | 1.658E-07 |
| 8300.00 | 14940.00 | 9.777E-01 | 6.239E-04 | 6.244E-04 | 8.354E-03 | 6.605E-06 | 7.021E-06 | 1.499E-07 |
| 8600.00 | 15480.00 | 9.447E-01 | 8.809E-04 | 8.814E-04 | 6.393E-03 | 8.226E-06 | 8.573E-06 | 1.367E-07 |
| 9000.00 | 16200.00 | 9.032E-01 | 1.347E-03 | 1.347E-03 | 4.583E-03 | 1.072E-05 | 1.093E-05 | 1.223E-07 |
| 9300.00 | 16740.00 | 8.739E-01 | 1.809E-03 | 1.809E-03 | 3.629E-03 | 1.284E-05 | 1.291E-05 | 1.134E-07 |
| 9600.00 | 17280.00 | 8.460E-01 | 2.386E-03 | 2.386E-03 | 2.908E-03 | 1.517E-05 | 1.506E-05 | 1.057E-07 |
| 10000.00 | 18000.00 | 8.106E-01 | 3.363E-03 | 3.363E-03 | 2.202E-03 | 1.857E-05 | 1.817E-05 | 9.707E-08 |
| 10500.00 | 18900.00 | 7.690E-01 | 4.981E-03 | 4.980E-03 | 1.592E-03 | 2.323E-05 | 2.242E-05 | 8.804E-08 |
| 11000.00 | 19800.00 | 7.298E-01 | 7.118E-03 | 7.116E-03 | 1.176E-03 | 2.826E-05 | 2.697E-05 | 8.050E-08 |
| 11500.00 | 20700.00 | 6.924E-01 | 9.854E-03 | 9.853E-03 | 8.842E-04 | 3.352E-05 | 3.169E-05 | 7.388E-08 |
| 12000.00 | 21600.00 | 6.563E-01 | 1.327E-02 | 1.326E-02 | 6.740E-04 | 3.883E-05 | 3.646E-05 | 6.791E-08 |
| 12500.00 | 22500.00 | 6.211E-01 | 1.741E-02 | 1.741E-02 | 5.191E-04 | 4.402E-05 | 4.110E-05 | 6.230E-08 |
| 13000.00 | 23400.00 | 5.865E-01 | 2.233E-02 | 2.233E-02 | 4.028E-04 | 4.889E-05 | 4.544E-05 | 5.692E-08 |
| 13500.00 | 24300.00 | 5.523E-01 | 2.805E-02 | 2.805E-02 | 3.140E-04 | 5.322E-05 | 4.929E-05 | 5.162E-08 |
| 14000.00 | 25200.00 | 5.182E-01 | 3.455E-02 | 3.455E-02 | 2.454E-04 | 5.683E-05 | 5.249E-05 | 4.637E-08 |
| 15000.00 | 27000.00 | 4.502E-01 | 4.971E-02 | 4.970E-02 | 1.496E-04 | 6.118E-05 | 5.633E-05 | 3.602E-08 |
| 16000.00 | 28800.00 | 3.828E-01 | 6.710E-02 | 6.709E-02 | 8.977E-05 | 6.118E-05 | 5.624E-05 | 2.631E-08 |
| 17000.00 | 30600.00 | 3.175E-01 | 8.553E-02 | 8.552E-02 | 5.241E-05 | 5.683E-05 | 5.222E-05 | 1.783E-08 |
| 18000.00 | 32400.00 | 2.563E-01 | 1.035E-01 | 1.035E-01 | 2.957E-05 | 4.912E-05 | 4.516E-05 | 1.112E-08 |
| 19000.00 | 34200.00 | 2.013E-01 | 1.196E-01 | 1.196E-01 | 1.608E-05 | 3.965E-05 | 3.649E-05 | 6.374E-09 |
| 20000.00 | 36000.00 | 1.544E-01 | 1.327E-01 | 1.327E-01 | 8.453E-06 | 3.009E-05 | 2.774E-05 | 3.371E-09 |
| 21000.00 | 37800.00 | 1.162E-01 | 1.422E-01 | 1.422E-01 | 4.345E-06 | 2.169E-05 | 2.003E-05 | 1.665E-09 |
| 22000.00 | 39600.00 | 8.647E-02 | 1.482E-01 | 1.482E-01 | 2.208E-06 | 1.504E-05 | 1.392E-05 | 7.802E-10 |
| 23000.00 | 41400.00 | 6.407E-02 | 1.511E-01 | 1.511E-01 | 1.124E-06 | 1.015E-05 | 9.415E-06 | 3.533E-10 |
| 24000.00 | 43200.00 | 4.762E-02 | 1.516E-01 | 1.516E-01 | 5.824E-07 | 6.755E-06 | 6.278E-06 | 1.571E-10 |
| 25000.00 | 45000.00 | 3.572E-02 | 1.504E-01 | 1.504E-01 | 3.091E-07 | 4.471E-06 | 4.164E-06 | 6.955E-11 |
| 26000.00 | 46800.00 | 2.721E-02 | 1.480E-01 | 1.480E-01 | 1.688E-07 | 2.964E-06 | 2.766E-06 | 3.095E-11 |
| 27000.00 | 48600.00 | 2.107E-02 | 1.449E-01 | 1.449E-01 | 9.514E-08 | 1.979E-06 | 1.851E-06 | 1.391E-11 |
| 28000.00 | 50400.00 | 1.660E-02 | 1.414E-01 | 1.414E-01 | 5.532E-08 | 1.335E-06 | 1.252E-06 | 6.395E-12 |
| 29000.00 | 52200.00 | 1.332E-02 | 1.377E-01 | 1.377E-01 | 3.331E-08 | 9.124E-07 | 8.569E-07 | 3.028E-12 |
| 30000.00 | 54000.00 | 1.088E-02 | 1.339E-01 | 1.339E-01 | 2.066E-08 | 6.314E-07 | 5.942E-07 | 1.475E-12 |
| 32000.00 | 57600.00 | 7.646E-03 | 1.265E-01 | 1.265E-01 | 8.555E-09 | 3.147E-07 | 2.973E-07 | 3.805E-13 |
| 34000.00 | 61200.00 | 5.667E-03 | 1.196E-01 | 1.196E-01 | 3.855E-09 | 1.652E-07 | 1.566E-07 | 1.091E-13 |
| 36000.00 | 64800.00 | 4.410E-03 | 1.133E-01 | 1.133E-01 | 1.903E-09 | 9.086E-08 | 8.643E-08 | 3.443E-14 |
| 38000.00 | 68400.00 | 3.580E-03 | 1.074E-01 | 1.074E-01 | 9.897E-10 | 5.214E-08 | 4.976E-08 | 1.182E-14 |
| 40000.00 | 72000.00 | 2.977E-03 | 1.022E-01 | 1.022E-01 | 5.449E-10 | 3.109E-08 | 2.976E-08 | 4.375E-15 |
| 43000.00 | 77400.00 | 2.366E-03 | 9.507E-02 | 9.507E-02 | 2.391E-10 | 1.523E-08 | 1.464E-08 | 1.114E-15 |
| 46000.00 | 82800.00 | 1.925E-03 | 8.890E-02 | 8.890E-02 | | 7.950E-09 | 7.677E-09 | |
| 50000.00 | 90000.00 | 1.550E-03 | 8.179E-02 | 8.179E-02 | | 3.641E-09 | 3.527E-09 | |
| 55000.00 | 99000.00 | 1.225E-03 | 7.435E-02 | 7.435E-02 | | 1.530E-09 | 1.489E-09 | |
| 60000.00 | 108000.00 | 9.957E-04 | 6.815E-02 | 6.815E-02 | | 7.089E-10 | 6.928E-10 | |
| 65000.00 | 117000.00 | 8.316E-04 | 6.290E-02 | 6.290E-02 | | 3.557E-10 | 3.489E-10 | |
| 70000.00 | 126000.00 | 7.061E-04 | 5.840E-02 | 5.840E-02 | | 1.905E-10 | 1.875E-10 | |
| 80000.00 | 144000.00 | 4.865E-04 | 5.112E-02 | 5.112E-02 | | 6.391E-11 | 6.320E-11 | |
| 90000.00 | 162000.00 | 3.382E-04 | 4.546E-02 | 4.546E-02 | | 2.513E-11 | 2.496E-11 | |
| 100000.00 | 180000.00 | 2.450E-04 | 4.093E-02 | 4.093E-02 | | 1.114E-11 | 1.110E-11 | |
| 110000.00 | 198000.00 | 1.846E-04 | 3.721E-02 | 3.721E-02 | | 5.415E-12 | 5.412E-12 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(k) Pressure, $1.01325 \times 10^{7}$ N/m$^2$ (100 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 400.00 | 720.00 | 9.113E-26 | | | 6.829E+01 | | | |
| 500.00 | 900.00 | 3.799E-20 | | | 5.463E+01 | | | |
| 600.00 | 1080.00 | 2.101E-16 | | | 4.553E+01 | | | |
| 700.00 | 1260.00 | 9.846E-14 | | | 3.902E+01 | | | |
| 800.00 | 1440.00 | 9.868E-12 | | | 3.414E+01 | | | |
| 900.00 | 1620.00 | 3.538E-10 | | | 3.035E+01 | | | |
| 1000.00 | 1800.00 | 6.181E-09 | | | 2.732E+01 | | | |
| 1100.00 | 1980.00 | 6.400E-08 | | | 2.483E+01 | | | |
| 1200.00 | 2160.00 | 4.477E-07 | | | 2.276E+01 | | | |
| 1300.00 | 2340.00 | 2.316E-06 | | | 2.101E+01 | | | |
| 1400.00 | 2520.00 | 9.457E-06 | | 8.076E-21 | 1.951E+01 | 2.421E-24 | | 8.078E-21 |
| 1500.00 | 2700.00 | 3.194E-05 | | 1.807E-19 | 1.821E+01 | 1.077E-22 | | 1.809E-19 |
| 1600.00 | 2880.00 | 9.249E-05 | | 2.742E-18 | 1.707E+01 | 2.960E-21 | | 2.745E-18 |
| 1700.00 | 3060.00 | 2.359E-04 | | 3.024E-17 | 1.607E+01 | 5.472E-20 | | 3.030E-17 |
| 1800.00 | 3240.00 | 5.414E-04 | | 2.555E-16 | 1.517E+01 | 7.270E-19 | | 2.563E-16 |
| 1900.00 | 3420.00 | 1.137E-03 | | 1.726E-15 | 1.438E+01 | 7.316E-18 | | 1.733E-15 |
| 2000.00 | 3600.00 | 2.213E-03 | 9.984E-23 | 9.628E-15 | 1.366E+01 | 5.815E-17 | 1.564E-22 | 9.686E-15 |
| 2100.00 | 3780.00 | 4.038E-03 | 1.771E-21 | 4.564E-14 | 1.300E+01 | 3.777E-16 | 2.439E-21 | 4.601E-14 |
| 2200.00 | 3960.00 | 6.965E-03 | 2.423E-20 | 1.878E-13 | 1.241E+01 | 2.051E-15 | 2.969E-20 | 1.899E-13 |
| 2300.00 | 4140.00 | 1.145E-02 | 2.644E-19 | 6.837E-13 | 1.186E+01 | 9.662E-15 | 2.913E-19 | 6.933E-13 |
| 2400.00 | 4320.00 | 1.802E-02 | 2.368E-18 | 2.235E-12 | 1.136E+01 | 3.967E-14 | 2.366E-18 | 2.274E-12 |
| 2500.00 | 4500.00 | 2.733E-02 | 1.782E-17 | 6.645E-12 | 1.090E+01 | 1.450E-13 | 1.628E-17 | 6.790E-12 |
| 2600.00 | 4680.00 | 4.010E-02 | 1.149E-16 | 1.817E-11 | 1.047E+01 | 4.777E-13 | 9.668E-17 | 1.865E-11 |
| 2700.00 | 4860.00 | 5.710E-02 | 6.462E-16 | 4.610E-11 | 1.006E+01 | 1.436E-12 | 5.037E-16 | 4.753E-11 |
| 2800.00 | 5040.00 | 7.918E-02 | 3.216E-15 | 1.094E-10 | 9.676E+00 | 3.975E-12 | 2.335E-15 | 1.134E-10 |
| 2900.00 | 5220.00 | 1.072E-01 | 1.434E-14 | 2.445E-10 | 9.312E+00 | 1.022E-11 | 9.743E-15 | 2.547E-10 |
| 3000.00 | 5400.00 | 1.421E-01 | 5.793E-14 | 5.176E-10 | 8.963E+00 | 2.459E-11 | 3.699E-14 | 5.421E-10 |
| 3100.00 | 5580.00 | 1.846E-01 | 2.141E-13 | 1.043E-09 | 8.627E+00 | 5.557E-11 | 1.289E-13 | 1.099E-09 |
| 3200.00 | 5760.00 | 2.355E-01 | 7.296E-13 | 2.010E-09 | 8.300E+00 | 1.193E-10 | 4.158E-13 | 2.129E-09 |
| 3400.00 | 6120.00 | 3.655E-01 | 6.844E-12 | 6.628E-09 | 7.668E+00 | 4.727E-10 | 3.519E-12 | 7.090E-09 |
| 3600.00 | 6480.00 | 5.361E-01 | 5.021E-11 | 1.903E-08 | 7.051E+00 | 1.579E-09 | 2.347E-11 | 2.054E-08 |
| 3800.00 | 6840.00 | 7.485E-01 | 2.994E-10 | 4.858E-08 | 6.440E+00 | 4.552E-09 | 1.278E-10 | 5.270E-08 |
| 4000.00 | 7200.00 | 1.001E+00 | 1.496E-09 | 1.121E-07 | 5.828E+00 | 1.156E-08 | 5.848E-10 | 1.215E-07 |
| 4200.00 | 7560.00 | 1.288E+00 | 6.413E-09 | 2.370E-07 | 5.215E+00 | 2.627E-08 | 2.296E-09 | 2.545E-07 |
| 4400.00 | 7920.00 | 1.599E+00 | 2.402E-08 | 4.652E-07 | 4.609E+00 | 5.421E-08 | 7.865E-09 | 4.875E-07 |
| 4600.00 | 8280.00 | 1.923E+00 | 7.970E-08 | 8.583E-07 | 4.015E+00 | 1.030E-07 | 2.378E-08 | 8.578E-07 |
| 4800.00 | 8640.00 | 2.245E+00 | 2.363E-07 | 1.507E-06 | 3.445E+00 | 1.827E-07 | 6.400E-08 | 1.389E-06 |
| 5000.00 | 9000.00 | 2.552E+00 | 6.299E-07 | 2.546E-06 | 2.911E+00 | 3.056E-07 | 1.541E-07 | 2.071E-06 |
| 5200.00 | 9360.00 | 2.831E+00 | 1.516E-06 | 4.199E-06 | 2.422E+00 | 4.931E-07 | 3.332E-07 | 2.843E-06 |
| 5400.00 | 9720.00 | 3.070E+00 | 3.314E-06 | 6.800E-06 | 1.988E+00 | 7.580E-07 | 6.508E-07 | 3.603E-06 |
| 5600.00 | 10080.00 | 3.265E+00 | 6.631E-06 | 1.087E-05 | 1.612E+00 | 1.155E-06 | 1.158E-06 | 4.245E-06 |
| 5800.00 | 10440.00 | 3.416E+00 | 1.228E-05 | 1.715E-05 | 1.294E+00 | 1.726E-06 | 1.900E-06 | 4.697E-06 |
| 6000.00 | 10800.00 | 3.521E+00 | 2.129E-05 | 2.665E-05 | 1.032E+00 | 2.497E-06 | 2.913E-06 | 4.943E-06 |
| 6300.00 | 11340.00 | 3.605E+00 | 4.407E-05 | 4.991E-05 | 7.293E-01 | 4.145E-06 | 5.002E-06 | 4.984E-06 |
| 6600.00 | 11880.00 | 3.623E+00 | 8.328E-05 | 8.938E-05 | 5.154E-01 | 6.523E-06 | 7.849E-06 | 4.770E-06 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(k) Concluded. Pressure, $1.01325 \times 10^{7}$ N/m$^2$ (100 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 7000.00 | 12600.00 | 3.574E+00 | 1.751E-04 | 1.813E-04 | 3.280F-01 | 1.106E-05 | 1.296E-05 | 4.313E-06 |
| 7300.00 | 13140.00 | 3.504E+00 | 2.874E-04 | 2.936E-04 | 2.370E-01 | 1.564E-05 | 1.788E-05 | 3.945E-06 |
| 7600.00 | 13680.00 | 3.419E+00 | 4.521F-04 | 4.582E-04 | 1.737E-01 | 2.136E-05 | 2.382E-05 | 3.598E-06 |
| 8000.00 | 14400.00 | 3.295E+00 | 7.823E-04 | 7.879E-04 | 1.177E-01 | 3.091E-05 | 3.341E-05 | 3.190E-06 |
| 8300.00 | 14940.00 | 3.199E+00 | 1.139E-03 | 1.144E-03 | 8.945E-02 | 3.960E-05 | 4.193E-05 | 2.929E-06 |
| 8600.00 | 15480.00 | 3.104E+00 | 1.614E-03 | 1.619E-03 | 6.901E-02 | 4.965E-05 | 5.163E-05 | 2.704E-06 |
| 9000.00 | 16200.00 | 2.980E+00 | 2.480E-03 | 2.484E-03 | 4.989E-02 | 6.522E-05 | 6.639E-05 | 2.451E-06 |
| 9300.00 | 16740.00 | 2.891E+00 | 3.341E-03 | 3.343E-03 | 3.970E-02 | 7.851E-05 | 7.885E-05 | 2.291E-06 |
| 9600.00 | 17280.00 | 2.805E+00 | 4.418E-03 | 4.420E-03 | 3.196E-02 | 9.316E-05 | 9.245E-05 | 2.152E-06 |
| 10000.00 | 18000.00 | 2.695E+00 | 6.251E-03 | 6.250E-03 | 2.434E-02 | 1.147E-04 | 1.123F-04 | 1.994E-05 |
| 10500.00 | 18900.00 | 2.565E+00 | 9.299E-03 | 9.296E-03 | 1.772E-02 | 1.447E-04 | 1.396E-04 | 1.829E-06 |
| 11000.00 | 19800.00 | 2.444E+00 | 1.335E-02 | 1.334E-02 | 1.319E-02 | 1.774E-04 | 1.694E-04 | 1.693E-06 |
| 11500.00 | 20700.00 | 2.329E+00 | 1.857E-02 | 1.856E-02 | 1.000E-02 | 2.124E-04 | 2.009E-04 | 1.575E-06 |
| 12000.00 | 21600.00 | 2.220E+00 | 2.514E-02 | 2.512E-02 | 7.709E-03 | 2.488E-04 | 2.337E-04 | 1.472E-06 |
| 12500.00 | 22500.00 | 2.115E+00 | 3.319E-02 | 3.317E-02 | 6.017E-03 | 2.857E-04 | 2.668E-04 | 1.378E-06 |
| 13000.00 | 23400.00 | 2.014E+00 | 4.286E-02 | 4.284E-02 | 4.746E-03 | 3.221E-04 | 2.995E-04 | 1.288E-06 |
| 13500.00 | 24300.00 | 1.915E+00 | 5.425E-02 | 5.422E-02 | 3.775E-03 | 3.570E-04 | 3.308E-04 | 1.202E-06 |
| 14000.00 | 25200.00 | 1.819E+00 | 6.740E-02 | 6.737E-02 | 3.021E-03 | 3.893E-04 | 3.598E-04 | 1.116E-06 |
| 15000.00 | 27000.00 | 1.630E+00 | 9.900E-02 | 9.897E-02 | 1.958E-03 | 4.420E-04 | 4.070E-04 | 9.444E-07 |
| 16000.00 | 28800.00 | 1.445E+00 | 1.371E-01 | 1.371E-01 | 1.276E-03 | 4.734E-04 | 4.352E-04 | 7.710E-07 |
| 17000.00 | 30600.00 | 1.265E+00 | 1.804E-01 | 1.804E-01 | 8.273E-04 | 4.796E-04 | 4.407E-04 | 6.021E-07 |
| 18000.00 | 32400.00 | 1.089E+00 | 2.267E-01 | 2.267E-01 | 5.296F-04 | 4.604E-04 | 4.233E-04 | 4.463E-07 |
| 19000.00 | 34200.00 | 9.223E-01 | 2.733E-01 | 2.732E-01 | 3.326E-04 | 4.192E-04 | 3.859E-04 | 3.119E-07 |
| 20000.00 | 36000.00 | 7.676E-01 | 3.174E-01 | 3.173E-01 | 2.051E-04 | 3.633E-04 | 3.349E-04 | 2.054E-07 |
| 21000.00 | 37800.00 | 6.284E-01 | 3.565E-01 | 3.565E-01 | 1.238E-04 | 3.007E-04 | 2.778E-04 | 1.277E-07 |
| 22000.00 | 39600.00 | 5.071E-01 | 3.890E-01 | 3.890E-01 | 7.337E-05 | 2.390E-04 | 2.212E-04 | 7.505E-08 |
| 23000.00 | 41400.00 | 4.045E-01 | 4.140E-01 | 4.140F-01 | 4.291E-05 | 1.835E-04 | 1.702E-04 | 4.211E-08 |
| 24000.00 | 43200.00 | 3.201E-01 | 4.314E-01 | 4.314E-01 | 2.491E-05 | 1.370E-04 | 1.273E-04 | 2.270E-08 |
| 25000.00 | 45000.00 | 2.524E-01 | 4.420E-01 | 4.420E-01 | 1.446E-05 | 1.002E-04 | 9.333E-05 | 1.189E-08 |
| 26000.00 | 46800.00 | 1.991E-01 | 4.468E-01 | 4.468E-01 | 8.436E-06 | 7.231E-05 | 6.748E-05 | 6.101E-09 |
| 27000.00 | 48600.00 | 1.576E-01 | 4.469E-01 | 4.469E-01 | 4.980E-06 | 5.177E-05 | 4.842E-05 | 3.085E-09 |
| 28000.00 | 50400.00 | 1.255E-01 | 4.436E-01 | 4.436E-01 | 2.984E-06 | 3.697E-05 | 3.465E-05 | 1.562E-09 |
| 29000.00 | 52200.00 | 1.008E-01 | 4.379E-01 | 4.379E-01 | 1.820E-06 | 2.644E-05 | 2.483E-05 | 7.993E-10 |
| 30000.00 | 54000.00 | 8.175E-02 | 4.304E-01 | 4.304E-01 | 1.131E-06 | 1.898E-05 | 1.787E-05 | 4.148E-10 |
| 32000.00 | 57600.00 | 5.549E-02 | 4.127E-01 | 4.127E-01 | 4.692E-07 | 9.991E-06 | 9.438E-06 | 1.175E-10 |
| 34000.00 | 61200.00 | 3.965E-02 | 3.935E-01 | 3.935E-01 | 2.111E-07 | 5.428E-06 | 5.146E-06 | 3.584E-11 |
| 36000.00 | 64800.00 | 2.960E-02 | 3.745E-01 | 3.745E-01 | 1.015E-07 | 3.058E-06 | 2.909E-06 | 1.179E-11 |
| 38000.00 | 68400.00 | 2.286E-02 | 3.565E-01 | 3.565E-01 | 5.212E-08 | 1.786E-06 | 1.704E-06 | 4.175E-12 |
| 40000.00 | 72000.00 | 1.831E-02 | 3.396E-01 | 3.396E-01 | 2.831E-08 | 1.078E-06 | 1.031E-06 | 1.581E-12 |
| 43000.00 | 77400.00 | 1.375E-02 | 3.167E-01 | 3.167E-01 | 1.219E-08 | 5.349E-07 | 5.140E-07 | 4.125E-13 |
| 46000.00 | 82800.00 | 1.073E-02 | 2.964E-01 | 2.964E-01 | 5.695E-09 | 2.821E-07 | 2.721E-07 | 1.214E-13 |
| 50000.00 | 90000.00 | 8.228E-03 | 2.728E-01 | 2.728E-01 | | 1.301E-07 | 1.261E-07 | |
| 55000.00 | 99000.00 | 6.240E-03 | 2.480E-01 | 2.480E-01 | | 5.506E-08 | 5.358E-08 | |
| 60000.00 | 108000.00 | 4.970E-03 | 2.273E-01 | 2.273E-01 | | 2.564E-08 | 2.505E-08 | |
| 65000.00 | 117000.00 | 4.029E-03 | 2.098E-01 | 2.098E-01 | | 1.291E-08 | 1.266E-08 | |
| 70000.00 | 126000.00 | 3.401E-03 | 1.948E-01 | 1.948E-01 | | 6.933E-09 | 6.821E-09 | |
| 80000.00 | 144000.00 | 2.507E-03 | 1.704E-01 | 1.704E-01 | | 2.331E-09 | 2.306E-09 | |
| 90000.00 | 162000.00 | 1.934E-03 | 1.514E-01 | 1.514E-01 | | 9.180E-10 | 9.117E-10 | |
| 100000.00 | 180000.00 | 1.515E-03 | 1.363E-01 | 1.363E-01 | | 4.074E-10 | 4.059E-10 | |
| 110000.00 | 198000.00 | 1.135E-03 | 1.239E-01 | 1.239E-01 | | 1.985E-10 | 1.984E-10 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(*l*) Pressure, $3.03975 \times 10^{7}$ N/m$^2$ (300 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o / V L_o$ | | | | | | |
| 1100.00 | 1980.00 | 1.108E-07 | | | 7.450E+01 | | | |
| 1200.00 | 2160.00 | 7.754E-07 | | | 6.829E+01 | | | |
| 1300.00 | 2340.00 | 4.012E-06 | | | 6.303E+01 | | | |
| 1400.00 | 2520.00 | 1.638E-05 | | 1.841E-20 | 5.853E+01 | 9.558E-24 | | 1.842E-20 |
| 1500.00 | 2700.00 | 5.533E-05 | | 4.118E-19 | 5.463E+01 | 4.253E-22 | | 4.122E-19 |
| 1600.00 | 2880.00 | 1.602E-04 | | 6.249E-18 | 5.122E+01 | 1.168E-20 | | 6.261E-18 |
| 1700.00 | 3060.00 | 4.086E-04 | | 6.889E-17 | 4.820E+01 | 2.159E-19 | | 6.910E-17 |
| 1800.00 | 3240.00 | 9.378E-04 | | 5.819E-16 | 4.552E+01 | 2.867E-18 | | 5.847E-16 |
| 1900.00 | 3420.00 | 1.969E-03 | | 3.927E-15 | 4.313E+01 | 2.884E-17 | | 3.956E-15 |
| 2000.00 | 3600.00 | 3.833E-03 | 7.603E-23 | 2.190E-14 | 4.097E+01 | 2.291E-16 | 2.063E-22 | 2.213E-14 |
| 2100.00 | 3780.00 | 6.994E-03 | 1.350E-21 | 1.037E-13 | 3.901E+01 | 1.487E-15 | 3.220E-21 | 1.052E-13 |
| 2200.00 | 3960.00 | 1.207E-02 | 1.848E-20 | 4.265E-13 | 3.724E+01 | 8.107E-15 | 3.923E-20 | 4.345E-13 |
| 2300.00 | 4140.00 | 1.983E-02 | 2.019E-19 | 1.551E-12 | 3.561E+01 | 3.797E-14 | 3.854E-19 | 1.589E-12 |
| 2400.00 | 4320.00 | 3.123E-02 | 1.811E-18 | 5.065E-12 | 3.411E+01 | 1.558E-13 | 3.135E-18 | 5.220E-12 |
| 2500.00 | 4500.00 | 4.737E-02 | 1.364E-17 | 1.504E-11 | 3.273E+01 | 5.687E-13 | 2.160E-17 | 1.561E-11 |
| 2600.00 | 4680.00 | 6.950E-02 | 8.809E-17 | 4.108E-11 | 3.145E+01 | 1.872E-12 | 1.285E-16 | 4.295E-11 |
| 2700.00 | 4860.00 | 9.902E-02 | 4.961E-16 | 1.041E-10 | 3.025E+01 | 5.624E-12 | 6.706E-16 | 1.097E-10 |
| 2800.00 | 5040.00 | 1.374E-01 | 2.473E-15 | 2.469E-10 | 2.913E+01 | 1.556E-11 | 3.115E-15 | 2.624E-10 |
| 2900.00 | 5220.00 | 1.861E-01 | 1.104E-14 | 5.513E-10 | 2.807E+01 | 4.002E-11 | 1.303E-14 | 5.913E-10 |
| 3000.00 | 5400.00 | 2.469E-01 | 4.468E-14 | 1.166E-09 | 2.707E+01 | 9.629E-11 | 4.958E-14 | 1.263E-09 |
| 3100.00 | 5580.00 | 3.211E-01 | 1.653E-13 | 2.350E-09 | 2.611E+01 | 2.182E-10 | 1.732E-13 | 2.568E-09 |
| 3200.00 | 5760.00 | 4.104E-01 | 5.643E-13 | 4.530E-09 | 2.520E+01 | 4.683E-10 | 5.603E-13 | 4.997E-09 |
| 3400.00 | 6120.00 | 6.393E-01 | 5.305E-12 | 1.496E-08 | 2.346E+01 | 1.866E-09 | 4.771E-12 | 1.682E-08 |
| 3600.00 | 6480.00 | 9.430E-01 | 3.899E-11 | 4.313E-08 | 2.182E+01 | 6.294E-09 | 3.206E-11 | 4.936E-08 |
| 3800.00 | 6840.00 | 1.327E+00 | 2.329E-10 | 1.108E-07 | 2.024E+01 | 1.841E-08 | 1.763E-10 | 1.289E-07 |
| 4000.00 | 7200.00 | 1.793E+00 | 1.165E-09 | 2.580E-07 | 1.869E+01 | 4.766E-08 | 8.159E-10 | 3.037E-07 |
| 4200.00 | 7560.00 | 2.336E+00 | 5.008E-09 | 5.517E-07 | 1.717E+01 | 1.110E-07 | 3.254E-09 | 6.544E-07 |
| 4400.00 | 7920.00 | 2.949E+00 | 1.886E-08 | 1.096E-06 | 1.568E+01 | 2.355E-07 | 1.138E-08 | 1.301E-06 |
| 4600.00 | 8280.00 | 3.616E+00 | 6.319E-08 | 2.043E-06 | 1.420E+01 | 4.610E-07 | 3.546E-08 | 2.405E-06 |
| 4800.00 | 8640.00 | 4.320E+00 | 1.909E-07 | 3.604E-06 | 1.275E+01 | 8.406E-07 | 9.948E-08 | 4.154E-06 |
| 5000.00 | 9000.00 | 5.040E+00 | 5.251E-07 | 6.068E-06 | 1.135E+01 | 1.442E-06 | 2.536E-07 | 6.731E-06 |
| 5200.00 | 9360.00 | 5.753E+00 | 1.325E-06 | 9.830E-06 | 1.001E+01 | 2.346E-06 | 5.916E-07 | 1.025E-05 |
| 5400.00 | 9720.00 | 6.437E+00 | 3.084E-06 | 1.543E-05 | 8.738E+00 | 3.655E-06 | 1.270E-06 | 1.474E-05 |
| 5600.00 | 10080.00 | 7.074E+00 | 6.653E-06 | 2.365E-05 | 7.559E+00 | 5.493E-06 | 2.517E-06 | 1.998E-05 |
| 5800.00 | 10440.00 | 7.645E+00 | 1.336E-05 | 3.559E-05 | 6.483E+00 | 8.020E-06 | 4.630E-06 | 2.561E-05 |
| 6000.00 | 10800.00 | 8.142E+00 | 2.510E-05 | 5.278E-05 | 5.516E+00 | 1.143E-05 | 7.944E-06 | 3.116E-05 |
| 6300.00 | 11340.00 | 8.732E+00 | 5.778E-05 | 9.322E-05 | 4.275E+00 | 1.875E-05 | 1.588E-05 | 3.831E-05 |
| 6600.00 | 11880.00 | 9.139E+00 | 1.186E-04 | 1.604E-04 | 3.278E+00 | 2.953E-05 | 2.818E-05 | 4.320E-05 |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

($l$) Concluded. Pressure, $3.03975\times10^{7}$ N/m$^2$ (300 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_i N_o/VL_o$ | | | | | | |
| 7000.00 | 12600.00 | 9.425E+00 | 2.688E-04 | 3.165E-04 | 2.281E+00 | 5.090E-05 | 5.248E-05 | 4.606E-05 |
| 7300.00 | 13140.00 | 9.487E+00 | 4.582E-04 | 5.081E-04 | 1.737E+00 | 7.329E-05 | 7.716E-05 | 4.609E-05 |
| 7600.00 | 13680.00 | 9.453E+00 | 7.399E-04 | 7.907E-04 | 1.328E+00 | 1.019E-04 | 1.077E-04 | 4.499E-05 |
| 8000.00 | 14400.00 | 9.302E+00 | 1.311E-03 | 1.361E-03 | 9.378E-01 | 1.508E-04 | 1.581E-04 | 4.262E-05 |
| 8300.00 | 14940.00 | 9.139E+00 | 1.933E-03 | 1.981E-03 | 7.299E-01 | 1.959E-04 | 2.034E-04 | 4.058E-05 |
| 8600.00 | 15480.00 | 8.949E+00 | 2.768E-03 | 2.813E-03 | 5.736E-01 | 2.487E-04 | 2.551E-04 | 3.853E-05 |
| 9000.00 | 16200.00 | 8.673E+00 | 4.293E-03 | 4.333E-03 | 4.226E-01 | 3.311E-04 | 3.345E-04 | 3.594E-05 |
| 9300.00 | 15740.00 | 8.459E+00 | 5.818E-03 | 5.852E-03 | 3.400E-01 | 4.021E-04 | 4.018E-04 | 3.415E-05 |
| 9600.00 | 17280.00 | 8.244E+00 | 7.733E-03 | 7.760E-03 | 2.762E-01 | 4.809E-04 | 4.756E-04 | 3.255E-05 |
| 10000.00 | 18000.00 | 7.960E+00 | 1.100E-02 | 1.102E-02 | 2.123E-01 | 5.975E-04 | 5.840E-04 | 3.063E-05 |
| 10500.00 | 18900.00 | 7.615E+00 | 1.648E-02 | 1.648E-02 | 1.561E-01 | 7.611E-04 | 7.343E-04 | 2.855E-05 |
| 11000.00 | 19800.00 | 7.285E+00 | 2.379E-02 | 2.377E-02 | 1.172E-01 | 9.424E-04 | 8.996E-04 | 2.681E-05 |
| 11500.00 | 20700.00 | 6.970E+00 | 3.328E-02 | 3.324E-02 | 8.961E-02 | 1.139E-03 | 1.078E-03 | 2.529E-05 |
| 12000.00 | 21600.00 | 6.671E+00 | 4.529E-02 | 4.523E-02 | 6.962E-02 | 1.346E-03 | 1.265E-03 | 2.396E-05 |
| 12500.00 | 22500.00 | 6.384E+00 | 6.013E-02 | 6.006E-02 | 5.483E-02 | 1.552E-03 | 1.459E-03 | 2.275E-05 |
| 13000.00 | 23400.00 | 6.109E+00 | 7.811E-02 | 7.801E-02 | 4.368E-02 | 1.780E-03 | 1.656E-03 | 2.162E-05 |
| 13500.00 | 24300.00 | 5.844E+00 | 9.947E-02 | 9.934E-02 | 3.514E-02 | 1.997E-03 | 1.852E-03 | 2.054E-05 |
| 14000.00 | 25200.00 | 5.588E+00 | 1.244E-01 | 1.243E-01 | 2.850E-02 | 2.207E-03 | 2.041E-03 | 1.947E-05 |
| 15000.00 | 27000.00 | 5.094E+00 | 1.854E-01 | 1.853E-01 | 1.910E-02 | 2.588E-03 | 2.385E-03 | 1.731E-05 |
| 16000.00 | 28800.00 | 4.620E+00 | 2.613E-01 | 2.611E-01 | 1.301E-02 | 2.886E-03 | 2.654E-03 | 1.505E-05 |
| 17000.00 | 30600.00 | 4.160E+00 | 3.507E-01 | 3.505E-01 | 8.923E-03 | 3.073E-03 | 2.826E-03 | 1.273E-05 |
| 18000.00 | 32400.00 | 3.714E+00 | 4.510E-01 | 4.508E-01 | 6.123E-03 | 3.133E-03 | 2.882E-03 | 1.040E-05 |
| 19000.00 | 34200.00 | 3.282E+00 | 5.582E-01 | 5.580E-01 | 4.185E-03 | 3.054E-03 | 2.822E-03 | 8.165E-06 |
| 20000.00 | 36000.00 | 2.869E+00 | 6.676E-01 | 6.674E-01 | 2.835E-03 | 2.881E-03 | 2.656E-03 | 6.143E-06 |
| 21000.00 | 37800.00 | 2.480E+00 | 7.742E-01 | 7.740E-01 | 1.902E-03 | 2.608E-03 | 2.410E-03 | 4.424E-06 |
| 22000.00 | 39600.00 | 2.121E+00 | 8.733E-01 | 8.732E-01 | 1.262E-03 | 2.282E-03 | 2.112E-03 | 3.048E-06 |
| 23000.00 | 41400.00 | 1.796E+00 | 9.614E-01 | 9.612E-01 | 8.282E-04 | 1.935E-03 | 1.794E-03 | 2.015E-06 |
| 24000.00 | 43200.00 | 1.507E+00 | 1.036E+00 | 1.036E+00 | 5.383E-04 | 1.595E-03 | 1.483E-03 | 1.282E-06 |
| 25000.00 | 45000.00 | 1.255E+00 | 1.095E+00 | 1.095E+00 | 3.473E-04 | 1.285E-03 | 1.196E-03 | 7.884E-07 |
| 26000.00 | 46800.00 | 1.042E+00 | 1.140E+00 | 1.140E+00 | 2.231E-04 | 1.014E-03 | 9.466E-04 | 4.705E-07 |
| 27000.00 | 48600.00 | 8.610E-01 | 1.171E+00 | 1.171E+00 | 1.431E-04 | 7.885E-04 | 7.375E-04 | 2.732E-07 |
| 28000.00 | 50400.00 | 7.110E-01 | 1.189E+00 | 1.189E+00 | 9.202E-05 | 6.051E-04 | 5.681E-04 | 1.566E-07 |
| 29000.00 | 52200.00 | 5.878E-01 | 1.197E+00 | 1.197E+00 | 5.944E-05 | 4.623E-04 | 4.341E-04 | 8.941E-08 |
| 30000.00 | 54000.00 | 4.872E-01 | 1.196E+00 | 1.196E+00 | 3.868E-05 | 3.510E-04 | 3.303E-04 | 5.102E-08 |
| 32000.00 | 57600.00 | 3.390E-01 | 1.177E+00 | 1.177E+00 | 1.686E-05 | 2.018E-04 | 1.906E-04 | 1.693E-08 |
| 34000.00 | 61200.00 | 2.414E-01 | 1.142E+00 | 1.142E+00 | 7.701E-06 | 1.171E-04 | 1.110E-04 | 5.743E-09 |
| 36000.00 | 64800.00 | 1.765E-01 | 1.100E+00 | 1.100E+00 | 3.728E-06 | 6.913E-05 | 6.576E-05 | 2.053E-09 |
| 38000.00 | 68400.00 | 1.340E-01 | 1.054E+00 | 1.054E+00 | 1.909E-06 | 4.159E-05 | 3.978E-05 | 7.695E-10 |
| 40000.00 | 72000.00 | 1.045E-01 | 1.010E+00 | 1.010E+00 | 1.024E-06 | 2.578E-05 | 2.467E-05 | 3.044E-10 |
| 43000.00 | 77400.00 | 7.509E-02 | 9.458E-01 | 9.458E-01 | 4.364E-07 | 1.314E-05 | 1.262E-05 | 8.332E-11 |
| 46000.00 | 82800.00 | 5.678E-02 | 8.874E-01 | 8.874E-01 | 2.072E-07 | 7.050E-06 | 6.800E-06 | 2.531E-11 |
| 50000.00 | 90000.00 | 4.148E-02 | 8.183E-01 | 8.183E-01 | 8.329E-08 | 3.306E-06 | 3.202E-06 | 5.966E-12 |
| 55000.00 | 99000.00 | 2.962E-02 | 7.449E-01 | 7.449E-01 | | 1.418E-06 | 1.380E-06 | |
| 60000.00 | 108000.00 | 2.272E-02 | 6.829E-01 | 6.829E-01 | | 6.662E-07 | 6.511E-07 | |
| 65000.00 | 117000.00 | 1.816E-02 | 6.302E-01 | 6.302E-01 | | 3.375E-07 | 3.310E-07 | |
| 70000.00 | 126000.00 | 1.495E-02 | 5.850E-01 | 5.850E-01 | | 1.821E-07 | 1.792E-07 | |
| 80000.00 | 144000.00 | 1.060E-02 | 5.116E-01 | 5.116E-01 | | 6.165E-08 | 6.097E-08 | |
| 90000.00 | 162000.00 | 8.095E-03 | 4.546E-01 | 4.546E-01 | | 2.437E-08 | 2.420E-08 | |
| 100000.00 | 180000.00 | 6.401E-03 | 4.090E-01 | 4.090E-01 | | 1.084E-08 | 1.080E-08 | |
| 110000.00 | 198000.00 | 5.131E-03 | 3.718E-01 | 3.718E-01 | | 5.290E-09 | 5.287E-09 | |

TABLE I. - Continued. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(m) Pressure, $1.01325\times10^{8}$ N/m$^2$ (1000 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | °R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_iN_o/VL_o$ | | | | | | |
| 3200.00 | 5760.00 | 7.520E-01 | 4.329E-13 | 1.082E-08 | 8.461E+01 | 2.051E-09 | 7.877E-13 | 1.287E-08 |
| 3400.00 | 6120.00 | 1.174E+00 | 4.094E-12 | 3.564E-08 | 7.916E+01 | 8.166E-09 | 6.763E-12 | 4.379E-08 |
| 3600.00 | 6480.00 | 1.738E+00 | 3.025E-11 | 1.026E-07 | 7.414E+01 | 2.759E-08 | 4.585E-11 | 1.301E-07 |
| 3800.00 | 6840.00 | 2.458E+00 | 1.815E-10 | 2.638E-07 | 6.942E+01 | 8.116E-08 | 2.545E-10 | 3.445E-07 |
| 4000.00 | 7200.00 | 3.341E+00 | 9.122E-10 | 6.159E-07 | 6.495E+01 | 2.121E-07 | 1.190E-09 | 8.259E-07 |
| 4200.00 | 7560.00 | 4.390E+00 | 3.935E-09 | 1.324E-06 | 6.065E+01 | 5.004E-07 | 4.804E-09 | 1.816E-06 |
| 4400.00 | 7920.00 | 5.597E+00 | 1.487E-08 | 2.650E-06 | 5.648E+01 | 1.081E-06 | 1.705E-08 | 3.699E-06 |
| 4600.00 | 8280.00 | 6.949E+00 | 5.009E-08 | 4.983E-06 | 5.243E+01 | 2.161E-06 | 5.401E-08 | 7.040E-06 |
| 4800.00 | 8640.00 | 8.424E+00 | 1.524E-07 | 8.875E-06 | 4.848E+01 | 4.036E-06 | 1.548E-07 | 1.260E-05 |
| 5000.00 | 9000.00 | 9.995E+00 | 4.234E-07 | 1.507E-05 | 4.464E+01 | 7.101E-06 | 4.056E-07 | 2.134E-05 |
| 5200.00 | 9360.00 | 1.163E+01 | 1.085E-06 | 2.456E-05 | 4.090E+01 | 1.185E-05 | 9.796E-07 | 3.434E-05 |
| 5400.00 | 9720.00 | 1.330E+01 | 2.584E-06 | 3.860E-05 | 3.729E+01 | 1.888E-05 | 2.198E-06 | 5.269E-05 |
| 5600.00 | 10080.00 | 1.496E+01 | 5.756E-06 | 5.880E-05 | 3.382E+01 | 2.888E-05 | 4.606E-06 | 7.732E-05 |
| 5800.00 | 10440.00 | 1.659E+01 | 1.206E-05 | 8.723E-05 | 3.051E+01 | 4.254E-05 | 9.063E-06 | 1.088E-04 |
| 6000.00 | 10800.00 | 1.814E+01 | 2.384E-05 | 1.265E-04 | 2.738E+01 | 6.108E-05 | 1.681E-05 | 1.470E-04 |
| 6300.00 | 11340.00 | 2.028E+01 | 6.008E-05 | 2.136E-04 | 2.307E+01 | 9.981E-05 | 3.836E-05 | 2.150E-04 |
| 6600.00 | 11880.00 | 2.214E+01 | 1.359E-04 | 3.491E-04 | 1.925E+01 | 1.557E-04 | 7.826E-05 | 2.906E-04 |
| 7000.00 | 12600.00 | 2.410E+01 | 3.482E-04 | 6.462E-04 | 1.492E+01 | 2.658E-04 | 1.738E-04 | 3.901E-04 |
| 7300.00 | 13140.00 | 2.518E+01 | 6.414E-04 | 9.998E-04 | 1.224E+01 | 3.828E-04 | 2.867E-04 | 4.545E-04 |
| 7600.00 | 13680.00 | 2.594E+01 | 1.104E-03 | 1.515E-03 | 9.998E+00 | 5.359E-04 | 4.412E-04 | 5.055E-04 |
| 8000.00 | 14400.00 | 2.652E+01 | 2.089E-03 | 2.553E-03 | 7.621E+00 | 8.051E-04 | 7.182E-04 | 5.519E-04 |
| 8300.00 | 14940.00 | 2.668E+01 | 3.196E-03 | 3.686E-03 | 6.221E+00 | 1.054E-03 | 9.816E-04 | 5.718E-04 |
| 8600.00 | 15480.00 | 2.665E+01 | 4.711E-03 | 5.213E-03 | 5.091E+00 | 1.373E-03 | 1.294E-03 | 5.820E-04 |
| 9000.00 | 16200.00 | 2.641E+01 | 7.528E-03 | 8.030E-03 | 3.919E+00 | 1.869E-03 | 1.786E-03 | 5.843E-04 |
| 9300.00 | 16740.00 | 2.611E+01 | 1.038E-02 | 1.087E-02 | 3.238E+00 | 2.304E-03 | 2.212E-03 | 5.804E-04 |
| 9600.00 | 17280.00 | 2.573E+01 | 1.399E-02 | 1.445E-02 | 2.690E+00 | 2.795E-03 | 2.686E-03 | 5.735E-04 |
| 10000.00 | 18000.00 | 2.515E+01 | 2.021E-02 | 2.063E-02 | 2.120E+00 | 3.534E-03 | 3.389E-03 | 5.615E-04 |
| 10500.00 | 18900.00 | 2.435E+01 | 3.073E-02 | 3.106E-02 | 1.596E+00 | 4.588E-03 | 4.379E-03 | 5.445E-04 |
| 11000.00 | 19800.00 | 2.351E+01 | 4.492E-02 | 4.515E-02 | 1.221E+00 | 5.778E-03 | 5.484E-03 | 5.275E-04 |
| 11500.00 | 20700.00 | 2.267E+01 | 6.351E-02 | 6.362E-02 | 9.481E-01 | 7.088E-03 | 6.689E-03 | 5.107E-04 |
| 12000.00 | 21600.00 | 2.184E+01 | 8.725E-02 | 8.722E-02 | 7.462E-01 | 8.500E-03 | 7.981E-03 | 4.948E-04 |
| 12500.00 | 22500.00 | 2.102E+01 | 1.169E-01 | 1.167E-01 | 5.946E-01 | 9.993E-03 | 9.341E-03 | 4.795E-04 |

TABLE I. - Concluded. CONCENTRATIONS OF SPECIES IN SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(m) Concluded. Pressure, $1.01325\times10^{8}$ N/m$^2$ (1000 atm)

| Temperature, T | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | H | $H^+$ | $e^-$ | $H_2$ | $H^-$ | $H_2^+$ | $H_3^+$ |
| | | Dimensionless concentration, $n_iN_o/VL_o$ | | | | | | |
| 13000.00 | 23400.00 | 2.023E+01 | 1.531E-01 | 1.527E-01 | 4.790E-01 | 1.154E-02 | 1.075E-02 | 4.648E-04 |
| 13500.00 | 24300.00 | 1.946E+01 | 1.965E-01 | 1.960E-01 | 3.896E-01 | 1.312E-02 | 1.218E-02 | 4.501E-04 |
| 14000.00 | 25200.00 | 1.872E+01 | 2.477E-01 | 2.471E-01 | 3.197E-01 | 1.471E-02 | 1.362E-02 | 4.353E-04 |
| 15000.00 | 27000.00 | 1.729E+01 | 3.754E-01 | 3.744E-01 | 2.197E-01 | 1.776E-02 | 1.639E-02 | 4.040E-04 |
| 16000.00 | 28800.00 | 1.592E+01 | 5.380E-01 | 5.367E-01 | 1.543E-01 | 2.047E-02 | 1.886E-02 | 3.692E-04 |
| 17000.00 | 30600.00 | 1.462E+01 | 7.353E-01 | 7.338E-01 | 1.100E-01 | 2.265E-02 | 2.086E-02 | 3.309E-04 |
| 18000.00 | 32400.00 | 1.335E+01 | 9.641E-01 | 9.625E-01 | 7.912E-02 | 2.414E-02 | 2.223E-02 | 2.895E-04 |
| 19000.00 | 34200.00 | 1.215E+01 | 1.219E+00 | 1.217E+00 | 5.716E-02 | 2.485E-02 | 2.290E-02 | 2.463E-04 |
| 20000.00 | 36000.00 | 1.098E+01 | 1.491E+00 | 1.490E+00 | 4.136E-02 | 2.475E-02 | 2.285E-02 | 2.034E-04 |
| 21000.00 | 37800.00 | 9.855E+00 | 1.773E+00 | 1.771E+00 | 2.988E-02 | 2.393E-02 | 2.212E-02 | 1.629E-04 |
| 22000.00 | 39600.00 | 8.788E+00 | 2.053E+00 | 2.051E+00 | 2.153E-02 | 2.250E-02 | 2.083E-02 | 1.262E-04 |
| 23000.00 | 41400.00 | 7.786E+00 | 2.322E+00 | 2.321E+00 | 1.544E-02 | 2.060E-02 | 1.911E-02 | 9.471E-05 |
| 24000.00 | 43200.00 | 6.855E+00 | 2.572E+00 | 2.570E+00 | 1.101E-02 | 1.840E-02 | 1.711E-02 | 6.879E-05 |
| 25000.00 | 45000.00 | 6.001E+00 | 2.796E+00 | 2.795E+00 | 7.830E-03 | 1.610E-02 | 1.500E-02 | 4.853E-05 |
| 26000.00 | 46800.00 | 5.227E+00 | 2.991E+00 | 2.990E+00 | 5.544E-03 | 1.382E-02 | 1.290E-02 | 3.329E-05 |
| 27000.00 | 48600.00 | 4.533E+00 | 3.154E+00 | 3.154E+00 | 3.913E-03 | 1.167E-02 | 1.091E-02 | 2.221E-05 |
| 28000.00 | 50400.00 | 3.918E+00 | 3.286E+00 | 3.285E+00 | 2.756E-03 | 9.715E-03 | 9.107E-03 | 1.455E-05 |
| 29000.00 | 52200.00 | 3.379E+00 | 3.386E+00 | 3.386E+00 | 1.939E-03 | 7.997E-03 | 7.511E-03 | 9.460E-06 |
| 30000.00 | 54000.00 | 2.909E+00 | 3.458E+00 | 3.458E+00 | 1.365E-03 | 6.522E-03 | 6.138E-03 | 6.095E-06 |
| 32000.00 | 57600.00 | 2.155E+00 | 3.529E+00 | 3.529E+00 | 6.803E-04 | 4.256E-03 | 4.020E-03 | 2.495E-06 |
| 34000.00 | 61200.00 | 1.603E+00 | 3.525E+00 | 3.525E+00 | 3.449E-04 | 2.739E-03 | 2.596E-03 | 1.018E-06 |
| 36000.00 | 64800.00 | 1.205E+00 | 3.470E+00 | 3.470E+00 | 1.795E-04 | 1.757E-03 | 1.671E-03 | 4.202E-07 |
| 38000.00 | 68400.00 | 9.231E-01 | 3.380E+00 | 3.380E+00 | 9.629E-05 | 1.130E-03 | 1.078E-03 | 1.764E-07 |
| 40000.00 | 72000.00 | 7.194E-01 | 3.273E+00 | 3.273E+00 | 5.331E-05 | 7.349E-04 | 7.033E-04 | 7.629E-08 |
| 43000.00 | 77400.00 | 5.108E-01 | 3.102E+00 | 3.102E+00 | 2.325E-05 | 3.960E-04 | 3.805E-04 | 2.308E-08 |
| 46000.00 | 82800.00 | 3.756E-01 | 2.932E+00 | 2.932E+00 | 1.083E-05 | 2.213E-04 | 2.134E-04 | 7.549E-09 |
| 50000.00 | 90000.00 | 2.640E-01 | 2.718E+00 | 2.718E+00 | 4.378E-06 | 1.076E-04 | 1.043E-04 | 1.904E-09 |
| 55000.00 | 99000.00 | 1.825E-01 | 2.482E+00 | 2.482E+00 | 1.578E-06 | 4.754E-05 | 4.627E-05 | 4.023E-10 |
| 60000.00 | 108000.00 | 1.326E-01 | 2.279E+00 | 2.279E+00 | | 2.281E-05 | 2.229E-05 | |
| 65000.00 | 117000.00 | 9.996E-02 | 2.106E+00 | 2.106E+00 | | 1.174E-05 | 1.151E-05 | |
| 70000.00 | 126000.00 | 8.004E-02 | 1.955E+00 | 1.955E+00 | | 6.393E-06 | 6.290E-06 | |
| 80000.00 | 144000.00 | 5.507E-02 | 1.709E+00 | 1.709E+00 | | 2.193E-06 | 2.169E-06 | |
| 90000.00 | 162000.00 | 4.099E-02 | 1.517E+00 | 1.517E+00 | | 8.741E-07 | 8.681E-07 | |
| 100000.00 | 180000.00 | 3.112E-02 | 1.365E+00 | 1.365E+00 | | 3.914E-07 | 3.901E-07 | |
| 110000.00 | 198000.00 | 2.493E-02 | 1.240E+00 | 1.240E+00 | | 1.917E-07 | 1.916E-07 | |

TABLE II. - THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(a) Pressure, $1.01325\times10^{2}$ N/m$^2$ (0.001 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 100.00 | 180.0 | -2.1284E+05 | -9.1537E+04 | 78.41 | 18.734 | 2.0156 | 13.967 | 3.337 | 2.456E-01 | 1.534E-05 | 1.419 |
| 150.00 | 270.0 | -2.1217E+05 | -9.1250E+04 | 83.84 | 20.031 | 2.0156 | 13.174 | 3.148 | 1.638E-01 | 1.022E-05 | 1.456 |
| 200.00 | 360.0 | -2.1150E+05 | -9.0963E+04 | 87.68 | 20.949 | 2.0156 | 13.619 | 3.254 | 1.228E-01 | 7.668E-06 | 1.434 |
| 250.00 | 450.0 | -2.1081E+05 | -9.0665E+04 | 90.77 | 21.687 | 2.0156 | 14.064 | 3.360 | 9.826E-02 | 6.134E-06 | 1.415 |
| 298.15 | 536.7 | -2.1013E+05 | -9.0371E+04 | 93.27 | 22.285 | 2.0156 | 14.299 | 3.417 | 8.239E-02 | 5.143E-06 | 1.405 |
| 400.00 | 720.0 | -2.0866E+05 | -8.9739E+04 | 97.50 | 23.296 | 2.0156 | 14.479 | 3.460 | 6.141E-02 | 3.834E-06 | 1.398 |
| 500.00 | 900.0 | -2.0721E+05 | -8.9116E+04 | 100.74 | 24.070 | 2.0156 | 14.519 | 3.469 | 4.913E-02 | 3.067E-06 | 1.397 |
| 600.00 | 1080.0 | -2.0576E+05 | -8.8491E+04 | 103.39 | 24.703 | 2.0156 | 14.550 | 3.476 | 4.094E-02 | 2.556E-06 | 1.396 |
| 700.00 | 1260.0 | -2.0430E+05 | -8.7864E+04 | 105.63 | 25.239 | 2.0156 | 14.607 | 3.490 | 3.509E-02 | 2.191E-06 | 1.394 |
| 800.00 | 1440.0 | -2.0283E+05 | -8.7234E+04 | 107.59 | 25.707 | 2.0156 | 14.696 | 3.511 | 3.071E-02 | 1.917E-06 | 1.390 |
| 900.00 | 1620.0 | -2.0136E+05 | -8.6599E+04 | 109.33 | 26.122 | 2.0156 | 14.825 | 3.542 | 2.729E-02 | 1.704E-06 | 1.386 |
| 1000.00 | 1800.0 | -1.9987E+05 | -8.5958E+04 | 110.90 | 26.497 | 2.0156 | 14.985 | 3.580 | 2.456E-02 | 1.534E-06 | 1.380 |
| 1100.00 | 1980.0 | -1.9835E+05 | -8.5310E+04 | 112.34 | 26.840 | 2.0156 | 15.173 | 3.625 | 2.233E-02 | 1.394E-06 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 113.66 | 27.158 | 2.0156 | 15.389 | 3.677 | 2.047E-02 | 1.278E-06 | 1.366 |
| 1300.00 | 2340.0 | -1.9528E+05 | -8.3986E+04 | 114.91 | 27.455 | 2.0156 | 15.650 | 3.739 | 1.890E-02 | 1.180E-06 | 1.358 |
| 1400.00 | 2520.0 | -1.9370E+05 | -8.3305E+04 | 116.08 | 27.735 | 2.0155 | 16.042 | 3.833 | 1.754E-02 | 1.095E-06 | 1.347 |
| 1500.00 | 2700.0 | -1.9205E+05 | -8.2601E+04 | 117.21 | 28.005 | 2.0151 | 16.769 | 4.007 | 1.637E-02 | 1.022E-06 | 1.330 |
| 1600.00 | 2880.0 | -1.9032E+05 | -8.1852E+04 | 118.33 | 28.273 | 2.0139 | 18.265 | 4.364 | 1.534E-02 | 9.576E-07 | 1.302 |
| 1700.00 | 3060.0 | -1.8835E+05 | -8.1008E+04 | 119.52 | 28.557 | 2.0110 | 21.335 | 5.098 | 1.442E-02 | 9.000E-07 | 1.261 |
| 1800.00 | 3240.0 | -1.8595E+05 | -7.9976E+04 | 120.89 | 28.885 | 2.0043 | 27.284 | 6.519 | 1.357E-02 | 8.472E-07 | 1.214 |
| 1900.00 | 3420.0 | -1.8274E+05 | -7.8592E+04 | 122.63 | 29.300 | 1.9908 | 38.075 | 9.097 | 1.277E-02 | 7.971E-07 | 1.171 |
| 2000.00 | 3600.0 | -1.7809E+05 | -7.6593E+04 | 125.01 | 29.868 | 1.9653 | 56.409 | 13.478 | 1.198E-02 | 7.476E-07 | 1.139 |
| 2100.00 | 3780.0 | -1.7109E+05 | -7.3583E+04 | 128.42 | 30.683 | 1.9214 | 85.692 | 20.475 | 1.115E-02 | 6.961E-07 | 1.120 |
| 2200.00 | 3960.0 | -1.6046E+05 | -6.9012E+04 | 133.35 | 31.862 | 1.8520 | 129.611 | 30.968 | 1.026E-02 | 6.404E-07 | 1.109 |
| 2300.00 | 4140.0 | -1.4460E+05 | -6.2189E+04 | 140.40 | 33.545 | 1.7516 | 190.541 | 45.526 | 9.281E-03 | 5.794E-07 | 1.105 |
| 2400.00 | 4320.0 | -1.2189E+05 | -5.2421E+04 | 150.05 | 35.852 | 1.6215 | 265.115 | 63.344 | 8.234E-03 | 5.140E-07 | 1.104 |
| 2500.00 | 4500.0 | -9.1672E+04 | -3.9426E+04 | 162.37 | 38.796 | 1.4732 | 336.108 | 80.307 | 7.181E-03 | 4.483E-07 | 1.106 |
| 2600.00 | 4680.0 | -5.5925E+04 | -2.4052E+04 | 176.39 | 42.145 | 1.3284 | 359.350 | 88.249 | 5.226E-03 | 3.887E-07 | 1.111 |
| 2700.00 | 4860.0 | -2.0018E+04 | -8.6093E+03 | 189.95 | 45.384 | 1.2392 | 337.733 | 80.695 | 5.458E-03 | 3.407E-07 | 1.119 |
| 2800.00 | 5040.0 | 9.9771E+03 | 4.2909E+03 | 200.86 | 47.992 | 1.1261 | 257.735 | 61.581 | 4.901E-03 | 3.060E-07 | 1.131 |
| 2900.00 | 5220.0 | 3.1412E+04 | 1.3509E+04 | 208.39 | 49.791 | 1.0748 | 173.352 | 41.422 | 4.517E-03 | 2.820E-07 | 1.151 |
| 3000.00 | 5400.0 | 4.5408E+04 | 1.9529E+04 | 213.14 | 50.927 | 1.0456 | 110.895 | 26.496 | 4.247E-03 | 2.652E-07 | 1.182 |
| 3100.00 | 5580.0 | 5.4386E+04 | 2.3390E+04 | 216.09 | 51.631 | 1.0294 | 72.110 | 17.229 | 4.047E-03 | 2.526E-07 | 1.229 |
| 3200.00 | 5760.0 | 6.0378E+04 | 2.5967E+04 | 218.00 | 52.086 | 1.0204 | 49.856 | 11.912 | 3.886E-03 | 2.426E-07 | 1.293 |
| 3400.00 | 5120.0 | 6.8041E+04 | 2.9263E+04 | 220.32 | 52.642 | 1.0124 | 30.460 | 7.278 | 3.629E-03 | 2.265E-07 | 1.441 |
| 3600.00 | 5480.0 | 7.3399E+04 | 3.1567E+04 | 221.86 | 53.008 | 1.0097 | 24.236 | 5.791 | 3.418E-03 | 2.134E-07 | 1.556 |
| 3800.00 | 5840.0 | 7.7995E+04 | 3.3544E+04 | 223.10 | 53.305 | 1.0087 | 22.079 | 5.275 | 3.235E-03 | 2.019E-07 | 1.617 |
| 4000.00 | 7200.0 | 8.2317E+04 | 3.5403E+04 | 224.21 | 53.570 | 1.0082 | 21.268 | 5.082 | 3.072E-03 | 1.918E-07 | 1.644 |
| 4200.00 | 7560.0 | 8.6534E+04 | 3.7216E+04 | 225.24 | 53.816 | 1.0080 | 20.949 | 5.005 | 2.925E-03 | 1.826E-07 | 1.655 |
| 4400.00 | 7920.0 | 9.0713E+04 | 3.9012E+04 | 226.21 | 54.048 | 1.0079 | 20.837 | 4.979 | 2.792E-03 | 1.743E-07 | 1.659 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 4600.00 | 8280.0 | 9.4875E+04 | 4.0804E+04 | 227.13 | 54.269 | 1.0079 | 20.839 | 4.979 | 2.670E-03 | 1.667E-07 | 1.658 |
| 4800.00 | 8640.0 | 9.9052E+04 | 4.2600E+04 | 228.02 | 54.482 | 1.0078 | 20.940 | 5.003 | 2.559E-03 | 1.597E-07 | 1.653 |
| 5000.00 | 9000.0 | 1.0325E+05 | 4.4410E+04 | 228.88 | 54.687 | 1.0077 | 21.163 | 5.057 | 2.456E-03 | 1.533E-07 | 1.643 |
| 5200.00 | 9360.0 | 1.0753E+05 | 4.6246E+04 | 229.72 | 54.887 | 1.0076 | 21.560 | 5.151 | 2.362E-03 | 1.474E-07 | 1.627 |
| 5400.00 | 9720.0 | 1.1190E+05 | 4.8126E+04 | 230.54 | 55.084 | 1.0075 | 22.214 | 5.308 | 2.274E-03 | 1.419E-07 | 1.602 |
| 5600.00 | 10080.0 | 1.1644E+05 | 5.0078E+04 | 231.37 | 55.281 | 1.0072 | 23.238 | 5.552 | 2.192E-03 | 1.368E-07 | 1.568 |
| 5800.00 | 10440.0 | 1.2123E+05 | 5.2139E+04 | 232.21 | 55.482 | 1.0067 | 24.783 | 5.921 | 2.115E-03 | 1.321E-07 | 1.524 |
| 6000.00 | 10800.0 | 1.2640E+05 | 5.4361E+04 | 233.09 | 55.691 | 1.0060 | 27.041 | 6.461 | 2.043E-03 | 1.276E-07 | 1.473 |
| 6300.00 | 11340.0 | 1.3524E+05 | 5.8161E+04 | 234.52 | 56.034 | 1.0041 | 32.301 | 7.718 | 1.942E-03 | 1.213E-07 | 1.391 |
| 6600.00 | 11880.0 | 1.4610E+05 | 6.2833E+04 | 236.20 | 56.436 | 1.0009 | 40.737 | 9.733 | 1.848E-03 | 1.154E-07 | 1.315 |
| 7000.00 | 12600.0 | 1.6575E+05 | 7.1289E+04 | 239.09 | 57.126 | 0.9931 | 59.202 | 14.145 | 1.729E-03 | 1.079E-07 | 1.235 |
| 7300.00 | 13140.0 | 1.8653E+05 | 8.0224E+04 | 241.99 | 57.820 | 0.9835 | 80.563 | 19.249 | 1.642E-03 | 1.025E-07 | 1.195 |
| 7600.00 | 13680.0 | 2.1495E+05 | 9.2444E+04 | 245.80 | 58.730 | 0.9692 | 110.445 | 26.389 | 1.554E-03 | 9.702E-08 | 1.167 |
| 8000.00 | 14400.0 | 2.6973E+05 | 1.1600E+05 | 252.82 | 60.406 | 0.9407 | 166.952 | 39.890 | 1.433E-03 | 8.947E-08 | 1.145 |
| 8300.00 | 14940.0 | 3.2803E+05 | 1.4108E+05 | 259.97 | 62.114 | 0.9109 | 223.950 | 53.509 | 1.338E-03 | 8.350E-08 | 1.135 |
| 8600.00 | 15480.0 | 4.0543E+05 | 1.7435E+05 | 269.11 | 64.300 | 0.8733 | 293.865 | 70.213 | 1.238E-03 | 7.727E-08 | 1.130 |
| 9000.00 | 16200.0 | 5.4417E+05 | 2.3403E+05 | 284.87 | 68.064 | 0.8122 | 401.727 | 95.985 | 1.100E-03 | 6.868E-08 | 1.127 |
| 9300.00 | 16740.0 | 6.7692E+05 | 2.9113E+05 | 299.37 | 71.529 | 0.7509 | 481.721 | 115.098 | 9.976E-04 | 6.228E-08 | 1.127 |
| 9600.00 | 17280.0 | 8.3131E+05 | 3.5753E+05 | 315.71 | 75.432 | 0.7089 | 542.660 | 129.658 | 9.004E-04 | 5.621E-08 | 1.129 |
| 10000.00 | 18000.0 | 1.0551E+06 | 4.5376E+05 | 338.54 | 80.888 | 0.6452 | 561.926 | 134.261 | 7.868E-04 | 4.912E-08 | 1.134 |
| 10500.00 | 18900.0 | 1.3177E+06 | 5.6672E+05 | 364.19 | 87.016 | 0.5846 | 470.399 | 112.393 | 6.790E-04 | 4.239E-08 | 1.146 |
| 11000.00 | 19800.0 | 1.5160E+06 | 6.5199E+05 | 382.66 | 91.430 | 0.5472 | 321.929 | 76.919 | 6.067E-04 | 3.788E-08 | 1.167 |
| 11500.00 | 20700.0 | 1.6446E+06 | 7.0731E+05 | 394.12 | 94.167 | 0.5268 | 200.626 | 47.936 | 5.587E-04 | 3.488E-08 | 1.204 |
| 12000.00 | 21600.0 | 1.7247E+06 | 7.4173E+05 | 400.94 | 95.798 | 0.5163 | 126.636 | 30.257 | 5.247E-04 | 3.276E-08 | 1.261 |
| 12500.00 | 22500.0 | 1.7769E+06 | 7.6421E+05 | 405.22 | 96.818 | 0.5109 | 86.663 | 20.706 | 4.985E-04 | 3.112E-08 | 1.337 |
| 13000.00 | 23400.0 | 1.8145E+06 | 7.8036E+05 | 408.16 | 97.523 | 0.5081 | 65.826 | 15.728 | 4.766E-04 | 2.975E-08 | 1.421 |
| 13500.00 | 24300.0 | 1.8444E+06 | 7.9322E+05 | 410.42 | 98.063 | 0.5065 | 54.927 | 13.124 | 4.575E-04 | 2.856E-08 | 1.497 |
| 14000.00 | 25200.0 | 1.8702E+06 | 8.0434E+05 | 412.30 | 98.512 | 0.5056 | 49.102 | 11.732 | 4.404E-04 | 2.749E-08 | 1.555 |
| 15000.00 | 27000.0 | 1.9164E+06 | 8.2418E+05 | 415.49 | 99.273 | 0.5048 | 44.097 | 10.536 | 4.103E-04 | 2.562E-08 | 1.622 |
| 16000.00 | 28800.0 | 1.9595E+06 | 8.4272E+05 | 418.27 | 99.938 | 0.5045 | 42.414 | 10.134 | 3.844E-04 | 2.400E-08 | 1.649 |
| 17000.00 | 30600.0 | 2.0015E+06 | 8.6080E+05 | 420.82 | 100.548 | 0.5043 | 41.784 | 9.983 | 3.617E-04 | 2.258E-08 | 1.659 |
| 18000.00 | 32400.0 | 2.0432E+06 | 8.7871E+05 | 423.20 | 101.116 | 0.5042 | 41.523 | 9.921 | 3.415E-04 | 2.132E-08 | 1.663 |
| 19000.00 | 34200.0 | 2.0846E+06 | 8.9654E+05 | 425.44 | 101.652 | 0.5042 | 41.404 | 9.893 | 3.235E-04 | 2.019E-08 | 1.665 |
| 20000.00 | 36000.0 | 2.1260E+06 | 9.1433E+05 | 427.57 | 102.159 | 0.5041 | 41.347 | 9.879 | 3.073E-04 | 1.918E-08 | 1.666 |
| 21000.00 | 37800.0 | 2.1673E+06 | 9.3211E+05 | 429.58 | 102.641 | 0.5041 | 41.316 | 9.872 | 2.926E-04 | 1.827E-08 | 1.666 |
| 22000.00 | 39600.0 | 2.2086E+06 | 9.4987E+05 | 431.51 | 103.100 | 0.5041 | 41.299 | 9.868 | 2.793E-04 | 1.744E-08 | 1.667 |
| 23000.00 | 41400.0 | 2.2499E+06 | 9.6763E+05 | 433.34 | 103.539 | 0.5041 | 41.289 | 9.865 | 2.671E-04 | 1.668E-08 | 1.667 |
| 24000.00 | 43200.0 | 2.2912E+06 | 9.8539E+05 | 435.10 | 103.958 | 0.5041 | 41.281 | 9.863 | 2.560E-04 | 1.598E-08 | 1.667 |
| 25000.00 | 45000.0 | 2.3325E+06 | 1.0031E+06 | 436.78 | 104.361 | 0.5041 | 41.276 | 9.862 | 2.458E-04 | 1.534E-08 | 1.667 |
| 26000.00 | 46800.0 | 2.3738E+06 | 1.0209E+06 | 438.40 | 104.748 | 0.5040 | 41.273 | 9.861 | 2.363E-04 | 1.475E-08 | 1.667 |
| 27000.00 | 48600.0 | 2.4150E+06 | 1.0386E+06 | 439.96 | 105.120 | 0.5040 | 41.270 | 9.861 | 2.275E-04 | 1.420E-08 | 1.667 |
| 28000.00 | 50400.0 | 2.4563E+06 | 1.0564E+06 | 441.46 | 105.479 | 0.5040 | 41.268 | 9.860 | 2.194E-04 | 1.370E-08 | 1.667 |
| 29000.00 | 52200.0 | 2.4976E+06 | 1.0741E+06 | 442.91 | 105.825 | 0.5040 | 41.267 | 9.860 | 2.118E-04 | 1.322E-08 | 1.667 |
| 30000.00 | 54000.0 | 2.5388E+06 | 1.0919E+06 | 444.31 | 106.159 | 0.5040 | 41.265 | 9.859 | 2.048E-04 | 1.278E-08 | 1.667 |
| 32000.00 | 57600.0 | 2.6214E+06 | 1.1274E+06 | 446.97 | 106.795 | 0.5040 | 41.263 | 9.859 | 1.920E-04 | 1.198E-08 | 1.667 |
| 34000.00 | 61200.0 | 2.7039E+06 | 1.1629E+06 | 449.47 | 107.393 | 0.5040 | 41.261 | 9.859 | 1.807E-04 | 1.128E-08 | 1.667 |
| 36000.00 | 64800.0 | 2.7864E+06 | 1.1984E+06 | 451.83 | 107.957 | 0.5040 | 41.260 | 9.858 | 1.706E-04 | 1.065E-08 | 1.667 |
| 38000.00 | 68400.0 | 2.8689E+06 | 1.2339E+06 | 454.06 | 108.490 | 0.5040 | 41.259 | 9.858 | 1.616E-04 | 1.009E-08 | 1.667 |
| 40000.00 | 72000.0 | 2.9514E+06 | 1.2693E+06 | 456.18 | 108.995 | 0.5040 | 41.257 | 9.858 | 1.536E-04 | 9.586E-09 | 1.667 |
| 43000.00 | 77400.0 | 3.0752E+06 | 1.3226E+06 | 459.16 | 109.708 | 0.5040 | 41.257 | 9.857 | 1.428E-04 | 8.917E-09 | 1.667 |
| 46000.00 | 82800.0 | 3.1990E+06 | 1.3758E+06 | 461.94 | 110.373 | 0.5040 | 41.256 | 9.857 | 1.335E-04 | 8.335E-09 | 1.667 |
| 50000.00 | 90000.0 | 3.3643E+06 | 1.4468E+06 | 465.38 | 111.195 | 0.5039 | 41.254 | 9.857 | 1.228E-04 | 7.668E-09 | 1.667 |
| 55000.00 | 99000.0 | 3.5703E+06 | 1.5355E+06 | 469.32 | 112.134 | 0.5039 | 41.253 | 9.857 | 1.117E-04 | 6.971E-09 | 1.667 |
| 60000.00 | 108000.0 | 3.7765E+06 | 1.6242E+06 | 472.91 | 112.992 | 0.5039 | 41.252 | 9.856 | 1.024E-04 | 6.390E-09 | 1.667 |
| 65000.00 | 117000.0 | 3.9828E+06 | 1.7129E+06 | 476.21 | 113.781 | 0.5039 | 41.252 | 9.856 | 9.448E-05 | 5.899E-09 | 1.667 |
| 70000.00 | 126000.0 | 4.1890E+06 | 1.8016E+06 | 479.27 | 114.511 | 0.5039 | 41.252 | 9.855 | 8.774E-05 | 5.477E-09 | 1.667 |
| 80000.00 | 144000.0 | 4.6016E+06 | 1.9790E+06 | 484.77 | 115.827 | 0.5039 | 41.251 | 9.856 | 7.677E-05 | 4.792E-09 | 1.667 |
| 90000.00 | 162000.0 | 5.0141E+06 | 2.1564E+06 | 489.63 | 116.988 | 0.5039 | 41.250 | 9.856 | 6.824E-05 | 4.260E-09 | 1.667 |
| 100000.00 | 180000.0 | 5.4266E+06 | 2.3338E+06 | 493.98 | 118.027 | 0.5039 | 41.250 | 9.856 | 6.141E-05 | 3.834E-09 | 1.667 |
| 110000.00 | 198000.0 | 5.8391E+06 | 2.5112E+06 | 497.91 | 118.966 | 0.5039 | 41.250 | 9.855 | 5.583E-05 | 3.485E-09 | 1.667 |

TABLE II. - Continued. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(b) Pressure, $3.03975 \times 10^{2}$ N/m$^2$ (0.003 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 100.00 | 180.0 | -2.1284E+05 | -9.1537E+04 | 73.88 | 17.652 | 2.0156 | 13.956 | 3.334 | 7.369E-01 | 4.601E-05 | 1.420 |
| 150.00 | 270.0 | -2.1217E+05 | -9.1250E+04 | 79.30 | 18.948 | 2.0156 | 13.170 | 3.147 | 4.913E-01 | 3.067E-05 | 1.456 |
| 200.00 | 360.0 | -2.1150E+05 | -9.0963E+04 | 83.15 | 19.866 | 2.0156 | 13.614 | 3.253 | 3.685E-01 | 2.300E-05 | 1.435 |
| 250.00 | 450.0 | -2.1081E+05 | -9.0665E+04 | 86.24 | 20.605 | 2.0156 | 14.062 | 3.360 | 2.948E-01 | 1.840E-05 | 1.415 |
| 298.15 | 536.7 | -2.1013E+05 | -9.0371E+04 | 88.74 | 21.202 | 2.0156 | 14.303 | 3.417 | 2.472E-01 | 1.543E-05 | 1.405 |
| 400.00 | 720.0 | -2.0866E+05 | -8.9739E+04 | 92.97 | 22.214 | 2.0156 | 14.479 | 3.460 | 1.842E-01 | 1.150E-05 | 1.398 |
| 500.00 | 900.0 | -2.0721E+05 | -8.9116E+04 | 96.21 | 22.987 | 2.0156 | 14.516 | 3.468 | 1.474E-01 | 9.201E-06 | 1.397 |
| 600.00 | 1080.0 | -2.0575E+05 | -8.8491E+04 | 98.86 | 23.620 | 2.0156 | 14.546 | 3.475 | 1.228E-01 | 7.668E-06 | 1.396 |
| 700.00 | 1260.0 | -2.0430E+05 | -8.7864E+04 | 101.10 | 24.157 | 2.0156 | 14.606 | 3.490 | 1.053E-01 | 5.572E-06 | 1.394 |
| 800.00 | 1440.0 | -2.0283E+05 | -8.7234E+04 | 103.06 | 24.624 | 2.0156 | 14.697 | 3.512 | 9.212E-02 | 5.751E-06 | 1.390 |
| 900.00 | 1620.0 | -2.0136E+05 | -8.6599E+04 | 104.80 | 25.039 | 2.0156 | 14.826 | 3.542 | 8.188E-02 | 5.112E-06 | 1.385 |
| 1000.00 | 1800.0 | -1.9987E+05 | -8.5958E+04 | 106.37 | 25.414 | 2.0156 | 14.986 | 3.581 | 7.369E-02 | 4.601E-06 | 1.380 |
| 1100.00 | 1980.0 | -1.9836E+05 | -8.5310E+04 | 107.80 | 25.758 | 2.0156 | 15.172 | 3.625 | 6.699E-02 | 4.182E-06 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 109.13 | 26.075 | 2.0156 | 15.383 | 3.675 | 6.141E-02 | 3.834E-06 | 1.366 |
| 1300.00 | 2340.0 | -1.9528E+05 | -8.3986E+04 | 110.37 | 26.372 | 2.0156 | 15.624 | 3.733 | 5.669E-02 | 3.539E-06 | 1.359 |
| 1400.00 | 2520.0 | -1.9371E+05 | -8.3308E+04 | 111.54 | 26.651 | 2.0156 | 15.942 | 3.809 | 5.264E-02 | 3.286E-06 | 1.350 |
| 1500.00 | 2700.0 | -1.9209E+05 | -8.2612E+04 | 112.66 | 26.917 | 2.0153 | 16.454 | 3.931 | 4.912E-02 | 3.067E-06 | 1.337 |
| 1600.00 | 2880.0 | -1.9040E+05 | -8.1886E+04 | 113.75 | 27.178 | 2.0147 | 17.407 | 4.159 | 4.604E-02 | 2.874E-06 | 1.317 |
| 1700.00 | 3060.0 | -1.8859E+05 | -8.1102E+04 | 114.85 | 27.442 | 2.0130 | 19.266 | 4.603 | 4.329E-02 | 2.703E-06 | 1.287 |
| 1800.00 | 3240.0 | -1.8649E+05 | -8.0206E+04 | 116.04 | 27.726 | 2.0091 | 22.785 | 5.444 | 4.081E-02 | 2.548E-06 | 1.247 |
| 1900.00 | 3420.0 | -1.8393E+05 | -7.9103E+04 | 117.43 | 28.057 | 2.0012 | 29.096 | 6.952 | 3.851E-02 | 2.404E-06 | 1.205 |
| 2000.00 | 3600.0 | -1.8053E+05 | -7.7641E+04 | 119.17 | 28.473 | 1.9863 | 39.771 | 9.502 | 3.631E-02 | 2.267E-06 | 1.168 |
| 2100.00 | 3780.0 | -1.7576E+05 | -7.5590E+04 | 121.49 | 29.028 | 1.9601 | 56.830 | 13.578 | 3.413E-02 | 2.130E-06 | 1.141 |
| 2200.00 | 3960.0 | -1.6887E+05 | -7.2627E+04 | 124.69 | 29.793 | 1.9175 | 82.669 | 19.752 | 3.187E-02 | 1.989E-06 | 1.124 |
| 2300.00 | 4140.0 | -1.5885E+05 | -6.8319E+04 | 129.14 | 30.855 | 1.8532 | 119.714 | 28.603 | 2.946E-02 | 1.839E-06 | 1.115 |
| 2400.00 | 4320.0 | -1.4450E+05 | -6.2147E+04 | 135.24 | 32.313 | 1.7632 | 169.384 | 40.471 | 2.686E-02 | 1.677E-06 | 1.110 |
| 2500.00 | 4500.0 | -1.2462E+05 | -5.3595E+04 | 143.35 | 34.250 | 1.6483 | 229.579 | 54.853 | 2.410E-02 | 1.505E-06 | 1.109 |
| 2600.00 | 4680.0 | -9.8559E+04 | -4.2388E+04 | 153.56 | 36.690 | 1.5160 | 290.218 | 69.342 | 2.132E-02 | 1.331E-06 | 1.111 |
| 2700.00 | 4860.0 | -6.7251E+04 | -2.8923E+04 | 165.37 | 39.512 | 1.3815 | 330.339 | 78.928 | 1.871E-02 | 1.168E-06 | 1.115 |
| 2800.00 | 5040.0 | -3.3958E+04 | -1.4605E+04 | 177.48 | 42.405 | 1.2622 | 327.096 | 78.153 | 1.648E-02 | 1.029E-06 | 1.122 |
| 2900.00 | 5220.0 | -3.3869E+03 | -1.4566E+03 | 188.21 | 44.970 | 1.1702 | 278.144 | 66.457 | 1.475E-02 | 9.210E-07 | 1.131 |
| 3000.00 | 5400.0 | 2.0961E+04 | 9.0147E+03 | 196.47 | 46.943 | 1.1072 | 207.882 | 49.669 | 1.349E-02 | 8.423E-07 | 1.145 |
| 3100.00 | 5580.0 | 3.8413E+04 | 1.6519E+04 | 202.20 | 48.312 | 1.0675 | 143.601 | 34.311 | 1.259E-02 | 7.860E-07 | 1.167 |
| 3200.00 | 5760.0 | 5.0280E+04 | 2.1624E+04 | 205.97 | 49.213 | 1.0437 | 96.913 | 23.156 | 1.192E-02 | 7.444E-07 | 1.200 |
| 3400.00 | 5120.0 | 6.4044E+04 | 2.7544E+04 | 210.16 | 50.213 | 1.0214 | 48.595 | 11.611 | 1.098E-02 | 6.857E-07 | 1.303 |
| 3600.00 | 5480.0 | 7.1730E+04 | 3.0849E+04 | 212.36 | 50.739 | 1.0134 | 31.222 | 7.460 | 1.029E-02 | 6.425E-07 | 1.435 |
| 3800.00 | 5840.0 | 7.7244E+04 | 3.3221E+04 | 213.85 | 51.096 | 1.0103 | 24.936 | 5.958 | 9.720E-03 | 6.068E-07 | 1.542 |
| 4000.00 | 7200.0 | 8.1953E+04 | 3.5246E+04 | 215.06 | 51.385 | 1.0090 | 22.520 | 5.381 | 9.223E-03 | 5.758E-07 | 1.605 |
| 4200.00 | 7560.0 | 8.6344E+04 | 3.7134E+04 | 216.13 | 51.641 | 1.0084 | 21.528 | 5.144 | 8.778E-03 | 5.480E-07 | 1.636 |
| 4400.00 | 7920.0 | 9.0601E+04 | 3.8965E+04 | 217.12 | 51.877 | 1.0082 | 21.105 | 5.043 | 8.377E-03 | 5.230E-07 | 1.650 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4600.00 | 8280.0 | 9.4802E+04 | 4.0772E+04 | 218.06 | 52.100 | 1.0080 | 20.938 | 5.003 | 8.012E-03 | 5.001E-07 | 1.655 |
| 4800.00 | 8640.0 | 9.8985E+04 | 4.2571E+04 | 218.95 | 52.313 | 1.0079 | 20.912 | 4.996 | 7.677E-03 | 4.793E-07 | 1.655 |
| 5000.00 | 9000.0 | 1.0317E+05 | 4.4373E+04 | 219.80 | 52.517 | 1.0078 | 20.996 | 5.017 | 7.369E-03 | 4.601E-07 | 1.651 |
| 5200.00 | 9360.0 | 1.0739E+05 | 4.6187E+04 | 220.63 | 52.715 | 1.0078 | 21.201 | 5.066 | 7.085E-03 | 4.423E-07 | 1.642 |
| 5400.00 | 9720.0 | 1.1167E+05 | 4.8025E+04 | 221.43 | 52.908 | 1.0076 | 21.565 | 5.153 | 6.822E-03 | 4.259E-07 | 1.627 |
| 5600.00 | 10080.0 | 1.1603E+05 | 4.9903E+04 | 222.23 | 53.097 | 1.0075 | 22.148 | 5.292 | 6.577E-03 | 4.106E-07 | 1.605 |
| 5800.00 | 10440.0 | 1.2054E+05 | 5.1843E+04 | 223.02 | 53.286 | 1.0072 | 23.035 | 5.504 | 6.349E-03 | 3.963E-07 | 1.575 |
| 6000.00 | 10800.0 | 1.2527E+05 | 5.3877E+04 | 223.82 | 53.478 | 1.0068 | 24.336 | 5.815 | 6.135E-03 | 3.830E-07 | 1.537 |
| 6300.00 | 11340.0 | 1.3299E+05 | 5.7197E+04 | 225.08 | 53.778 | 1.0057 | 27.372 | 6.540 | 5.836E-03 | 3.643E-07 | 1.468 |
| 6600.00 | 11880.0 | 1.4188E+05 | 6.1019E+04 | 226.45 | 54.107 | 1.0038 | 32.243 | 7.704 | 5.561E-03 | 3.471E-07 | 1.394 |
| 7000.00 | 12600.0 | 1.5672E+05 | 6.7403E+04 | 228.63 | 54.628 | 0.9993 | 42.914 | 10.253 | 5.219E-03 | 3.258E-07 | 1.304 |
| 7300.00 | 13140.0 | 1.7134E+05 | 7.3690E+04 | 230.68 | 55.116 | 0.9936 | 55.271 | 13.206 | 4.976E-03 | 3.107E-07 | 1.250 |
| 7600.00 | 13680.0 | 1.9038E+05 | 8.1878E+04 | 233.23 | 55.726 | 0.9851 | 72.599 | 17.346 | 4.739E-03 | 2.959E-07 | 1.210 |
| 8000.00 | 14400.0 | 2.2560E+05 | 9.7026E+04 | 237.74 | 56.803 | 0.9678 | 105.607 | 25.233 | 4.423E-03 | 2.761E-07 | 1.175 |
| 8300.00 | 14940.0 | 2.6215E+05 | 1.1274E+05 | 242.22 | 57.874 | 0.9492 | 139.466 | 33.323 | 4.182E-03 | 2.611E-07 | 1.158 |
| 8600.00 | 15480.0 | 3.1018E+05 | 1.3340E+05 | 247.90 | 59.231 | 0.9248 | 182.365 | 43.573 | 3.932E-03 | 2.455E-07 | 1.147 |
| 9000.00 | 16200.0 | 3.9697E+05 | 1.7073E+05 | 257.75 | 61.585 | 0.8825 | 254.316 | 60.764 | 3.586E-03 | 2.239E-07 | 1.138 |
| 9300.00 | 16740.0 | 4.8263E+05 | 2.0757E+05 | 267.11 | 63.821 | 0.8437 | 317.826 | 75.939 | 3.318E-03 | 2.072E-07 | 1.135 |
| 9600.00 | 17280.0 | 5.8805E+05 | 2.5290E+05 | 278.26 | 66.485 | 0.8000 | 385.020 | 91.993 | 3.049E-03 | 1.903E-07 | 1.134 |
| 10000.00 | 18000.0 | 7.5889E+05 | 3.2638E+05 | 295.69 | 70.649 | 0.7379 | 465.647 | 111.257 | 2.700E-03 | 1.685E-07 | 1.135 |
| 10500.00 | 18900.0 | 1.0068E+06 | 4.3301E+05 | 319.87 | 76.427 | 0.6633 | 511.943 | 122.319 | 2.312E-03 | 1.443E-07 | 1.139 |
| 11000.00 | 19800.0 | 1.2548E+06 | 5.3966E+05 | 342.95 | 81.942 | 0.6032 | 464.617 | 111.011 | 2.007E-03 | 1.253E-07 | 1.149 |
| 11500.00 | 20700.0 | 1.4605E+06 | 6.2814E+05 | 361.26 | 86.317 | 0.5621 | 353.031 | 84.350 | 1.789E-03 | 1.117E-07 | 1.166 |
| 12000.00 | 21600.0 | 1.6078E+06 | 6.9149E+05 | 373.82 | 89.317 | 0.5373 | 240.058 | 57.357 | 1.639E-03 | 1.023E-07 | 1.193 |
| 12500.00 | 22500.0 | 1.7060E+06 | 7.3372E+05 | 381.85 | 91.235 | 0.5232 | 158.583 | 37.890 | 1.532E-03 | 9.564E-08 | 1.235 |
| 13000.00 | 23400.0 | 1.7717E+06 | 7.6197E+05 | 387.01 | 92.468 | 0.5154 | 108.620 | 25.953 | 1.451E-03 | 9.058E-08 | 1.293 |
| 13500.00 | 24300.0 | 1.8182E+06 | 7.8196E+05 | 390.52 | 93.307 | 0.5110 | 79.999 | 19.114 | 1.385E-03 | 8.648E-08 | 1.364 |
| 14000.00 | 25200.0 | 1.8538E+06 | 7.9726E+05 | 393.11 | 93.926 | 0.5085 | 63.905 | 15.269 | 1.329E-03 | 8.297E-08 | 1.437 |
| 15000.00 | 27000.0 | 1.9092E+06 | 8.2111E+05 | 396.94 | 94.842 | 0.5061 | 49.574 | 11.845 | 1.235E-03 | 7.707E-08 | 1.553 |
| 16000.00 | 28800.0 | 1.9559E+06 | 8.4119E+05 | 399.96 | 95.562 | 0.5052 | 44.644 | 10.667 | 1.155E-03 | 7.212E-08 | 1.616 |
| 17000.00 | 30600.0 | 1.9995E+06 | 8.5993E+05 | 402.60 | 96.194 | 0.5048 | 42.780 | 10.222 | 1.086E-03 | 6.781E-08 | 1.644 |
| 18000.00 | 32400.0 | 2.0418E+06 | 8.7814E+05 | 405.02 | 96.772 | 0.5045 | 42.011 | 10.038 | 1.025E-03 | 6.401E-08 | 1.656 |
| 19000.00 | 34200.0 | 2.0836E+06 | 8.9612E+05 | 407.28 | 97.312 | 0.5044 | 41.665 | 9.955 | 9.711E-04 | 6.063E-08 | 1.662 |
| 20000.00 | 36000.0 | 2.1252E+06 | 9.1400E+05 | 409.41 | 97.822 | 0.5043 | 41.497 | 9.915 | 9.224E-04 | 5.758E-08 | 1.664 |
| 21000.00 | 37800.0 | 2.1667E+06 | 9.3183E+05 | 411.44 | 98.305 | 0.5043 | 41.410 | 9.894 | 8.783E-04 | 5.483E-08 | 1.666 |
| 22000.00 | 39600.0 | 2.2080E+06 | 9.4963E+05 | 413.36 | 98.765 | 0.5042 | 41.362 | 9.883 | 8.383E-04 | 5.233E-08 | 1.666 |
| 23000.00 | 41400.0 | 2.2494E+06 | 9.6741E+05 | 415.20 | 99.204 | 0.5042 | 41.334 | 9.875 | 8.018E-04 | 5.005E-08 | 1.667 |
| 24000.00 | 43200.0 | 2.2907E+06 | 9.8518E+05 | 416.96 | 99.625 | 0.5042 | 41.315 | 9.871 | 7.683E-04 | 4.796E-08 | 1.667 |
| 25000.00 | 45000.0 | 2.3320E+06 | 1.0029E+06 | 418.65 | 100.028 | 0.5042 | 41.305 | 9.869 | 7.375E-04 | 4.604E-08 | 1.667 |
| 26000.00 | 46800.0 | 2.3733E+06 | 1.0207E+06 | 420.27 | 100.415 | 0.5041 | 41.295 | 9.867 | 7.091E-04 | 4.427E-08 | 1.667 |
| 27000.00 | 48600.0 | 2.4146E+06 | 1.0385E+06 | 421.83 | 100.787 | 0.5041 | 41.289 | 9.865 | 6.828E-04 | 4.263E-08 | 1.667 |
| 28000.00 | 50400.0 | 2.4559E+06 | 1.0562E+06 | 423.33 | 101.146 | 0.5041 | 41.285 | 9.864 | 6.584E-04 | 4.110E-08 | 1.667 |
| 29000.00 | 52200.0 | 2.4972E+06 | 1.0740E+06 | 424.78 | 101.492 | 0.5041 | 41.282 | 9.863 | 6.357E-04 | 3.968E-08 | 1.667 |
| 30000.00 | 54000.0 | 2.5385E+06 | 1.0917E+06 | 426.18 | 101.826 | 0.5041 | 41.279 | 9.863 | 6.144E-04 | 3.836E-08 | 1.667 |
| 32000.00 | 57600.0 | 2.6210E+06 | 1.1272E+06 | 428.84 | 102.463 | 0.5041 | 41.274 | 9.862 | 5.760E-04 | 3.596E-08 | 1.667 |
| 34000.00 | 61200.0 | 2.7036E+06 | 1.1627E+06 | 431.34 | 103.061 | 0.5040 | 41.270 | 9.861 | 5.421E-04 | 3.384E-08 | 1.667 |
| 36000.00 | 64800.0 | 2.7861E+06 | 1.1982E+06 | 433.70 | 103.624 | 0.5040 | 41.268 | 9.860 | 5.120E-04 | 3.196E-08 | 1.667 |
| 38000.00 | 68400.0 | 2.8685E+06 | 1.2337E+06 | 435.93 | 104.158 | 0.5040 | 41.266 | 9.860 | 4.850E-04 | 3.028E-08 | 1.667 |
| 40000.00 | 72000.0 | 2.9512E+06 | 1.2692E+06 | 438.05 | 104.663 | 0.5040 | 41.264 | 9.859 | 4.607E-04 | 2.876E-08 | 1.667 |
| 43000.00 | 77400.0 | 3.0750E+06 | 1.3225E+06 | 441.03 | 105.376 | 0.5040 | 41.262 | 9.859 | 4.286E-04 | 2.675E-08 | 1.667 |
| 46000.00 | 82800.0 | 3.1987E+06 | 1.3757E+06 | 443.82 | 106.041 | 0.5040 | 41.260 | 9.858 | 4.006E-04 | 2.501E-08 | 1.667 |
| 50000.00 | 90000.0 | 3.3638E+06 | 1.4467E+06 | 447.26 | 106.863 | 0.5040 | 41.258 | 9.858 | 3.685E-04 | 2.301E-08 | 1.667 |
| 55000.00 | 99000.0 | 3.5701E+06 | 1.5354E+06 | 451.19 | 107.803 | 0.5040 | 41.256 | 9.857 | 3.350E-04 | 2.091E-08 | 1.667 |
| 60000.00 | 108000.0 | 3.7764E+06 | 1.6241E+06 | 454.78 | 108.661 | 0.5040 | 41.256 | 9.857 | 3.071E-04 | 1.917E-08 | 1.667 |
| 65000.00 | 117000.0 | 3.9826E+06 | 1.7128E+06 | 458.08 | 109.450 | 0.5039 | 41.254 | 9.857 | 2.835E-04 | 1.770E-08 | 1.667 |
| 70000.00 | 126000.0 | 4.1889E+06 | 1.8015E+06 | 461.14 | 110.180 | 0.5039 | 41.254 | 9.857 | 2.632E-04 | 1.643E-08 | 1.667 |
| 80000.00 | 144000.0 | 4.6014E+06 | 1.9790E+06 | 466.65 | 111.496 | 0.5039 | 41.252 | 9.856 | 2.303E-04 | 1.438E-08 | 1.667 |
| 90000.00 | 162000.0 | 5.0139E+06 | 2.1564E+06 | 471.51 | 112.657 | 0.5039 | 41.252 | 9.856 | 2.047E-04 | 1.278E-08 | 1.667 |
| 100000.00 | 180000.0 | 5.4265E+06 | 2.3338E+06 | 475.85 | 113.696 | 0.5039 | 41.251 | 9.856 | 1.842E-04 | 1.150E-08 | 1.667 |
| 110000.00 | 198000.0 | 5.8390E+06 | 2.5112E+06 | 479.78 | 114.635 | 0.5039 | 41.250 | 9.856 | 1.675E-04 | 1.046E-08 | 1.667 |

TABLE II. - Continued. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(c) Pressure, $1.01325\times10^{3}$ N/m$^2$ (0.01 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 100.00 | 180.0 | -2.1284E+05 | -9.1537E+04 | 68.91 | 16.465 | 2.0156 | 13.967 | 3.337 | 2.456E+00 | 1.534E-04 | 1.419 |
| 150.00 | 270.0 | -2.1217E+05 | -9.1250E+04 | 74.34 | 17.762 | 2.0156 | 13.174 | 3.148 | 1.638E+00 | 1.022E-04 | 1.456 |
| 200.00 | 360.0 | -2.1150E+05 | -9.0963E+04 | 78.18 | 18.680 | 2.0155 | 13.617 | 3.253 | 1.228E+00 | 7.668E-05 | 1.435 |
| 250.00 | 450.0 | -2.1081E+05 | -9.0665E+04 | 81.27 | 19.418 | 2.0156 | 14.067 | 3.361 | 9.826E-01 | 6.134E-05 | 1.415 |
| 298.15 | 536.7 | -2.1013E+05 | -9.0371E+04 | 83.77 | 20.015 | 2.0156 | 14.301 | 3.417 | 8.239E-01 | 5.143E-05 | 1.405 |
| 400.00 | 720.0 | -2.0865E+05 | -8.9739E+04 | 88.01 | 21.027 | 2.0156 | 14.478 | 3.459 | 6.141E-01 | 3.834E-05 | 1.398 |
| 500.00 | 900.0 | -2.0721E+05 | -8.9116E+04 | 91.24 | 21.800 | 2.0156 | 14.517 | 3.468 | 4.913E-01 | 3.067E-05 | 1.397 |
| 600.00 | 1080.0 | -2.0575E+05 | -8.8491E+04 | 93.89 | 22.433 | 2.0156 | 14.548 | 3.476 | 4.094E-01 | 2.556E-05 | 1.396 |
| 700.00 | 1260.0 | -2.0430E+05 | -8.7864E+04 | 96.14 | 22.970 | 2.0156 | 14.606 | 3.490 | 3.509E-01 | 2.191E-05 | 1.394 |
| 800.00 | 1440.0 | -2.0283E+05 | -8.7234E+04 | 98.09 | 23.437 | 2.0156 | 14.697 | 3.512 | 3.071E-01 | 1.917E-05 | 1.390 |
| 900.00 | 1620.0 | -2.0135E+05 | -8.6599E+04 | 99.83 | 23.853 | 2.0156 | 14.826 | 3.542 | 2.729E-01 | 1.704E-05 | 1.385 |
| 1000.00 | 1800.0 | -1.9987E+05 | -8.5958E+04 | 101.40 | 24.228 | 2.0156 | 14.984 | 3.580 | 2.456E-01 | 1.534E-05 | 1.380 |
| 1100.00 | 1980.0 | -1.9835E+05 | -8.5310E+04 | 102.84 | 24.571 | 2.0156 | 15.171 | 3.625 | 2.233E-01 | 1.394E-05 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 104.17 | 24.889 | 2.0156 | 15.380 | 3.675 | 2.047E-01 | 1.278E-05 | 1.366 |
| 1300.00 | 2340.0 | -1.9528E+05 | -8.3987E+04 | 105.41 | 25.185 | 2.0156 | 15.609 | 3.729 | 1.890E-01 | 1.180E-05 | 1.359 |
| 1400.00 | 2520.0 | -1.9371E+05 | -8.3310E+04 | 106.57 | 25.463 | 2.0156 | 15.881 | 3.794 | 1.755E-01 | 1.095E-05 | 1.351 |
| 1500.00 | 2700.0 | -1.9210E+05 | -8.2619E+04 | 107.68 | 25.728 | 2.0155 | 16.259 | 3.885 | 1.637E-01 | 1.022E-05 | 1.341 |
| 1600.00 | 2880.0 | -1.9045E+05 | -8.1908E+04 | 108.75 | 25.983 | 2.0151 | 16.878 | 4.033 | 1.535E-01 | 9.582E-06 | 1.327 |
| 1700.00 | 3060.0 | -1.8871E+05 | -8.1161E+04 | 109.80 | 26.235 | 2.0142 | 17.988 | 4.298 | 1.444E-01 | 9.014E-06 | 1.306 |
| 1800.00 | 3240.0 | -1.8682E+05 | -8.0348E+04 | 110.88 | 26.493 | 2.0121 | 20.004 | 4.780 | 1.362E-01 | 8.504E-06 | 1.277 |
| 1900.00 | 3420.0 | -1.8466E+05 | -7.9418E+04 | 112.05 | 26.772 | 2.0077 | 23.548 | 5.626 | 1.288E-01 | 8.039E-06 | 1.241 |
| 2000.00 | 3600.0 | -1.8203E+05 | -7.8288E+04 | 113.39 | 27.093 | 1.9994 | 29.478 | 7.043 | 1.218E-01 | 7.606E-06 | 1.204 |
| 2100.00 | 3780.0 | -1.7865E+05 | -7.6832E+04 | 115.04 | 27.488 | 1.9848 | 38.914 | 9.298 | 1.152E-01 | 7.191E-06 | 1.172 |
| 2200.00 | 3960.0 | -1.7409E+05 | -7.4871E+04 | 117.16 | 27.994 | 1.9607 | 53.221 | 12.716 | 1.086E-01 | 6.780E-06 | 1.148 |
| 2300.00 | 4140.0 | -1.6779E+05 | -7.2163E+04 | 119.95 | 28.662 | 1.9230 | 73.936 | 17.666 | 1.019E-01 | 6.361E-06 | 1.132 |
| 2400.00 | 4320.0 | -1.5904E+05 | -6.8398E+04 | 123.68 | 29.551 | 1.8681 | 102.573 | 24.508 | 9.486E-02 | 5.922E-06 | 1.123 |
| 2500.00 | 4500.0 | -1.4698E+05 | -6.3212E+04 | 128.60 | 30.726 | 1.7929 | 140.103 | 33.475 | 8.740E-02 | 5.456E-06 | 1.118 |
| 2600.00 | 4680.0 | -1.3074E+05 | -5.6228E+04 | 134.96 | 32.246 | 1.6970 | 185.808 | 44.395 | 7.954E-02 | 4.966E-06 | 1.116 |
| 2700.00 | 4860.0 | -1.0969E+05 | -4.7173E+04 | 142.90 | 34.143 | 1.5842 | 235.244 | 56.207 | 7.151E-02 | 4.464E-06 | 1.117 |
| 2800.00 | 5040.0 | -8.3905E+04 | -3.6085E+04 | 152.27 | 36.382 | 1.4634 | 278.071 | 66.440 | 6.369E-02 | 3.976E-06 | 1.120 |
| 2900.00 | 5220.0 | -5.4797E+04 | -2.3567E+04 | 162.48 | 38.822 | 1.3467 | 299.166 | 71.480 | 5.659E-02 | 3.533E-06 | 1.125 |
| 3000.00 | 5400.0 | -2.5191E+04 | -1.0834E+04 | 172.52 | 41.221 | 1.2457 | 287.125 | 68.603 | 5.060E-02 | 3.159E-06 | 1.131 |
| 3100.00 | 5580.0 | 1.6173E+03 | 6.9558E+02 | 181.32 | 43.322 | 1.1672 | 245.202 | 58.586 | 4.589E-02 | 2.865E-06 | 1.141 |
| 3200.00 | 5760.0 | 2.3413E+04 | 1.0069E+04 | 188.24 | 44.976 | 1.1114 | 190.124 | 45.427 | 4.233E-02 | 2.642E-06 | 1.155 |
| 3400.00 | 5120.0 | 5.1555E+04 | 2.2172E+04 | 196.80 | 47.021 | 1.0505 | 99.020 | 23.659 | 3.765E-02 | 2.351E-06 | 1.204 |
| 3600.00 | 6480.0 | 6.6164E+04 | 2.8456E+04 | 200.99 | 48.022 | 1.0259 | 53.405 | 12.760 | 3.473E-02 | 2.168E-06 | 1.290 |
| 3800.00 | 5840.0 | 7.4673E+04 | 3.2115E+04 | 203.29 | 48.572 | 1.0160 | 34.510 | 8.246 | 3.258E-02 | 2.034E-06 | 1.403 |
| 4000.00 | 7200.0 | 8.0694E+04 | 3.4705E+04 | 204.84 | 48.942 | 1.0118 | 26.821 | 6.408 | 3.083E-02 | 1.924E-06 | 1.507 |
| 4200.00 | 7560.0 | 8.5689E+04 | 3.6853E+04 | 206.06 | 49.233 | 1.0099 | 23.567 | 5.631 | 2.930E-02 | 1.829E-06 | 1.578 |
| 4400.00 | 7920.0 | 9.0238E+04 | 3.8809E+04 | 207.11 | 49.486 | 1.0090 | 22.117 | 5.284 | 2.795E-02 | 1.745E-06 | 1.618 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4600.00 | 8280.0 | 9.4586E+04 | 4.0679E+04 | 208.08 | 49.717 | 1.0085 | 21.447 | 5.124 | 2.672E-02 | 1.668E-06 | 1.639 |
| 4800.00 | 8640.0 | 9.8841E+04 | 4.2509E+04 | 208.99 | 49.933 | 1.0082 | 21.143 | 5.052 | 2.560E-02 | 1.598E-06 | 1.649 |
| 5000.00 | 9000.0 | 1.0306E+05 | 4.4322E+04 | 209.85 | 50.139 | 1.0080 | 21.038 | 5.027 | 2.457E-02 | 1.534E-06 | 1.651 |
| 5200.00 | 9360.0 | 1.0726E+05 | 4.6132E+04 | 210.67 | 50.336 | 1.0079 | 21.067 | 5.034 | 2.362E-02 | 1.475E-06 | 1.649 |
| 5400.00 | 9720.0 | 1.1149E+05 | 4.7950E+04 | 211.47 | 50.526 | 1.0078 | 21.218 | 5.070 | 2.274E-02 | 1.420E-06 | 1.642 |
| 5600.00 | 10080.0 | 1.1576E+05 | 4.9786E+04 | 212.25 | 50.712 | 1.0077 | 21.510 | 5.139 | 2.193E-02 | 1.369E-06 | 1.630 |
| 5800.00 | 10440.0 | 1.2011E+05 | 5.1655E+04 | 213.01 | 50.894 | 1.0075 | 21.979 | 5.251 | 2.117E-02 | 1.322E-06 | 1.612 |
| 6000.00 | 10800.0 | 1.2457E+05 | 5.3574E+04 | 213.76 | 51.075 | 1.0073 | 22.681 | 5.419 | 2.046E-02 | 1.277E-06 | 1.587 |
| 6300.00 | 11340.0 | 1.3160E+05 | 5.6598E+04 | 214.91 | 51.348 | 1.0067 | 24.335 | 5.814 | 1.947E-02 | 1.216E-06 | 1.538 |
| 6600.00 | 11880.0 | 1.3927E+05 | 5.9897E+04 | 216.10 | 51.632 | 1.0056 | 27.000 | 6.451 | 1.857E-02 | 1.159E-06 | 1.477 |
| 7000.00 | 12600.0 | 1.5114E+05 | 6.5000E+04 | 217.84 | 52.049 | 1.0031 | 32.846 | 7.848 | 1.746E-02 | 1.090E-06 | 1.389 |
| 7300.00 | 13140.0 | 1.6195E+05 | 6.9649E+04 | 219.35 | 52.410 | 1.0000 | 39.623 | 9.457 | 1.669E-02 | 1.042E-06 | 1.328 |
| 7600.00 | 13680.0 | 1.7518E+05 | 7.5342E+04 | 221.13 | 52.834 | 0.9953 | 49.137 | 11.740 | 1.596E-02 | 9.963E-07 | 1.277 |
| 8000.00 | 14400.0 | 1.9824E+05 | 8.5257E+04 | 224.08 | 53.539 | 0.9855 | 67.310 | 16.082 | 1.501E-02 | 9.373E-07 | 1.225 |
| 8300.00 | 14940.0 | 2.2112E+05 | 9.5099E+04 | 226.89 | 54.210 | 0.9748 | 86.065 | 20.564 | 1.431E-02 | 8.936E-07 | 1.197 |
| 8600.00 | 15480.0 | 2.5040E+05 | 1.0769E+05 | 230.35 | 55.037 | 0.9604 | 110.105 | 26.307 | 1.361E-02 | 8.498E-07 | 1.177 |
| 9000.00 | 16200.0 | 3.0237E+05 | 1.3004E+05 | 236.25 | 56.447 | 0.9345 | 151.616 | 36.226 | 1.266E-02 | 7.902E-07 | 1.160 |
| 9300.00 | 16740.0 | 3.5351E+05 | 1.5203E+05 | 241.83 | 57.781 | 0.9095 | 190.435 | 45.501 | 1.192E-02 | 7.443E-07 | 1.152 |
| 9600.00 | 17280.0 | 4.1727E+05 | 1.7946E+05 | 248.58 | 59.393 | 0.8794 | 235.691 | 56.314 | 1.117E-02 | 6.973E-07 | 1.147 |
| 10000.00 | 18000.0 | 5.2494E+05 | 2.2576E+05 | 259.56 | 62.016 | 0.8323 | 303.709 | 72.566 | 1.015E-02 | 6.336E-07 | 1.143 |
| 10500.00 | 18900.0 | 6.9861E+05 | 3.0045E+05 | 276.49 | 66.061 | 0.7554 | 389.305 | 93.017 | 8.893E-03 | 5.552E-07 | 1.142 |
| 11000.00 | 19800.0 | 9.0984E+05 | 3.9130E+05 | 296.13 | 70.755 | 0.6973 | 448.232 | 107.097 | 7.736E-03 | 4.829E-07 | 1.145 |
| 11500.00 | 20700.0 | 1.1370E+06 | 4.8902E+05 | 316.33 | 75.581 | 0.6368 | 449.338 | 107.361 | 6.760E-03 | 4.220E-07 | 1.152 |
| 12000.00 | 21600.0 | 1.3437E+06 | 5.8003E+05 | 334.35 | 79.888 | 0.5901 | 388.698 | 92.872 | 6.003E-03 | 3.748E-07 | 1.164 |
| 12500.00 | 22500.0 | 1.5207E+06 | 6.5402E+05 | 348.42 | 83.247 | 0.5579 | 297.877 | 71.172 | 5.449E-03 | 3.402E-07 | 1.182 |
| 13000.00 | 23400.0 | 1.6477E+06 | 7.0862E+05 | 358.39 | 85.630 | 0.5374 | 212.965 | 50.884 | 5.047E-03 | 3.151E-07 | 1.209 |
| 13500.00 | 24300.0 | 1.7374E+06 | 7.4723E+05 | 365.17 | 87.251 | 0.5249 | 150.058 | 35.853 | 4.747E-03 | 2.964E-07 | 1.249 |
| 14000.00 | 25200.0 | 1.8013E+06 | 7.7471E+05 | 369.82 | 88.363 | 0.5174 | 108.747 | 25.983 | 4.512E-03 | 2.817E-07 | 1.300 |
| 15000.00 | 27000.0 | 1.8861E+06 | 8.1116E+05 | 375.69 | 89.764 | 0.5101 | 57.486 | 16.124 | 4.151E-03 | 2.591E-07 | 1.423 |
| 16000.00 | 28800.0 | 1.9447E+06 | 8.3636E+05 | 379.48 | 90.669 | 0.5072 | 52.129 | 12.455 | 3.868E-03 | 2.415E-07 | 1.531 |
| 17000.00 | 30600.0 | 1.9934E+06 | 8.5730E+05 | 382.43 | 91.375 | 0.5056 | 46.151 | 11.027 | 3.631E-03 | 2.267E-07 | 1.598 |
| 18000.00 | 32400.0 | 2.0381E+06 | 8.7654E+05 | 384.99 | 91.986 | 0.5053 | 43.649 | 10.429 | 3.425E-03 | 2.138E-07 | 1.633 |
| 19000.00 | 34200.0 | 2.0811E+06 | 8.9504E+05 | 387.32 | 92.542 | 0.5050 | 42.522 | 10.160 | 3.242E-03 | 2.024E-07 | 1.650 |
| 20000.00 | 36000.0 | 2.1233E+06 | 9.1319E+05 | 389.48 | 93.060 | 0.5048 | 41.979 | 10.030 | 3.078E-03 | 1.922E-07 | 1.658 |
| 21000.00 | 37800.0 | 2.1652E+06 | 9.3118E+05 | 391.52 | 93.547 | 0.5046 | 41.701 | 9.964 | 2.931E-03 | 1.830E-07 | 1.662 |
| 22000.00 | 39600.0 | 2.2069E+06 | 9.4908E+05 | 393.46 | 94.010 | 0.5045 | 41.548 | 9.927 | 2.797E-03 | 1.746E-07 | 1.665 |
| 23000.00 | 41400.0 | 2.2483E+06 | 9.6693E+05 | 395.31 | 94.451 | 0.5045 | 41.460 | 9.906 | 2.675E-03 | 1.670E-07 | 1.666 |
| 24000.00 | 43200.0 | 2.2897E+06 | 9.8475E+05 | 397.07 | 94.872 | 0.5044 | 41.408 | 9.894 | 2.563E-03 | 1.600E-07 | 1.666 |
| 25000.00 | 45000.0 | 2.3311E+06 | 1.0026E+06 | 398.76 | 95.276 | 0.5044 | 41.374 | 9.886 | 2.460E-03 | 1.536E-07 | 1.667 |
| 26000.00 | 46800.0 | 2.3725E+06 | 1.0203E+06 | 400.38 | 95.664 | 0.5043 | 41.351 | 9.880 | 2.365E-03 | 1.477E-07 | 1.667 |
| 27000.00 | 48600.0 | 2.4138E+06 | 1.0381E+06 | 401.94 | 96.037 | 0.5043 | 41.334 | 9.876 | 2.277E-03 | 1.422E-07 | 1.667 |
| 28000.00 | 50400.0 | 2.4551E+06 | 1.0559E+06 | 403.45 | 96.396 | 0.5043 | 41.323 | 9.873 | 2.196E-03 | 1.371E-07 | 1.667 |
| 29000.00 | 52200.0 | 2.4965E+06 | 1.0737E+06 | 404.90 | 96.742 | 0.5042 | 41.315 | 9.871 | 2.120E-03 | 1.323E-07 | 1.667 |
| 30000.00 | 54000.0 | 2.5378E+06 | 1.0914E+06 | 406.30 | 97.077 | 0.5042 | 41.308 | 9.870 | 2.049E-03 | 1.279E-07 | 1.667 |
| 32000.00 | 57600.0 | 2.6204E+06 | 1.1270E+06 | 408.96 | 97.714 | 0.5042 | 41.298 | 9.867 | 1.921E-03 | 1.199E-07 | 1.667 |
| 34000.00 | 61200.0 | 2.7030E+06 | 1.1625E+06 | 411.47 | 98.312 | 0.5041 | 41.290 | 9.866 | 1.808E-03 | 1.128E-07 | 1.667 |
| 36000.00 | 64800.0 | 2.7855E+06 | 1.1980E+06 | 413.83 | 98.876 | 0.5041 | 41.286 | 9.864 | 1.707E-03 | 1.066E-07 | 1.667 |
| 38000.00 | 68400.0 | 2.8681E+06 | 1.2335E+06 | 416.06 | 99.409 | 0.5041 | 41.282 | 9.864 | 1.617E-03 | 1.010E-07 | 1.667 |
| 40000.00 | 72000.0 | 2.9507E+06 | 1.2690E+06 | 418.18 | 99.915 | 0.5041 | 41.277 | 9.862 | 1.536E-03 | 9.590E-08 | 1.667 |
| 43000.00 | 77400.0 | 3.0745E+06 | 1.3223E+06 | 421.16 | 100.629 | 0.5041 | 41.273 | 9.861 | 1.429E-03 | 8.920E-08 | 1.667 |
| 46000.00 | 82800.0 | 3.1983E+06 | 1.3755E+06 | 423.95 | 101.294 | 0.5040 | 41.271 | 9.861 | 1.336E-03 | 8.338E-08 | 1.667 |
| 50000.00 | 90000.0 | 3.3634E+06 | 1.4465E+06 | 427.39 | 102.116 | 0.5040 | 41.266 | 9.860 | 1.229E-03 | 7.670E-08 | 1.667 |
| 55000.00 | 99000.0 | 3.5697E+06 | 1.5352E+06 | 431.32 | 103.056 | 0.5040 | 41.263 | 9.859 | 1.117E-03 | 6.973E-08 | 1.667 |
| 60000.00 | 108000.0 | 3.7760E+06 | 1.6240E+06 | 434.91 | 103.914 | 0.5040 | 41.261 | 9.859 | 1.024E-03 | 6.391E-08 | 1.667 |
| 65000.00 | 117000.0 | 3.9823E+06 | 1.7127E+06 | 438.21 | 104.703 | 0.5040 | 41.259 | 9.858 | 9.450E-04 | 5.899E-08 | 1.667 |
| 70000.00 | 126000.0 | 4.1886E+06 | 1.8014E+06 | 441.27 | 105.433 | 0.5040 | 41.257 | 9.858 | 8.775E-04 | 5.478E-08 | 1.667 |
| 80000.00 | 144000.0 | 4.6012E+06 | 1.9789E+06 | 446.78 | 106.749 | 0.5040 | 41.256 | 9.857 | 7.677E-04 | 4.793E-08 | 1.667 |
| 90000.00 | 162000.0 | 5.0137E+06 | 2.1563E+06 | 451.64 | 107.911 | 0.5039 | 41.254 | 9.857 | 6.824E-04 | 4.260E-08 | 1.667 |
| 100000.00 | 180000.0 | 5.4263E+06 | 2.3337E+06 | 455.99 | 108.949 | 0.5039 | 41.253 | 9.857 | 6.142E-04 | 3.834E-08 | 1.667 |
| 110000.00 | 198000.0 | 5.8389E+06 | 2.5111E+06 | 459.92 | 109.888 | 0.5039 | 41.252 | 9.856 | 5.583E-04 | 3.486E-08 | 1.667 |

TABLE II. - Continued. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(d) Pressure, $3.03975 \times 10^{3}$ N/m$^2$ (0.03 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 100.00 | 180.0 | -2.1284E+05 | -9.1537E+04 | 64.38 | 15.382 | 2.0156 | 13.961 | 3.336 | 7.369E+00 | 4.601E-04 | 1.419 |
| 150.00 | 270.0 | -2.1217E+05 | -9.1250E+04 | 69.81 | 16.679 | 2.0156 | 13.174 | 3.148 | 4.913E+00 | 3.067E-04 | 1.456 |
| 200.00 | 360.0 | -2.1150E+05 | -9.0963E+04 | 73.65 | 17.597 | 2.0156 | 13.614 | 3.253 | 3.685E+00 | 2.300E-04 | 1.435 |
| 250.00 | 450.0 | -2.1081E+05 | -9.0669E+04 | 76.74 | 18.335 | 2.0156 | 14.060 | 3.359 | 2.948E+00 | 1.840E-04 | 1.415 |
| 298.15 | 536.7 | -2.1013E+05 | -9.0371E+04 | 79.24 | 18.933 | 2.0156 | 14.299 | 3.417 | 2.472E+00 | 1.543E-04 | 1.405 |
| 400.00 | 720.0 | -2.0866E+05 | -8.9739E+04 | 83.47 | 19.944 | 2.0156 | 14.478 | 3.459 | 1.842E+00 | 1.150E-04 | 1.398 |
| 500.00 | 900.0 | -2.0721E+05 | -8.9116E+04 | 86.71 | 20.717 | 2.0156 | 14.517 | 3.468 | 1.474E+00 | 9.201E-05 | 1.397 |
| 600.00 | 1080.0 | -2.0576E+05 | -8.8491E+04 | 89.36 | 21.350 | 2.0156 | 14.548 | 3.476 | 1.228E+00 | 7.668E-05 | 1.396 |
| 700.00 | 1260.0 | -2.0430E+05 | -8.7864E+04 | 91.60 | 21.887 | 2.0156 | 14.604 | 3.489 | 1.053E+00 | 6.572E-05 | 1.394 |
| 800.00 | 1440.0 | -2.0283E+05 | -8.7234E+04 | 93.56 | 22.355 | 2.0156 | 14.695 | 3.511 | 9.212E-01 | 5.751E-05 | 1.390 |
| 900.00 | 1620.0 | -2.0136E+05 | -8.6599E+04 | 95.30 | 22.770 | 2.0156 | 14.825 | 3.542 | 8.188E-01 | 5.112E-05 | 1.386 |
| 1000.00 | 1800.0 | -1.9987E+05 | -8.5958E+04 | 96.87 | 23.145 | 2.0156 | 14.984 | 3.580 | 7.369E-01 | 4.601E-05 | 1.380 |
| 1100.00 | 1980.0 | -1.9835E+05 | -8.5310E+04 | 98.31 | 23.488 | 2.0156 | 15.172 | 3.625 | 6.699E-01 | 4.182E-05 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 99.63 | 23.806 | 2.0156 | 15.378 | 3.674 | 6.141E-01 | 3.834E-05 | 1.367 |
| 1300.00 | 2340.0 | -1.9528E+05 | -8.3987E+04 | 100.87 | 24.102 | 2.0156 | 15.600 | 3.727 | 5.669E-01 | 3.539E-05 | 1.359 |
| 1400.00 | 2520.0 | -1.9371E+05 | -8.3311E+04 | 102.04 | 24.380 | 2.0155 | 15.849 | 3.787 | 5.264E-01 | 3.286E-05 | 1.352 |
| 1500.00 | 2700.0 | -1.9211E+05 | -8.2623E+04 | 103.14 | 24.644 | 2.0155 | 16.160 | 3.861 | 4.913E-01 | 3.067E-05 | 1.344 |
| 1600.00 | 2880.0 | -1.9048E+05 | -8.1919E+04 | 104.20 | 24.896 | 2.0153 | 16.606 | 3.968 | 4.605E-01 | 2.875E-05 | 1.333 |
| 1700.00 | 3060.0 | -1.8878E+05 | -8.1190E+04 | 105.23 | 25.142 | 2.0148 | 17.335 | 4.142 | 4.333E-01 | 2.705E-05 | 1.318 |
| 1800.00 | 3240.0 | -1.8699E+05 | -8.0421E+04 | 106.25 | 25.386 | 2.0136 | 18.582 | 4.440 | 4.090E-01 | 2.553E-05 | 1.296 |
| 1900.00 | 3420.0 | -1.8504E+05 | -7.9580E+04 | 107.31 | 25.639 | 2.0111 | 20.707 | 4.948 | 3.870E-01 | 2.416E-05 | 1.269 |
| 2000.00 | 3600.0 | -1.8280E+05 | -7.8620E+04 | 108.45 | 25.912 | 2.0063 | 24.207 | 5.784 | 3.668E-01 | 2.290E-05 | 1.237 |
| 2100.00 | 3780.0 | -1.8013E+05 | -7.7468E+04 | 109.75 | 26.224 | 1.9977 | 29.730 | 7.103 | 3.478E-01 | 2.171E-05 | 1.205 |
| 2200.00 | 3960.0 | -1.7675E+05 | -7.6022E+04 | 111.32 | 26.597 | 1.9835 | 38.072 | 9.097 | 3.296E-01 | 2.058E-05 | 1.177 |
| 2300.00 | 4140.0 | -1.7239E+05 | -7.4140E+04 | 113.26 | 27.061 | 1.9611 | 50.157 | 11.984 | 3.117E-01 | 1.946E-05 | 1.155 |
| 2400.00 | 4320.0 | -1.6653E+05 | -7.1640E+04 | 115.73 | 27.652 | 1.9276 | 66.984 | 15.005 | 2.936E-01 | 1.833E-05 | 1.140 |
| 2500.00 | 4500.0 | -1.5880E+05 | -6.8297E+04 | 118.90 | 28.409 | 1.8801 | 89.507 | 21.386 | 2.749E-01 | 1.716E-05 | 1.130 |
| 2600.00 | 4680.0 | -1.4846E+05 | -6.3850E+04 | 122.95 | 29.377 | 1.8164 | 118.364 | 28.281 | 2.554E-01 | 1.594E-05 | 1.125 |
| 2700.00 | 4860.0 | -1.3492E+05 | -5.8027E+04 | 128.06 | 30.597 | 1.7358 | 153.334 | 36.636 | 2.350E-01 | 1.467E-05 | 1.123 |
| 2800.00 | 5040.0 | -1.1765E+05 | -5.0601E+04 | 134.33 | 32.097 | 1.6401 | 192.388 | 45.968 | 2.141E-01 | 1.337E-05 | 1.123 |
| 2900.00 | 5220.0 | -9.6473E+04 | -4.1491E+04 | 141.76 | 33.872 | 1.5342 | 230.502 | 55.074 | 1.934E-01 | 1.207E-05 | 1.125 |
| 3000.00 | 5400.0 | -7.1865E+04 | -3.0908E+04 | 150.10 | 35.864 | 1.4261 | 259.218 | 61.935 | 1.738E-01 | 1.085E-05 | 1.129 |
| 3100.00 | 5580.0 | -4.5265E+04 | -1.9467E+04 | 158.82 | 37.948 | 1.3248 | 268.964 | 64.264 | 1.562E-01 | 9.754E-06 | 1.134 |
| 3200.00 | 5760.0 | -1.8883E+04 | -8.1211E+03 | 167.20 | 39.950 | 1.2378 | 254.682 | 60.851 | 1.414E-01 | 8.829E-06 | 1.141 |
| 3400.00 | 6120.0 | 2.4903E+04 | 1.0710E+04 | 180.50 | 43.127 | 1.1184 | 177.141 | 42.324 | 1.203E-01 | 7.507E-06 | 1.165 |
| 3600.00 | 6480.0 | 5.2272E+04 | 2.2481E+04 | 188.34 | 45.000 | 1.0586 | 101.546 | 24.262 | 1.075E-01 | 6.711E-06 | 1.208 |
| 3800.00 | 6840.0 | 6.7782E+04 | 2.9151E+04 | 192.54 | 46.005 | 1.0315 | 58.576 | 13.996 | 9.926E-02 | 6.196E-06 | 1.280 |
| 4000.00 | 7200.0 | 7.7212E+04 | 3.3207E+04 | 194.97 | 46.584 | 1.0196 | 38.366 | 9.167 | 9.319E-02 | 5.818E-06 | 1.376 |
| 4200.00 | 7560.0 | 8.3851E+04 | 3.6062E+04 | 196.59 | 46.971 | 1.0139 | 29.219 | 6.981 | 8.826E-02 | 5.510E-06 | 1.472 |
| 4400.00 | 7920.0 | 8.9220E+04 | 3.8371E+04 | 197.84 | 47.269 | 1.0112 | 24.995 | 5.972 | 8.402E-02 | 5.245E-06 | 1.548 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4600.00 | 8280.0 | 9.3992E+04 | 4.0424E+04 | 198.90 | 47.523 | 1.0098 | 22.970 | 5.488 | 8.026E-02 | 5.010E-06 | 1.596 |
| 4800.00 | 8640.0 | 9.8474E+04 | 4.2351E+04 | 199.85 | 47.751 | 1.0090 | 21.967 | 5.249 | 7.685E-02 | 4.798E-06 | 1.624 |
| 5000.00 | 9000.0 | 1.0281E+05 | 4.4217E+04 | 200.74 | 47.962 | 1.0085 | 21.469 | 5.130 | 7.375E-02 | 4.604E-06 | 1.639 |
| 5200.00 | 9360.0 | 1.0708E+05 | 4.6052E+04 | 201.57 | 48.162 | 1.0083 | 21.245 | 5.076 | 7.089E-02 | 4.426E-06 | 1.645 |
| 5400.00 | 9720.0 | 1.1132E+05 | 4.7877E+04 | 202.38 | 48.354 | 1.0081 | 21.195 | 5.064 | 6.825E-02 | 4.261E-06 | 1.645 |
| 5600.00 | 10080.0 | 1.1557E+05 | 4.9703E+04 | 203.15 | 48.538 | 1.0079 | 21.282 | 5.085 | 6.580E-02 | 4.108E-06 | 1.641 |
| 5800.00 | 10440.0 | 1.1984E+05 | 5.1542E+04 | 203.90 | 48.717 | 1.0078 | 21.503 | 5.138 | 6.353E-02 | 3.966E-06 | 1.631 |
| 6000.00 | 10800.0 | 1.2418E+05 | 5.3406E+04 | 204.63 | 48.893 | 1.0076 | 21.878 | 5.227 | 6.140E-02 | 3.833E-06 | 1.617 |
| 6300.00 | 11340.0 | 1.3087E+05 | 5.6283E+04 | 205.72 | 49.153 | 1.0072 | 22.806 | 5.449 | 5.845E-02 | 3.649E-06 | 1.584 |
| 6600.00 | 11880.0 | 1.3792E+05 | 5.9317E+04 | 206.81 | 49.414 | 1.0066 | 24.331 | 5.813 | 5.576E-02 | 3.481E-06 | 1.540 |
| 7000.00 | 12600.0 | 1.4827E+05 | 6.3766E+04 | 208.33 | 49.778 | 1.0051 | 27.699 | 6.618 | 5.250E-02 | 3.277E-06 | 1.466 |
| 7300.00 | 13140.0 | 1.5713E+05 | 6.7577E+04 | 209.57 | 50.074 | 1.0033 | 31.613 | 7.553 | 5.025E-02 | 3.137E-06 | 1.407 |
| 7600.00 | 13680.0 | 1.6739E+05 | 7.1992E+04 | 210.95 | 50.403 | 1.0005 | 37.113 | 8.867 | 4.813E-02 | 3.005E-06 | 1.351 |
| 8000.00 | 14400.0 | 1.8421E+05 | 7.9223E+04 | 213.10 | 50.917 | 0.9948 | 47.633 | 11.381 | 4.547E-02 | 2.838E-06 | 1.287 |
| 8300.00 | 14940.0 | 2.0005E+05 | 8.6039E+04 | 215.05 | 51.382 | 0.9885 | 58.513 | 13.980 | 4.354E-02 | 2.718E-06 | 1.249 |
| 8600.00 | 15480.0 | 2.1962E+05 | 9.4455E+04 | 217.36 | 51.935 | 0.9799 | 72.507 | 17.324 | 4.166E-02 | 2.601E-06 | 1.220 |
| 9000.00 | 16200.0 | 2.5327E+05 | 1.0892E+05 | 221.18 | 52.847 | 0.9640 | 96.884 | 23.149 | 3.917E-02 | 2.445E-06 | 1.192 |
| 9300.00 | 16740.0 | 2.8570E+05 | 1.2287E+05 | 224.72 | 53.694 | 0.9483 | 120.063 | 28.687 | 3.729E-02 | 2.328E-06 | 1.178 |
| 9600.00 | 17280.0 | 3.2576E+05 | 1.4010E+05 | 228.96 | 54.706 | 0.9288 | 147.836 | 35.322 | 3.539E-02 | 2.209E-06 | 1.167 |
| 10000.00 | 18000.0 | 3.9349E+05 | 1.6923E+05 | 235.87 | 56.356 | 0.8967 | 192.155 | 45.912 | 3.280E-02 | 2.048E-06 | 1.158 |
| 10500.00 | 18900.0 | 5.0555E+05 | 2.1742E+05 | 246.79 | 58.966 | 0.8470 | 257.596 | 61.548 | 2.952E-02 | 1.843E-06 | 1.152 |
| 11000.00 | 19800.0 | 6.5181E+05 | 2.8033E+05 | 260.39 | 62.214 | 0.7892 | 327.073 | 78.148 | 2.627E-02 | 1.640E-06 | 1.150 |
| 11500.00 | 20700.0 | 8.3073E+05 | 3.5728E+05 | 276.28 | 66.013 | 0.7282 | 384.959 | 91.979 | 2.319E-02 | 1.448E-06 | 1.152 |
| 12000.00 | 21600.0 | 1.0313E+06 | 4.4356E+05 | 293.36 | 70.092 | 0.6703 | 410.523 | 98.087 | 2.047E-02 | 1.278E-06 | 1.156 |
| 12500.00 | 22500.0 | 1.2335E+06 | 5.3053E+05 | 309.87 | 74.039 | 0.6213 | 390.812 | 93.377 | 1.822E-02 | 1.137E-06 | 1.165 |
| 13000.00 | 23400.0 | 1.4158E+06 | 6.0891E+05 | 324.18 | 77.457 | 0.5836 | 333.595 | 79.706 | 1.646E-02 | 1.027E-06 | 1.177 |
| 13500.00 | 24300.0 | 1.5649E+06 | 6.7298E+05 | 335.44 | 80.146 | 0.5570 | 261.904 | 62.577 | 1.513E-02 | 9.443E-07 | 1.196 |
| 14000.00 | 25200.0 | 1.6788E+06 | 7.2202E+05 | 343.74 | 82.130 | 0.5392 | 196.311 | 46.905 | 1.412E-02 | 8.815E-07 | 1.223 |
| 15000.00 | 27000.0 | 1.8272E+06 | 7.8582E+05 | 354.01 | 84.584 | 0.5202 | 110.504 | 26.403 | 1.271E-02 | 7.935E-07 | 1.303 |
| 16000.00 | 28800.0 | 1.9155E+06 | 8.2382E+05 | 359.73 | 85.950 | 0.5122 | 71.663 | 17.123 | 1.173E-02 | 7.324E-07 | 1.409 |
| 17000.00 | 30600.0 | 1.9778E+06 | 8.5061E+05 | 363.51 | 86.854 | 0.5087 | 55.235 | 13.197 | 1.096E-02 | 6.844E-07 | 1.509 |
| 18000.00 | 32400.0 | 2.0290E+06 | 8.7263E+05 | 366.44 | 87.554 | 0.5070 | 48.111 | 11.495 | 1.032E-02 | 6.441E-07 | 1.578 |
| 19000.00 | 34200.0 | 2.0753E+06 | 8.9253E+05 | 368.95 | 88.152 | 0.5061 | 44.850 | 10.716 | 9.756E-03 | 6.090E-07 | 1.619 |
| 20000.00 | 36000.0 | 2.1193E+06 | 9.1144E+05 | 371.20 | 88.692 | 0.5056 | 43.273 | 10.339 | 9.257E-03 | 5.779E-07 | 1.641 |
| 21000.00 | 37800.0 | 2.1621E+06 | 9.2986E+05 | 373.29 | 89.191 | 0.5053 | 42.463 | 10.146 | 8.809E-03 | 5.499E-07 | 1.653 |
| 22000.00 | 39600.0 | 2.2043E+06 | 9.4802E+05 | 375.26 | 89.661 | 0.5051 | 42.024 | 10.041 | 8.404E-03 | 5.247E-07 | 1.659 |
| 23000.00 | 41400.0 | 2.2452E+06 | 9.6603E+05 | 377.12 | 90.106 | 0.5049 | 41.775 | 9.981 | 8.036E-03 | 5.016E-07 | 1.663 |
| 24000.00 | 43200.0 | 2.2879E+06 | 9.8397E+05 | 378.90 | 90.530 | 0.5048 | 41.624 | 9.945 | 7.698E-03 | 4.806E-07 | 1.665 |
| 25000.00 | 45000.0 | 2.3295E+06 | 1.0018E+06 | 380.59 | 90.936 | 0.5047 | 41.531 | 9.923 | 7.388E-03 | 4.612E-07 | 1.666 |
| 26000.00 | 45800.0 | 2.3710E+06 | 1.0197E+06 | 382.22 | 91.325 | 0.5047 | 41.471 | 9.909 | 7.103E-03 | 4.434E-07 | 1.666 |
| 27000.00 | 48600.0 | 2.4124E+06 | 1.0375E+06 | 383.79 | 91.698 | 0.5046 | 41.430 | 9.899 | 6.838E-03 | 4.269E-07 | 1.667 |
| 28000.00 | 50400.0 | 2.4538E+06 | 1.0553E+06 | 385.29 | 92.058 | 0.5045 | 41.400 | 9.892 | 5.593E-03 | 4.116E-07 | 1.667 |
| 29000.00 | 52200.0 | 2.4952E+06 | 1.0731E+06 | 386.75 | 92.405 | 0.5045 | 41.380 | 9.887 | 6.365E-03 | 3.973E-07 | 1.667 |
| 30000.00 | 54000.0 | 2.5365E+06 | 1.0909E+06 | 388.15 | 92.741 | 0.5045 | 41.363 | 9.883 | 6.152E-03 | 3.840E-07 | 1.667 |
| 32000.00 | 57600.0 | 2.6193E+06 | 1.1265E+06 | 390.82 | 93.378 | 0.5044 | 41.340 | 9.877 | 5.766E-03 | 3.600E-07 | 1.667 |
| 34000.00 | 61200.0 | 2.7020E+06 | 1.1620E+06 | 393.32 | 93.977 | 0.5043 | 41.325 | 9.874 | 5.426E-03 | 3.387E-07 | 1.667 |
| 36000.00 | 64800.0 | 2.7846E+06 | 1.1976E+06 | 395.69 | 94.542 | 0.5043 | 41.315 | 9.871 | 5.124E-03 | 3.199E-07 | 1.667 |
| 38000.00 | 68400.0 | 2.8672E+06 | 1.2331E+06 | 397.92 | 95.075 | 0.5042 | 41.306 | 9.869 | 4.853E-03 | 3.030E-07 | 1.667 |
| 40000.00 | 72000.0 | 2.9498E+06 | 1.2686E+06 | 400.04 | 95.582 | 0.5042 | 41.301 | 9.868 | 4.610E-03 | 2.878E-07 | 1.667 |
| 43000.00 | 77400.0 | 3.0737E+06 | 1.3219E+06 | 403.03 | 96.295 | 0.5042 | 41.292 | 9.866 | 4.288E-03 | 2.677E-07 | 1.667 |
| 46000.00 | 82800.0 | 3.1976E+06 | 1.3752E+06 | 405.81 | 96.961 | 0.5041 | 41.287 | 9.865 | 4.008E-03 | 2.502E-07 | 1.667 |
| 50000.00 | 90000.0 | 3.3627E+06 | 1.4462E+06 | 409.25 | 97.783 | 0.5041 | 41.281 | 9.863 | 3.687E-03 | 2.302E-07 | 1.667 |
| 55000.00 | 99000.0 | 3.5691E+06 | 1.5350E+06 | 413.19 | 98.723 | 0.5041 | 41.274 | 9.862 | 3.351E-03 | 2.092E-07 | 1.667 |
| 60000.00 | 108000.0 | 3.7755E+06 | 1.6237E+06 | 416.78 | 99.581 | 0.5040 | 41.270 | 9.861 | 3.072E-03 | 1.918E-07 | 1.667 |
| 65000.00 | 117000.0 | 3.9818E+06 | 1.7125E+06 | 420.08 | 100.371 | 0.5040 | 41.267 | 9.860 | 2.835E-03 | 1.770E-07 | 1.667 |
| 70000.00 | 125000.0 | 4.1881E+06 | 1.8012E+06 | 423.14 | 101.101 | 0.5040 | 41.265 | 9.859 | 2.633E-03 | 1.644E-07 | 1.667 |
| 80000.00 | 144000.0 | 4.6008E+06 | 1.9787E+06 | 428.65 | 102.418 | 0.5040 | 41.261 | 9.858 | 2.303E-03 | 1.438E-07 | 1.667 |
| 90000.00 | 162000.0 | 5.0134E+06 | 2.1561E+06 | 433.51 | 103.579 | 0.5040 | 41.258 | 9.858 | 2.047E-03 | 1.278E-07 | 1.667 |
| 100000.00 | 180000.0 | 5.4259E+06 | 2.3336E+06 | 437.86 | 104.618 | 0.5040 | 41.256 | 9.857 | 1.843E-03 | 1.150E-07 | 1.667 |
| 110000.00 | 198000.0 | 5.8385E+06 | 2.5110E+06 | 441.79 | 105.557 | 0.5040 | 41.254 | 9.857 | 1.675E-03 | 1.046E-07 | 1.667 |

TABLE II. - Continued. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM

IN DEBYE-HUCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(e) Pressure, $1.01325 \times 10^{4}$ N/m$^2$ (0.1 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 100.00 | 180.0 | -2.1284E+05 | -9.1537E+04 | 59.41 | 14.196 | 2.0155 | 13.961 | 3.336 | 2.456E+01 | 1.534E-03 | 1.419 |
| 150.00 | 270.0 | -2.1217E+05 | -9.1250E+04 | 64.84 | 15.492 | 2.0156 | 13.167 | 3.146 | 1.638E+01 | 1.022E-03 | 1.456 |
| 200.00 | 360.0 | -2.1150E+05 | -9.0963E+04 | 68.68 | 16.410 | 2.0156 | 13.614 | 3.253 | 1.228E+01 | 7.668E-04 | 1.435 |
| 250.00 | 450.0 | -2.1081E+05 | -9.0665E+04 | 71.77 | 17.149 | 2.0156 | 14.064 | 3.360 | 9.826E+00 | 6.134E-04 | 1.415 |
| 298.15 | 536.7 | -2.1013E+05 | -9.0371E+04 | 74.27 | 17.746 | 2.0156 | 14.331 | 3.417 | 8.239E+00 | 5.143E-04 | 1.405 |
| 400.00 | 720.0 | -2.0866E+05 | -8.9739E+04 | 78.51 | 18.758 | 2.0156 | 14.478 | 3.459 | 6.141E+00 | 3.834E-04 | 1.398 |
| 500.00 | 900.0 | -2.0721E+05 | -8.9116E+04 | 81.74 | 19.531 | 2.0156 | 14.520 | 3.469 | 4.913E+00 | 3.067E-04 | 1.397 |
| 600.00 | 1080.0 | -2.0575E+05 | -8.8491E+04 | 84.39 | 20.164 | 2.0156 | 14.546 | 3.476 | 4.094E+00 | 2.556E-04 | 1.396 |
| 700.00 | 1260.0 | -2.0433E+05 | -8.7864E+04 | 86.64 | 20.701 | 2.0156 | 14.607 | 3.490 | 3.509E+00 | 2.191E-04 | 1.394 |
| 800.00 | 1440.0 | -2.0283E+05 | -8.7234E+04 | 88.59 | 21.168 | 2.0156 | 14.696 | 3.511 | 3.071E+00 | 1.917E-04 | 1.390 |
| 900.00 | 1620.0 | -2.0135E+05 | -8.6599E+04 | 90.33 | 21.583 | 2.0156 | 14.827 | 3.543 | 2.729E+00 | 1.704E-04 | 1.385 |
| 1000.00 | 1800.0 | -1.9987E+05 | -8.5958E+04 | 91.90 | 21.958 | 2.0156 | 14.985 | 3.580 | 2.456E+00 | 1.534E-04 | 1.380 |
| 1100.00 | 1980.0 | -1.9835E+05 | -8.5310E+04 | 93.34 | 22.302 | 2.0156 | 15.171 | 3.625 | 2.233E+00 | 1.394E-04 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 94.67 | 22.619 | 2.0156 | 15.378 | 3.674 | 2.047E+00 | 1.278E-04 | 1.367 |
| 1300.00 | 2340.0 | -1.9528E+05 | -8.3987E+04 | 95.91 | 22.915 | 2.0156 | 15.594 | 3.726 | 1.890E+00 | 1.180E-04 | 1.360 |
| 1400.00 | 2520.0 | -1.9371E+05 | -8.3311E+04 | 97.07 | 23.193 | 2.0156 | 15.831 | 3.782 | 1.755E+00 | 1.095E-04 | 1.353 |
| 1500.00 | 2700.0 | -1.9212E+05 | -8.2625E+04 | 98.17 | 23.457 | 2.0156 | 16.098 | 3.845 | 1.638E+00 | 1.022E-04 | 1.345 |
| 1600.00 | 2880.0 | -1.9049E+05 | -8.1926E+04 | 99.22 | 23.707 | 2.0155 | 16.438 | 3.928 | 1.535E+00 | 9.584E-05 | 1.336 |
| 1700.00 | 3060.0 | -1.8882E+05 | -8.1209E+04 | 100.23 | 23.949 | 2.0152 | 16.930 | 4.045 | 1.445E+00 | 9.019E-05 | 1.325 |
| 1800.00 | 3240.0 | -1.8710E+05 | -8.0465E+04 | 101.22 | 24.185 | 2.0145 | 17.702 | 4.230 | 1.364E+00 | 8.515E-05 | 1.310 |
| 1900.00 | 3420.0 | -1.8527E+05 | -7.9679E+04 | 102.21 | 24.421 | 2.0131 | 18.952 | 4.528 | 1.291E+00 | 8.061E-05 | 1.291 |
| 2000.00 | 3600.0 | -1.8328E+05 | -7.8825E+04 | 103.23 | 24.664 | 2.0105 | 20.950 | 5.006 | 1.225E+00 | 7.648E-05 | 1.266 |
| 2100.00 | 3780.0 | -1.8104E+05 | -7.7862E+04 | 104.32 | 24.925 | 2.0058 | 24.054 | 5.747 | 1.164E+00 | 7.267E-05 | 1.238 |
| 2200.00 | 3950.0 | -1.7842E+05 | -7.6734E+04 | 105.54 | 25.216 | 1.9979 | 28.699 | 6.857 | 1.107E+00 | 6.909E-05 | 1.211 |
| 2300.00 | 4140.0 | -1.7523E+05 | -7.5364E+04 | 106.95 | 25.554 | 1.9854 | 35.399 | 8.458 | 1.052E+00 | 6.567E-05 | 1.186 |
| 2400.00 | 4320.0 | -1.7125E+05 | -7.3651E+04 | 108.65 | 25.959 | 1.9664 | 44.727 | 10.687 | 9.985E-01 | 6.233E-05 | 1.166 |
| 2500.00 | 4500.0 | -1.6618E+05 | -7.1470E+04 | 110.71 | 26.453 | 1.9389 | 57.282 | 13.685 | 9.452E-01 | 5.901E-05 | 1.151 |
| 2600.00 | 4680.0 | -1.5967E+05 | -6.8670E+04 | 113.27 | 27.063 | 1.9009 | 73.635 | 17.594 | 8.910E-01 | 5.562E-05 | 1.141 |
| 2700.00 | 4860.0 | -1.5131E+05 | -6.5076E+04 | 116.42 | 27.816 | 1.8507 | 94.212 | 22.510 | 8.353E-01 | 5.215E-05 | 1.135 |
| 2800.00 | 5040.0 | -1.4068E+05 | -6.0504E+04 | 120.28 | 28.739 | 1.7872 | 119.088 | 28.454 | 7.779E-01 | 4.856E-05 | 1.131 |
| 2900.00 | 5220.0 | -1.2737E+05 | -5.4779E+04 | 124.95 | 29.854 | 1.7109 | 147.635 | 35.275 | 7.190E-01 | 4.488E-05 | 1.130 |
| 3000.00 | 5400.0 | -1.1109E+05 | -4.7778E+04 | 130.46 | 31.172 | 1.6238 | 178.006 | 42.531 | 6.596E-01 | 4.118E-05 | 1.131 |
| 3100.00 | 5580.0 | -9.1826E+04 | -3.9492E+04 | 136.78 | 32.681 | 1.5300 | 206.651 | 49.375 | 6.015E-01 | 3.755E-05 | 1.134 |
| 3200.00 | 5760.0 | -6.9992E+04 | -3.0102E+04 | 143.71 | 34.337 | 1.4350 | 228.366 | 54.564 | 5.465E-01 | 3.412E-05 | 1.137 |
| 3400.00 | 6120.0 | -2.3011E+04 | -9.8967E+03 | 157.95 | 37.739 | 1.2654 | 230.893 | 55.168 | 4.536E-01 | 2.831E-05 | 1.150 |
| 3600.00 | 6480.0 | 1.8585E+04 | 7.9930E+03 | 169.85 | 40.583 | 1.1472 | 178.904 | 42.746 | 3.883E-01 | 2.424E-05 | 1.170 |
| 3800.00 | 6840.0 | 4.7851E+04 | 2.0579E+04 | 177.78 | 42.477 | 1.0796 | 115.583 | 27.616 | 3.462E-01 | 2.162E-05 | 1.203 |
| 4000.00 | 7200.0 | 6.6172E+04 | 2.8459E+04 | 182.49 | 43.602 | 1.0450 | 71.445 | 17.070 | 3.184E-01 | 1.988E-05 | 1.257 |
| 4200.00 | 7560.0 | 7.7753E+04 | 3.3440E+04 | 185.32 | 44.278 | 1.0277 | 47.013 | 11.233 | 2.982E-01 | 1.862E-05 | 1.331 |
| 4400.00 | 7920.0 | 8.5764E+04 | 3.6885E+04 | 187.18 | 44.724 | 1.0189 | 34.511 | 8.245 | 2.822E-01 | 1.762E-05 | 1.416 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4600.00 | 8280.0 | 9.1962E+04 | 3.9551E+04 | 188.56 | 45.053 | 1.0142 | 28.170 | 6.731 | 2.687E-01 | 1.677E-05 | 1.494 |
| 4800.00 | 8640.0 | 9.7233E+04 | 4.1818E+04 | 189.68 | 45.321 | 1.0117 | 24.891 | 5.947 | 2.569E-01 | 1.604E-05 | 1.554 |
| 5000.00 | 9000.0 | 1.0202E+05 | 4.3876E+04 | 190.66 | 45.555 | 1.0103 | 23.153 | 5.532 | 2.462E-01 | 1.537E-05 | 1.594 |
| 5200.00 | 9360.0 | 1.0655E+05 | 4.5823E+04 | 191.55 | 45.767 | 1.0094 | 22.215 | 5.308 | 2.366E-01 | 1.477E-05 | 1.618 |
| 5400.00 | 9720.0 | 1.1093E+05 | 4.7710E+04 | 192.38 | 45.965 | 1.0089 | 21.719 | 5.189 | 2.277E-01 | 1.421E-05 | 1.632 |
| 5600.00 | 10080.0 | 1.1525E+05 | 4.9567E+04 | 193.16 | 46.152 | 1.0085 | 21.488 | 5.134 | 2.195E-01 | 1.370E-05 | 1.638 |
| 5800.00 | 10440.0 | 1.1954E+05 | 5.1412E+04 | 193.91 | 46.332 | 1.0082 | 21.439 | 5.123 | 2.118E-01 | 1.323E-05 | 1.637 |
| 6000.00 | 10800.0 | 1.2384E+05 | 5.3259E+04 | 194.64 | 46.506 | 1.0080 | 21.537 | 5.146 | 2.047E-01 | 1.278E-05 | 1.632 |
| 6300.00 | 11340.0 | 1.3035E+05 | 5.6061E+04 | 195.70 | 46.759 | 1.0077 | 21.952 | 5.245 | 1.949E-01 | 1.217E-05 | 1.615 |
| 6600.00 | 11880.0 | 1.3704E+05 | 5.8940E+04 | 196.74 | 47.007 | 1.0073 | 22.736 | 5.432 | 1.860E-01 | 1.161E-05 | 1.588 |
| 7000.00 | 12600.0 | 1.4647E+05 | 6.2992E+04 | 198.13 | 47.338 | 1.0064 | 24.548 | 5.865 | 1.752E-01 | 1.094E-05 | 1.536 |
| 7300.00 | 13140.0 | 1.5413E+05 | 6.6289E+04 | 199.20 | 47.594 | 1.0054 | 26.681 | 6.375 | 1.678E-01 | 1.048E-05 | 1.488 |
| 7600.00 | 13680.0 | 1.6256E+05 | 6.9915E+04 | 200.33 | 47.865 | 1.0039 | 29.691 | 7.094 | 1.610E-01 | 1.005E-05 | 1.436 |
| 8000.00 | 14400.0 | 1.7552E+05 | 7.5487E+04 | 201.99 | 48.261 | 1.0007 | 35.462 | 8.473 | 1.524E-01 | 9.517E-06 | 1.369 |
| 8300.00 | 14940.0 | 1.8702E+05 | 8.0431E+04 | 203.40 | 48.598 | 0.9971 | 41.442 | 9.902 | 1.464E-01 | 9.140E-06 | 1.324 |
| 8600.00 | 15480.0 | 2.0056E+05 | 8.6255E+04 | 205.00 | 48.981 | 0.9923 | 49.147 | 11.743 | 1.406E-01 | 8.779E-06 | 1.285 |
| 9000.00 | 16200.0 | 2.2278E+05 | 9.5811E+04 | 207.52 | 49.584 | 0.9833 | 62.617 | 14.961 | 1.332E-01 | 8.313E-06 | 1.244 |
| 9300.00 | 16740.0 | 2.4363E+05 | 1.0469E+05 | 209.78 | 50.123 | 0.9742 | 75.507 | 18.041 | 1.277E-01 | 7.971E-06 | 1.221 |
| 9600.00 | 17280.0 | 2.6835E+05 | 1.1541E+05 | 212.42 | 50.753 | 0.9627 | 91.107 | 21.768 | 1.223E-01 | 7.632E-06 | 1.203 |
| 10000.00 | 18000.0 | 3.0970E+05 | 1.3319E+05 | 216.63 | 51.760 | 0.9432 | 116.539 | 27.845 | 1.150E-01 | 7.180E-06 | 1.186 |
| 10500.00 | 18900.0 | 3.7752E+05 | 1.6236E+05 | 223.24 | 53.340 | 0.9114 | 155.209 | 37.323 | 1.059E-01 | 6.610E-06 | 1.172 |
| 11000.00 | 19800.0 | 4.6729E+05 | 2.0097E+05 | 231.59 | 55.333 | 0.8713 | 204.091 | 48.764 | 9.665E-02 | 6.034E-06 | 1.164 |
| 11500.00 | 20700.0 | 5.8251E+05 | 2.5052E+05 | 241.82 | 57.779 | 0.8238 | 257.242 | 61.463 | 8.746E-02 | 5.460E-06 | 1.161 |
| 12000.00 | 21600.0 | 7.2429E+05 | 3.1150E+05 | 253.88 | 60.661 | 0.7717 | 308.826 | 73.788 | 7.856E-02 | 4.904E-06 | 1.160 |
| 12500.00 | 22500.0 | 8.8923E+05 | 3.8246E+05 | 267.35 | 63.878 | 0.7188 | 348.017 | 83.152 | 7.029E-02 | 4.388E-06 | 1.162 |
| 13000.00 | 23400.0 | 1.0683E+06 | 4.5944E+05 | 281.39 | 67.233 | 0.6693 | 363.157 | 85.769 | 6.297E-02 | 3.931E-06 | 1.167 |
| 13500.00 | 24300.0 | 1.2474E+06 | 5.3647E+05 | 294.91 | 70.464 | 0.6257 | 348.221 | 83.201 | 5.580E-02 | 3.546E-06 | 1.174 |
| 14000.00 | 25200.0 | 1.4122E+06 | 6.0737E+05 | 306.91 | 73.331 | 0.5927 | 307.814 | 73.546 | 5.181E-02 | 3.234E-06 | 1.188 |
| 15000.00 | 27000.0 | 1.6678E+06 | 7.1726E+05 | 324.59 | 77.553 | 0.5487 | 203.308 | 48.577 | 4.477E-02 | 2.795E-06 | 1.226 |
| 16000.00 | 28800.0 | 1.8285E+06 | 7.8640E+05 | 334.99 | 80.040 | 0.5272 | 124.998 | 29.866 | 4.031E-02 | 2.517E-06 | 1.289 |
| 17000.00 | 30600.0 | 1.9300E+06 | 8.3003E+05 | 341.16 | 81.514 | 0.5170 | 82.747 | 19.771 | 3.720E-02 | 2.322E-06 | 1.374 |
| 18000.00 | 32400.0 | 2.0013E+06 | 8.6070E+05 | 345.25 | 82.491 | 0.5119 | 62.349 | 14.897 | 3.478E-02 | 2.171E-06 | 1.466 |
| 19000.00 | 34200.0 | 2.0581E+06 | 8.8514E+05 | 348.33 | 83.226 | 0.5093 | 52.443 | 12.530 | 3.277E-02 | 2.045E-06 | 1.540 |
| 20000.00 | 36000.0 | 2.1078E+06 | 9.0651E+05 | 350.88 | 83.835 | 0.5078 | 47.507 | 11.351 | 3.103E-02 | 1.937E-06 | 1.591 |
| 21000.00 | 37800.0 | 2.1539E+06 | 9.2633E+05 | 353.13 | 84.373 | 0.5070 | 44.942 | 10.738 | 2.949E-02 | 1.841E-06 | 1.622 |
| 22000.00 | 39600.0 | 2.1981E+06 | 9.4533E+05 | 355.18 | 84.865 | 0.5064 | 43.548 | 10.405 | 2.811E-02 | 1.755E-06 | 1.641 |
| 23000.00 | 41400.0 | 2.2412E+06 | 9.6387E+05 | 357.10 | 85.323 | 0.5060 | 42.751 | 10.215 | 2.687E-02 | 1.677E-06 | 1.652 |
| 24000.00 | 43200.0 | 2.2837E+06 | 9.8215E+05 | 358.91 | 85.755 | 0.5057 | 42.282 | 10.103 | 2.573E-02 | 1.606E-06 | 1.658 |
| 25000.00 | 45000.0 | 2.3258E+06 | 1.0003E+06 | 360.63 | 86.166 | 0.5055 | 41.994 | 10.034 | 2.469E-02 | 1.541E-06 | 1.662 |
| 26000.00 | 46800.0 | 2.3677E+06 | 1.0183E+06 | 362.28 | 86.559 | 0.5053 | 41.809 | 9.989 | 2.373E-02 | 1.481E-06 | 1.664 |
| 27000.00 | 48600.0 | 2.4094E+06 | 1.0362E+06 | 363.85 | 86.936 | 0.5052 | 41.687 | 9.960 | 2.284E-02 | 1.426E-06 | 1.666 |
| 28000.00 | 50400.0 | 2.4511E+06 | 1.0541E+06 | 365.37 | 87.298 | 0.5051 | 41.603 | 9.940 | 2.201E-02 | 1.374E-06 | 1.666 |
| 29000.00 | 52200.0 | 2.4926E+06 | 1.0720E+06 | 366.83 | 87.647 | 0.5050 | 41.544 | 9.926 | 2.125E-02 | 1.327E-06 | 1.667 |
| 30000.00 | 54000.0 | 2.5342E+06 | 1.0899E+06 | 368.24 | 87.983 | 0.5049 | 41.496 | 9.915 | 2.054E-02 | 1.282E-06 | 1.667 |
| 32000.00 | 57600.0 | 2.6171E+06 | 1.1255E+06 | 370.91 | 88.623 | 0.5048 | 41.439 | 9.901 | 1.924E-02 | 1.201E-06 | 1.668 |
| 34000.00 | 61200.0 | 2.6999E+06 | 1.1612E+06 | 373.43 | 89.223 | 0.5047 | 41.404 | 9.893 | 1.811E-02 | 1.130E-06 | 1.668 |
| 36000.00 | 64800.0 | 2.7827E+06 | 1.1968E+06 | 375.79 | 89.788 | 0.5046 | 41.378 | 9.887 | 1.710E-02 | 1.067E-06 | 1.668 |
| 38000.00 | 68400.0 | 2.8655E+06 | 1.2324E+06 | 378.03 | 90.323 | 0.5045 | 41.361 | 9.882 | 1.619E-02 | 1.011E-06 | 1.668 |
| 40000.00 | 72000.0 | 2.9482E+06 | 1.2679E+06 | 380.15 | 90.830 | 0.5045 | 41.346 | 9.879 | 1.538E-02 | 9.601E-07 | 1.668 |
| 43000.00 | 77400.0 | 3.0722E+06 | 1.3213E+06 | 383.14 | 91.544 | 0.5044 | 41.331 | 9.875 | 1.430E-02 | 8.929E-07 | 1.667 |
| 46000.00 | 82800.0 | 3.1962E+06 | 1.3746E+06 | 385.93 | 92.210 | 0.5043 | 41.320 | 9.873 | 1.337E-02 | 8.345E-07 | 1.667 |
| 50000.00 | 90000.0 | 3.3614E+06 | 1.4457E+06 | 389.37 | 93.033 | 0.5043 | 41.307 | 9.870 | 1.230E-02 | 7.676E-07 | 1.667 |
| 55000.00 | 99000.0 | 3.5679E+06 | 1.5345E+06 | 393.31 | 93.974 | 0.5042 | 41.297 | 9.867 | 1.118E-02 | 6.977E-07 | 1.667 |
| 60000.00 | 108000.0 | 3.7744E+06 | 1.6233E+06 | 396.90 | 94.833 | 0.5042 | 41.289 | 9.865 | 1.024E-02 | 6.395E-07 | 1.667 |
| 65000.00 | 117000.0 | 3.9809E+06 | 1.7121E+06 | 400.21 | 95.622 | 0.5041 | 41.282 | 9.864 | 9.454E-03 | 5.902E-07 | 1.667 |
| 70000.00 | 126000.0 | 4.1872E+06 | 1.8008E+06 | 403.27 | 96.353 | 0.5041 | 41.278 | 9.863 | 8.778E-03 | 5.480E-07 | 1.667 |
| 80000.00 | 144000.0 | 4.6000E+06 | 1.9783E+06 | 408.78 | 97.670 | 0.5040 | 41.271 | 9.861 | 7.680E-03 | 4.794E-07 | 1.667 |
| 90000.00 | 162000.0 | 5.0125E+06 | 2.1558E+06 | 413.64 | 98.832 | 0.5040 | 41.266 | 9.860 | 6.826E-03 | 4.261E-07 | 1.667 |
| 100000.00 | 180000.0 | 5.4253E+06 | 2.3333E+06 | 417.99 | 99.870 | 0.5040 | 41.263 | 9.859 | 5.143E-03 | 3.835E-07 | 1.667 |
| 110000.00 | 198000.0 | 5.8379E+06 | 2.5107E+06 | 421.92 | 100.810 | 0.5040 | 41.260 | 9.858 | 5.584E-03 | 3.486E-07 | 1.667 |

TABLE II. - Continued. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(f) Pressure, $3.03975 \times 10^{4}$ N/m$^2$ (0.3 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 100.00 | 180.0 | -2.1284E+05 | -9.1537E+04 | 54.88 | 13.113 | 2.0156 | 13.956 | 3.334 | 7.369E+01 | 4.601E-03 | 1.420 |
| 150.00 | 270.0 | -2.1217E+05 | -9.1250E+04 | 60.31 | 14.410 | 2.0156 | 13.170 | 3.147 | 4.913E+01 | 3.067E-03 | 1.456 |
| 200.00 | 360.0 | -2.1150E+05 | -9.0963E+04 | 64.15 | 15.328 | 2.0156 | 13.617 | 3.253 | 3.685E+01 | 2.300E-03 | 1.435 |
| 250.00 | 450.0 | -2.1081E+05 | -9.0665E+04 | 67.24 | 16.066 | 2.0156 | 14.064 | 3.360 | 2.948E+01 | 1.840E-03 | 1.415 |
| 298.15 | 536.7 | -2.1013E+05 | -9.0371E+04 | 69.74 | 16.663 | 2.0156 | 14.305 | 3.418 | 2.472E+01 | 1.543E-03 | 1.405 |
| 400.00 | 720.0 | -2.0865E+05 | -8.9739E+04 | 73.98 | 17.675 | 2.0156 | 14.479 | 3.460 | 1.842E+01 | 1.150E-03 | 1.398 |
| 500.00 | 900.0 | -2.0721E+05 | -8.9116E+04 | 77.21 | 18.448 | 2.0156 | 14.518 | 3.469 | 1.474E+01 | 9.201E-04 | 1.397 |
| 600.00 | 1080.0 | -2.0576E+05 | -8.8491E+04 | 79.86 | 19.081 | 2.0156 | 14.548 | 3.476 | 1.228E+01 | 7.668E-04 | 1.396 |
| 700.00 | 1260.0 | -2.0430E+05 | -8.7864E+04 | 82.11 | 19.618 | 2.0155 | 14.506 | 3.490 | 1.053E+01 | 6.572E-04 | 1.394 |
| 800.00 | 1440.0 | -2.0283E+05 | -8.7234E+04 | 84.06 | 20.085 | 2.0155 | 14.696 | 3.511 | 9.212E+00 | 5.751E-04 | 1.390 |
| 900.00 | 1620.0 | -2.0136E+05 | -8.6599E+04 | 85.80 | 20.501 | 2.0156 | 14.824 | 3.542 | 8.188E+00 | 5.112E-04 | 1.386 |
| 1000.00 | 1800.0 | -1.9987E+05 | -8.5958E+04 | 87.37 | 20.876 | 2.0156 | 14.986 | 3.581 | 7.369E+00 | 4.601E-04 | 1.380 |
| 1100.00 | 1980.0 | -1.9835E+05 | -8.5310E+04 | 88.81 | 21.219 | 2.0156 | 15.171 | 3.625 | 6.699E+00 | 4.182E-04 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 90.14 | 21.536 | 2.0156 | 15.375 | 3.674 | 6.141E+00 | 3.834E-04 | 1.367 |
| 1300.00 | 2340.0 | -1.9528E+05 | -8.3987E+04 | 91.38 | 21.833 | 2.0156 | 15.592 | 3.725 | 5.669E+00 | 3.539E-04 | 1.360 |
| 1400.00 | 2520.0 | -1.9371E+05 | -8.3312E+04 | 92.54 | 22.111 | 2.0156 | 15.820 | 3.780 | 5.264E+00 | 3.286E-04 | 1.353 |
| 1500.00 | 2700.0 | -1.9212E+05 | -8.2626E+04 | 93.64 | 22.373 | 2.0156 | 16.056 | 3.839 | 4.913E+00 | 3.067E-04 | 1.346 |
| 1600.00 | 2880.0 | -1.9050E+05 | -8.1929E+04 | 94.69 | 22.623 | 2.0156 | 16.353 | 3.907 | 4.606E+00 | 2.875E-04 | 1.338 |
| 1700.00 | 3060.0 | -1.8885E+05 | -8.1218E+04 | 95.69 | 22.863 | 2.0154 | 16.723 | 3.996 | 4.334E+00 | 2.706E-04 | 1.329 |
| 1800.00 | 3240.0 | -1.8715E+05 | -8.0488E+04 | 96.66 | 23.094 | 2.0150 | 17.253 | 4.122 | 4.093E+00 | 2.555E-04 | 1.318 |
| 1900.00 | 3420.0 | -1.8539E+05 | -7.9730E+04 | 97.61 | 23.322 | 2.0142 | 18.054 | 4.314 | 3.876E+00 | 2.420E-04 | 1.304 |
| 2000.00 | 3600.0 | -1.8352E+05 | -7.8929E+04 | 98.56 | 23.550 | 2.0127 | 19.284 | 4.607 | 3.679E+00 | 2.297E-04 | 1.286 |
| 2100.00 | 3780.0 | -1.8151E+05 | -7.8063E+04 | 99.55 | 23.785 | 2.0100 | 21.148 | 5.053 | 3.499E+00 | 2.185E-04 | 1.264 |
| 2200.00 | 3960.0 | -1.7927E+05 | -7.7098E+04 | 100.59 | 24.034 | 2.0054 | 23.898 | 5.710 | 3.333E+00 | 2.080E-04 | 1.240 |
| 2300.00 | 4140.0 | -1.7669E+05 | -7.5990E+04 | 101.74 | 24.308 | 1.9981 | 27.834 | 6.650 | 3.176E+00 | 1.983E-04 | 1.216 |
| 2400.00 | 4320.0 | -1.7365E+05 | -7.4682E+04 | 103.03 | 24.617 | 1.9869 | 33.289 | 7.954 | 3.027E+00 | 1.890E-04 | 1.195 |
| 2500.00 | 4500.0 | -1.6997E+05 | -7.3100E+04 | 104.53 | 24.975 | 1.9706 | 40.522 | 9.705 | 2.882E+00 | 1.799E-04 | 1.176 |
| 2600.00 | 4680.0 | -1.6545E+05 | -7.1156E+04 | 106.30 | 25.399 | 1.9477 | 50.202 | 11.995 | 2.739E+00 | 1.710E-04 | 1.162 |
| 2700.00 | 4860.0 | -1.5984E+05 | -6.8745E+04 | 108.42 | 25.904 | 1.9167 | 62.370 | 14.902 | 2.595E+00 | 1.620E-04 | 1.152 |
| 2800.00 | 5040.0 | -1.5289E+05 | -6.5750E+04 | 110.95 | 26.508 | 1.8764 | 77.396 | 18.492 | 2.450E+00 | 1.530E-04 | 1.145 |
| 2900.00 | 5220.0 | -1.4425E+05 | -6.2045E+04 | 113.97 | 27.230 | 1.8259 | 95.394 | 22.793 | 2.302E+00 | 1.437E-04 | 1.141 |
| 3000.00 | 5400.0 | -1.3371E+05 | -5.7505E+04 | 117.54 | 28.085 | 1.7649 | 116.174 | 27.757 | 2.151E+00 | 1.343E-04 | 1.139 |
| 3100.00 | 5580.0 | -1.2095E+05 | -5.2022E+04 | 121.72 | 29.083 | 1.6942 | 139.047 | 33.223 | 1.998E+00 | 1.247E-04 | 1.139 |
| 3200.00 | 5760.0 | -1.0588E+05 | -4.5534E+04 | 126.51 | 30.227 | 1.6158 | 162.578 | 38.845 | 1.845E+00 | 1.152E-04 | 1.140 |
| 3400.00 | 5120.0 | -6.9155E+04 | -2.9742E+04 | 137.63 | 32.884 | 1.4488 | 201.371 | 48.114 | 1.558E+00 | 9.726E-05 | 1.146 |
| 3600.00 | 5480.0 | -2.7472E+04 | -1.1815E+04 | 149.54 | 35.729 | 1.2954 | 208.510 | 49.819 | 1.316E+00 | 8.213E-05 | 1.158 |
| 3800.00 | 5840.0 | 1.1528E+04 | 4.9578E+03 | 160.09 | 38.250 | 1.1797 | 175.082 | 42.072 | 1.135E+00 | 7.086E-05 | 1.175 |
| 4000.00 | 7200.0 | 4.1825E+04 | 1.7988E+04 | 167.87 | 40.109 | 1.1057 | 126.573 | 30.244 | 1.011E+00 | 6.309E-05 | 1.202 |
| 4200.00 | 7560.0 | 6.2715E+04 | 2.6972E+04 | 172.98 | 41.329 | 1.0631 | 84.688 | 20.235 | 9.254E-01 | 5.777E-05 | 1.243 |
| 4400.00 | 7920.0 | 7.6696E+04 | 3.2985E+04 | 176.23 | 42.107 | 1.0396 | 57.433 | 13.723 | 8.638E-01 | 5.393E-05 | 1.299 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4600.00 | 8280.0 | 8.6451E+04 | 3.7181E+04 | 178.40 | 42.626 | 1.0266 | 41.624 | 9.945 | 8.159E-01 | 5.094E-05 | 1.368 |
| 4800.00 | 8640.0 | 9.3807E+04 | 4.0344E+04 | 179.97 | 43.000 | 1.0193 | 32.797 | 7.836 | 7.764E-01 | 4.847E-05 | 1.440 |
| 5000.00 | 9000.0 | 9.9827E+04 | 4.2933E+04 | 181.20 | 43.294 | 1.0151 | 27.874 | 6.660 | 7.422E-01 | 4.634E-05 | 1.504 |
| 5200.00 | 9360.0 | 1.0510E+05 | 4.5200E+04 | 182.23 | 43.541 | 1.0126 | 25.089 | 5.995 | 7.119E-01 | 4.444E-05 | 1.554 |
| 5400.00 | 9720.0 | 1.0994E+05 | 4.7283E+04 | 183.15 | 43.759 | 1.0110 | 23.490 | 5.613 | 6.845E-01 | 4.273E-05 | 1.588 |
| 5600.00 | 10080.0 | 1.1454E+05 | 4.9260E+04 | 183.98 | 43.959 | 1.0100 | 22.569 | 5.392 | 6.594E-01 | 4.117E-05 | 1.611 |
| 5800.00 | 10440.0 | 1.1899E+05 | 5.1177E+04 | 184.76 | 44.146 | 1.0093 | 22.055 | 5.270 | 6.362E-01 | 3.972E-05 | 1.623 |
| 6000.00 | 10800.0 | 1.2338E+05 | 5.3061E+04 | 185.51 | 44.324 | 1.0089 | 21.804 | 5.210 | 6.147E-01 | 3.838E-05 | 1.629 |
| 6300.00 | 11340.0 | 1.2990E+05 | 5.5869E+04 | 186.57 | 44.577 | 1.0083 | 21.772 | 5.202 | 5.852E-01 | 3.653E-05 | 1.626 |
| 6600.00 | 11880.0 | 1.3647E+05 | 5.8694E+04 | 187.59 | 44.821 | 1.0079 | 22.077 | 5.275 | 5.583E-01 | 3.486E-05 | 1.613 |
| 7000.00 | 12600.0 | 1.4547E+05 | 6.2564E+04 | 188.91 | 45.137 | 1.0073 | 23.020 | 5.500 | 5.261E-01 | 3.284E-05 | 1.580 |
| 7300.00 | 13140.0 | 1.5254E+05 | 6.5605E+04 | 189.90 | 45.373 | 1.0066 | 24.211 | 5.785 | 5.041E-01 | 3.147E-05 | 1.546 |
| 7600.00 | 13680.0 | 1.6005E+05 | 6.8834E+04 | 190.91 | 45.614 | 1.0057 | 25.927 | 6.195 | 4.838E-01 | 3.020E-05 | 1.505 |
| 8000.00 | 14400.0 | 1.7104E+05 | 7.3561E+04 | 192.32 | 45.950 | 1.0038 | 29.249 | 6.988 | 4.587E-01 | 2.864E-05 | 1.445 |
| 8300.00 | 14940.0 | 1.8031E+05 | 7.7547E+04 | 193.45 | 46.222 | 1.0017 | 32.705 | 7.814 | 4.412E-01 | 2.755E-05 | 1.400 |
| 8600.00 | 15480.0 | 1.9075E+05 | 8.2043E+04 | 194.69 | 46.518 | 0.9988 | 37.168 | 8.880 | 4.247E-01 | 2.651E-05 | 1.357 |
| 9000.00 | 16200.0 | 2.0712E+05 | 8.9077E+04 | 196.55 | 46.961 | 0.9935 | 44.987 | 10.749 | 4.036E-01 | 2.520E-05 | 1.308 |
| 9300.00 | 16740.0 | 2.2170E+05 | 9.5349E+04 | 198.14 | 47.342 | 0.9881 | 52.490 | 12.541 | 3.885E-01 | 2.425E-05 | 1.277 |
| 9600.00 | 17280.0 | 2.3877E+05 | 1.0269E+05 | 199.95 | 47.773 | 0.9812 | 61.601 | 14.718 | 3.738E-01 | 2.333E-05 | 1.252 |
| 10000.00 | 18000.0 | 2.6629E+05 | 1.1453E+05 | 202.75 | 48.444 | 0.9693 | 76.557 | 18.292 | 3.545E-01 | 2.213E-05 | 1.226 |
| 10500.00 | 18900.0 | 3.1025E+05 | 1.3343E+05 | 207.04 | 49.468 | 0.9494 | 100.277 | 23.959 | 3.308E-01 | 2.065E-05 | 1.202 |
| 11000.00 | 19800.0 | 3.6757E+05 | 1.5808E+05 | 212.37 | 50.741 | 0.9232 | 129.989 | 31.058 | 3.072E-01 | 1.918E-05 | 1.187 |
| 11500.00 | 20700.0 | 4.4122E+05 | 1.8976E+05 | 218.91 | 52.304 | 0.8903 | 165.552 | 39.555 | 2.835E-01 | 1.770E-05 | 1.177 |
| 12000.00 | 21600.0 | 5.3389E+05 | 2.2961E+05 | 226.79 | 54.187 | 0.8514 | 205.675 | 49.142 | 2.600E-01 | 1.623E-05 | 1.172 |
| 12500.00 | 22500.0 | 6.4717E+05 | 2.7833E+05 | 236.03 | 56.396 | 0.8077 | 247.327 | 59.094 | 2.369E-01 | 1.479E-05 | 1.169 |
| 13000.00 | 23400.0 | 7.8061E+05 | 3.3572E+05 | 246.50 | 58.896 | 0.7614 | 285.287 | 68.164 | 2.150E-01 | 1.342E-05 | 1.169 |
| 13500.00 | 24300.0 | 9.3069E+05 | 4.0027E+05 | 257.83 | 61.602 | 0.7154 | 312.673 | 74.707 | 1.946E-01 | 1.215E-05 | 1.171 |
| 14000.00 | 25200.0 | 1.0901E+06 | 4.6882E+05 | 269.42 | 64.372 | 0.6724 | 321.996 | 76.935 | 1.765E-01 | 1.102E-05 | 1.179 |
| 15000.00 | 27000.0 | 1.3998E+06 | 6.0203E+05 | 290.80 | 69.481 | 0.6033 | 285.881 | 68.305 | 1.479E-01 | 9.236E-06 | 1.197 |
| 16000.00 | 28800.0 | 1.6477E+06 | 7.0866E+05 | 306.83 | 73.311 | 0.5597 | 208.018 | 49.702 | 1.287E-01 | 8.034E-06 | 1.229 |
| 17000.00 | 30600.0 | 1.8194E+06 | 7.8247E+05 | 317.26 | 75.803 | 0.5356 | 139.194 | 33.258 | 1.159E-01 | 7.234E-06 | 1.279 |
| 18000.00 | 32400.0 | 1.9348E+06 | 8.3209E+05 | 323.87 | 77.383 | 0.5228 | 95.547 | 22.829 | 1.068E-01 | 6.666E-06 | 1.347 |
| 19000.00 | 34200.0 | 2.0169E+06 | 8.6742E+05 | 328.33 | 78.448 | 0.5160 | 71.256 | 17.025 | 9.981E-02 | 6.231E-06 | 1.425 |
| 20000.00 | 36000.0 | 2.0813E+06 | 8.9497E+05 | 331.62 | 79.235 | 0.5123 | 58.241 | 13.916 | 9.409E-02 | 5.874E-06 | 1.497 |
| 21000.00 | 37800.0 | 2.1353E+06 | 9.1836E+05 | 334.29 | 79.871 | 0.5102 | 51.194 | 12.232 | 8.920E-02 | 5.569E-06 | 1.554 |
| 22000.00 | 39600.0 | 2.1844E+06 | 9.3947E+05 | 336.58 | 80.418 | 0.5089 | 47.303 | 11.302 | 8.490E-02 | 5.300E-06 | 1.595 |
| 23000.00 | 41400.0 | 2.2305E+06 | 9.5930E+05 | 338.63 | 80.910 | 0.5081 | 45.111 | 10.779 | 8.105E-02 | 5.060E-06 | 1.621 |
| 24000.00 | 43200.0 | 2.2751E+06 | 9.7846E+05 | 340.53 | 81.363 | 0.5074 | 43.970 | 10.506 | 7.755E-02 | 4.841E-06 | 1.640 |
| 25000.00 | 45000.0 | 2.3185E+06 | 9.9718E+05 | 342.31 | 81.788 | 0.5070 | 43.156 | 10.311 | 7.436E-02 | 4.642E-06 | 1.650 |
| 26000.00 | 46800.0 | 2.3615E+06 | 1.0156E+06 | 343.99 | 82.190 | 0.5066 | 42.639 | 10.188 | 7.143E-02 | 4.459E-06 | 1.656 |
| 27000.00 | 48600.0 | 2.4039E+06 | 1.0339E+06 | 345.60 | 82.574 | 0.5063 | 42.299 | 10.107 | 6.874E-02 | 4.291E-06 | 1.661 |
| 28000.00 | 50400.0 | 2.4461E+06 | 1.0520E+06 | 347.13 | 82.940 | 0.5061 | 42.061 | 10.050 | 6.624E-02 | 4.135E-06 | 1.664 |
| 29000.00 | 52200.0 | 2.4881E+06 | 1.0701E+06 | 348.61 | 83.293 | 0.5059 | 41.902 | 10.012 | 6.392E-02 | 3.990E-06 | 1.665 |
| 30000.00 | 54000.0 | 2.5299E+06 | 1.0881E+06 | 350.02 | 83.632 | 0.5057 | 41.788 | 9.984 | 6.176E-02 | 3.856E-06 | 1.666 |
| 32000.00 | 57600.0 | 2.6134E+06 | 1.1239E+06 | 352.72 | 84.275 | 0.5055 | 41.641 | 9.949 | 5.786E-02 | 3.612E-06 | 1.667 |
| 34000.00 | 61200.0 | 2.6965E+06 | 1.1597E+06 | 355.24 | 84.878 | 0.5053 | 41.555 | 9.929 | 5.442E-02 | 3.397E-06 | 1.668 |
| 36000.00 | 64800.0 | 2.7796E+06 | 1.1954E+06 | 357.62 | 85.445 | 0.5051 | 41.499 | 9.915 | 5.137E-02 | 3.207E-06 | 1.668 |
| 38000.00 | 68400.0 | 2.8625E+06 | 1.2311E+06 | 359.86 | 85.981 | 0.5050 | 41.455 | 9.905 | 4.865E-02 | 3.037E-06 | 1.668 |
| 40000.00 | 72000.0 | 2.9454E+06 | 1.2668E+06 | 361.99 | 86.490 | 0.5049 | 41.428 | 9.898 | 4.620E-02 | 2.884E-06 | 1.668 |
| 43000.00 | 77400.0 | 3.0697E+06 | 1.3202E+06 | 364.98 | 87.205 | 0.5047 | 41.398 | 9.891 | 4.296E-02 | 2.682E-06 | 1.668 |
| 46000.00 | 82800.0 | 3.1938E+06 | 1.3736E+06 | 367.77 | 87.872 | 0.5046 | 41.375 | 9.885 | 4.014E-02 | 2.506E-06 | 1.668 |
| 50000.00 | 90000.0 | 3.3593E+06 | 1.4447E+06 | 371.22 | 88.697 | 0.5045 | 41.354 | 9.881 | 3.692E-02 | 2.305E-06 | 1.668 |
| 55000.00 | 99000.0 | 3.5660E+06 | 1.5336E+06 | 375.16 | 89.638 | 0.5044 | 41.334 | 9.876 | 3.355E-02 | 2.095E-06 | 1.668 |
| 60000.00 | 108000.0 | 3.7728E+06 | 1.6225E+06 | 378.76 | 90.498 | 0.5043 | 41.319 | 9.872 | 3.075E-02 | 1.919E-06 | 1.667 |
| 65000.00 | 117000.0 | 3.9792E+06 | 1.7114E+06 | 382.07 | 91.288 | 0.5043 | 41.309 | 9.870 | 2.838E-02 | 1.771E-06 | 1.667 |
| 70000.00 | 126000.0 | 4.1857E+06 | 1.8002E+06 | 385.13 | 92.019 | 0.5042 | 41.300 | 9.868 | 2.635E-02 | 1.645E-06 | 1.667 |
| 80000.00 | 144000.0 | 4.5985E+06 | 1.9778E+06 | 390.64 | 93.337 | 0.5041 | 41.287 | 9.865 | 2.305E-02 | 1.439E-06 | 1.667 |
| 90000.00 | 162000.0 | 5.0115E+06 | 2.1553E+06 | 395.51 | 94.499 | 0.5041 | 41.279 | 9.863 | 2.048E-02 | 1.279E-06 | 1.667 |
| 100000.00 | 180000.0 | 5.4242E+06 | 2.3328E+06 | 399.86 | 95.538 | 0.5041 | 41.273 | 9.861 | 1.843E-02 | 1.151E-06 | 1.667 |
| 110000.00 | 198000.0 | 5.8370E+06 | 2.5103E+06 | 403.79 | 96.478 | 0.5040 | 41.269 | 9.860 | 1.676E-02 | 1.046E-06 | 1.667 |

TABLE II. - Continued. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(g) Pressure, $1.01325 \times 10^{5}$ N/m$^2$ (1 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 100.00 | 180.0 | -2.1284E+05 | -9.1537E+04 | 49.92 | 11.926 | 2.0156 | 13.961 | 3.336 | 2.456E+02 | 1.534E-02 | 1.419 |
| 150.00 | 270.0 | -2.1217E+05 | -9.1250E+04 | 55.34 | 13.223 | 2.0156 | 13.170 | 3.147 | 1.638E+02 | 1.022E-02 | 1.456 |
| 200.00 | 360.0 | -2.1150E+05 | -9.0963E+04 | 59.19 | 14.141 | 2.0156 | 13.617 | 3.253 | 1.228E+02 | 7.668E-03 | 1.435 |
| 250.00 | 450.0 | -2.1081E+05 | -9.0665E+04 | 62.27 | 14.879 | 2.0156 | 14.064 | 3.360 | 9.826E+01 | 6.134E-03 | 1.415 |
| 298.15 | 536.7 | -2.1013E+05 | -9.0371E+04 | 64.77 | 15.477 | 2.0156 | 14.303 | 3.417 | 8.239E+01 | 5.143E-03 | 1.405 |
| 400.00 | 720.0 | -2.0865E+05 | -8.9739E+04 | 69.01 | 16.488 | 2.0156 | 14.478 | 3.459 | 5.141E+01 | 3.834E-03 | 1.398 |
| 500.00 | 900.0 | -2.0721E+05 | -8.9116E+04 | 72.24 | 17.262 | 2.0156 | 14.518 | 3.469 | 4.913E+01 | 3.067E-03 | 1.397 |
| 600.00 | 1080.0 | -2.0576E+05 | -8.8491E+04 | 74.89 | 17.895 | 2.0156 | 14.547 | 3.476 | 4.094E+01 | 2.556E-03 | 1.396 |
| 700.00 | 1260.0 | -2.0430E+05 | -8.7864E+04 | 77.14 | 18.431 | 2.0156 | 14.606 | 3.490 | 3.509E+01 | 2.191E-03 | 1.394 |
| 800.00 | 1440.0 | -2.0283E+05 | -8.7234E+04 | 79.10 | 18.899 | 2.0156 | 14.697 | 3.512 | 3.071E+01 | 1.917E-03 | 1.390 |
| 900.00 | 1620.0 | -2.0136E+05 | -8.6599E+04 | 80.83 | 19.314 | 2.0156 | 14.824 | 3.542 | 2.729E+01 | 1.704E-03 | 1.386 |
| 1000.00 | 1800.0 | -1.9987E+05 | -8.5958E+04 | 82.40 | 19.689 | 2.0156 | 14.984 | 3.580 | 2.456E+01 | 1.534E-03 | 1.380 |
| 1100.00 | 1980.0 | -1.9835E+05 | -8.5310E+04 | 83.84 | 20.032 | 2.0155 | 15.172 | 3.625 | 2.233E+01 | 1.394E-03 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 85.17 | 20.350 | 2.0156 | 15.375 | 3.674 | 2.047E+01 | 1.278E-03 | 1.367 |
| 1300.00 | 2340.0 | -1.9529E+05 | -8.3987E+04 | 86.41 | 20.646 | 2.0156 | 15.589 | 3.725 | 1.890E+01 | 1.180E-03 | 1.360 |
| 1400.00 | 2520.0 | -1.9371E+05 | -8.3312E+04 | 87.57 | 20.924 | 2.0156 | 15.814 | 3.778 | 1.755E+01 | 1.095E-03 | 1.353 |
| 1500.00 | 2700.0 | -1.9212E+05 | -8.2627E+04 | 88.67 | 21.186 | 2.0156 | 16.047 | 3.834 | 1.638E+01 | 1.022E-03 | 1.346 |
| 1600.00 | 2880.0 | -1.9050E+05 | -8.1931E+04 | 89.72 | 21.436 | 2.0156 | 16.300 | 3.895 | 1.535E+01 | 9.584E-04 | 1.339 |
| 1700.00 | 3060.0 | -1.8886E+05 | -8.1224E+04 | 90.71 | 21.674 | 2.0155 | 16.595 | 3.965 | 1.445E+01 | 9.020E-04 | 1.332 |
| 1800.00 | 3240.0 | -1.8718E+05 | -8.0503E+04 | 91.67 | 21.903 | 2.0153 | 16.975 | 4.056 | 1.364E+01 | 8.518E-04 | 1.323 |
| 1900.00 | 3420.0 | -1.8546E+05 | -7.9762E+04 | 92.60 | 22.126 | 2.0149 | 17.500 | 4.181 | 1.292E+01 | 8.068E-04 | 1.313 |
| 2000.00 | 3600.0 | -1.8367E+05 | -7.8994E+04 | 93.52 | 22.344 | 2.0140 | 18.253 | 4.361 | 1.227E+01 | 7.661E-04 | 1.300 |
| 2100.00 | 3780.0 | -1.8180E+05 | -7.8187E+04 | 94.43 | 22.563 | 2.0125 | 19.352 | 4.624 | 1.168E+01 | 7.291E-04 | 1.284 |
| 2200.00 | 3960.0 | -1.7979E+05 | -7.7323E+04 | 95.37 | 22.786 | 2.0100 | 20.932 | 5.001 | 1.113E+01 | 6.951E-04 | 1.266 |
| 2300.00 | 4140.0 | -1.7759E+05 | -7.6377E+04 | 96.34 | 23.020 | 2.0060 | 23.157 | 5.533 | 1.063E+01 | 6.635E-04 | 1.246 |
| 2400.00 | 4320.0 | -1.7513E+05 | -7.5319E+04 | 97.39 | 23.270 | 1.9998 | 26.213 | 6.263 | 1.015E+01 | 6.339E-04 | 1.226 |
| 2500.00 | 4500.0 | -1.7231E+05 | -7.4108E+04 | 98.54 | 23.544 | 1.9907 | 30.298 | 7.239 | 9.704E+00 | 6.058E-04 | 1.207 |
| 2600.00 | 4680.0 | -1.6903E+05 | -7.2695E+04 | 99.83 | 23.852 | 1.9778 | 35.621 | 8.511 | 9.271E+00 | 5.787E-04 | 1.191 |
| 2700.00 | 4860.0 | -1.6514E+05 | -7.1023E+04 | 101.29 | 24.202 | 1.9602 | 42.340 | 10.128 | 8.848E+00 | 5.523E-04 | 1.177 |
| 2800.00 | 5040.0 | -1.6050E+05 | -6.9025E+04 | 102.98 | 24.606 | 1.9358 | 50.795 | 12.137 | 8.430E+00 | 5.263E-04 | 1.166 |
| 2900.00 | 5220.0 | -1.5492E+05 | -6.6628E+04 | 104.94 | 25.073 | 1.9067 | 61.001 | 14.575 | 8.013E+00 | 5.002E-04 | 1.158 |
| 3000.00 | 5400.0 | -1.4823E+05 | -6.3751E+04 | 107.20 | 25.614 | 1.8691 | 73.135 | 17.457 | 7.593E+00 | 4.740E-04 | 1.153 |
| 3100.00 | 5580.0 | -1.4024E+05 | -6.0313E+04 | 109.82 | 26.240 | 1.8237 | 87.101 | 20.811 | 7.169E+00 | 4.476E-04 | 1.150 |
| 3200.00 | 5760.0 | -1.3075E+05 | -5.6235E+04 | 112.83 | 26.960 | 1.7704 | 102.812 | 24.565 | 6.742E+00 | 4.209E-04 | 1.148 |
| 3400.00 | 6120.0 | -1.0678E+05 | -4.5922E+04 | 120.09 | 28.694 | 1.6431 | 137.287 | 32.802 | 5.889E+00 | 3.677E-04 | 1.149 |
| 3600.00 | 6480.0 | -7.6043E+04 | -3.2704E+04 | 128.87 | 30.790 | 1.4997 | 168.504 | 40.261 | 5.077E+00 | 3.169E-04 | 1.155 |
| 3800.00 | 6840.0 | -4.0471E+04 | -1.7406E+04 | 138.48 | 33.087 | 1.3501 | 183.375 | 43.814 | 4.362E+00 | 2.723E-04 | 1.165 |
| 4000.00 | 7200.0 | -4.4383E+03 | -1.9088E+03 | 147.72 | 35.295 | 1.2431 | 172.608 | 41.241 | 3.787E+00 | 2.364E-04 | 1.179 |
| 4200.00 | 7560.0 | 2.7199E+04 | 1.1698E+04 | 155.45 | 37.141 | 1.1574 | 141.596 | 33.832 | 3.358E+00 | 2.097E-04 | 1.199 |
| 4400.00 | 7920.0 | 5.1883E+04 | 2.2316E+04 | 161.20 | 38.515 | 1.1008 | 105.687 | 25.252 | 3.049E+00 | 1.903E-04 | 1.227 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4600.00 | 8280.0 | 6.9914E+04 | 3.0068E+04 | 165.21 | 39.473 | 1.0556 | 76.081 | 18.178 | 2.823E+00 | 1.762E-04 | 1.266 |
| 4800.00 | 8640.0 | 8.2934E+04 | 3.5668E+04 | 167.98 | 40.136 | 1.0442 | 55.563 | 13.276 | 2.651E+00 | 1.655E-04 | 1.315 |
| 5000.00 | 9000.0 | 9.2635E+04 | 3.9841E+04 | 169.96 | 40.609 | 1.0313 | 42.493 | 10.153 | 2.514E+00 | 1.569E-04 | 1.372 |
| 5200.00 | 9360.0 | 1.0026E+05 | 4.3121E+04 | 171.46 | 40.967 | 1.0233 | 34.447 | 8.230 | 2.398E+00 | 1.497E-04 | 1.432 |
| 5400.00 | 9720.0 | 1.0662E+05 | 4.5855E+04 | 172.66 | 41.254 | 1.0183 | 29.528 | 7.055 | 2.298E+00 | 1.435E-04 | 1.487 |
| 5600.00 | 10080.0 | 1.1220E+05 | 4.8255E+04 | 173.67 | 41.496 | 1.0151 | 26.507 | 6.333 | 2.209E+00 | 1.379E-04 | 1.533 |
| 5800.00 | 10440.0 | 1.1730E+05 | 5.0448E+04 | 174.57 | 41.710 | 1.0130 | 24.637 | 5.887 | 2.129E+00 | 1.329E-04 | 1.567 |
| 6000.00 | 10800.0 | 1.2210E+05 | 5.2513E+04 | 175.38 | 41.905 | 1.0116 | 23.481 | 5.610 | 2.055E+00 | 1.283E-04 | 1.591 |
| 6300.00 | 11340.0 | 1.2899E+05 | 5.5475E+04 | 176.50 | 42.172 | 1.0101 | 22.551 | 5.388 | 1.954E+00 | 1.220E-04 | 1.611 |
| 6600.00 | 11880.0 | 1.3569E+05 | 5.8358E+04 | 177.54 | 42.421 | 1.0092 | 22.215 | 5.308 | 1.864E+00 | 1.163E-04 | 1.617 |
| 7000.00 | 12600.0 | 1.4459E+05 | 6.2185E+04 | 178.85 | 42.733 | 1.0084 | 22.376 | 5.346 | 1.756E+00 | 1.096E-04 | 1.606 |
| 7300.00 | 13140.0 | 1.5137E+05 | 6.5101E+04 | 179.80 | 42.960 | 1.0078 | 22.884 | 5.468 | 1.682E+00 | 1.050E-04 | 1.588 |
| 7600.00 | 13680.0 | 1.5835E+05 | 6.8104E+04 | 180.74 | 43.184 | 1.0071 | 23.735 | 5.671 | 1.615E+00 | 1.008E-04 | 1.562 |
| 8000.00 | 14400.0 | 1.6817E+05 | 7.2327E+04 | 182.00 | 43.485 | 1.0059 | 25.489 | 6.090 | 1.532E+00 | 9.566E-05 | 1.517 |
| 8300.00 | 14940.0 | 1.7609E+05 | 7.5731E+04 | 182.97 | 43.717 | 1.0047 | 27.359 | 6.537 | 1.475E+00 | 9.209E-05 | 1.480 |
| 8600.00 | 15480.0 | 1.8465E+05 | 7.9412E+04 | 183.98 | 43.959 | 1.0031 | 29.795 | 7.119 | 1.421E+00 | 8.874E-05 | 1.440 |
| 9000.00 | 16200.0 | 1.9738E+05 | 8.4888E+04 | 185.43 | 44.304 | 1.0000 | 34.090 | 8.145 | 1.354E+00 | 8.454E-05 | 1.389 |
| 9300.00 | 16740.0 | 2.0821E+05 | 8.9544E+04 | 186.61 | 44.587 | 0.9970 | 38.226 | 9.133 | 1.307E+00 | 8.157E-05 | 1.354 |
| 9600.00 | 17280.0 | 2.2040E+05 | 9.4791E+04 | 187.90 | 44.895 | 0.9931 | 43.252 | 10.337 | 1.261E+00 | 7.872E-05 | 1.322 |
| 10000.00 | 18000.0 | 2.3931E+05 | 1.0292E+05 | 189.83 | 45.356 | 0.9863 | 51.561 | 12.319 | 1.202E+00 | 7.506E-05 | 1.286 |
| 10500.00 | 18900.0 | 2.6825E+05 | 1.1537E+05 | 192.65 | 46.030 | 0.9748 | 64.821 | 15.488 | 1.132E+00 | 7.067E-05 | 1.251 |
| 11000.00 | 19800.0 | 3.0473E+05 | 1.3106E+05 | 196.04 | 46.840 | 0.9592 | 81.676 | 19.515 | 1.064E+00 | 6.640E-05 | 1.226 |
| 11500.00 | 20700.0 | 3.5058E+05 | 1.5078E+05 | 200.11 | 47.814 | 0.9390 | 102.414 | 24.470 | 9.964E-01 | 6.220E-05 | 1.208 |
| 12000.00 | 21600.0 | 4.0779E+05 | 1.7538E+05 | 204.98 | 48.976 | 0.9139 | 127.070 | 30.361 | 9.299E-01 | 5.805E-05 | 1.195 |
| 12500.00 | 22500.0 | 4.7824E+05 | 2.0568E+05 | 210.73 | 50.350 | 0.8839 | 155.248 | 37.093 | 8.641E-01 | 5.394E-05 | 1.187 |
| 13000.00 | 23400.0 | 5.6345E+05 | 2.4233E+05 | 217.41 | 51.946 | 0.8495 | 185.879 | 44.412 | 7.993E-01 | 4.990E-05 | 1.182 |
| 13500.00 | 24300.0 | 6.6421E+05 | 2.8566E+05 | 225.01 | 53.762 | 0.8118 | 216.985 | 51.844 | 7.362E-01 | 4.596E-05 | 1.179 |
| 14000.00 | 25200.0 | 7.7990E+05 | 3.3541E+05 | 233.42 | 55.772 | 0.7722 | 244.195 | 58.346 | 6.761E-01 | 4.220E-05 | 1.182 |
| 15000.00 | 27000.0 | 1.0447E+06 | 4.4931E+05 | 251.67 | 60.133 | 0.6944 | 279.119 | 66.690 | 5.685E-01 | 3.549E-05 | 1.189 |
| 16000.00 | 28800.0 | 1.3228E+06 | 5.6889E+05 | 269.62 | 64.420 | 0.6291 | 258.860 | 64.239 | 4.834E-01 | 3.018E-05 | 1.203 |
| 17000.00 | 30600.0 | 1.5696E+06 | 6.7505E+05 | 284.60 | 67.999 | 0.5823 | 220.799 | 52.756 | 4.214E-01 | 2.631E-05 | 1.227 |
| 18000.00 | 32400.0 | 1.7618E+06 | 7.5763E+05 | 295.59 | 70.627 | 0.5526 | 164.070 | 39.201 | 3.775E-01 | 2.357E-05 | 1.263 |
| 19000.00 | 34200.0 | 1.9018E+06 | 8.1790E+05 | 303.19 | 72.441 | 0.5348 | 118.811 | 28.388 | 3.461E-01 | 2.160E-05 | 1.313 |
| 20000.00 | 36000.0 | 2.0044E+06 | 8.6205E+05 | 308.47 | 73.703 | 0.5244 | 88.816 | 21.221 | 3.222E-01 | 2.011E-05 | 1.373 |
| 21000.00 | 37800.0 | 2.0832E+06 | 8.9595E+05 | 312.33 | 74.624 | 0.5182 | 70.436 | 16.829 | 3.030E-01 | 1.892E-05 | 1.437 |
| 22000.00 | 39600.0 | 2.1477E+06 | 9.2369E+05 | 315.34 | 75.344 | 0.5145 | 59.513 | 14.220 | 2.870E-01 | 1.792E-05 | 1.497 |
| 23000.00 | 41400.0 | 2.2036E+06 | 9.4773E+05 | 317.83 | 75.939 | 0.5121 | 52.916 | 12.643 | 2.731E-01 | 1.705E-05 | 1.546 |
| 24000.00 | 43200.0 | 2.2544E+06 | 9.6957E+05 | 320.00 | 76.458 | 0.5106 | 48.919 | 11.688 | 2.603E-01 | 1.628E-05 | 1.583 |
| 25000.00 | 45000.0 | 2.3020E+06 | 9.9004E+05 | 321.95 | 76.924 | 0.5095 | 46.480 | 11.106 | 2.493E-01 | 1.559E-05 | 1.610 |
| 26000.00 | 46800.0 | 2.3475E+06 | 1.0097E+06 | 323.74 | 77.353 | 0.5088 | 44.861 | 10.719 | 2.397E-01 | 1.496E-05 | 1.628 |
| 27000.00 | 48600.0 | 2.3920E+06 | 1.0287E+06 | 325.42 | 77.754 | 0.5083 | 43.869 | 10.482 | 2.305E-01 | 1.439E-05 | 1.640 |
| 28000.00 | 50400.0 | 2.4355E+06 | 1.0474E+06 | 327.01 | 78.133 | 0.5079 | 43.166 | 10.314 | 2.220E-01 | 1.386E-05 | 1.649 |
| 29000.00 | 52200.0 | 2.4784E+06 | 1.0659E+06 | 328.52 | 78.494 | 0.5076 | 42.726 | 10.209 | 2.142E-01 | 1.337E-05 | 1.655 |
| 30000.00 | 54000.0 | 2.5209E+06 | 1.0842E+06 | 329.97 | 78.840 | 0.5073 | 42.357 | 10.120 | 2.069E-01 | 1.291E-05 | 1.659 |
| 32000.00 | 57600.0 | 2.6054E+06 | 1.1205E+06 | 332.70 | 79.493 | 0.5069 | 42.166 | 10.075 | 1.937E-01 | 1.209E-05 | 1.666 |
| 34000.00 | 61200.0 | 2.6895E+06 | 1.1567E+06 | 335.25 | 80.102 | 0.5065 | 41.926 | 10.017 | 1.821E-01 | 1.137E-05 | 1.668 |
| 36000.00 | 64800.0 | 2.7732E+06 | 1.1927E+06 | 337.65 | 80.674 | 0.5062 | 41.779 | 9.982 | 1.718E-01 | 1.073E-05 | 1.668 |
| 38000.00 | 68400.0 | 2.8566E+06 | 1.2286E+06 | 339.90 | 81.214 | 0.5059 | 41.682 | 9.959 | 1.626E-01 | 1.015E-05 | 1.669 |
| 40000.00 | 72000.0 | 2.9399E+06 | 1.2644E+06 | 342.04 | 81.724 | 0.5057 | 41.613 | 9.943 | 1.544E-01 | 9.639E-06 | 1.669 |
| 43000.00 | 77400.0 | 3.0645E+06 | 1.3180E+06 | 345.05 | 82.443 | 0.5054 | 41.544 | 9.926 | 1.435E-01 | 8.959E-06 | 1.669 |
| 46000.00 | 82800.0 | 3.1892E+06 | 1.3716E+06 | 347.85 | 83.113 | 0.5052 | 41.495 | 9.914 | 1.341E-01 | 8.370E-06 | 1.669 |
| 50000.00 | 90000.0 | 3.3551E+06 | 1.4429E+06 | 351.31 | 83.939 | 0.5050 | 41.446 | 9.903 | 1.233E-01 | 7.695E-06 | 1.669 |
| 55000.00 | 99000.0 | 3.5622E+06 | 1.5320E+06 | 355.26 | 84.883 | 0.5048 | 41.408 | 9.894 | 1.120E-01 | 6.991E-06 | 1.668 |
| 60000.00 | 108000.0 | 3.7692E+06 | 1.6210E+06 | 358.86 | 85.744 | 0.5047 | 41.381 | 9.887 | 1.026E-01 | 6.405E-06 | 1.668 |
| 65000.00 | 117000.0 | 3.9760E+06 | 1.7100E+06 | 362.18 | 86.535 | 0.5046 | 41.350 | 9.882 | 9.468E-02 | 5.911E-06 | 1.668 |
| 70000.00 | 126000.0 | 4.1829E+06 | 1.7989E+06 | 365.24 | 87.268 | 0.5045 | 41.343 | 9.878 | 8.789E-02 | 5.487E-06 | 1.668 |
| 80000.00 | 144000.0 | 4.5961E+06 | 1.9767E+06 | 370.76 | 88.586 | 0.5043 | 41.320 | 9.873 | 7.687E-02 | 4.799E-06 | 1.667 |
| 90000.00 | 162000.0 | 5.0092E+06 | 2.1543E+06 | 375.63 | 89.749 | 0.5042 | 41.306 | 9.869 | 6.831E-02 | 4.264E-06 | 1.667 |
| 100000.00 | 180000.0 | 5.4222E+06 | 2.3320E+06 | 379.98 | 90.789 | 0.5042 | 41.294 | 9.866 | 6.147E-02 | 3.837E-06 | 1.667 |
| 110000.00 | 198000.0 | 5.8351E+06 | 2.5095E+06 | 383.92 | 91.729 | 0.5041 | 41.286 | 9.865 | 5.587E-02 | 3.488E-06 | 1.667 |

TABLE II. - Continued. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(h) Pressure, $3.03975 \times 10^5$ N/m$^2$ (3 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 100.00 | 180.0 | -2.1284E+05 | -9.1537E+04 | 45.38 | 10.844 | 2.0155 | 13.967 | 3.337 | 7.369E+02 | 4.601E-02 | 1.419 |
| 150.00 | 270.0 | -2.1217E+05 | -9.1250E+04 | 50.81 | 12.140 | 2.0156 | 13.163 | 3.145 | 4.913E+02 | 3.067E-02 | 1.456 |
| 200.00 | 360.0 | -2.1150E+05 | -9.0963E+04 | 54.65 | 13.058 | 2.0156 | 13.622 | 3.255 | 3.685E+02 | 2.300E-02 | 1.434 |
| 250.00 | 450.0 | -2.1081E+05 | -9.0665E+04 | 57.74 | 13.797 | 2.0156 | 14.060 | 3.359 | 2.948E+02 | 1.840E-02 | 1.415 |
| 298.15 | 536.7 | -2.1013E+05 | -9.0371E+04 | 60.24 | 14.394 | 2.0156 | 14.305 | 3.418 | 2.472E+02 | 1.543E-02 | 1.405 |
| 400.00 | 720.0 | -2.0866E+05 | -8.9739E+04 | 64.48 | 15.406 | 2.0156 | 14.478 | 3.459 | 1.842E+02 | 1.150E-02 | 1.398 |
| 500.00 | 900.0 | -2.0721E+05 | -8.9116E+04 | 67.71 | 16.179 | 2.0155 | 14.517 | 3.468 | 1.474E+02 | 9.201E-03 | 1.397 |
| 600.00 | 1080.0 | -2.0575E+05 | -8.8491E+04 | 70.36 | 16.812 | 2.0155 | 14.548 | 3.476 | 1.228E+02 | 7.668E-03 | 1.396 |
| 700.00 | 1260.0 | -2.0430E+05 | -8.7864E+04 | 72.61 | 17.349 | 2.0156 | 14.605 | 3.490 | 1.053E+02 | 6.572E-03 | 1.394 |
| 800.00 | 1440.0 | -2.0283E+05 | -8.7234E+04 | 74.57 | 17.816 | 2.0156 | 14.697 | 3.512 | 9.212E+01 | 5.751E-03 | 1.390 |
| 900.00 | 1620.0 | -2.0135E+05 | -8.6599E+04 | 76.30 | 18.231 | 2.0156 | 14.825 | 3.542 | 8.188E+01 | 5.112E-03 | 1.386 |
| 1000.00 | 1800.0 | -1.9987E+05 | -8.5958E+04 | 77.87 | 18.606 | 2.0156 | 14.984 | 3.580 | 7.369E+01 | 4.601E-03 | 1.380 |
| 1100.00 | 1980.0 | -1.9836E+05 | -8.5310E+04 | 79.31 | 18.950 | 2.0156 | 15.171 | 3.625 | 6.699E+01 | 4.182E-03 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 80.64 | 19.267 | 2.0156 | 15.375 | 3.674 | 6.141E+01 | 3.834E-03 | 1.367 |
| 1300.00 | 2340.0 | -1.9528E+05 | -8.3987E+04 | 81.88 | 19.563 | 2.0156 | 15.590 | 3.725 | 5.669E+01 | 3.539E-03 | 1.360 |
| 1400.00 | 2520.0 | -1.9371E+05 | -8.3312E+04 | 83.04 | 19.841 | 2.0156 | 15.812 | 3.778 | 5.264E+01 | 3.286E-03 | 1.353 |
| 1500.00 | 2700.0 | -1.9212E+05 | -8.2627E+04 | 84.14 | 20.104 | 2.0155 | 16.038 | 3.832 | 4.913E+01 | 3.067E-03 | 1.346 |
| 1600.00 | 2880.0 | -1.9051E+05 | -8.1932E+04 | 85.18 | 20.353 | 2.0156 | 16.272 | 3.888 | 4.606E+01 | 2.875E-03 | 1.340 |
| 1700.00 | 3060.0 | -1.8887E+05 | -8.1227E+04 | 86.18 | 20.590 | 2.0156 | 16.530 | 3.950 | 4.335E+01 | 2.706E-03 | 1.333 |
| 1800.00 | 3240.0 | -1.8720E+05 | -8.0510E+04 | 87.13 | 20.818 | 2.0154 | 16.833 | 4.022 | 4.094E+01 | 2.556E-03 | 1.326 |
| 1900.00 | 3420.0 | -1.8550E+05 | -7.9778E+04 | 88.05 | 21.038 | 2.0152 | 17.215 | 4.113 | 3.878E+01 | 2.421E-03 | 1.318 |
| 2000.00 | 3600.0 | -1.8375E+05 | -7.9027E+04 | 88.94 | 21.252 | 2.0147 | 17.726 | 4.235 | 3.683E+01 | 2.299E-03 | 1.308 |
| 2100.00 | 3780.0 | -1.8195E+05 | -7.8251E+04 | 89.83 | 21.462 | 2.0138 | 18.433 | 4.404 | 3.506E+01 | 2.189E-03 | 1.297 |
| 2200.00 | 3960.0 | -1.8005E+05 | -7.7438E+04 | 90.70 | 21.672 | 2.0124 | 19.414 | 4.639 | 3.344E+01 | 2.088E-03 | 1.283 |
| 2300.00 | 4140.0 | -1.7805E+05 | -7.6575E+04 | 91.60 | 21.885 | 2.0101 | 20.764 | 4.961 | 3.195E+01 | 1.995E-03 | 1.268 |
| 2400.00 | 4320.0 | -1.7589E+05 | -7.5645E+04 | 92.52 | 22.105 | 2.0065 | 22.591 | 5.398 | 3.057E+01 | 1.908E-03 | 1.251 |
| 2500.00 | 4500.0 | -1.7351E+05 | -7.4624E+04 | 93.49 | 22.337 | 2.0012 | 25.009 | 5.975 | 2.927E+01 | 1.827E-03 | 1.234 |
| 2600.00 | 4680.0 | -1.7086E+05 | -7.3484E+04 | 94.52 | 22.585 | 1.9936 | 28.141 | 6.724 | 2.803E+01 | 1.750E-03 | 1.218 |
| 2700.00 | 4860.0 | -1.6786E+05 | -7.2191E+04 | 95.66 | 22.856 | 1.9832 | 32.110 | 7.672 | 2.686E+01 | 1.677E-03 | 1.203 |
| 2800.00 | 5040.0 | -1.6441E+05 | -7.0708E+04 | 96.91 | 23.155 | 1.9693 | 37.035 | 8.849 | 2.571E+01 | 1.605E-03 | 1.190 |
| 2900.00 | 5220.0 | -1.6041E+05 | -6.8990E+04 | 98.31 | 23.490 | 1.9512 | 43.027 | 10.280 | 2.460E+01 | 1.536E-03 | 1.180 |
| 3000.00 | 5400.0 | -1.5575E+05 | -6.6990E+04 | 99.89 | 23.866 | 1.9282 | 50.177 | 11.989 | 2.350E+01 | 1.467E-03 | 1.172 |
| 3100.00 | 5580.0 | -1.5034E+05 | -6.4657E+04 | 101.67 | 24.291 | 1.8998 | 58.552 | 13.990 | 2.241E+01 | 1.399E-03 | 1.166 |
| 3200.00 | 5760.0 | -1.4401E+05 | -6.1936E+04 | 103.67 | 24.771 | 1.8655 | 68.173 | 16.289 | 2.131E+01 | 1.331E-03 | 1.161 |
| 3400.00 | 6120.0 | -1.2818E+05 | -5.5126E+04 | 108.47 | 25.916 | 1.7787 | 90.883 | 21.715 | 1.913E+01 | 1.194E-03 | 1.158 |
| 3600.00 | 6480.0 | -1.0745E+05 | -4.6212E+04 | 114.38 | 27.330 | 1.6700 | 116.623 | 27.865 | 1.696E+01 | 1.059E-03 | 1.159 |
| 3800.00 | 6840.0 | -8.1604E+04 | -3.5096E+04 | 121.37 | 28.998 | 1.5473 | 141.129 | 33.720 | 1.489E+01 | 9.293E-04 | 1.164 |
| 4000.00 | 7200.0 | -5.1542E+04 | -2.2167E+04 | 129.07 | 30.839 | 1.4231 | 157.480 | 37.627 | 1.301E+01 | 8.120E-04 | 1.173 |
| 4200.00 | 7560.0 | -1.9613E+04 | -8.4349E+03 | 136.86 | 32.700 | 1.3106 | 158.994 | 37.989 | 1.141E+01 | 7.122E-04 | 1.185 |
| 4400.00 | 7920.0 | 1.0969E+04 | 4.7176E+03 | 143.98 | 34.400 | 1.2192 | 144.467 | 34.518 | 1.013E+01 | 6.324E-04 | 1.200 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4600.00 | 8280.0 | 3.7503E+04 | 1.6129E+04 | 149.88 | 35.810 | 1.1512 | 119.936 | 28.656 | 9.150E+00 | 5.712E-04 | 1.221 |
| 4800.00 | 8640.0 | 5.8852E+04 | 2.5311E+04 | 154.42 | 36.897 | 1.1040 | 93.898 | 22.435 | 8.409E+00 | 5.250E-04 | 1.248 |
| 5000.00 | 9000.0 | 7.5341E+04 | 3.2402E+04 | 157.79 | 37.702 | 1.0725 | 71.908 | 17.181 | 7.942E+00 | 4.896E-04 | 1.283 |
| 5200.00 | 9360.0 | 8.7995E+04 | 3.7845E+04 | 160.28 | 38.295 | 1.0517 | 55.575 | 13.279 | 7.595E+00 | 4.616E-04 | 1.325 |
| 5400.00 | 9720.0 | 9.7906E+04 | 4.2107E+04 | 162.15 | 38.742 | 1.0382 | 44.259 | 10.575 | 7.329E+00 | 4.388E-04 | 1.372 |
| 5600.00 | 10080.0 | 1.0595E+05 | 4.5566E+04 | 163.61 | 39.092 | 1.0292 | 36.678 | 8.763 | 6.719E+00 | 4.195E-04 | 1.422 |
| 5800.00 | 10440.0 | 1.1275E+05 | 4.8490E+04 | 164.80 | 39.377 | 1.0231 | 31.665 | 7.566 | 6.449E+00 | 4.026E-04 | 1.469 |
| 6000.00 | 10800.0 | 1.1873E+05 | 5.1061E+04 | 165.82 | 39.619 | 1.0190 | 28.357 | 6.775 | 5.209E+00 | 3.876E-04 | 1.510 |
| 6300.00 | 11340.0 | 1.2674E+05 | 5.4508E+04 | 167.12 | 39.931 | 1.0150 | 25.376 | 6.063 | 5.390E+00 | 3.677E-04 | 1.557 |
| 6600.00 | 11880.0 | 1.3409E+05 | 5.7669E+04 | 168.26 | 40.203 | 1.0126 | 23.795 | 5.685 | 5.509E+00 | 3.502E-04 | 1.587 |
| 7000.00 | 12600.0 | 1.4339E+05 | 6.1669E+04 | 169.63 | 40.530 | 1.0106 | 22.886 | 5.468 | 5.278E+00 | 3.295E-04 | 1.603 |
| 7300.00 | 13140.0 | 1.5023E+05 | 6.4610E+04 | 170.59 | 40.759 | 1.0095 | 22.764 | 5.439 | 5.056E+00 | 3.156E-04 | 1.601 |
| 7600.00 | 13680.0 | 1.5709E+05 | 6.7559E+04 | 171.51 | 40.979 | 1.0087 | 22.996 | 5.494 | 4.852E+00 | 3.029E-04 | 1.590 |
| 8000.00 | 14400.0 | 1.6643E+05 | 7.1576E+04 | 172.71 | 41.265 | 1.0076 | 23.803 | 5.687 | 4.605E+00 | 2.875E-04 | 1.564 |
| 8300.00 | 14940.0 | 1.7371E+05 | 7.4707E+04 | 173.60 | 41.478 | 1.0067 | 24.791 | 5.923 | 4.434E+00 | 2.768E-04 | 1.537 |
| 8600.00 | 15480.0 | 1.8134E+05 | 7.7989E+04 | 174.50 | 41.694 | 1.0056 | 26.141 | 6.246 | 4.275E+00 | 2.669E-04 | 1.506 |
| 9000.00 | 16200.0 | 1.9225E+05 | 8.2684E+04 | 175.74 | 41.990 | 1.0037 | 28.583 | 6.829 | 4.078E+00 | 2.546E-04 | 1.462 |
| 9300.00 | 16740.0 | 2.0117E+05 | 8.6520E+04 | 176.72 | 42.223 | 1.0018 | 30.965 | 7.398 | 3.939E+00 | 2.459E-04 | 1.428 |
| 9600.00 | 17280.0 | 2.1089E+05 | 9.0698E+04 | 177.74 | 42.469 | 0.9995 | 33.883 | 8.096 | 3.807E+00 | 2.377E-04 | 1.395 |
| 10000.00 | 18000.0 | 2.2537E+05 | 9.6926E+04 | 179.22 | 42.822 | 0.9954 | 38.717 | 9.251 | 3.640E+00 | 2.272E-04 | 1.354 |
| 10500.00 | 18900.0 | 2.4659E+05 | 1.0605E+05 | 181.29 | 43.316 | 0.9885 | 46.480 | 11.105 | 3.443E+00 | 2.150E-04 | 1.311 |
| 11000.00 | 19800.0 | 2.7221E+05 | 1.1707E+05 | 183.67 | 43.885 | 0.9790 | 56.413 | 13.479 | 3.256E+00 | 2.033E-04 | 1.276 |
| 11500.00 | 20700.0 | 3.0343E+05 | 1.3048E+05 | 186.44 | 44.547 | 0.9665 | 68.758 | 16.428 | 3.076E+00 | 1.920E-04 | 1.249 |
| 12000.00 | 21600.0 | 3.4140E+05 | 1.4683E+05 | 189.68 | 45.320 | 0.9505 | 83.688 | 19.996 | 2.901E+00 | 1.811E-04 | 1.229 |
| 12500.00 | 22500.0 | 3.8753E+05 | 1.6667E+05 | 193.44 | 46.219 | 0.9310 | 101.256 | 24.193 | 2.729E+00 | 1.704E-04 | 1.215 |
| 13000.00 | 23400.0 | 4.4307E+05 | 1.9056E+05 | 197.80 | 47.259 | 0.9077 | 121.329 | 28.989 | 2.561E+00 | 1.599E-04 | 1.204 |
| 13500.00 | 24300.0 | 5.0921E+05 | 2.1900E+05 | 202.78 | 48.452 | 0.8807 | 143.492 | 34.285 | 2.395E+00 | 1.495E-04 | 1.197 |
| 14000.00 | 25200.0 | 5.8679E+05 | 2.5236E+05 | 208.43 | 49.799 | 0.8506 | 166.955 | 39.891 | 2.233E+00 | 1.394E-04 | 1.192 |
| 15000.00 | 27000.0 | 7.7564E+05 | 3.3359E+05 | 221.43 | 52.907 | 0.7840 | 210.465 | 50.287 | 1.926E+00 | 1.202E-04 | 1.192 |
| 16000.00 | 28800.0 | 1.0032E+06 | 4.3144E+05 | 236.10 | 56.412 | 0.7161 | 241.007 | 57.584 | 1.653E+00 | 1.032E-04 | 1.198 |
| 17000.00 | 30600.0 | 1.2485E+06 | 5.3698E+05 | 250.97 | 59.965 | 0.6555 | 244.672 | 58.460 | 1.427E+00 | 8.910E-05 | 1.209 |
| 18000.00 | 32400.0 | 1.4829E+06 | 6.3776E+05 | 264.37 | 63.166 | 0.6079 | 220.050 | 52.577 | 1.251E+00 | 7.811E-05 | 1.228 |
| 19000.00 | 34200.0 | 1.6836E+06 | 7.2406E+05 | 275.23 | 65.761 | 0.5740 | 180.165 | 43.047 | 1.119E+00 | 6.988E-05 | 1.255 |
| 20000.00 | 35000.0 | 1.8433E+06 | 7.9277E+05 | 283.44 | 67.723 | 0.5513 | 140.293 | 33.520 | 1.021E+00 | 6.375E-05 | 1.292 |
| 21000.00 | 37800.0 | 1.9670E+06 | 8.4594E+05 | 289.49 | 69.168 | 0.5367 | 108.592 | 25.946 | 9.461E-01 | 5.907E-05 | 1.337 |
| 22000.00 | 39600.0 | 2.0636E+06 | 8.8752E+05 | 294.00 | 70.245 | 0.5274 | 86.225 | 20.602 | 8.867E-01 | 5.535E-05 | 1.389 |
| 23000.00 | 41400.0 | 2.1418E+06 | 9.2115E+05 | 297.48 | 71.078 | 0.5213 | 71.224 | 17.018 | 8.378E-01 | 5.230E-05 | 1.443 |
| 24000.00 | 43200.0 | 2.2079E+06 | 9.4954E+05 | 300.30 | 71.752 | 0.5174 | 61.519 | 14.699 | 7.961E-01 | 4.970E-05 | 1.493 |
| 25000.00 | 45000.0 | 2.2660E+06 | 9.7454E+05 | 302.69 | 72.321 | 0.5147 | 55.147 | 13.176 | 7.598E-01 | 4.743E-05 | 1.536 |
| 26000.00 | 46800.0 | 2.3189E+06 | 9.9731E+05 | 304.77 | 72.819 | 0.5128 | 51.029 | 12.193 | 7.274E-01 | 4.541E-05 | 1.570 |
| 27000.00 | 48600.0 | 2.3685E+06 | 1.0186E+06 | 306.65 | 73.268 | 0.5115 | 48.300 | 11.540 | 6.982E-01 | 4.359E-05 | 1.596 |
| 28000.00 | 50400.0 | 2.4158E+06 | 1.0390E+06 | 308.38 | 73.680 | 0.5105 | 46.348 | 11.074 | 6.717E-01 | 4.193E-05 | 1.616 |
| 29000.00 | 52200.0 | 2.4614E+06 | 1.0586E+06 | 309.99 | 74.065 | 0.5098 | 45.096 | 10.775 | 6.473E-01 | 4.041E-05 | 1.630 |
| 30000.00 | 54000.0 | 2.5061E+06 | 1.0778E+06 | 311.50 | 74.428 | 0.5093 | 44.154 | 10.550 | 6.247E-01 | 3.900E-05 | 1.641 |
| 32000.00 | 57600.0 | 2.5932E+06 | 1.1153E+06 | 314.33 | 75.103 | 0.5085 | 43.101 | 10.298 | 5.843E-01 | 3.648E-05 | 1.653 |
| 34000.00 | 61200.0 | 2.6787E+06 | 1.1520E+06 | 316.93 | 75.724 | 0.5079 | 42.452 | 10.143 | 5.490E-01 | 3.427E-05 | 1.660 |
| 36000.00 | 64800.0 | 2.7632E+06 | 1.1884E+06 | 319.35 | 76.303 | 0.5075 | 42.092 | 10.057 | 5.178E-01 | 3.233E-05 | 1.664 |
| 38000.00 | 68400.0 | 2.8472E+06 | 1.2245E+06 | 321.63 | 76.848 | 0.5072 | 41.919 | 10.016 | 4.900E-01 | 3.059E-05 | 1.666 |
| 40000.00 | 72000.0 | 2.9308E+06 | 1.2605E+06 | 323.78 | 77.362 | 0.5070 | 41.743 | 9.974 | 4.651E-01 | 2.904E-05 | 1.667 |
| 43000.00 | 77400.0 | 3.0562E+06 | 1.3144E+06 | 326.81 | 78.086 | 0.5066 | 41.802 | 9.988 | 4.321E-01 | 2.698E-05 | 1.670 |
| 46000.00 | 82800.0 | 3.1815E+06 | 1.3683E+06 | 329.63 | 78.759 | 0.5062 | 41.701 | 9.964 | 4.035E-01 | 2.519E-05 | 1.670 |
| 50000.00 | 90000.0 | 3.3481E+06 | 1.4399E+06 | 333.11 | 79.590 | 0.5059 | 41.611 | 9.942 | 3.708E-01 | 2.315E-05 | 1.670 |
| 55000.00 | 99000.0 | 3.5560E+06 | 1.5293E+06 | 337.07 | 80.537 | 0.5055 | 41.537 | 9.924 | 3.367E-01 | 2.102E-05 | 1.669 |
| 60000.00 | 108000.0 | 3.7635E+06 | 1.6186E+06 | 340.69 | 81.400 | 0.5052 | 41.485 | 9.912 | 3.084E-01 | 1.925E-05 | 1.669 |
| 65000.00 | 117000.0 | 3.9708E+06 | 1.7078E+06 | 344.01 | 82.194 | 0.5050 | 41.442 | 9.902 | 2.845E-01 | 1.776E-05 | 1.669 |
| 70000.00 | 126000.0 | 4.1780E+06 | 1.7968E+06 | 347.08 | 82.927 | 0.5049 | 41.414 | 9.895 | 2.640E-01 | 1.648E-05 | 1.668 |
| 80000.00 | 144000.0 | 4.5919E+06 | 1.9749E+06 | 352.61 | 84.249 | 0.5047 | 41.375 | 9.886 | 2.308E-01 | 1.441E-05 | 1.668 |
| 90000.00 | 162000.0 | 5.0055E+06 | 2.1527E+06 | 357.48 | 85.413 | 0.5045 | 41.348 | 9.879 | 2.051E-01 | 1.280E-05 | 1.668 |
| 100000.00 | 180000.0 | 5.4189E+06 | 2.3305E+06 | 361.84 | 86.454 | 0.5044 | 41.327 | 9.874 | 1.845E-01 | 1.152E-05 | 1.668 |
| 110000.00 | 198000.0 | 5.8321E+06 | 2.5082E+06 | 365.77 | 87.395 | 0.5043 | 41.313 | 9.871 | 1.677E-01 | 1.047E-05 | 1.667 |

TABLE II. - Continued. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(i) Pressure, $1.01325 \times 10^{6}$ N/m$^2$ (10 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 100.00 | 180.0 | -2.1284E+05 | -9.1537E+04 | 40.42 | 9.657 | 2.0156 | 13.967 | 3.337 | 2.456E+03 | 1.534E-01 | 1.419 |
| 150.00 | 270.0 | -2.1217E+05 | -9.1250E+04 | 45.84 | 10.954 | 2.0155 | 13.174 | 3.148 | 1.638E+03 | 1.022E-01 | 1.456 |
| 200.00 | 360.0 | -2.1150E+05 | -9.0963E+04 | 49.69 | 11.872 | 2.0156 | 13.617 | 3.253 | 1.228E+03 | 7.668E-02 | 1.435 |
| 250.00 | 450.0 | -2.1081E+05 | -9.0665E+04 | 52.78 | 12.610 | 2.0156 | 14.062 | 3.360 | 9.826E+02 | 6.134E-02 | 1.415 |
| 298.15 | 536.7 | -2.1013E+05 | -9.0371E+04 | 55.28 | 13.207 | 2.0155 | 14.299 | 3.417 | 8.239E+02 | 5.143E-02 | 1.405 |
| 400.00 | 720.0 | -2.0866E+05 | -8.9739E+04 | 59.51 | 14.219 | 2.0156 | 14.479 | 3.460 | 6.141E+02 | 3.834E-02 | 1.398 |
| 500.00 | 900.0 | -2.0721E+05 | -8.9116E+04 | 62.75 | 14.992 | 2.0156 | 14.517 | 3.468 | 4.913E+02 | 3.067E-02 | 1.397 |
| 600.00 | 1080.0 | -2.0575E+05 | -8.8491E+04 | 65.40 | 15.625 | 2.0155 | 14.547 | 3.475 | 4.094E+02 | 2.556E-02 | 1.396 |
| 700.00 | 1260.0 | -2.0430E+05 | -8.7864E+04 | 67.64 | 16.162 | 2.0156 | 14.605 | 3.490 | 3.509E+02 | 2.191E-02 | 1.394 |
| 800.00 | 1440.0 | -2.0283E+05 | -8.7234E+04 | 69.60 | 16.629 | 2.0156 | 14.695 | 3.511 | 3.071E+02 | 1.917E-02 | 1.390 |
| 900.00 | 1620.0 | -2.0135E+05 | -8.6599E+04 | 71.34 | 17.045 | 2.0156 | 14.825 | 3.542 | 2.729E+02 | 1.704E-02 | 1.386 |
| 1000.00 | 1800.0 | -1.9987E+05 | -8.5958E+04 | 72.91 | 17.420 | 2.0156 | 14.984 | 3.580 | 2.456E+02 | 1.534E-02 | 1.380 |
| 1100.00 | 1980.0 | -1.9836E+05 | -8.5310E+04 | 74.34 | 17.763 | 2.0156 | 15.171 | 3.625 | 2.233E+02 | 1.394E-02 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 75.67 | 18.081 | 2.0156 | 15.375 | 3.674 | 2.047E+02 | 1.278E-02 | 1.367 |
| 1300.00 | 2340.0 | -1.9529E+05 | -8.3987E+04 | 76.91 | 18.377 | 2.0156 | 15.590 | 3.725 | 1.890E+02 | 1.180E-02 | 1.360 |
| 1400.00 | 2520.0 | -1.9371E+05 | -8.3312E+04 | 78.07 | 18.655 | 2.0156 | 15.810 | 3.777 | 1.755E+02 | 1.095E-02 | 1.353 |
| 1500.00 | 2700.0 | -1.9212E+05 | -8.2627E+04 | 79.17 | 18.917 | 2.0156 | 16.031 | 3.830 | 1.638E+02 | 1.022E-02 | 1.346 |
| 1600.00 | 2880.0 | -1.9051E+05 | -8.1933E+04 | 80.21 | 19.166 | 2.0155 | 16.256 | 3.884 | 1.535E+02 | 9.584E-03 | 1.340 |
| 1700.00 | 3060.0 | -1.8887E+05 | -8.1229E+04 | 81.21 | 19.403 | 2.0155 | 16.490 | 3.940 | 1.445E+02 | 9.020E-03 | 1.334 |
| 1800.00 | 3240.0 | -1.8721E+05 | -8.0514E+04 | 82.16 | 19.630 | 2.0155 | 16.745 | 4.001 | 1.365E+02 | 8.519E-03 | 1.328 |
| 1900.00 | 3420.0 | -1.8552E+05 | -7.9788E+04 | 83.07 | 19.848 | 2.0154 | 17.040 | 4.071 | 1.293E+02 | 8.070E-03 | 1.321 |
| 2000.00 | 3600.0 | -1.8380E+05 | -7.9048E+04 | 83.95 | 20.059 | 2.0151 | 17.401 | 4.158 | 1.228E+02 | 7.666E-03 | 1.313 |
| 2100.00 | 3780.0 | -1.8204E+05 | -7.8290E+04 | 84.81 | 20.264 | 2.0147 | 17.866 | 4.269 | 1.169E+02 | 7.299E-03 | 1.305 |
| 2200.00 | 3960.0 | -1.8022E+05 | -7.7509E+04 | 85.66 | 20.466 | 2.0139 | 18.476 | 4.414 | 1.116E+02 | 6.964E-03 | 1.295 |
| 2300.00 | 4140.0 | -1.7834E+05 | -7.6698E+04 | 86.50 | 20.666 | 2.0126 | 19.285 | 4.608 | 1.066E+02 | 6.657E-03 | 1.284 |
| 2400.00 | 4320.0 | -1.7635E+05 | -7.5847E+04 | 87.34 | 20.868 | 2.0106 | 20.352 | 4.863 | 1.021E+02 | 6.374E-03 | 1.272 |
| 2500.00 | 4500.0 | -1.7425E+05 | -7.4943E+04 | 88.20 | 21.073 | 2.0077 | 21.740 | 5.194 | 9.787E+01 | 5.110E-03 | 1.258 |
| 2600.00 | 4680.0 | -1.7200E+05 | -7.3971E+04 | 89.08 | 21.284 | 2.0035 | 23.516 | 5.619 | 9.391E+01 | 5.863E-03 | 1.245 |
| 2700.00 | 4860.0 | -1.6954E+05 | -7.2913E+04 | 90.01 | 21.506 | 1.9978 | 25.750 | 6.152 | 9.017E+01 | 5.629E-03 | 1.231 |
| 2800.00 | 5040.0 | -1.6683E+05 | -7.1749E+04 | 90.99 | 21.741 | 1.9900 | 28.507 | 6.811 | 8.661E+01 | 5.407E-03 | 1.218 |
| 2900.00 | 5220.0 | -1.6382E+05 | -7.0453E+04 | 92.05 | 21.994 | 1.9798 | 31.851 | 7.610 | 8.320E+01 | 5.194E-03 | 1.207 |
| 3000.00 | 5400.0 | -1.6044E+05 | -6.9000E+04 | 93.20 | 22.267 | 1.9668 | 35.841 | 8.564 | 7.990E+01 | 4.988E-03 | 1.197 |
| 3100.00 | 5580.0 | -1.5662E+05 | -6.7360E+04 | 94.45 | 22.565 | 1.9504 | 40.526 | 9.683 | 7.667E+01 | 4.787E-03 | 1.188 |
| 3200.00 | 5760.0 | -1.5231E+05 | -6.5503E+04 | 95.82 | 22.893 | 1.9303 | 45.943 | 10.977 | 7.351E+01 | 4.589E-03 | 1.182 |
| 3400.00 | 6120.0 | -1.4185E+05 | -6.1010E+04 | 98.98 | 23.649 | 1.8778 | 59.037 | 14.106 | 6.731E+01 | 4.202E-03 | 1.173 |
| 3600.00 | 6480.0 | -1.2850E+05 | -5.5265E+04 | 102.79 | 24.560 | 1.8076 | 74.972 | 17.913 | 6.119E+01 | 3.820E-03 | 1.169 |
| 3800.00 | 6840.0 | -1.1173E+05 | -4.8053E+04 | 107.32 | 25.642 | 1.7207 | 92.953 | 22.209 | 5.519E+01 | 3.445E-03 | 1.170 |
| 4000.00 | 7200.0 | -9.1300E+04 | -3.9266E+04 | 112.56 | 26.893 | 1.6212 | 111.191 | 26.567 | 4.939E+01 | 3.083E-03 | 1.174 |
| 4200.00 | 7560.0 | -6.7433E+04 | -2.9001E+04 | 118.38 | 28.284 | 1.5156 | 126.725 | 30.279 | 4.398E+01 | 2.745E-03 | 1.181 |
| 4400.00 | 7920.0 | -4.1033E+04 | -1.7647E+04 | 124.51 | 29.750 | 1.4122 | 135.920 | 32.476 | 3.911E+01 | 2.442E-03 | 1.190 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4600.00 | 8280.0 | -1.3679E+04 | -5.8829E+03 | 130.59 | 31.203 | 1.3186 | 135.985 | 32.491 | 3.494E+01 | 2.181E-03 | 1.202 |
| 4800.00 | 8640.0 | 1.2735E+04 | 5.4768E+03 | 136.22 | 32.546 | 1.2400 | 126.751 | 30.285 | 3.148E+01 | 1.965E-03 | 1.217 |
| 5000.00 | 9000.0 | 3.6587E+04 | 1.5735E+04 | 141.09 | 33.710 | 1.1778 | 111.029 | 26.528 | 2.871E+01 | 1.792E-03 | 1.235 |
| 5200.00 | 9360.0 | 5.6992E+04 | 2.4511E+04 | 145.09 | 34.667 | 1.1311 | 92.961 | 22.211 | 2.651E+01 | 1.655E-03 | 1.258 |
| 5400.00 | 9720.0 | 7.3846E+04 | 3.1759E+04 | 148.27 | 35.427 | 1.0971 | 75.955 | 18.148 | 2.476E+01 | 1.546E-03 | 1.285 |
| 5600.00 | 10080.0 | 8.7565E+04 | 3.7660E+04 | 150.77 | 36.023 | 1.0728 | 61.770 | 14.759 | 2.335E+01 | 1.458E-03 | 1.318 |
| 5800.00 | 10440.0 | 9.8769E+04 | 4.2478E+04 | 152.74 | 36.493 | 1.0556 | 50.787 | 12.135 | 2.218E+01 | 1.385E-03 | 1.354 |
| 6000.00 | 10800.0 | 1.0807E+05 | 4.6478E+04 | 154.31 | 36.870 | 1.0433 | 42.647 | 10.190 | 2.119E+01 | 1.323E-03 | 1.393 |
| 6300.00 | 11340.0 | 1.1954E+05 | 5.1410E+04 | 156.18 | 37.316 | 1.0312 | 34.480 | 8.238 | 1.995E+01 | 1.245E-03 | 1.451 |
| 6600.00 | 11880.0 | 1.2908E+05 | 5.5515E+04 | 157.66 | 37.670 | 1.0235 | 29.571 | 7.065 | 1.890E+01 | 1.180E-03 | 1.503 |
| 7000.00 | 12600.0 | 1.4011E+05 | 6.0256E+04 | 159.28 | 38.058 | 1.0176 | 25.977 | 6.207 | 1.772E+01 | 1.106E-03 | 1.552 |
| 7300.00 | 13140.0 | 1.4767E+05 | 6.3509E+04 | 160.34 | 38.311 | 1.0147 | 24.573 | 5.871 | 1.694E+01 | 1.058E-03 | 1.575 |
| 7600.00 | 13680.0 | 1.5492E+05 | 6.6626E+04 | 161.32 | 38.543 | 1.0127 | 23.844 | 5.697 | 1.624E+01 | 1.014E-03 | 1.585 |
| 8000.00 | 14400.0 | 1.6438E+05 | 7.0696E+04 | 162.53 | 38.833 | 1.0108 | 23.586 | 5.635 | 1.540E+01 | 9.613E-04 | 1.583 |
| 8300.00 | 14940.0 | 1.7148E+05 | 7.3749E+04 | 163.40 | 39.041 | 1.0096 | 23.802 | 5.687 | 1.482E+01 | 9.254E-04 | 1.573 |
| 8600.00 | 15480.0 | 1.7869E+05 | 7.6851E+04 | 164.25 | 39.245 | 1.0085 | 24.322 | 5.811 | 1.429E+01 | 8.922E-04 | 1.556 |
| 9000.00 | 16200.0 | 1.8863E+05 | 8.1126E+04 | 165.38 | 39.515 | 1.0070 | 25.475 | 6.087 | 1.364E+01 | 8.513E-04 | 1.526 |
| 9300.00 | 16740.0 | 1.9645E+05 | 8.4489E+04 | 166.24 | 39.719 | 1.0057 | 26.696 | 6.379 | 1.318E+01 | 8.228E-04 | 1.499 |
| 9600.00 | 17280.0 | 2.0468E+05 | 8.8029E+04 | 167.11 | 39.927 | 1.0042 | 28.246 | 6.749 | 1.275E+01 | 7.959E-04 | 1.471 |
| 10000.00 | 18000.0 | 2.1648E+05 | 9.3105E+04 | 168.31 | 40.215 | 1.0017 | 30.870 | 7.376 | 1.221E+01 | 7.622E-04 | 1.433 |
| 10500.00 | 18900.0 | 2.3294E+05 | 1.0018E+05 | 169.92 | 40.599 | 0.9976 | 35.152 | 8.399 | 1.158E+01 | 7.231E-04 | 1.387 |
| 11000.00 | 19800.0 | 2.5185E+05 | 1.0831E+05 | 171.68 | 41.019 | 0.9921 | 40.690 | 9.722 | 1.100E+01 | 6.865E-04 | 1.346 |
| 11500.00 | 20700.0 | 2.7386E+05 | 1.1778E+05 | 173.63 | 41.486 | 0.9848 | 47.629 | 11.380 | 1.044E+01 | 6.520E-04 | 1.311 |
| 12000.00 | 21600.0 | 2.9973E+05 | 1.2891E+05 | 175.83 | 42.012 | 0.9754 | 55.101 | 13.404 | 9.919E+00 | 6.192E-04 | 1.282 |
| 12500.00 | 22500.0 | 3.3024E+05 | 1.4203E+05 | 178.32 | 42.607 | 0.9637 | 65.203 | 15.818 | 9.412E+00 | 5.876E-04 | 1.259 |
| 13000.00 | 23400.0 | 3.6621E+05 | 1.5750E+05 | 181.14 | 43.281 | 0.9493 | 77.982 | 18.632 | 8.922E+00 | 5.570E-04 | 1.242 |
| 13500.00 | 24300.0 | 4.0849E+05 | 1.7568E+05 | 184.33 | 44.043 | 0.9322 | 91.410 | 21.841 | 8.445E+00 | 5.272E-04 | 1.228 |
| 14000.00 | 25200.0 | 4.5788E+05 | 1.9692E+05 | 187.92 | 44.901 | 0.9123 | 106.353 | 25.411 | 7.978E+00 | 4.981E-04 | 1.217 |
| 15000.00 | 27000.0 | 5.8005E+05 | 2.4947E+05 | 196.34 | 46.911 | 0.8650 | 137.959 | 32.963 | 7.080E+00 | 4.420E-04 | 1.209 |
| 16000.00 | 28800.0 | 7.3464E+05 | 3.1595E+05 | 206.30 | 49.291 | 0.8100 | 170.887 | 40.830 | 6.235E+00 | 3.893E-04 | 1.205 |
| 17000.00 | 30600.0 | 9.1973E+05 | 3.9555E+05 | 217.50 | 51.968 | 0.7522 | 197.692 | 47.235 | 5.467E+00 | 3.413E-04 | 1.208 |
| 18000.00 | 32400.0 | 1.1257E+06 | 4.8415E+05 | 229.27 | 54.779 | 0.6970 | 211.635 | 50.566 | 4.798E+00 | 2.995E-04 | 1.215 |
| 19000.00 | 34200.0 | 1.3371E+06 | 5.7506E+05 | 240.69 | 57.509 | 0.6491 | 208.223 | 49.751 | 4.241E+00 | 2.648E-04 | 1.229 |
| 20000.00 | 36000.0 | 1.5370E+06 | 6.6105E+05 | 250.95 | 59.960 | 0.6106 | 189.585 | 45.298 | 3.794E+00 | 2.368E-04 | 1.248 |
| 21000.00 | 37800.0 | 1.7135E+06 | 7.3695E+05 | 259.57 | 62.020 | 0.5816 | 152.659 | 38.864 | 3.442E+00 | 2.149E-04 | 1.273 |
| 22000.00 | 39600.0 | 1.8621E+06 | 8.0085E+05 | 266.49 | 63.674 | 0.5607 | 134.860 | 32.222 | 3.166E+00 | 1.977E-04 | 1.306 |
| 23000.00 | 41400.0 | 1.9845E+06 | 8.5348E+05 | 271.95 | 64.977 | 0.5460 | 110.730 | 26.457 | 2.947E+00 | 1.840E-04 | 1.342 |
| 24000.00 | 43200.0 | 2.0853E+06 | 8.9686E+05 | 276.25 | 66.005 | 0.5358 | 91.859 | 21.948 | 2.769E+00 | 1.728E-04 | 1.383 |
| 25000.00 | 45000.0 | 2.1693E+06 | 9.3321E+05 | 279.71 | 66.832 | 0.5286 | 77.928 | 18.619 | 2.620E+00 | 1.635E-04 | 1.426 |
| 26000.00 | 46800.0 | 2.2425E+06 | 9.6445E+05 | 282.57 | 67.515 | 0.5235 | 67.946 | 16.234 | 2.492E+00 | 1.556E-04 | 1.468 |
| 27000.00 | 48600.0 | 2.3065E+06 | 9.9202E+05 | 285.00 | 68.095 | 0.5199 | 60.713 | 14.506 | 2.381E+00 | 1.486E-04 | 1.508 |
| 28000.00 | 50400.0 | 2.3647E+06 | 1.0170E+06 | 287.12 | 68.602 | 0.5173 | 55.721 | 13.313 | 2.282E+00 | 1.425E-04 | 1.542 |
| 29000.00 | 52200.0 | 2.4185E+06 | 1.0402E+06 | 289.02 | 69.056 | 0.5153 | 52.181 | 12.468 | 2.193E+00 | 1.369E-04 | 1.569 |
| 30000.00 | 54000.0 | 2.4693E+06 | 1.0620E+06 | 290.75 | 69.459 | 0.5139 | 49.544 | 11.838 | 2.112E+00 | 1.319E-04 | 1.592 |
| 32000.00 | 57600.0 | 2.5649E+06 | 1.1031E+06 | 293.85 | 70.210 | 0.5118 | 46.386 | 11.083 | 1.970E+00 | 1.230E-04 | 1.623 |
| 34000.00 | 61200.0 | 2.6558E+06 | 1.1422E+06 | 296.62 | 70.871 | 0.5105 | 44.498 | 10.632 | 1.847E+00 | 1.153E-04 | 1.642 |
| 36000.00 | 64800.0 | 2.7437E+06 | 1.1800E+06 | 299.14 | 71.474 | 0.5097 | 43.530 | 10.401 | 1.740E+00 | 1.086E-04 | 1.653 |
| 38000.00 | 68400.0 | 2.8301E+06 | 1.2171E+06 | 301.49 | 72.035 | 0.5090 | 42.865 | 10.242 | 1.645E+00 | 1.027E-04 | 1.659 |
| 40000.00 | 72000.0 | 2.9154E+06 | 1.2538E+06 | 303.69 | 72.560 | 0.5085 | 42.513 | 10.158 | 1.560E+00 | 9.738E-05 | 1.663 |
| 43000.00 | 77400.0 | 3.0422E+06 | 1.3084E+06 | 306.76 | 73.294 | 0.5080 | 42.087 | 10.056 | 1.448E+00 | 9.041E-05 | 1.666 |
| 46000.00 | 82800.0 | 3.1682E+06 | 1.3626E+06 | 309.60 | 73.973 | 0.5076 | 41.861 | 10.002 | 1.352E+00 | 8.439E-05 | 1.668 |
| 50000.00 | 90000.0 | 3.3354E+06 | 1.4345E+06 | 313.10 | 74.809 | 0.5072 | 41.758 | 9.977 | 1.242E+00 | 7.751E-05 | 1.668 |
| 55000.00 | 99000.0 | 3.5436E+06 | 1.5240E+06 | 317.08 | 75.750 | 0.5069 | 41.562 | 9.931 | 1.127E+00 | 7.036E-05 | 1.669 |
| 60000.00 | 108000.0 | 3.7522E+06 | 1.6137E+06 | 320.72 | 76.629 | 0.5064 | 41.491 | 9.961 | 1.032E+00 | 6.440E-05 | 1.671 |
| 65000.00 | 117000.0 | 3.9605E+06 | 1.7033E+06 | 324.05 | 77.426 | 0.5060 | 41.618 | 9.944 | 9.512E-01 | 5.938E-05 | 1.670 |
| 70000.00 | 125000.0 | 4.1684E+06 | 1.7927E+06 | 327.14 | 78.163 | 0.5057 | 41.562 | 9.931 | 8.824E-01 | 5.509E-05 | 1.670 |
| 80000.00 | 144000.0 | 4.5837E+06 | 1.9713E+06 | 332.68 | 79.489 | 0.5053 | 41.486 | 9.912 | 7.710E-01 | 4.813E-05 | 1.669 |
| 90000.00 | 162000.0 | 4.9982E+06 | 2.1496E+06 | 337.57 | 80.656 | 0.5050 | 41.428 | 9.898 | 6.847E-01 | 4.275E-05 | 1.669 |
| 100000.00 | 180000.0 | 5.4123E+06 | 2.3277E+06 | 341.93 | 81.699 | 0.5048 | 41.394 | 9.890 | 6.158E-01 | 3.845E-05 | 1.668 |
| 110000.00 | 198000.0 | 5.8261E+06 | 2.5057E+06 | 345.88 | 82.641 | 0.5046 | 41.369 | 9.884 | 5.596E-01 | 3.493E-05 | 1.668 |

TABLE II. - Continued. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(j) Pressure, $3.03975 \times 10^{6}$ N/m$^2$ (30 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 150.00 | 270.0 | -2.1217E+05 | -9.1250E+04 | 41.31 | 9.871 | 2.0156 | 13.174 | 3.148 | 4.913E+03 | 3.067E-01 | 1.456 |
| 200.00 | 360.0 | -2.1150E+05 | -9.0963E+04 | 45.16 | 10.789 | 2.0156 | 13.619 | 3.254 | 3.685E+03 | 2.300E-01 | 1.434 |
| 250.00 | 450.0 | -2.1081E+05 | -9.0665E+04 | 48.25 | 11.527 | 2.0156 | 14.069 | 3.361 | 2.948E+03 | 1.840E-01 | 1.415 |
| 298.15 | 536.7 | -2.1013E+05 | -9.0371E+04 | 50.75 | 12.125 | 2.0156 | 14.305 | 3.418 | 2.472E+03 | 1.543E-01 | 1.405 |
| 400.00 | 720.0 | -2.0865E+05 | -8.9739E+04 | 54.98 | 13.136 | 2.0156 | 14.479 | 3.460 | 1.842E+03 | 1.150E-01 | 1.398 |
| 500.00 | 900.0 | -2.0721E+05 | -8.9116E+04 | 58.22 | 13.909 | 2.0156 | 14.517 | 3.468 | 1.474E+03 | 9.201E-02 | 1.397 |
| 600.00 | 1080.0 | -2.0576E+05 | -8.8491E+04 | 60.86 | 14.542 | 2.0156 | 14.548 | 3.476 | 1.228E+03 | 7.668E-02 | 1.396 |
| 700.00 | 1260.0 | -2.0430E+05 | -8.7864E+04 | 63.11 | 15.079 | 2.0155 | 14.607 | 3.490 | 1.053E+03 | 6.572E-02 | 1.394 |
| 800.00 | 1440.0 | -2.0283E+05 | -8.7234E+04 | 65.07 | 15.547 | 2.0155 | 14.697 | 3.512 | 9.212E+02 | 5.751E-02 | 1.390 |
| 900.00 | 1620.0 | -2.0135E+05 | -8.6599E+04 | 66.81 | 15.962 | 2.0156 | 14.826 | 3.542 | 8.188E+02 | 5.112E-02 | 1.385 |
| 1000.00 | 1800.0 | -1.9987E+05 | -8.5958E+04 | 68.38 | 16.337 | 2.0156 | 14.984 | 3.580 | 7.369E+02 | 4.601E-02 | 1.380 |
| 1100.00 | 1980.0 | -1.9835E+05 | -8.5310E+04 | 69.81 | 16.680 | 2.0156 | 15.171 | 3.625 | 6.699E+02 | 4.182E-02 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 71.14 | 16.998 | 2.0156 | 15.375 | 3.673 | 6.141E+02 | 3.834E-02 | 1.367 |
| 1300.00 | 2340.0 | -1.9529E+05 | -8.3987E+04 | 72.38 | 17.294 | 2.0156 | 15.589 | 3.725 | 5.569E+02 | 3.539E-02 | 1.360 |
| 1400.00 | 2520.0 | -1.9371E+05 | -8.3312E+04 | 73.54 | 17.572 | 2.0156 | 15.808 | 3.777 | 5.264E+02 | 3.286E-02 | 1.353 |
| 1500.00 | 2700.0 | -1.9212E+05 | -8.2627E+04 | 74.64 | 17.834 | 2.0156 | 16.028 | 3.830 | 4.913E+02 | 3.067E-02 | 1.347 |
| 1600.00 | 2880.0 | -1.9051E+05 | -8.1933E+04 | 75.68 | 18.083 | 2.0156 | 16.247 | 3.882 | 4.606E+02 | 2.875E-02 | 1.340 |
| 1700.00 | 3060.0 | -1.8887E+05 | -8.1230E+04 | 76.67 | 18.320 | 2.0156 | 16.469 | 3.935 | 4.335E+02 | 2.706E-02 | 1.334 |
| 1800.00 | 3240.0 | -1.8722E+05 | -8.0517E+04 | 77.62 | 18.546 | 2.0156 | 16.700 | 3.990 | 4.094E+02 | 2.556E-02 | 1.328 |
| 1900.00 | 3420.0 | -1.8553E+05 | -7.9793E+04 | 78.53 | 18.764 | 2.0155 | 16.950 | 4.050 | 3.878E+02 | 2.421E-02 | 1.322 |
| 2000.00 | 3600.0 | -1.8382E+05 | -7.9058E+04 | 79.41 | 18.973 | 2.0154 | 17.234 | 4.118 | 3.684E+02 | 2.300E-02 | 1.316 |
| 2100.00 | 3780.0 | -1.8208E+05 | -7.8310E+04 | 80.26 | 19.176 | 2.0151 | 17.575 | 4.199 | 3.508E+02 | 2.190E-02 | 1.310 |
| 2200.00 | 3960.0 | -1.8031E+05 | -7.7545E+04 | 81.08 | 19.373 | 2.0146 | 17.995 | 4.300 | 3.348E+02 | 2.090E-02 | 1.302 |
| 2300.00 | 4140.0 | -1.7848E+05 | -7.6761E+04 | 81.90 | 19.567 | 2.0139 | 18.528 | 4.427 | 3.201E+02 | 1.998E-02 | 1.294 |
| 2400.00 | 4320.0 | -1.7660E+05 | -7.5950E+04 | 82.70 | 19.759 | 2.0127 | 19.206 | 4.589 | 3.066E+02 | 1.914E-02 | 1.285 |
| 2500.00 | 4500.0 | -1.7463E+05 | -7.5106E+04 | 83.50 | 19.950 | 2.0111 | 20.066 | 4.794 | 2.941E+02 | 1.836E-02 | 1.274 |
| 2600.00 | 4680.0 | -1.7258E+05 | -7.4220E+04 | 84.31 | 20.143 | 2.0086 | 21.149 | 5.053 | 2.824E+02 | 1.763E-02 | 1.264 |
| 2700.00 | 4860.0 | -1.7043E+05 | -7.3283E+04 | 85.13 | 20.340 | 2.0053 | 22.493 | 5.374 | 2.715E+02 | 1.695E-02 | 1.253 |
| 2800.00 | 5040.0 | -1.6807E+05 | -7.2281E+04 | 85.97 | 20.542 | 2.0008 | 24.136 | 5.767 | 2.612E+02 | 1.631E-02 | 1.241 |
| 2900.00 | 5220.0 | -1.6555E+05 | -7.1202E+04 | 86.86 | 20.752 | 1.9948 | 26.119 | 6.241 | 2.515E+02 | 1.570E-02 | 1.231 |
| 3000.00 | 5400.0 | -1.6283E+05 | -7.0029E+04 | 87.78 | 20.973 | 1.9871 | 28.475 | 6.804 | 2.422E+02 | 1.512E-02 | 1.220 |
| 3100.00 | 5580.0 | -1.5985E+05 | -6.8747E+04 | 88.76 | 21.207 | 1.9774 | 31.234 | 7.463 | 2.332E+02 | 1.456E-02 | 1.211 |
| 3200.00 | 5760.0 | -1.5657E+05 | -6.7337E+04 | 89.80 | 21.455 | 1.9655 | 34.423 | 8.225 | 2.246E+02 | 1.402E-02 | 1.203 |
| 3400.00 | 5120.0 | -1.4894E+05 | -6.4056E+04 | 92.11 | 22.007 | 1.9335 | 42.165 | 10.074 | 2.079E+02 | 1.298E-02 | 1.191 |
| 3600.00 | 5480.0 | -1.3958E+05 | -6.0030E+04 | 94.78 | 22.646 | 1.8895 | 51.755 | 12.366 | 1.919E+02 | 1.198E-02 | 1.184 |
| 3800.00 | 5840.0 | -1.2812E+05 | -5.5103E+04 | 97.87 | 23.385 | 1.8325 | 63.065 | 15.068 | 1.763E+02 | 1.101E-02 | 1.180 |
| 4000.00 | 7200.0 | -1.1427E+05 | -4.9143E+04 | 101.43 | 24.234 | 1.7529 | 75.688 | 18.084 | 1.611E+02 | 1.006E-02 | 1.181 |
| 4200.00 | 7560.0 | -9.7814E+04 | -4.2067E+04 | 105.44 | 25.192 | 1.6828 | 88.826 | 21.223 | 1.465E+02 | 9.145E-03 | 1.184 |
| 4400.00 | 7920.0 | -7.8785E+04 | -3.3883E+04 | 109.86 | 26.249 | 1.5956 | 101.208 | 24.182 | 1.326E+02 | 8.277E-03 | 1.189 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4600.00 | 8280.0 | -5.7492E+04 | -2.4726E+04 | 114.59 | 27.379 | 1.5061 | 111.156 | 26.559 | 1.197E+02 | 7.473E-03 | 1.197 |
| 4800.00 | 8640.0 | -3.4601E+04 | -1.4881E+04 | 119.46 | 28.543 | 1.4194 | 116.924 | 27.937 | 1.081E+02 | 6.749E-03 | 1.206 |
| 5000.00 | 9000.0 | -1.1084E+04 | -4.7668E+03 | 124.26 | 29.690 | 1.3398 | 117.303 | 28.027 | 9.797E+01 | 6.116E-03 | 1.218 |
| 5200.00 | 9350.0 | 1.1952E+04 | 5.1404E+03 | 128.78 | 30.769 | 1.2704 | 112.200 | 26.808 | 8.932E+01 | 5.576E-03 | 1.232 |
| 5400.00 | 9720.0 | 3.3505E+04 | 1.4410E+04 | 132.85 | 31.742 | 1.2125 | 102.763 | 24.553 | 8.210E+01 | 5.125E-03 | 1.248 |
| 5600.00 | 10080.0 | 5.2896E+04 | 2.2749E+04 | 136.38 | 32.584 | 1.1661 | 90.902 | 21.719 | 7.613E+01 | 4.753E-03 | 1.267 |
| 5800.00 | 10440.0 | 6.9835E+04 | 3.0034E+04 | 139.35 | 33.295 | 1.1298 | 78.539 | 18.765 | 7.122E+01 | 4.446E-03 | 1.289 |
| 6000.00 | 10800.0 | 8.4373E+04 | 3.6287E+04 | 141.81 | 33.884 | 1.1020 | 67.066 | 16.024 | 6.715E+01 | 4.192E-03 | 1.314 |
| 6300.00 | 11340.0 | 1.0227E+05 | 4.3986E+04 | 144.73 | 34.580 | 1.0722 | 52.962 | 12.654 | 6.222E+01 | 3.884E-03 | 1.357 |
| 6600.00 | 11880.0 | 1.1655E+05 | 5.0125E+04 | 146.94 | 35.109 | 1.0526 | 42.813 | 10.229 | 5.831E+01 | 3.640E-03 | 1.404 |
| 7000.00 | 12600.0 | 1.3179E+05 | 5.6679E+04 | 149.19 | 35.646 | 1.0363 | 34.167 | 8.164 | 5.413E+01 | 3.379E-03 | 1.464 |
| 7300.00 | 13140.0 | 1.4140E+05 | 6.0814E+04 | 150.53 | 35.967 | 1.0286 | 30.206 | 7.217 | 5.152E+01 | 3.216E-03 | 1.504 |
| 7600.00 | 13680.0 | 1.5005E+05 | 6.4534E+04 | 151.69 | 36.244 | 1.0232 | 27.651 | 6.607 | 4.922E+01 | 3.073E-03 | 1.534 |
| 8000.00 | 14400.0 | 1.6067E+05 | 6.9102E+04 | 153.06 | 36.570 | 1.0183 | 25.675 | 6.135 | 4.654E+01 | 2.905E-03 | 1.560 |
| 8300.00 | 14940.0 | 1.6825E+05 | 7.2360E+04 | 153.99 | 36.792 | 1.0157 | 24.917 | 5.953 | 4.474E+01 | 2.793E-03 | 1.568 |
| 8600.00 | 15480.0 | 1.7567E+05 | 7.5550E+04 | 154.86 | 37.002 | 1.0137 | 24.603 | 5.878 | 4.309E+01 | 2.690E-03 | 1.568 |
| 9000.00 | 16200.0 | 1.8551E+05 | 7.9785E+04 | 155.98 | 37.269 | 1.0114 | 24.722 | 5.907 | 4.109E+01 | 2.565E-03 | 1.557 |
| 9300.00 | 16740.0 | 1.9299E+05 | 8.3000E+04 | 156.80 | 37.464 | 1.0099 | 25.154 | 6.010 | 3.970E+01 | 2.479E-03 | 1.543 |
| 9600.00 | 17280.0 | 2.0063E+05 | 8.6287E+04 | 157.61 | 37.658 | 1.0085 | 25.856 | 6.178 | 3.841E+01 | 2.398E-03 | 1.524 |
| 10000.00 | 18000.0 | 2.1123E+05 | 9.0845E+04 | 158.69 | 37.916 | 1.0064 | 27.204 | 6.500 | 3.680E+01 | 2.297E-03 | 1.495 |
| 10500.00 | 18900.0 | 2.2539E+05 | 9.6935E+04 | 160.07 | 38.246 | 1.0035 | 29.572 | 7.066 | 3.495E+01 | 2.182E-03 | 1.455 |
| 11000.00 | 19800.0 | 2.4094E+05 | 1.0362E+05 | 161.52 | 38.592 | 0.9998 | 32.751 | 7.825 | 3.325E+01 | 2.075E-03 | 1.414 |
| 11500.00 | 20700.0 | 2.5829E+05 | 1.1108E+05 | 163.06 | 38.960 | 0.9952 | 36.813 | 8.796 | 3.166E+01 | 1.976E-03 | 1.376 |
| 12000.00 | 21600.0 | 2.7791E+05 | 1.1952E+05 | 164.73 | 39.359 | 0.9893 | 41.833 | 9.995 | 3.017E+01 | 1.884E-03 | 1.343 |
| 12500.00 | 22500.0 | 3.0029E+05 | 1.2915E+05 | 166.56 | 39.795 | 0.9820 | 47.878 | 11.440 | 2.876E+01 | 1.796E-03 | 1.313 |
| 13000.00 | 23400.0 | 3.2597E+05 | 1.4019E+05 | 168.57 | 40.276 | 0.9729 | 55.001 | 13.142 | 2.742E+01 | 1.712E-03 | 1.289 |
| 13500.00 | 24300.0 | 3.5548E+05 | 1.5288E+05 | 170.80 | 40.808 | 0.9620 | 63.227 | 15.107 | 2.613E+01 | 1.631E-03 | 1.269 |
| 14000.00 | 25200.0 | 3.8938E+05 | 1.6746E+05 | 173.26 | 41.397 | 0.9491 | 72.549 | 17.334 | 2.488E+01 | 1.553E-03 | 1.253 |
| 15000.00 | 27000.0 | 4.7239E+05 | 2.0316E+05 | 178.98 | 42.764 | 0.9171 | 93.327 | 22.299 | 2.250E+01 | 1.405E-03 | 1.233 |
| 16000.00 | 28800.0 | 5.7729E+05 | 2.4827E+05 | 185.74 | 44.378 | 0.8774 | 116.726 | 27.889 | 2.025E+01 | 1.264E-03 | 1.222 |
| 17000.00 | 30600.0 | 7.0614E+05 | 3.0369E+05 | 193.53 | 46.241 | 0.8317 | 140.855 | 33.655 | 1.813E+01 | 1.132E-03 | 1.217 |
| 18000.00 | 32400.0 | 8.5804E+05 | 3.6902E+05 | 202.20 | 48.312 | 0.7829 | 162.214 | 38.758 | 1.619E+01 | 1.010E-03 | 1.219 |
| 19000.00 | 34200.0 | 1.0287E+06 | 4.4240E+05 | 211.42 | 50.514 | 0.7344 | 177.750 | 42.470 | 1.444E+01 | 9.013E-04 | 1.222 |
| 20000.00 | 36000.0 | 1.2102E+06 | 5.2049E+05 | 220.72 | 52.738 | 0.6894 | 183.722 | 43.897 | 1.291E+01 | 8.062E-04 | 1.232 |
| 21000.00 | 37800.0 | 1.3927E+06 | 5.9896E+05 | 229.63 | 54.865 | 0.6502 | 179.531 | 42.896 | 1.162E+01 | 7.256E-04 | 1.246 |
| 22000.00 | 39600.0 | 1.5665E+06 | 6.7369E+05 | 237.71 | 56.797 | 0.6178 | 166.841 | 39.864 | 1.055E+01 | 6.588E-04 | 1.265 |
| 23000.00 | 41400.0 | 1.7247E+06 | 7.4175E+05 | 244.75 | 58.479 | 0.5921 | 149.102 | 35.625 | 9.675E+00 | 6.040E-04 | 1.287 |
| 24000.00 | 43200.0 | 1.8642E+06 | 8.0175E+05 | 250.70 | 59.899 | 0.5723 | 129.958 | 31.051 | 8.959E+00 | 5.593E-04 | 1.314 |
| 25000.00 | 45000.0 | 1.9850E+06 | 8.5371E+05 | 255.64 | 61.080 | 0.5574 | 112.010 | 25.763 | 8.369E+00 | 5.225E-04 | 1.347 |
| 26000.00 | 46800.0 | 2.0891E+06 | 8.9847E+05 | 259.73 | 62.058 | 0.5464 | 96.615 | 23.084 | 7.879E+00 | 4.918E-04 | 1.380 |
| 27000.00 | 48600.0 | 2.1792E+06 | 9.3724E+05 | 263.15 | 62.874 | 0.5381 | 84.185 | 20.114 | 7.463E+00 | 4.659E-04 | 1.415 |
| 28000.00 | 50400.0 | 2.2584E+06 | 9.7127E+05 | 266.03 | 63.564 | 0.5319 | 74.492 | 17.798 | 7.104E+00 | 4.435E-04 | 1.450 |
| 29000.00 | 52200.0 | 2.3290E+06 | 1.0016E+06 | 268.52 | 64.158 | 0.5272 | 67.079 | 16.027 | 6.790E+00 | 4.239E-04 | 1.483 |
| 30000.00 | 54000.0 | 2.3931E+06 | 1.0292E+06 | 270.71 | 64.680 | 0.5236 | 61.334 | 14.655 | 5.511E+00 | 4.065E-04 | 1.515 |
| 32000.00 | 57600.0 | 2.5075E+06 | 1.0785E+06 | 274.42 | 65.568 | 0.5187 | 53.869 | 12.871 | 6.034E+00 | 3.767E-04 | 1.566 |
| 34000.00 | 61200.0 | 2.6106E+06 | 1.1228E+06 | 277.56 | 66.318 | 0.5156 | 49.554 | 11.840 | 5.634E+00 | 3.517E-04 | 1.601 |
| 36000.00 | 64800.0 | 2.7068E+06 | 1.1641E+06 | 280.32 | 66.978 | 0.5135 | 46.757 | 11.172 | 5.291E+00 | 3.303E-04 | 1.626 |
| 38000.00 | 68400.0 | 2.7985E+06 | 1.2036E+06 | 282.82 | 67.575 | 0.5122 | 45.212 | 10.802 | 4.992E+00 | 3.116E-04 | 1.641 |
| 40000.00 | 72000.0 | 2.8880E+06 | 1.2420E+06 | 285.13 | 68.125 | 0.5112 | 44.096 | 10.536 | 4.727E+00 | 2.951E-04 | 1.652 |
| 43000.00 | 77400.0 | 3.0188E+06 | 1.2983E+06 | 288.30 | 68.884 | 0.5101 | 43.242 | 10.332 | 4.381E+00 | 2.735E-04 | 1.660 |
| 46000.00 | 82800.0 | 3.1478E+06 | 1.3538E+06 | 291.21 | 69.579 | 0.5093 | 42.700 | 10.202 | 4.084E+00 | 2.550E-04 | 1.664 |
| 50000.00 | 90000.0 | 3.3173E+06 | 1.4267E+06 | 294.76 | 70.428 | 0.5086 | 42.247 | 10.094 | 3.747E+00 | 2.339E-04 | 1.667 |
| 55000.00 | 99000.0 | 3.5277E+06 | 1.5172E+06 | 298.79 | 71.390 | 0.5080 | 41.953 | 10.024 | 3.398E+00 | 2.121E-04 | 1.669 |
| 60000.00 | 108000.0 | 3.7369E+06 | 1.6072E+06 | 302.45 | 72.264 | 0.5076 | 41.730 | 9.971 | 3.109E+00 | 1.941E-04 | 1.669 |
| 65000.00 | 117000.0 | 3.9454E+06 | 1.6968E+06 | 305.80 | 73.064 | 0.5072 | 41.621 | 9.944 | 2.866E+00 | 1.789E-04 | 1.670 |
| 70000.00 | 126000.0 | 4.1535E+06 | 1.7863E+06 | 308.89 | 73.804 | 0.5069 | 41.610 | 9.942 | 2.658E+00 | 1.659E-04 | 1.669 |
| 80000.00 | 144000.0 | 4.5702E+06 | 1.9655E+06 | 314.46 | 75.135 | 0.5063 | 41.668 | 9.956 | 2.321E+00 | 1.449E-04 | 1.671 |
| 90000.00 | 162000.0 | 4.9864E+06 | 2.1445E+06 | 319.37 | 76.307 | 0.5058 | 41.576 | 9.934 | 2.059E+00 | 1.286E-04 | 1.670 |
| 100000.00 | 180000.0 | 5.4017E+06 | 2.3231E+06 | 323.75 | 77.354 | 0.5054 | 41.502 | 9.916 | 1.851E+00 | 1.156E-04 | 1.669 |
| 110000.00 | 198000.0 | 5.8165E+06 | 2.5015E+06 | 327.70 | 78.299 | 0.5052 | 41.459 | 9.906 | 1.682E+00 | 1.050E-04 | 1.669 |

TABLE II. - Continued. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(k) Pressure, $1.01325 \times 10^{7}$ N/m$^2$ (100 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 400.00 | 720.0 | -2.0865E+05 | -8.9739E+04 | 50.01 | 11.950 | 2.0155 | 14.478 | 3.459 | 5.141E+03 | 3.834E-01 | 1.398 |
| 500.00 | 900.0 | -2.0721E+05 | -8.9116E+04 | 53.25 | 12.723 | 2.0155 | 14.516 | 3.458 | 4.913E+03 | 3.067E-01 | 1.397 |
| 600.00 | 1080.0 | -2.0575E+05 | -8.8491E+04 | 55.90 | 13.356 | 2.0156 | 14.545 | 3.476 | 4.094E+03 | 2.556E-01 | 1.396 |
| 700.00 | 1260.0 | -2.0430E+05 | -8.7864E+04 | 58.15 | 13.893 | 2.0156 | 14.607 | 3.490 | 3.509E+03 | 2.191E-01 | 1.394 |
| 800.00 | 1440.0 | -2.0283E+05 | -8.7234E+04 | 60.10 | 14.360 | 2.0156 | 14.696 | 3.511 | 3.071E+03 | 1.917E-01 | 1.390 |
| 900.00 | 1620.0 | -2.0136E+05 | -8.6599E+04 | 61.84 | 14.775 | 2.0156 | 14.825 | 3.542 | 2.729E+03 | 1.704E-01 | 1.386 |
| 1000.00 | 1800.0 | -1.9987E+05 | -8.5958E+04 | 63.41 | 15.150 | 2.0156 | 14.984 | 3.580 | 2.456E+03 | 1.534E-01 | 1.380 |
| 1100.00 | 1980.0 | -1.9835E+05 | -8.5310E+04 | 64.85 | 15.494 | 2.0156 | 15.171 | 3.625 | 2.233E+03 | 1.394E-01 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 66.17 | 15.811 | 2.0156 | 15.376 | 3.674 | 2.047E+03 | 1.278E-01 | 1.367 |
| 1300.00 | 2340.0 | -1.9528E+05 | -8.3987E+04 | 67.41 | 16.107 | 2.0156 | 15.589 | 3.725 | 1.890E+03 | 1.180E-01 | 1.360 |
| 1400.00 | 2520.0 | -1.9371E+05 | -8.3312E+04 | 68.58 | 16.385 | 2.0156 | 15.808 | 3.777 | 1.755E+03 | 1.095E-01 | 1.353 |
| 1500.00 | 2700.0 | -1.9212E+05 | -8.2628E+04 | 69.68 | 16.648 | 2.0156 | 16.026 | 3.829 | 1.638E+03 | 1.022E-01 | 1.347 |
| 1600.00 | 2880.0 | -1.9051E+05 | -8.1934E+04 | 70.72 | 16.896 | 2.0156 | 16.242 | 3.881 | 1.535E+03 | 9.584E-02 | 1.340 |
| 1700.00 | 3060.0 | -1.8887E+05 | -8.1231E+04 | 71.71 | 17.133 | 2.0155 | 16.456 | 3.932 | 1.445E+03 | 9.021E-02 | 1.335 |
| 1800.00 | 3240.0 | -1.8722E+05 | -8.0518E+04 | 72.65 | 17.359 | 2.0155 | 16.672 | 3.983 | 1.365E+03 | 8.519E-02 | 1.329 |
| 1900.00 | 3420.0 | -1.8554E+05 | -7.9796E+04 | 73.56 | 17.576 | 2.0156 | 16.895 | 4.037 | 1.293E+03 | 8.071E-02 | 1.323 |
| 2000.00 | 3600.0 | -1.8384E+05 | -7.9065E+04 | 74.43 | 17.785 | 2.0155 | 17.131 | 4.093 | 1.228E+03 | 7.667E-02 | 1.318 |
| 2100.00 | 3780.0 | -1.8211E+05 | -7.8322E+04 | 75.28 | 17.986 | 2.0153 | 17.395 | 4.156 | 1.170E+03 | 7.301E-02 | 1.312 |
| 2200.00 | 3960.0 | -1.8035E+05 | -7.7568E+04 | 76.09 | 18.181 | 2.0151 | 17.699 | 4.229 | 1.116E+03 | 6.969E-02 | 1.307 |
| 2300.00 | 4140.0 | -1.7857E+05 | -7.6799E+04 | 76.89 | 18.371 | 2.0147 | 18.060 | 4.315 | 1.068E+03 | 6.664E-02 | 1.300 |
| 2400.00 | 4320.0 | -1.7674E+05 | -7.6013E+04 | 77.66 | 18.556 | 2.0141 | 18.498 | 4.420 | 1.023E+03 | 6.385E-02 | 1.293 |
| 2500.00 | 4500.0 | -1.7487E+05 | -7.5207E+04 | 78.43 | 18.739 | 2.0131 | 19.033 | 4.548 | 9.813E+02 | 6.126E-02 | 1.286 |
| 2600.00 | 4680.0 | -1.7293E+05 | -7.4375E+04 | 79.19 | 18.921 | 2.0118 | 19.686 | 4.704 | 9.430E+02 | 5.887E-02 | 1.278 |
| 2700.00 | 4860.0 | -1.7093E+05 | -7.3511E+04 | 79.95 | 19.102 | 2.0100 | 20.480 | 4.893 | 9.072E+02 | 5.664E-02 | 1.270 |
| 2800.00 | 5040.0 | -1.6883E+05 | -7.2611E+04 | 80.71 | 19.283 | 2.0075 | 21.436 | 5.122 | 8.737E+02 | 5.455E-02 | 1.261 |
| 2900.00 | 5220.0 | -1.6663E+05 | -7.1665E+04 | 81.48 | 19.468 | 2.0042 | 22.575 | 5.394 | 8.422E+02 | 5.258E-02 | 1.252 |
| 3000.00 | 5400.0 | -1.6431E+05 | -7.0666E+04 | 82.27 | 19.656 | 1.9999 | 23.917 | 5.715 | 8.124E+02 | 5.072E-02 | 1.243 |
| 3100.00 | 5580.0 | -1.6184E+05 | -6.9605E+04 | 83.08 | 19.849 | 1.9945 | 25.480 | 6.088 | 7.841E+02 | 4.895E-02 | 1.235 |
| 3200.00 | 5760.0 | -1.5921E+05 | -6.8471E+04 | 83.91 | 20.049 | 1.9878 | 27.279 | 6.518 | 7.570E+02 | 4.726E-02 | 1.227 |
| 3400.00 | 6120.0 | -1.5333E+05 | -6.5945E+04 | 85.69 | 20.474 | 1.9698 | 31.631 | 7.558 | 7.060E+02 | 4.408E-02 | 1.214 |
| 3600.00 | 6480.0 | -1.4648E+05 | -6.2999E+04 | 87.65 | 20.942 | 1.9444 | 37.032 | 8.848 | 6.582E+02 | 4.109E-02 | 1.204 |
| 3800.00 | 6840.0 | -1.3845E+05 | -5.9544E+04 | 89.82 | 21.460 | 1.9107 | 43.484 | 10.390 | 6.128E+02 | 3.825E-02 | 1.197 |
| 4000.00 | 7200.0 | -1.2903E+05 | -5.5491E+04 | 92.23 | 22.037 | 1.8679 | 50.904 | 12.163 | 5.691E+02 | 3.553E-02 | 1.194 |
| 4200.00 | 7560.0 | -1.1803E+05 | -5.0764E+04 | 94.91 | 22.678 | 1.8161 | 59.117 | 14.125 | 5.270E+02 | 3.290E-02 | 1.193 |
| 4400.00 | 7920.0 | -1.0535E+05 | -4.5307E+04 | 97.86 | 23.382 | 1.7561 | 67.818 | 16.204 | 4.864E+02 | 3.036E-02 | 1.195 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4600.00 | 3280.0 | -9.0905E+04 | -3.9096E+04 | 101.07 | 24.149 | 1.6893 | 76.552 | 18.291 | 4.475E+02 | 2.794E-02 | 1.198 |
| 4800.00 | 3640.0 | -7.4763E+04 | -3.2154E+04 | 104.50 | 24.969 | 1.6180 | 84.712 | 20.240 | 4.108E+02 | 2.564E-02 | 1.204 |
| 5000.00 | 9000.0 | -5.7107E+04 | -2.4560E+04 | 108.11 | 25.830 | 1.5448 | 91.573 | 21.880 | 3.765E+02 | 2.351E-02 | 1.211 |
| 5200.00 | 9360.0 | -3.8270E+04 | -1.6459E+04 | 111.80 | 26.713 | 1.4726 | 96.395 | 23.032 | 3.451E+02 | 2.154E-02 | 1.220 |
| 5400.00 | 9720.0 | -1.8725E+04 | -8.0530E+03 | 115.49 | 27.594 | 1.4039 | 98.586 | 23.555 | 3.168E+02 | 1.978E-02 | 1.230 |
| 5600.00 | 10080.0 | 9.6983E+02 | 4.1710E+02 | 119.07 | 28.449 | 1.3408 | 97.870 | 23.384 | 2.918E+02 | 1.822E-02 | 1.242 |
| 5800.00 | 10440.0 | 2.0239E+04 | 8.7043E+03 | 122.45 | 29.257 | 1.2847 | 94.393 | 22.553 | 2.699E+02 | 1.685E-02 | 1.256 |
| 6000.00 | 10800.0 | 3.8579E+04 | 1.6592E+04 | 125.56 | 30.000 | 1.2362 | 88.692 | 21.191 | 2.511E+02 | 1.567E-02 | 1.271 |
| 6300.00 | 11340.0 | 6.3582E+04 | 2.7345E+04 | 129.63 | 30.972 | 1.1773 | 77.686 | 18.562 | 2.277E+02 | 1.422E-02 | 1.297 |
| 6600.00 | 11880.0 | 8.5131E+04 | 3.6613E+04 | 132.97 | 31.771 | 1.1333 | 66.049 | 15.781 | 2.093E+02 | 1.306E-02 | 1.327 |
| 7000.00 | 12600.0 | 1.0873E+05 | 4.6764E+04 | 136.45 | 32.602 | 1.0925 | 52.500 | 12.544 | 1.902E+02 | 1.187E-02 | 1.371 |
| 7300.00 | 13140.0 | 1.2325E+05 | 5.3008E+04 | 138.48 | 33.087 | 1.0716 | 44.635 | 10.665 | 1.789E+02 | 1.117E-02 | 1.407 |
| 7600.00 | 13680.0 | 1.3571E+05 | 5.8364E+04 | 140.15 | 33.487 | 1.0564 | 38.687 | 9.244 | 1.694E+02 | 1.058E-02 | 1.442 |
| 8000.00 | 14400.0 | 1.5000E+05 | 6.4511E+04 | 141.99 | 33.925 | 1.0423 | 33.175 | 7.927 | 1.588E+02 | 9.913E-03 | 1.484 |
| 8300.00 | 14940.0 | 1.5951E+05 | 6.8602E+04 | 143.15 | 34.204 | 1.0349 | 30.408 | 7.266 | 1.520E+02 | 9.486E-03 | 1.510 |
| 8600.00 | 15480.0 | 1.6833E+05 | 7.2394E+04 | 144.20 | 34.453 | 1.0292 | 28.497 | 6.809 | 1.459E+02 | 9.105E-03 | 1.530 |
| 9000.00 | 16200.0 | 1.7939E+05 | 7.7148E+04 | 145.45 | 34.754 | 1.0235 | 26.926 | 6.434 | 1.386E+02 | 8.653E-03 | 1.544 |
| 9300.00 | 16740.0 | 1.8735E+05 | 8.0577E+04 | 146.33 | 34.962 | 1.0203 | 26.300 | 6.284 | 1.337E+02 | 8.347E-03 | 1.548 |
| 9600.00 | 17280.0 | 1.9520E+05 | 8.3950E+04 | 147.16 | 35.160 | 1.0176 | 26.042 | 6.222 | 1.292E+02 | 8.065E-03 | 1.545 |
| 10000.00 | 18000.0 | 2.0562E+05 | 8.8434E+04 | 148.22 | 35.414 | 1.0145 | 26.172 | 6.253 | 1.237E+02 | 7.720E-03 | 1.534 |
| 10500.00 | 18900.0 | 2.1888E+05 | 9.4137E+04 | 149.51 | 35.723 | 1.0111 | 26.982 | 6.447 | 1.174E+02 | 7.328E-03 | 1.510 |
| 11000.00 | 19800.0 | 2.3271E+05 | 1.0008E+05 | 150.80 | 36.031 | 1.0078 | 28.440 | 6.795 | 1.117E+02 | 6.973E-03 | 1.480 |
| 11500.00 | 20700.0 | 2.4743E+05 | 1.0641E+05 | 152.11 | 36.343 | 1.0043 | 30.527 | 7.294 | 1.065E+02 | 6.647E-03 | 1.447 |
| 12000.00 | 21600.0 | 2.6335E+05 | 1.1326E+05 | 153.46 | 36.667 | 1.0002 | 33.247 | 7.944 | 1.017E+02 | 6.347E-03 | 1.413 |
| 12500.00 | 22500.0 | 2.8079E+05 | 1.2076E+05 | 154.89 | 37.007 | 0.9954 | 36.625 | 8.751 | 9.717E+01 | 6.066E-03 | 1.381 |
| 13000.00 | 23400.0 | 3.0008E+05 | 1.2906E+05 | 156.40 | 37.369 | 0.9897 | 40.679 | 9.720 | 9.294E+01 | 5.802E-03 | 1.352 |
| 13500.00 | 24300.0 | 3.2158E+05 | 1.3830E+05 | 158.02 | 37.755 | 0.9829 | 45.430 | 10.855 | 8.894E+01 | 5.553E-03 | 1.326 |
| 14000.00 | 25200.0 | 3.4563E+05 | 1.4865E+05 | 159.77 | 38.174 | 0.9749 | 50.884 | 12.158 | 8.514E+01 | 5.315E-03 | 1.304 |
| 15000.00 | 27000.0 | 4.0278E+05 | 1.7323E+05 | 163.71 | 39.115 | 0.9547 | 63.866 | 15.260 | 7.799E+01 | 4.869E-03 | 1.269 |
| 16000.00 | 28800.0 | 4.7361E+05 | 2.0369E+05 | 168.27 | 40.206 | 0.9286 | 77.951 | 18.625 | 7.135E+01 | 4.454E-03 | 1.251 |
| 17000.00 | 30600.0 | 5.5964E+05 | 2.4069E+05 | 173.48 | 41.449 | 0.8969 | 94.192 | 22.505 | 6.512E+01 | 4.065E-03 | 1.239 |
| 18000.00 | 32400.0 | 6.6210E+05 | 2.8475E+05 | 179.32 | 42.845 | 0.8605 | 110.850 | 26.486 | 5.928E+01 | 3.701E-03 | 1.233 |
| 19000.00 | 34200.0 | 7.8141E+05 | 3.3607E+05 | 185.76 | 44.384 | 0.8210 | 127.140 | 30.378 | 5.384E+01 | 3.361E-03 | 1.229 |
| 20000.00 | 36000.0 | 9.1557E+05 | 3.9376E+05 | 192.63 | 46.026 | 0.7803 | 140.627 | 33.600 | 4.885E+01 | 3.050E-03 | 1.232 |
| 21000.00 | 37800.0 | 1.0614E+06 | 4.5647E+05 | 199.74 | 47.724 | 0.7404 | 150.197 | 35.887 | 4.434E+01 | 2.768E-03 | 1.238 |
| 22000.00 | 39600.0 | 1.2143E+06 | 5.2223E+05 | 206.85 | 49.423 | 0.7031 | 154.753 | 36.975 | 4.033E+01 | 2.518E-03 | 1.248 |
| 23000.00 | 41400.0 | 1.3691E+06 | 5.8880E+05 | 213.73 | 51.066 | 0.6696 | 153.932 | 35.779 | 3.683E+01 | 2.299E-03 | 1.261 |
| 24000.00 | 43200.0 | 1.5205E+06 | 6.5394E+05 | 220.18 | 52.607 | 0.6405 | 148.255 | 35.423 | 3.381E+01 | 2.111E-03 | 1.277 |
| 25000.00 | 45000.0 | 1.6644E+06 | 7.1580E+05 | 226.05 | 54.011 | 0.6160 | 138.956 | 33.201 | 3.124E+01 | 1.950E-03 | 1.296 |
| 26000.00 | 46800.0 | 1.7978E+06 | 7.7317E+05 | 231.29 | 55.262 | 0.5959 | 127.590 | 30.485 | 2.905E+01 | 1.814E-03 | 1.317 |
| 27000.00 | 48600.0 | 1.9193E+06 | 8.2547E+05 | 235.89 | 56.360 | 0.5795 | 115.608 | 27.622 | 2.719E+01 | 1.697E-03 | 1.341 |
| 28000.00 | 50400.0 | 2.0291E+06 | 8.7268E+05 | 239.89 | 57.316 | 0.5664 | 104.090 | 24.870 | 2.560E+01 | 1.598E-03 | 1.367 |
| 29000.00 | 52200.0 | 2.1279E+06 | 9.1516E+05 | 243.36 | 58.147 | 0.5560 | 93.691 | 22.386 | 2.423E+01 | 1.512E-03 | 1.394 |
| 30000.00 | 54000.0 | 2.2170E+06 | 9.5347E+05 | 246.39 | 58.870 | 0.5477 | 84.693 | 20.236 | 2.303E+01 | 1.438E-03 | 1.422 |
| 32000.00 | 57600.0 | 2.3717E+06 | 1.0200E+06 | 251.40 | 60.068 | 0.5357 | 70.887 | 16.937 | 2.106E+01 | 1.314E-03 | 1.477 |
| 34000.00 | 61200.0 | 2.5031E+06 | 1.0765E+06 | 255.41 | 61.025 | 0.5281 | 61.351 | 14.659 | 1.948E+01 | 1.216E-03 | 1.528 |
| 36000.00 | 64800.0 | 2.6193E+06 | 1.1265E+06 | 258.75 | 61.824 | 0.5231 | 55.330 | 13.220 | 1.817E+01 | 1.134E-03 | 1.567 |
| 38000.00 | 68400.0 | 2.7258E+06 | 1.1723E+06 | 261.65 | 62.516 | 0.5196 | 51.408 | 12.283 | 1.706E+01 | 1.065E-03 | 1.597 |
| 40000.00 | 72000.0 | 2.8255E+06 | 1.2152E+06 | 264.23 | 63.132 | 0.5171 | 48.626 | 11.618 | 1.609E+01 | 1.005E-03 | 1.619 |
| 43000.00 | 77400.0 | 2.9675E+06 | 1.2763E+06 | 267.67 | 63.955 | 0.5146 | 46.236 | 11.047 | 1.486E+01 | 9.275E-04 | 1.640 |
| 46000.00 | 82800.0 | 3.1040E+06 | 1.3350E+06 | 270.76 | 64.692 | 0.5129 | 44.842 | 10.714 | 1.381E+01 | 8.621E-04 | 1.652 |
| 50000.00 | 90000.0 | 3.2803E+06 | 1.4108E+06 | 274.46 | 65.576 | 0.5114 | 43.524 | 10.399 | 1.264E+01 | 7.889E-04 | 1.662 |
| 55000.00 | 99000.0 | 3.4960E+06 | 1.5036E+06 | 278.59 | 66.564 | 0.5102 | 42.724 | 10.208 | 1.143E+01 | 7.138E-04 | 1.667 |
| 60000.00 | 108000.0 | 3.7088E+06 | 1.5951E+06 | 282.32 | 67.454 | 0.5094 | 42.409 | 10.133 | 1.045E+01 | 6.521E-04 | 1.668 |
| 65000.00 | 117000.0 | 3.9202E+06 | 1.6860E+06 | 285.71 | 68.266 | 0.5087 | 42.015 | 10.039 | 9.516E+00 | 6.003E-04 | 1.670 |
| 70000.00 | 126000.0 | 4.1300E+06 | 1.7762E+06 | 288.84 | 69.013 | 0.5083 | 41.938 | 10.020 | 8.911E+00 | 5.563E-04 | 1.670 |
| 80000.00 | 144000.0 | 4.5482E+06 | 1.9561E+06 | 294.45 | 70.353 | 0.5076 | 41.752 | 9.976 | 7.774E+00 | 4.853E-04 | 1.670 |
| 90000.00 | 162000.0 | 4.9647E+06 | 2.1352E+06 | 299.37 | 71.529 | 0.5071 | 41.597 | 9.939 | 6.896E+00 | 4.305E-04 | 1.670 |
| 100000.00 | 180000.0 | 5.3807E+06 | 2.3141E+06 | 303.77 | 72.580 | 0.5067 | 41.719 | 9.968 | 6.196E+00 | 3.868E-04 | 1.672 |
| 110000.00 | 198000.0 | 5.7975E+06 | 2.4933E+06 | 307.74 | 73.530 | 0.5062 | 41.637 | 9.948 | 5.624E+00 | 3.511E-04 | 1.671 |

TABLE II. - Continued. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(*l*) Pressure, $3.03975 \times 10^{7}$ N/m$^2$ (300 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 1100.00 | 1980.0 | -1.9836E+05 | -8.5310E+04 | 60.31 | 14.411 | 2.0156 | 15.171 | 3.625 | 5.699E+03 | 4.182E-01 | 1.373 |
| 1200.00 | 2160.0 | -1.9683E+05 | -8.4653E+04 | 61.64 | 14.728 | 2.0156 | 15.375 | 3.674 | 5.141E+03 | 3.834E-01 | 1.367 |
| 1300.00 | 2340.0 | -1.9528E+05 | -8.3987E+04 | 62.88 | 15.024 | 2.0156 | 15.589 | 3.725 | 5.669E+03 | 3.539E-01 | 1.360 |
| 1400.00 | 2520.0 | -1.9371E+05 | -8.3312E+04 | 64.05 | 15.302 | 2.0156 | 15.806 | 3.777 | 5.264E+03 | 3.286E-01 | 1.353 |
| 1500.00 | 2700.0 | -1.9212E+05 | -8.2628E+04 | 65.14 | 15.565 | 2.0156 | 16.026 | 3.829 | 4.913E+03 | 3.067E-01 | 1.347 |
| 1600.00 | 2880.0 | -1.9051E+05 | -8.1934E+04 | 66.18 | 15.814 | 2.0156 | 16.239 | 3.880 | 4.606E+03 | 2.875E-01 | 1.341 |
| 1700.00 | 3060.0 | -1.8888E+05 | -8.1231E+04 | 67.18 | 16.050 | 2.0156 | 16.450 | 3.930 | 4.335E+03 | 2.706E-01 | 1.335 |
| 1800.00 | 3240.0 | -1.8722E+05 | -8.0519E+04 | 68.12 | 16.276 | 2.0156 | 16.657 | 3.980 | 4.094E+03 | 2.556E-01 | 1.329 |
| 1900.00 | 3420.0 | -1.8554E+05 | -7.9798E+04 | 69.03 | 16.493 | 2.0156 | 16.865 | 4.030 | 3.878E+03 | 2.421E-01 | 1.324 |
| 2000.00 | 3600.0 | -1.8385E+05 | -7.9068E+04 | 69.90 | 16.701 | 2.0156 | 17.078 | 4.081 | 3.684E+03 | 2.300E-01 | 1.319 |
| 2100.00 | 3780.0 | -1.8213E+05 | -7.8329E+04 | 70.74 | 16.901 | 2.0155 | 17.304 | 4.134 | 3.509E+03 | 2.191E-01 | 1.314 |
| 2200.00 | 3960.0 | -1.8039E+05 | -7.7579E+04 | 71.55 | 17.095 | 2.0153 | 17.547 | 4.193 | 3.349E+03 | 2.091E-01 | 1.309 |
| 2300.00 | 4140.0 | -1.7862E+05 | -7.6819E+04 | 72.33 | 17.283 | 2.0151 | 17.821 | 4.258 | 3.203E+03 | 2.000E-01 | 1.304 |
| 2400.00 | 4320.0 | -1.7682E+05 | -7.6046E+04 | 73.10 | 17.465 | 2.0147 | 18.135 | 4.333 | 3.069E+03 | 1.916E-01 | 1.298 |
| 2500.00 | 4500.0 | -1.7499E+05 | -7.5258E+04 | 73.85 | 17.644 | 2.0142 | 18.503 | 4.421 | 2.946E+03 | 1.839E-01 | 1.292 |
| 2600.00 | 4680.0 | -1.7312E+05 | -7.4453E+04 | 74.58 | 17.819 | 2.0134 | 18.937 | 4.525 | 2.831E+03 | 1.767E-01 | 1.286 |
| 2700.00 | 4860.0 | -1.7120E+05 | -7.3628E+04 | 75.30 | 17.992 | 2.0124 | 19.449 | 4.647 | 2.725E+03 | 1.701E-01 | 1.280 |
| 2800.00 | 5040.0 | -1.6922E+05 | -7.2779E+04 | 76.02 | 18.164 | 2.0109 | 20.053 | 4.791 | 2.626E+03 | 1.639E-01 | 1.273 |
| 2900.00 | 5220.0 | -1.6718E+05 | -7.1902E+04 | 76.74 | 18.335 | 2.0090 | 20.761 | 4.960 | 2.533E+03 | 1.581E-01 | 1.266 |
| 3000.00 | 5400.0 | -1.6507E+05 | -7.0992E+04 | 77.45 | 18.506 | 2.0065 | 21.584 | 5.157 | 2.445E+03 | 1.527E-01 | 1.259 |
| 3100.00 | 5580.0 | -1.6285E+05 | -7.0044E+04 | 78.18 | 18.679 | 2.0034 | 22.533 | 5.384 | 2.363E+03 | 1.475E-01 | 1.253 |
| 3200.00 | 5760.0 | -1.6055E+05 | -6.9052E+04 | 78.91 | 18.854 | 1.9995 | 23.618 | 5.643 | 2.284E+03 | 1.426E-01 | 1.246 |
| 3400.00 | 6120.0 | -1.5558E+05 | -6.6912E+04 | 80.42 | 19.214 | 1.9889 | 26.220 | 6.265 | 2.139E+03 | 1.335E-01 | 1.233 |
| 3600.00 | 6480.0 | -1.5003E+05 | -6.4523E+04 | 82.00 | 19.593 | 1.9739 | 29.433 | 7.032 | 2.005E+03 | 1.251E-01 | 1.223 |
| 3800.00 | 6840.0 | -1.4377E+05 | -6.1831E+04 | 83.69 | 19.997 | 1.9535 | 33.266 | 7.948 | 1.880E+03 | 1.173E-01 | 1.214 |
| 4000.00 | 7200.0 | -1.3668E+05 | -5.8783E+04 | 85.51 | 20.431 | 1.9275 | 37.701 | 9.008 | 1.762E+03 | 1.100E-01 | 1.209 |
| 4200.00 | 7560.0 | -1.2865E+05 | -5.5330E+04 | 87.47 | 20.899 | 1.8950 | 42.683 | 10.198 | 1.650E+03 | 1.030E-01 | 1.205 |
| 4400.00 | 7920.0 | -1.1959E+05 | -5.1427E+04 | 89.58 | 21.403 | 1.8551 | 48.120 | 11.497 | 1.542E+03 | 9.628E-02 | 1.204 |
| 4600.00 | 8280.0 | -1.0938E+05 | -4.7042E+04 | 91.84 | 21.944 | 1.8111 | 53.877 | 12.873 | 1.439E+03 | 8.986E-02 | 1.205 |
| 4800.00 | 8640.0 | -9.8018E+04 | -4.2155E+04 | 94.26 | 22.522 | 1.7606 | 59.770 | 14.281 | 1.341E+03 | 8.372E-02 | 1.208 |
| 5000.00 | 9000.0 | -8.5480E+04 | -3.6763E+04 | 96.82 | 23.133 | 1.7057 | 65.567 | 15.666 | 1.247E+03 | 7.786E-02 | 1.212 |
| 5200.00 | 9360.0 | -7.1815E+04 | -3.0886E+04 | 99.50 | 23.773 | 1.6477 | 70.992 | 16.962 | 1.159E+03 | 7.232E-02 | 1.217 |
| 5400.00 | 9720.0 | -5.7129E+04 | -2.4570E+04 | 102.27 | 24.435 | 1.5881 | 75.735 | 18.095 | 1.075E+03 | 6.712E-02 | 1.224 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5600.00 | 10080.0 | -4.1587E+04 | -1.7886E+04 | 105.09 | 25.110 | 1.5285 | 79.488 | 18.992 | 9.979E+02 | 6.230E-02 | 1.232 |
| 5800.00 | 10440.0 | -2.5417E+04 | -1.0931E+04 | 107.93 | 25.788 | 1.4703 | 81.984 | 19.588 | 9.268E+02 | 5.786E-02 | 1.242 |
| 6000.00 | 10800.0 | -8.8899E+03 | -3.8233E+03 | 110.73 | 26.458 | 1.4149 | 83.037 | 19.840 | 8.621E+02 | 5.382E-02 | 1.252 |
| 6300.00 | 11340.0 | 1.5921E+04 | 6.8474E+03 | 114.77 | 27.422 | 1.3391 | 81.822 | 19.550 | 7.771E+02 | 4.851E-02 | 1.270 |
| 6600.00 | 11880.0 | 3.9905E+04 | 1.7162E+04 | 118.49 | 28.310 | 1.2739 | 77.634 | 18.549 | 7.057E+02 | 4.405E-02 | 1.290 |
| 7000.00 | 12600.0 | 6.9318E+04 | 2.9812E+04 | 122.82 | 29.345 | 1.2042 | 69.040 | 16.496 | 6.289E+02 | 3.926E-02 | 1.320 |
| 7300.00 | 13140.0 | 8.8939E+04 | 3.8251E+04 | 125.56 | 30.001 | 1.1537 | 61.748 | 14.754 | 5.828E+02 | 3.639E-02 | 1.345 |
| 7600.00 | 13680.0 | 1.0639E+05 | 4.5757E+04 | 127.91 | 30.561 | 1.1319 | 54.707 | 13.071 | 5.445E+02 | 3.399E-02 | 1.371 |
| 8000.00 | 14400.0 | 1.2659E+05 | 5.4443E+04 | 130.50 | 31.180 | 1.1000 | 46.550 | 11.125 | 5.027E+02 | 3.138E-02 | 1.408 |
| 8300.00 | 14940.0 | 1.3979E+05 | 6.0121E+04 | 132.12 | 31.567 | 1.0822 | 41.616 | 9.943 | 4.767E+02 | 2.976E-02 | 1.435 |
| 8600.00 | 15480.0 | 1.5166E+05 | 6.5224E+04 | 133.52 | 31.903 | 1.0682 | 37.653 | 8.996 | 4.541E+02 | 2.835E-02 | 1.460 |
| 9000.00 | 16200.0 | 1.6588E+05 | 7.1342E+04 | 135.14 | 32.289 | 1.0542 | 33.703 | 8.053 | 4.282E+02 | 2.673E-02 | 1.489 |
| 9300.00 | 16740.0 | 1.7565E+05 | 7.5546E+04 | 136.21 | 32.545 | 1.0461 | 31.570 | 7.543 | 4.113E+02 | 2.567E-02 | 1.506 |
| 9600.00 | 17280.0 | 1.8489E+05 | 7.9513E+04 | 137.19 | 32.778 | 1.0395 | 30.011 | 7.170 | 3.959E+02 | 2.472E-02 | 1.518 |
| 10000.00 | 18000.0 | 1.9659E+05 | 8.4548E+04 | 138.38 | 33.064 | 1.0327 | 28.651 | 6.846 | 3.776E+02 | 2.357E-02 | 1.526 |
| 10500.00 | 18900.0 | 2.1068E+05 | 9.0609E+04 | 139.76 | 33.392 | 1.0260 | 27.862 | 6.657 | 3.573E+02 | 2.230E-02 | 1.525 |
| 11000.00 | 19800.0 | 2.2458E+05 | 9.6588E+04 | 141.05 | 33.701 | 1.0206 | 27.865 | 6.658 | 3.393E+02 | 2.118E-02 | 1.513 |
| 11500.00 | 20700.0 | 2.3865E+05 | 1.0264E+05 | 142.30 | 34.000 | 1.0160 | 28.523 | 6.815 | 3.231E+02 | 2.017E-02 | 1.492 |
| 12000.00 | 21600.0 | 2.5320E+05 | 1.0890E+05 | 143.54 | 34.296 | 1.0116 | 29.755 | 7.109 | 3.084E+02 | 1.925E-02 | 1.467 |
| 12500.00 | 22500.0 | 2.6850E+05 | 1.1547E+05 | 144.79 | 34.594 | 1.0073 | 31.519 | 7.531 | 2.949E+02 | 1.841E-02 | 1.438 |
| 13000.00 | 23400.0 | 2.8481E+05 | 1.2249E+05 | 146.07 | 34.900 | 1.0026 | 33.796 | 8.075 | 2.824E+02 | 1.763E-02 | 1.410 |
| 13500.00 | 24300.0 | 3.0238E+05 | 1.3005E+05 | 147.39 | 35.217 | 0.9975 | 36.576 | 8.739 | 2.707E+02 | 1.690E-02 | 1.382 |
| 14000.00 | 25200.0 | 3.2145E+05 | 1.3825E+05 | 148.78 | 35.548 | 0.9917 | 39.853 | 9.522 | 2.597E+02 | 1.621E-02 | 1.357 |
| 15000.00 | 27000.0 | 3.6515E+05 | 1.5705E+05 | 151.79 | 36.268 | 0.9778 | 47.859 | 11.435 | 2.395E+02 | 1.495E-02 | 1.314 |
| 16000.00 | 28800.0 | 4.1767E+05 | 1.7963E+05 | 155.18 | 37.077 | 0.9599 | 56.910 | 13.598 | 2.210E+02 | 1.380E-02 | 1.286 |
| 17000.00 | 30600.0 | 4.7969E+05 | 2.0630E+05 | 158.93 | 37.973 | 0.9378 | 67.405 | 16.105 | 2.040E+02 | 1.274E-02 | 1.266 |
| 18000.00 | 32400.0 | 5.5275E+05 | 2.3773E+05 | 163.10 | 38.969 | 0.9116 | 78.742 | 18.814 | 1.882E+02 | 1.175E-02 | 1.253 |
| 19000.00 | 34200.0 | 6.3725E+05 | 2.7407E+05 | 167.65 | 40.058 | 0.8818 | 90.237 | 21.560 | 1.734E+02 | 1.083E-02 | 1.246 |
| 20000.00 | 36000.0 | 7.3361E+05 | 3.1551E+05 | 172.59 | 41.237 | 0.8495 | 102.190 | 24.415 | 1.595E+02 | 9.966E-03 | 1.240 |
| 21000.00 | 37800.0 | 8.4108E+05 | 3.6173E+05 | 177.82 | 42.488 | 0.8156 | 112.508 | 26.882 | 1.468E+02 | 9.167E-03 | 1.241 |
| 22000.00 | 39600.0 | 9.5804E+05 | 4.1203E+05 | 183.26 | 43.786 | 0.7815 | 121.055 | 28.926 | 1.351E+02 | 8.431E-03 | 1.245 |
| 23000.00 | 41400.0 | 1.0824E+06 | 4.6553E+05 | 188.78 | 45.105 | 0.7483 | 127.283 | 30.412 | 1.243E+02 | 7.760E-03 | 1.252 |
| 24000.00 | 43200.0 | 1.2117E+06 | 5.2112E+05 | 194.28 | 46.420 | 0.7170 | 130.773 | 31.246 | 1.146E+02 | 7.155E-03 | 1.261 |
| 25000.00 | 45000.0 | 1.3433E+06 | 5.7760E+05 | 199.64 | 47.700 | 0.6883 | 131.421 | 31.401 | 1.059E+02 | 6.613E-03 | 1.273 |
| 26000.00 | 45800.0 | 1.4736E+06 | 6.3378E+05 | 204.76 | 48.924 | 0.6625 | 129.397 | 30.917 | 9.825E+01 | 6.133E-03 | 1.288 |
| 27000.00 | 48600.0 | 1.6011E+06 | 6.8858E+05 | 209.57 | 50.074 | 0.6399 | 125.133 | 29.898 | 9.147E+01 | 5.710E-03 | 1.304 |
| 28000.00 | 50400.0 | 1.7234E+06 | 7.4118E+05 | 214.03 | 51.138 | 0.6203 | 119.220 | 28.485 | 8.553E+01 | 5.339E-03 | 1.322 |
| 29000.00 | 52200.0 | 1.8392E+06 | 7.9099E+05 | 218.10 | 52.110 | 0.6036 | 112.300 | 26.832 | 8.032E+01 | 5.014E-03 | 1.342 |
| 30000.00 | 54000.0 | 1.9478E+06 | 8.3771E+05 | 221.79 | 52.991 | 0.5894 | 104.959 | 25.078 | 7.575E+01 | 4.729E-03 | 1.363 |
| 32000.00 | 57600.0 | 2.1433E+06 | 9.2178E+05 | 228.11 | 54.503 | 0.5675 | 90.750 | 21.683 | 6.818E+01 | 4.256E-03 | 1.407 |
| 34000.00 | 61200.0 | 2.3123E+06 | 9.9448E+05 | 233.25 | 55.731 | 0.5522 | 78.747 | 18.815 | 5.221E+01 | 3.884E-03 | 1.452 |
| 36000.00 | 64800.0 | 2.4600E+06 | 1.0580E+06 | 237.49 | 56.744 | 0.5414 | 69.105 | 15.511 | 5.740E+01 | 3.583E-03 | 1.499 |
| 38000.00 | 68400.0 | 2.5909E+06 | 1.1143E+06 | 241.06 | 57.596 | 0.5341 | 62.146 | 14.849 | 5.344E+01 | 3.336E-03 | 1.536 |
| 40000.00 | 72000.0 | 2.7099E+06 | 1.1655E+06 | 244.13 | 58.331 | 0.5287 | 57.140 | 13.652 | 5.010E+01 | 3.127E-03 | 1.567 |
| 43000.00 | 77400.0 | 2.8732E+06 | 1.2357E+06 | 248.10 | 59.278 | 0.5232 | 52.150 | 12.460 | 4.591E+01 | 2.866E-03 | 1.602 |
| 46000.00 | 82800.0 | 3.0243E+06 | 1.3007E+06 | 251.52 | 60.096 | 0.5195 | 48.828 | 11.667 | 4.296E+01 | 2.650E-03 | 1.627 |
| 50000.00 | 90000.0 | 3.2143E+06 | 1.3824E+06 | 255.51 | 61.050 | 0.5164 | 46.407 | 11.088 | 3.866E+01 | 2.413E-03 | 1.646 |
| 55000.00 | 99000.0 | 3.4418E+06 | 1.4802E+06 | 259.88 | 62.092 | 0.5137 | 44.752 | 10.693 | 3.483E+01 | 2.174E-03 | 1.658 |
| 60000.00 | 108000.0 | 3.6619E+06 | 1.5749E+06 | 263.73 | 63.014 | 0.5122 | 43.506 | 10.395 | 3.173E+01 | 1.981E-03 | 1.666 |
| 65000.00 | 117000.0 | 3.8782E+06 | 1.6679E+06 | 267.22 | 63.847 | 0.5111 | 43.037 | 10.283 | 2.915E+01 | 1.820E-03 | 1.668 |
| 70000.00 | 126000.0 | 4.0920E+06 | 1.7599E+06 | 270.41 | 64.609 | 0.5103 | 42.562 | 10.169 | 2.698E+01 | 1.684E-03 | 1.670 |
| 80000.00 | 144000.0 | 4.5163E+06 | 1.9422E+06 | 276.10 | 65.969 | 0.5091 | 42.260 | 10.097 | 2.348E+01 | 1.466E-03 | 1.670 |
| 90000.00 | 162000.0 | 4.9363E+06 | 2.1228E+06 | 281.07 | 67.157 | 0.5084 | 41.912 | 10.014 | 2.080E+01 | 1.299E-03 | 1.670 |
| 100000.00 | 180000.0 | 5.3541E+06 | 2.3027E+06 | 285.50 | 68.214 | 0.5078 | 41.743 | 9.974 | 1.868E+01 | 1.166E-03 | 1.670 |
| 110000.00 | 198000.0 | 5.7714E+06 | 2.4821E+06 | 289.49 | 69.168 | 0.5074 | 41.718 | 9.968 | 1.695E+01 | 1.058E-03 | 1.669 |

TABLE II. - Concluded. THERMODYNAMIC PROPERTIES OF SPIN-EQUILIBRATED HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(m) Pressure, $1.01325\times10^{8}$ N/m$^2$ (1000 atm)

| Temperature, T | | Enthalpy, h | | Entropy, s | | Average molecular weight, g/g-mole or lb/lb-mole | Specific heat, $c_p$ | | Density, $\rho$ | | Isentropic exponent, $\gamma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | $^{o}$R | J/g | Btu/lb | J/(g)(K) | Btu/(lb)($^{o}$R) | | J/(g)(K) | Btu/(lb)($^{o}$R) | g/m$^3$ | lb/ft$^3$ | |
| 3200.00 | 5760.0 | -1.6139E+05 | -6.9410E+04 | 73.65 | 17.598 | 2.0068 | 21.355 | 5.102 | 7.643E+03 | 4.771E-01 | 1.261 |
| 3400.00 | 6120.0 | -1.5697E+05 | -6.7511E+04 | 74.99 | 17.918 | 2.0009 | 22.874 | 5.465 | 7.172E+03 | 4.477E-01 | 1.250 |
| 3600.00 | 6480.0 | -1.5222E+05 | -6.5466E+04 | 76.35 | 18.242 | 1.9926 | 24.725 | 5.908 | 6.745E+03 | 4.211E-01 | 1.241 |
| 3800.00 | 6840.0 | -1.4705E+05 | -6.3247E+04 | 77.74 | 18.575 | 1.9812 | 26.917 | 6.431 | 6.354E+03 | 3.967E-01 | 1.233 |
| 4000.00 | 7200.0 | -1.4143E+05 | -6.0826E+04 | 79.19 | 18.920 | 1.9663 | 29.444 | 7.035 | 5.991E+03 | 3.740E-01 | 1.226 |
| 4200.00 | 7560.0 | -1.3526E+05 | -5.8173E+04 | 80.69 | 19.280 | 1.9476 | 32.287 | 7.714 | 5.651E+03 | 3.528E-01 | 1.221 |
| 4400.00 | 7920.0 | -1.2850E+05 | -5.5263E+04 | 82.26 | 19.655 | 1.9248 | 35.413 | 8.461 | 5.331E+03 | 3.328E-01 | 1.218 |
| 4600.00 | 8280.0 | -1.2108E+05 | -5.2074E+04 | 83.91 | 20.049 | 1.8977 | 38.773 | 9.264 | 5.028E+03 | 3.139E-01 | 1.216 |
| 4800.00 | 8640.0 | -1.1298E+05 | -4.8588E+04 | 85.64 | 20.461 | 1.8665 | 42.311 | 10.109 | 4.739E+03 | 2.958E-01 | 1.216 |
| 5000.00 | 9000.0 | -1.0415E+05 | -4.4792E+04 | 87.44 | 20.891 | 1.8313 | 45.955 | 10.980 | 4.463E+03 | 2.786E-01 | 1.218 |
| 5200.00 | 9360.0 | -9.4592E+04 | -4.0682E+04 | 89.31 | 21.339 | 1.7925 | 49.622 | 11.856 | 4.201E+03 | 2.623E-01 | 1.220 |
| 5400.00 | 9720.0 | -8.4305E+04 | -3.6258E+04 | 91.25 | 21.803 | 1.7507 | 53.221 | 12.716 | 3.951E+03 | 2.467E-01 | 1.224 |
| 5600.00 | 10080.0 | -7.3315E+04 | -3.1531E+04 | 93.25 | 22.280 | 1.7065 | 56.646 | 13.535 | 3.714E+03 | 2.318E-01 | 1.229 |
| 5800.00 | 10440.0 | -6.1665E+04 | -2.6521E+04 | 95.29 | 22.768 | 1.6607 | 59.793 | 14.286 | 3.489E+03 | 2.178E-01 | 1.235 |
| 6000.00 | 10800.0 | -4.9423E+04 | -2.1256E+04 | 97.37 | 23.264 | 1.6141 | 62.553 | 14.946 | 3.278E+03 | 2.047E-01 | 1.242 |
| 6300.00 | 11340.0 | -3.0146E+04 | -1.2965E+04 | 100.50 | 24.013 | 1.5441 | 65.752 | 15.710 | 2.987E+03 | 1.865E-01 | 1.254 |
| 6600.00 | 11880.0 | -1.0108E+04 | -4.3471E+03 | 103.61 | 24.755 | 1.4765 | 67.594 | 16.150 | 2.726E+03 | 1.702E-01 | 1.267 |
| 7000.00 | 12600.0 | 1.7047E+04 | 7.3316E+03 | 107.60 | 25.710 | 1.3931 | 67.739 | 16.185 | 2.425E+03 | 1.514E-01 | 1.288 |
| 7300.00 | 13140.0 | 3.7171E+04 | 1.5986E+04 | 110.42 | 26.383 | 1.3374 | 66.203 | 15.818 | 2.233E+03 | 1.394E-01 | 1.306 |
| 7600.00 | 13680.0 | 5.6655E+04 | 2.4366E+04 | 113.03 | 27.008 | 1.2882 | 63.523 | 15.178 | 2.066E+03 | 1.290E-01 | 1.324 |
| 8000.00 | 14400.0 | 8.1146E+04 | 3.4899E+04 | 116.18 | 27.758 | 1.2327 | 58.765 | 14.041 | 1.878E+03 | 1.172E-01 | 1.350 |
| 8300.00 | 14940.0 | 9.8181E+04 | 4.2225E+04 | 118.27 | 28.258 | 1.1983 | 54.779 | 13.089 | 1.759E+03 | 1.098E-01 | 1.371 |
| 8600.00 | 15480.0 | 1.1401E+05 | 4.9034E+04 | 120.14 | 28.706 | 1.1693 | 50.778 | 12.132 | 1.657E+03 | 1.034E-01 | 1.392 |
| 9000.00 | 16200.0 | 1.3331E+05 | 5.7333E+04 | 122.34 | 29.230 | 1.1378 | 45.796 | 10.942 | 1.541E+03 | 9.618E-02 | 1.419 |
| 9300.00 | 16740.0 | 1.4654E+05 | 6.3024E+04 | 123.78 | 29.575 | 1.1187 | 42.492 | 10.153 | 1.466E+03 | 9.152E-02 | 1.438 |
| 9600.00 | 17280.0 | 1.5885E+05 | 6.8316E+04 | 125.08 | 29.887 | 1.1027 | 39.623 | 9.457 | 1.400E+03 | 8.740E-02 | 1.455 |
| 10000.00 | 18000.0 | 1.7404E+05 | 7.4852E+04 | 126.64 | 30.257 | 1.0854 | 36.489 | 8.718 | 1.323E+03 | 8.259E-02 | 1.475 |
| 10500.00 | 18900.0 | 1.9152E+05 | 8.2369E+04 | 128.34 | 30.665 | 1.0687 | 33.607 | 8.030 | 1.241E+03 | 7.744E-02 | 1.493 |
| 11000.00 | 19800.0 | 2.0782E+05 | 8.9377E+04 | 129.86 | 31.027 | 1.0558 | 31.719 | 7.579 | 1.170E+03 | 7.304E-02 | 1.502 |
| 11500.00 | 20700.0 | 2.2338E+05 | 9.6071E+04 | 131.24 | 31.358 | 1.0457 | 30.665 | 7.327 | 1.109E+03 | 6.920E-02 | 1.501 |
| 12000.00 | 21600.0 | 2.3860E+05 | 1.0261E+05 | 132.54 | 31.667 | 1.0374 | 30.301 | 7.240 | 1.054E+03 | 6.581E-02 | 1.492 |
| 12500.00 | 22500.0 | 2.5379E+05 | 1.0914E+05 | 133.78 | 31.963 | 1.0303 | 30.529 | 7.294 | 1.005E+03 | 6.276E-02 | 1.476 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13000.00 | 23400.0 | 2.6921E+05 | 1.1578E+05 | 134.99 | 32.253 | 1.0240 | 31.271 | 7.472 | 9.612E+02 | 6.000E-02 | 1.456 |
| 13500.00 | 24300.0 | 2.8513E+05 | 1.2263E+05 | 136.19 | 32.540 | 1.0181 | 32.473 | 7.759 | 9.207E+02 | 5.748E-02 | 1.433 |
| 14000.00 | 25200.0 | 3.0175E+05 | 1.2978E+05 | 137.40 | 32.829 | 1.0123 | 34.099 | 8.147 | 8.834E+02 | 5.515E-02 | 1.409 |
| 15000.00 | 27000.0 | 3.3793E+05 | 1.4534E+05 | 139.89 | 33.425 | 1.0003 | 38.504 | 9.200 | 8.162E+02 | 5.095E-02 | 1.363 |
| 16000.00 | 28800.0 | 3.7922E+05 | 1.6309E+05 | 142.56 | 34.061 | 0.9866 | 44.237 | 10.570 | 7.568E+02 | 4.725E-02 | 1.324 |
| 17000.00 | 30600.0 | 4.2623E+05 | 1.8331E+05 | 145.40 | 34.741 | 0.9705 | 50.246 | 12.005 | 7.033E+02 | 4.391E-02 | 1.300 |
| 18000.00 | 32400.0 | 4.7993E+05 | 2.0640E+05 | 148.46 | 35.472 | 0.9516 | 57.233 | 13.675 | 6.544E+02 | 4.086E-02 | 1.280 |
| 19000.00 | 34200.0 | 5.4092E+05 | 2.3264E+05 | 151.75 | 36.258 | 0.9299 | 64.808 | 15.485 | 6.094E+02 | 3.804E-02 | 1.266 |
| 20000.00 | 36000.0 | 6.0951E+05 | 2.6213E+05 | 155.26 | 37.097 | 0.9056 | 72.367 | 17.291 | 5.676E+02 | 3.543E-02 | 1.257 |
| 21000.00 | 37800.0 | 6.8559E+05 | 2.9486E+05 | 158.96 | 37.982 | 0.8793 | 79.753 | 19.055 | 5.286E+02 | 3.300E-02 | 1.253 |
| 22000.00 | 39600.0 | 7.6887E+05 | 3.3067E+05 | 162.83 | 38.905 | 0.8516 | 86.714 | 20.719 | 4.923E+02 | 3.073E-02 | 1.253 |
| 23000.00 | 41400.0 | 8.5923E+05 | 3.6953E+05 | 166.84 | 39.863 | 0.8233 | 93.754 | 22.403 | 4.586E+02 | 2.863E-02 | 1.251 |
| 24000.00 | 43200.0 | 9.5579E+05 | 4.1106E+05 | 170.94 | 40.843 | 0.7951 | 99.168 | 23.694 | 4.273E+02 | 2.667E-02 | 1.255 |
| 25000.00 | 45000.0 | 1.0572E+06 | 4.5467E+05 | 175.08 | 41.832 | 0.7676 | 103.416 | 24.709 | 3.984E+02 | 2.487E-02 | 1.262 |
| 26000.00 | 46800.0 | 1.1622E+06 | 4.9983E+05 | 179.19 | 42.815 | 0.7414 | 106.396 | 25.421 | 3.718E+02 | 2.321E-02 | 1.272 |
| 27000.00 | 48600.0 | 1.2695E+06 | 5.4600E+05 | 183.24 | 43.783 | 0.7168 | 108.070 | 25.821 | 3.475E+02 | 2.170E-02 | 1.283 |
| 28000.00 | 50400.0 | 1.3779E+06 | 5.9261E+05 | 187.18 | 44.724 | 0.6940 | 108.464 | 25.916 | 3.254E+02 | 2.032E-02 | 1.296 |
| 29000.00 | 52200.0 | 1.4861E+06 | 6.3913E+05 | 190.98 | 45.631 | 0.6732 | 107.682 | 25.729 | 3.054E+02 | 1.906E-02 | 1.310 |
| 30000.00 | 54000.0 | 1.5929E+06 | 6.8508E+05 | 194.61 | 46.497 | 0.6544 | 105.879 | 25.298 | 2.873E+02 | 1.793E-02 | 1.325 |
| 32000.00 | 57600.0 | 1.7992E+06 | 7.7380E+05 | 201.27 | 48.090 | 0.6227 | 99.995 | 23.892 | 2.562E+02 | 1.599E-02 | 1.359 |
| 34000.00 | 61200.0 | 1.9918E+06 | 8.5663E+05 | 207.12 | 49.487 | 0.5979 | 92.437 | 22.086 | 2.310E+02 | 1.442E-02 | 1.394 |
| 36000.00 | 64800.0 | 2.1689E+06 | 9.3273E+05 | 212.19 | 50.699 | 0.5789 | 84.445 | 20.177 | 2.104E+02 | 1.314E-02 | 1.436 |
| 38000.00 | 68400.0 | 2.3299E+06 | 1.0020E+06 | 216.58 | 51.747 | 0.5648 | 76.876 | 18.368 | 1.936E+02 | 1.209E-02 | 1.471 |
| 40000.00 | 72000.0 | 2.4773E+06 | 1.0653E+06 | 220.37 | 52.654 | 0.5540 | 70.375 | 16.815 | 1.796E+02 | 1.121E-02 | 1.503 |
| 43000.00 | 77400.0 | 2.6761E+06 | 1.1509E+06 | 225.21 | 53.810 | 0.5424 | 62.771 | 14.998 | 1.625E+02 | 1.014E-02 | 1.545 |
| 46000.00 | 82800.0 | 2.8559E+06 | 1.2282E+06 | 229.28 | 54.783 | 0.5343 | 57.360 | 13.705 | 1.487E+02 | 9.285E-03 | 1.580 |
| 50000.00 | 90000.0 | 3.0743E+06 | 1.3222E+06 | 233.88 | 55.881 | 0.5273 | 52.288 | 12.493 | 1.341E+02 | 8.372E-03 | 1.614 |
| 55000.00 | 99000.0 | 3.3259E+06 | 1.4304E+06 | 238.72 | 57.038 | 0.5218 | 48.708 | 11.638 | 1.198E+02 | 7.479E-03 | 1.639 |
| 60000.00 | 108000.0 | 3.5638E+06 | 1.5327E+06 | 242.89 | 58.035 | 0.5182 | 45.626 | 11.140 | 1.085E+02 | 6.770E-03 | 1.653 |
| 65000.00 | 117000.0 | 3.7935E+06 | 1.6315E+06 | 246.59 | 58.919 | 0.5156 | 45.339 | 10.833 | 9.918E+01 | 6.192E-03 | 1.660 |
| 70000.00 | 126000.0 | 4.0162E+06 | 1.7273E+06 | 249.92 | 59.714 | 0.5140 | 44.034 | 10.521 | 9.149E+01 | 5.712E-03 | 1.667 |
| 80000.00 | 144000.0 | 4.4521E+06 | 1.9147E+06 | 255.79 | 61.115 | 0.5119 | 43.232 | 10.330 | 7.932E+01 | 4.952E-03 | 1.670 |
| 90000.00 | 162000.0 | 4.8801E+06 | 2.0988E+06 | 260.86 | 62.328 | 0.5106 | 42.611 | 10.181 | 7.008E+01 | 4.375E-03 | 1.671 |
| 100000.00 | 180000.0 | 5.3050E+06 | 2.2816E+06 | 265.36 | 63.403 | 0.5096 | 42.384 | 10.127 | 6.278E+01 | 3.919E-03 | 1.670 |
| 110000.00 | 198000.0 | 5.7263E+06 | 2.4627E+06 | 269.40 | 64.368 | 0.5089 | 41.974 | 10.029 | 5.689E+01 | 3.552E-03 | 1.671 |

TABLE III. - CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM

IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(a) Stagnation pressure, $1.01325 \times 10^5$ N/m$^2$ (1 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^{o}$R | m/sec | ft/sec | | | Ideal, $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 2500 K; 4500$^{o}$ R<br>Sonic flow factor, $\psi$: 1.01E-02 (kg)(K$^{1/2}$)/(sec)(N); 2.81E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 2.05E+01 kg/(sec)(m$^2$); 4.20E+00 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 2500. | 4500. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.56E-01 | 2263. | 4073. | 3.41E+03 | 1.12E+04 | 1.00 | 1.00E+00 | 348. | 628. |
| DOWNSTREAM | 1.00E-01 | 1535. | 2762. | 6.20E+03 | 2.04E+04 | 2.13 | 2.06E+00 | 633. | 737. |
| DOWNSTREAM | 1.00E-02 | 825. | 1485. | 7.77E+03 | 2.55E+04 | 3.57 | 8.86E+00 | 792. | 837. |
| DOWNSTREAM | 1.00E-03 | 430. | 773. | 8.48E+03 | 2.78E+04 | 5.38 | 4.23E+01 | 864. | 886. |
| Stagnation temperature, $T_t$: 3500 K; 6300$^{o}$ R<br>Sonic flow factor, $\psi$: 8.78E-03 (kg)(K$^{1/2}$)/(sec)(N); 2.44E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.50E+01 kg/(sec)(m$^2$); 3.08E+00 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 3500. | 6300. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.76E-01 | 3334. | 6002. | 4.44E+03 | 1.46E+04 | 1.00 | 1.00E+00 | 453. | 849. |
| DOWNSTREAM | 1.00E-01 | 2888. | 5198. | 8.60E+03 | 2.82E+04 | 2.17 | 2.41E+00 | 877. | 1043. |
| DOWNSTREAM | 1.00E-02 | 2415. | 4347. | 1.14E+04 | 3.75E+04 | 3.28 | 1.40E+01 | 1166. | 1262. |
| DOWNSTREAM | 1.00E-03 | 1975. | 3556. | 1.32E+04 | 4.34E+04 | 4.28 | 9.35E+01 | 1347. | 1412. |
| Stagnation temperature, $T_t$: 5000 K; 9000$^{o}$ R<br>Sonic flow factor, $\psi$: 7.44E-03 (kg)(K$^{1/2}$)/(sec)(N); 2.07E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.07E+01 kg/(sec)(m$^2$); 2.18E+00 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 5000. | 9000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.53E-01 | 4450. | 8010. | 6.66E+03 | 2.19E+04 | 1.00 | 1.00E+00 | 679. | 1215. |
| DOWNSTREAM | 1.00E-01 | 3602. | 6484. | 1.21E+04 | 3.98E+04 | 2.20 | 2.27E+00 | 1238. | 1457. |
| DOWNSTREAM | 1.00E-02 | 2974. | 5353. | 1.58E+04 | 5.20E+04 | 3.38 | 1.29E+01 | 1615. | 1741. |
| DOWNSTREAM | 1.00E-03 | 2555. | 4598. | 1.82E+04 | 5.96E+04 | 4.42 | 8.84E+01 | 1853. | 1939. |

Stagnation temperature, $T_t$: 6000 K; 10 800° R
Sonic flow factor, $\psi$: 7.72E-03 (kg)($K^{1/2}$)/(sec)(N); 2.15E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 1.01E+01 kg/(sec)($m^2$); 2.07E+00 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 6000. | 10800. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.30E-01 | 4903. | 8825. | 7.50E+03 | 2.46E+04 | 1.00 | 1.00E+00 | 755. | 1306. |
| DOWNSTREAM | 1.00E-01 | 3729. | 6713. | 1.29E+04 | 4.23E+04 | 2.23 | 2.18E+00 | 1316. | 1539. |
| DOWNSTREAM | 1.00E-02 | 3031. | 5455. | 1.67E+04 | 5.46E+04 | 3.44 | 1.24E+01 | 1698. | 1825. |
| DOWNSTREAM | 1.00E-03 | 2593. | 4667. | 1.90E+04 | 6.24E+04 | 4.49 | 8.45E+01 | 1938. | 2025. |

Stagnation temperature, $T_t$: 7000 K; 12 600° R
Sonic flow factor, $\psi$: 7.90E-03 (kg)($K^{1/2}$)/(sec)(N); 2.20E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 9.56E+00 kg/(sec)($m^2$); 1.96E+00 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 7000. | 12600. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.05E-01 | 5442. | 9796. | 8.34E+03 | 2.74E+04 | 1.00 | 1.00E+00 | 850. | 1397. |
| DOWNSTREAM | 1.00E-01 | 3837. | 6907. | 1.36E+04 | 4.47E+04 | 2.27 | 2.06E+00 | 1388. | 1611. |
| DOWNSTREAM | 1.00E-02 | 3070. | 5526. | 1.74E+04 | 5.69E+04 | 3.51 | 1.17E+01 | 1770. | 1896. |
| DOWNSTREAM | 1.00E-03 | 2617. | 4711. | 1.97E+04 | 6.46E+04 | 4.58 | 7.98E+01 | 2009. | 2095. |

Stagnation temperature, $T_t$: 8000 K; 14 400° R
Sonic flow factor, $\psi$: 7.87E-03 (kg)($K^{1/2}$)/(sec)(N); 2.19E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 8.92E+00 kg/(sec)($m^2$); 1.83E+00 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 8000. | 14400. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.93E-01 | 5178. | 11120. | 9.08E+03 | 2.98E+04 | 1.00 | 1.00E+00 | 926. | 1498. |
| DOWNSTREAM | 1.00E-01 | 3974. | 7152. | 1.44E+04 | 4.73E+04 | 2.30 | 1.92E+00 | 1470. | 1693. |
| DOWNSTREAM | 1.00E-02 | 3109. | 5596. | 1.81E+04 | 5.95E+04 | 3.60 | 1.08E+01 | 1849. | 1974. |
| DOWNSTREAM | 1.00E-03 | 2640. | 4752. | 2.05E+04 | 6.71E+04 | 4.58 | 7.39E+01 | 2087. | 2172. |

Stagnation temperature, $T_t$: 10 000 K; 18 000° R
Sonic flow factor, $\psi$: 7.34E-03 (kg)($K^{1/2}$)/(sec)(N); 2.04E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 7.43E+00 kg/(sec)($m^2$); 1.52E+00 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 10000. | 18000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.28E-01 | 8653. | 15576. | 1.00E+04 | 3.28E+04 | 1.00 | 1.00E+00 | 1020. | 1753. |
| DOWNSTREAM | 1.00E-01 | 4828. | 8691. | 1.68E+04 | 5.52E+04 | 2.14 | 1.73E+00 | 1715. | 1955. |
| DOWNSTREAM | 1.00E-02 | 3228. | 5811. | 2.05E+04 | 6.74E+04 | 3.86 | 8.72E+00 | 2094. | 2215. |
| DOWNSTREAM | 1.00E-03 | 2699. | 4858. | 2.28E+04 | 7.48E+04 | 5.00 | 5.97E+01 | 2324. | 2407. |

Stagnation temperature, $T_t$: 12 000 K; 21 600° R
Sonic flow factor, $\psi$: 6.80E-03 (kg)($K^{1/2}$)/(sec)(N); 1.89E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 6.29+00 kg/(sec)($m^2$); 1.29E+00 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 12000. | 21600. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.65E-01 | 11174. | 20113. | 1.09E+04 | 3.58E+04 | 1.00 | 1.00E+00 | 1112. | 2039. |
| DOWNSTREAM | 1.00E-01 | 8596. | 15474. | 2.04E+04 | 6.68E+04 | 2.12 | 2.20E+00 | 2077. | 2437. |
| DOWNSTREAM | 1.00E-02 | 4022. | 7239. | 2.56E+04 | 8.38E+04 | 3.61 | 8.03E+00 | 2606. | 2738. |
| DOWNSTREAM | 1.00E-03 | 2850. | 5129. | 2.78E+04 | 9.12E+04 | 5.60 | 4.83E+01 | 2834. | 2913. |

TABLE III. - Continued. CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(a) Concluded. Stagnation pressure, $1.01325 \times 10^5$ N/m$^2$ (1 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^{o}$R | m/sec | ft/sec | | | Ideal, $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 14 000 K; 25 200$^{o}$ R<br>Sonic flow factor, $\psi$: 6.24E-03 (kg)(K$^{1/2}$)/(sec)(N); 1.74E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 5.34E+00 kg/(sec)(m$^2$); 1.09E+00 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 14000. | 25200. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.70E-01 | 13200. | 23759. | 1.27E+04 | 4.17E+04 | 1.00 | 1.00E+00 | 1296. | 2400. |
| DOWNSTREAM | 1.00E-01 | 11097. | 19974. | 2.42E+04 | 7.93E+04 | 2.17 | 2.33E+00 | 2456. | 2916. |
| DOWNSTREAM | 1.00E-02 | 8822. | 15880. | 3.17E+04 | 1.04E+05 | 3.34 | 1.29E+01 | 3233. | 3482. |
| DOWNSTREAM | 1.00E-03 | 6074. | 10934. | 3.61E+04 | 1.18E+05 | 4.23 | 7.33E+01 | 3681. | 3823. |
| Stagnation temperature, $T_t$: 16 000 K; 28 800$^{o}$ R<br>Sonic flow factor, $\psi$: 5.68E-03 (kg)(K$^{1/2}$)/(sec)(N); 1.58E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 4.55E+00 kg/(sec)(m$^2$); 9.31E-01 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 15000. | 28800. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.68E-01 | 14997. | 26994. | 1.51E+04 | 4.94E+04 | 1.00 | 1.00E+00 | 1536. | 2827. |
| DOWNSTREAM | 1.00E-01 | 12581. | 22646. | 2.85E+04 | 9.34E+04 | 2.18 | 2.31E+00 | 2902. | 3428. |
| DOWNSTREAM | 1.00E-02 | 10308. | 18554. | 3.73E+04 | 1.22E+05 | 3.35 | 1.30E+01 | 3803. | 4099. |
| DOWNSTREAM | 1.00E-03 | 8615. | 15506. | 4.27E+04 | 1.40E+05 | 4.43 | 8.63E+01 | 4357. | 4554. |
| Stagnation temperature, $T_t$: 18 000 K; 32 400$^{o}$ R<br>Sonic flow factor, $\psi$: 5.39E-03 (kg)(K$^{1/2}$)/(sec)(N); 1.50E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 4.07E+00 kg/(sec)(m$^2$); 8.34E-01 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 19000. | 32400. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.61E-01 | 15534. | 29761. | 1.71E+04 | 5.63E+04 | 1.00 | 1.00E+00 | 1749. | 3172. |
| DOWNSTREAM | 1.00E-01 | 13527. | 24348. | 3.18E+04 | 1.04E+05 | 2.19 | 2.27E+00 | 3241. | 3816. |
| DOWNSTREAM | 1.00E-02 | 10987. | 19776. | 4.14E+04 | 1.36E+05 | 3.39 | 1.27E+01 | 4223. | 4545. |
| DOWNSTREAM | 1.00E-03 | 9226. | 16606. | 4.73E+04 | 1.55E+05 | 4.48 | 8.42E+01 | 4826. | 5039. |

Stagnation temperature, $T_t$: 25 000 K; 45 000° R
Sonic flow factor, $\psi$: 5.54E-03 (kg)($K^{1/2}$)/(sec)(N); 1.54E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 3.55E+00 kg/(sec)($m^2$); 7.27E-01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 25000. | 45000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.23E-01 | 20189. | 36340. | 2.17E+04 | 7.11E+04 | 1.00 | 1.00E+00 | 2211. | 3733. |
| DOWNSTREAM | 1.00E-01 | 14818. | 26673. | 3.67E+04 | 1.20E+05 | 2.24 | 2.11E+00 | 3743. | 4357. |
| DOWNSTREAM | 1.00E-02 | 11647. | 20965. | 4.69E+04 | 1.54E+05 | 3.50 | 1.16E+01 | 4783. | 5121. |
| DOWNSTREAM | 1.00E-03 | 9709. | 17477. | 5.31E+04 | 1.74E+05 | 4.62 | 7.71E+01 | 5416. | 5640. |

Stagnation temperature, $T_t$: 35 000 K; 63 000° R
Sonic flow factor, $\psi$: 5.67E-03 (kg)($K^{1/2}$)/(sec)(N); 1.58E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 3.07E+00 kg/(sec)($m^2$); 6.29E-01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 35000. | 63000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.90E-01 | 26412. | 47541. | 2.67E+04 | 8.76E+04 | 1.00 | 1.00E+00 | 2722. | 4370. |
| DOWNSTREAM | 1.00E-01 | 16197. | 29155. | 4.19E+04 | 1.38E+05 | 2.30 | 1.85E+00 | 4276. | 4898. |
| DOWNSTREAM | 1.00E-02 | 12067. | 21720. | 5.21E+04 | 1.71E+05 | 3.59 | 9.96E+00 | 5313. | 5648. |
| DOWNSTREAM | 1.00E-03 | 9963. | 17934. | 5.83E+04 | 1.91E+05 | 4.85 | 6.62E+01 | 5941. | 6163. |

Stagnation temperature, $T_t$: 50 000 K; 90 000° R
Sonic flow factor, $\psi$: 5.67E-03 (kg)($K^{1/2}$)/(sec)(N); 1.58E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 2.57E+00 kg/(sec)($m^2$); 5.26E-01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 50000. | 90000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.87E-01 | 37533. | 67559. | 3.21E+04 | 1.05E+05 | 1.00 | 1.00E+00 | 3271. | 5231. |
| DOWNSTREAM | 1.00E-01 | 20184. | 36332. | 4.98E+04 | 1.63E+05 | 2.17 | 1.68E+00 | 5075. | 5751. |
| DOWNSTREAM | 1.00E-02 | 12628. | 22730. | 6.00E+04 | 1.97E+05 | 3.99 | 8.03E+00 | 6115. | 6438. |
| DOWNSTREAM | 1.00E-03 | 10236. | 18425. | 6.59E+04 | 2.16E+05 | 5.25 | 5.33E+01 | 6719. | 6933. |

Stagnation temperature, $T_t$: 75 000 K; 135 000° R
Sonic flow factor, $\psi$: 5.66E-03 (kg)($K^{1/2}$)/(sec)(N); 1.58E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 2.10E+00 kg/(sec)($m^2$); 4.29E-01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 75000. | 135000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.87E-01 | 56278. | 101301. | 3.93E+04 | 1.29E+05 | 1.00 | 1.00E+00 | 4009. | 6413. |
| DOWNSTREAM | 1.00E-01 | 29898. | 53816. | 6.10E+04 | 2.00E+05 | 2.13 | 1.67E+00 | 6219. | 7041. |
| DOWNSTREAM | 1.00E-02 | 13792. | 24826. | 7.23E+04 | 2.37E+05 | 4.31 | 6.30E+00 | 7370. | 7681. |
| DOWNSTREAM | 1.00E-03 | 10591. | 19064. | 7.79E+04 | 2.55E+05 | 5.88 | 4.06E+01 | 7939. | 8139. |

Stagnation temperature, $T_t$: 100 000 K; 180 000° R
Sonic flow factor, $\psi$: 5.66E-03 (kg)($K^{1/2}$)/(sec)(N); 1.58E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 1.81E+00 kg/(sec)($m^2$); 3.71E-01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 100000. | 180000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.87E-01 | 75031. | 135056. | 4.54E+04 | 1.49E+05 | 1.00 | 1.00E+00 | 4630. | 7407. |
| DOWNSTREAM | 1.00E-01 | 39836. | 71704. | 7.04E+04 | 2.31E+05 | 2.13 | 1.67E+00 | 7183. | 8133. |
| DOWNSTREAM | 1.00E-02 | 15156. | 29081. | 8.33E+04 | 2.73E+05 | 4.12 | 5.69E+00 | 8494. | 8818. |
| DOWNSTREAM | 1.00E-03 | 10914. | 19645. | 8.87E+04 | 2.91E+05 | 6.42 | 3.31E+01 | 9047. | 9236. |

TABLE III. - Continued. CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(b) Stagnation pressure, $1.01325 \times 10^6$ N/m$^2$ (10 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^\circ$R | m/sec | ft/sec | | | Ideal, $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 2500 K; 4500$^\circ$ R<br>Sonic flow factor, $\psi$: 1.03E-02 (kg)($K^{1/2}$)/(sec)(N); 2.87E+02 (lb)($^\circ R^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 2.09E+02 kg/(sec)(m$^2$); 4.28E+01 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 2500. | 4500. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.47E-01 | 2202. | 3963. | 3.42E+03 | 1.12E+04 | 1.00 | 1.00E+00 | 349. | 620. |
| DOWNSTREAM | 1.00E-01 | 1456. | 2621. | 6.09E+03 | 2.00E+04 | 2.14 | 2.03E+00 | 621. | 722. |
| DOWNSTREAM | 1.00E-02 | 779. | 1401. | 7.60E+03 | 2.49E+04 | 3.60 | 8.70E+00 | 775. | 818. |
| DOWNSTREAM | 1.00E-03 | 405. | 730. | 8.29E+03 | 2.72E+04 | 5.42 | 4.15E+01 | 845. | 866. |
| Stagnation temperature, $T_t$: 3500 K; 6300$^\circ$ R<br>Sonic flow factor, $\psi$: 9.57E-03 (kg)($K^{1/2}$)/(sec)(N); 2.66E+02 (lb)($^\circ R^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.64E+02 kg/(sec)(m$^2$); 3.36E+01 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 3500. | 6300. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.71E-01 | 3286. | 5914. | 4.12E+03 | 1.35E+04 | 1.00 | 1.00E+00 | 420. | 780. |
| DOWNSTREAM | 1.00E-01 | 2668. | 4802. | 7.86E+03 | 2.58E+04 | 2.15 | 2.32E+00 | 802. | 948. |
| DOWNSTREAM | 1.00E-02 | 1757. | 3163. | 1.02E+04 | 3.35E+04 | 3.31 | 1.15E+01 | 1043. | 1115. |
| DOWNSTREAM | 1.00E-03 | 961. | 1729. | 1.14E+04 | 3.74E+04 | 4.87 | 5.63E+01 | 1162. | 1197. |
| DOWNSTREAM | 1.00E-04 | 502. | 904. | 1.20E+04 | 3.93E+04 | 7.04 | 2.80E+02 | 1220. | 1238. |
| Stagnation temperature, $T_t$: 5000 K; 9000$^\circ$ R<br>Sonic flow factor, $\psi$: 7.77E-03 (kg)($K^{1/2}$)/(sec)(N); 2.16E+02 (lb)($^\circ R^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.11E+02 kg/(sec)(m$^2$); 2.28E+01 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 5000. | 9000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.62E-01 | 4642. | 8356. | 6.21E+03 | 2.04E+04 | 1.00 | 1.00E+00 | 633. | 1155. |
| DOWNSTREAM | 1.00E-01 | 3854. | 6938. | 1.16E+04 | 3.80E+04 | 2.18 | 2.29E+00 | 1181. | 1394. |
| DOWNSTREAM | 1.00E-02 | 3163. | 5693. | 1.52E+04 | 4.97E+04 | 3.36 | 1.30E+01 | 1546. | 1666. |
| DOWNSTREAM | 1.00E-03 | 2679. | 4822. | 1.74E+04 | 5.70E+04 | 4.42 | 8.75E+01 | 1773. | 1854. |
| DOWNSTREAM | 1.00E-04 | 2308. | 4155. | 1.90E+04 | 6.22E+04 | 5.43 | 6.39E+02 | 1933. | 1992. |

Stagnation temperature, $T_t$: 6000 K; 10 800° R
Sonic flow factor, $\psi$: 7.55E-03 (kg)($K^{1/2}$)/(sec)(N); 2.10E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 9.87E+01 kg/(sec)($m^2$); 2.02E+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 6000. | 10800. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.47E-01 | 5287. | 9517. | 7.30E+03 | 2.40E+04 | 1.00 | 1.00E+00 | 745. | 1317. |
| DOWNSTREAM | 1.00E-01 | 4167. | 7501. | 1.31E+04 | 4.29E+04 | 2.20 | 2.21E+00 | 1334. | 1565. |
| DOWNSTREAM | 1.00E-02 | 3347. | 6025. | 1.69E+04 | 5.55E+04 | 3.43 | 1.23E+01 | 1726. | 1855. |
| DOWNSTREAM | 1.00E-03 | 2820. | 5077. | 1.93E+04 | 6.33E+04 | 4.52 | 8.23E+01 | 1968. | 2054. |
| DOWNSTREAM | 1.00E-04 | 2437. | 4386. | 2.10E+04 | 6.88E+04 | 5.55 | 6.01E+02 | 2137. | 2200. |

Stagnation temperature, $T_t$: 7000 K; 12 600° R
Sonic flow factor, $\psi$: 7.71E-03 (kg)($K^{1/2}$)/(sec)(N); 2.15E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 9.34E+01 kg/(sec)($m^2$); 1.91E+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 7000. | 12600. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.29E-01 | 5787. | 10417. | 8.09E+03 | 2.66E+04 | 1.00 | 1.00E+00 | 825. | 1411. |
| DOWNSTREAM | 1.00E-01 | 4326. | 7787. | 1.39E+04 | 4.56E+04 | 2.22 | 2.13E+00 | 1417. | 1653. |
| DOWNSTREAM | 1.00E-02 | 3420. | 6156. | 1.78E+04 | 5.84E+04 | 3.48 | 1.18E+01 | 1816. | 1946. |
| DOWNSTREAM | 1.00E-03 | 2869. | 5164. | 2.02E+04 | 6.63E+04 | 4.59 | 7.87E+01 | 2060. | 2147. |
| DOWNSTREAM | 1.00E-04 | 2476. | 4458. | 2.19E+04 | 7.18E+04 | 5.63 | 5.75E+02 | 2232. | 2295. |

Stagnation temperature, $T_t$: 8000 K; 14 400° R
Sonic flow factor, $\psi$: 7.84E-03 (kg)($K^{1/2}$)/(sec)(N); 2.18E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 8.89E+01 kg/(sec)($m^2$); 1.82E+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 8000. | 14400. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.11E-01 | 6330. | 11393. | 8.86E+03 | 2.91E+04 | 1.00 | 1.00E+00 | 903. | 1497. |
| DOWNSTREAM | 1.00E-01 | 4459. | 8026. | 1.46E+04 | 4.79E+04 | 2.25 | 2.05E+00 | 1489. | 1727. |
| DOWNSTREAM | 1.00E-02 | 3471. | 6247. | 1.85E+04 | 6.08E+04 | 3.54 | 1.12E+01 | 1889. | 2020. |
| DOWNSTREAM | 1.00E-03 | 2900. | 5221. | 2.09E+04 | 6.87E+04 | 4.66 | 7.50E+01 | 2134. | 2222. |
| DOWNSTREAM | 1.00E-04 | 2501. | 4502. | 2.26E+04 | 7.42E+04 | 5.72 | 5.48E+02 | 2306. | 2370. |

Stagnation temperature, $T_t$: 10 000 K; 18 000° R
Sonic flow factor, $\psi$: 7.72E-03 (kg)($K^{1/2}$)/(sec)(N); 2.15E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 7.83E+01 kg/(sec)($m^2$); 1.60E+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 10000. | 18000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.98E-01 | 7960. | 14329. | 1.02E+04 | 3.34E+04 | 1.00 | 1.00E+00 | 1037. | 1695. |
| DOWNSTREAM | 1.00E-01 | 4829. | 8693. | 1.62E+04 | 5.33E+04 | 2.28 | 1.83E+00 | 1657. | 1898. |
| DOWNSTREAM | 1.00E-02 | 3570. | 6427. | 2.02E+04 | 6.62E+04 | 3.69 | 9.79E+00 | 2057. | 2186. |
| DOWNSTREAM | 1.00E-03 | 2957. | 5323. | 2.25E+04 | 7.40E+04 | 4.86 | 6.55E+01 | 2299. | 2386. |
| DOWNSTREAM | 1.00E-04 | 2543. | 4577. | 2.42E+04 | 7.94E+04 | 5.94 | 4.79E+02 | 2469. | 2532. |

Stagnation temperature, $T_t$: 12 000 K; 21 600° R
Sonic flow factor, $\psi$: 7.26E-03 (kg)($K^{1/2}$)/(sec)(N); 2.02E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 6.71E+01 kg/(sec)($m^2$); 1.37E+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 12000. | 21600. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.37E-01 | 10535. | 18963. | 1.09E+04 | 3.57E+04 | 1.00 | 1.00E+00 | 1110. | 1936. |
| DOWNSTREAM | 1.00E-01 | 6117. | 11010. | 1.87E+04 | 6.14E+04 | 2.08 | 1.78E+00 | 1907. | 2182. |
| DOWNSTREAM | 1.00E-02 | 3742. | 6735. | 2.28E+04 | 7.47E+04 | 3.91 | 8.26E+00 | 2322. | 2449. |
| DOWNSTREAM | 1.00E-03 | 3036. | 5464. | 2.51E+04 | 8.23E+04 | 5.17 | 5.48E+01 | 2559. | 2644. |
| DOWNSTREAM | 1.00E-04 | 2596. | 4673. | 2.67E+04 | 8.77E+04 | 6.30 | 4.01E+02 | 2725. | 2787. |

TABLE III. - Continued. CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(b) Concluded. Stagnation pressure, $1.01325 \times 10^{6}$ N/m$^2$ (10 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^{o}$R | m/sec | ft/sec | | | Ideal, $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 14 000 K; 25 200$^{o}$ R<br>Sonic flow factor, $\psi$: 6.86E-03 (kg)(K$^{1/2}$)/(sec)(N); 1.91E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 5.87E+01 kg/(sec)(m$^2$); 1.20E+01 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 14000. | 25200. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.60E-01 | 12896. | 23213. | 1.18E+04 | 3.88E+04 | 1.00 | 1.00E+00 | 1206. | 2191. |
| DOWNSTREAM | 1.00E-01 | 9605. | 17289. | 2.18E+04 | 7.15E+04 | 2.11 | 2.14E+00 | 2221. | 2598. |
| DOWNSTREAM | 1.00E-02 | 4501. | 8102. | 2.72E+04 | 8.91E+04 | 3.71 | 7.86E+00 | 2770. | 2908. |
| DOWNSTREAM | 1.00E-03 | 3195. | 5751. | 2.95E+04 | 9.68E+04 | 5.62 | 4.68E+01 | 3009. | 3092. |
| DOWNSTREAM | 1.00E-04 | 2684. | 4831. | 3.11E+04 | 1.02E+05 | 6.89 | 3.39E+02 | 3170. | 3230. |
| Stagnation temperature, $T_t$: 16 000 K; 28 800$^{o}$ R<br>Sonic flow factor, $\psi$: 6.46E-03 (kg)(K$^{1/2}$)/(sec)(N); 1.80E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 5.17E+01 kg/(sec)(m$^2$); 1.06E+01 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 16000. | 28800. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.66E-01 | 14915. | 26847. | 1.33E+04 | 4.36E+04 | 1.00 | 1.00E+00 | 1356. | 2487. |
| DOWNSTREAM | 1.00E-01 | 12122. | 21819. | 2.49E+04 | 8.18E+04 | 2.17 | 2.27E+00 | 2543. | 2996. |
| DOWNSTREAM | 1.00E-02 | 8815. | 15868. | 3.23E+04 | 1.06E+05 | 3.34 | 1.17E+01 | 3297. | 3531. |
| DOWNSTREAM | 1.00E-03 | 4244. | 7638. | 3.60E+04 | 1.18E+05 | 4.83 | 4.96E+01 | 3671. | 3770. |
| DOWNSTREAM | 1.00E-04 | 2868. | 5162. | 3.77E+04 | 1.24E+05 | 7.53 | 2.97E+02 | 3841. | 3900. |
| Stagnation temperature, $T_t$: 18 000 K; 32 400$^{o}$ R<br>Sonic flow factor, $\psi$: 6.03E-03 (kg)(K$^{1/2}$)/(sec)(N); 1.68E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 4.55E+01 kg/(sec)(m$^2$); 9.33E+00 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 18000. | 32400. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.66E-01 | 16757. | 30165. | 1.52E+04 | 4.97E+04 | 1.00 | 1.00E+00 | 1546. | 2830. |
| DOWNSTREAM | 1.00E-01 | 13758. | 24764. | 2.84E+04 | 9.32E+04 | 2.18 | 2.27E+00 | 2897. | 3413. |
| DOWNSTREAM | 1.00E-02 | 10872. | 19569. | 3.70E+04 | 1.21E+05 | 3.39 | 1.24E+01 | 3771. | 4053. |
| DOWNSTREAM | 1.00E-03 | 8513. | 15323. | 4.21E+04 | 1.38E+05 | 4.52 | 7.84E+01 | 4289. | 4467. |
| DOWNSTREAM | 1.00E-04 | 5091. | 9165. | 4.52E+04 | 1.48E+05 | 5.45 | 4.18E+02 | 4607. | 4702. |

Stagnation temperature, $T_t$: 25 000 K; 45 000° R
Sonic flow factor, $\psi$: 5.48E-03 (kg)($K^{1/2}$)/(sec)(N); 1.53E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 3.51E+01 kg/(sec)($m^2$); 7.19E+00 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 25000. | 45000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.44E-01 | 21738. | 39128. | 2.09E+04 | 6.85E+04 | 1.00 | 1.00E+00 | 2128. | 3727. |
| DOWNSTREAM | 1.00E-01 | 16646. | 29963. | 3.69E+04 | 1.21E+05 | 2.21 | 2.15E+00 | 3767. | 4401. |
| DOWNSTREAM | 1.00E-02 | 12940. | 23292. | 4.74E+04 | 1.56E+05 | 3.48 | 1.16E+01 | 4833. | 5175. |
| DOWNSTREAM | 1.00E-03 | 10585. | 19053. | 5.36E+04 | 1.76E+05 | 4.64 | 7.54E+01 | 5457. | 5689. |
| DOWNSTREAM | 1.00E-04 | 8880. | 15984. | 5.78E+04 | 1.90E+05 | 5.78 | 5.32E+02 | 5896. | 6053. |

Stagnation temperature, $T_t$: 35 000 K; 63 000° R
Sonic flow factor, $\psi$: 5.66E-03 (kg)($K^{1/2}$)/(sec)(N); 1.57E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 3.06E+01 kg/(sec)($m^2$); 6.27E+00 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 35000. | 63000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.04E-01 | 27208. | 48975. | 2.61E+04 | 8.57E+04 | 1.00 | 1.00E+00 | 2665. | 4365. |
| DOWNSTREAM | 1.00E-01 | 18267. | 32881. | 4.23E+04 | 1.39E+05 | 2.26 | 1.96E+00 | 4318. | 4981. |
| DOWNSTREAM | 1.00E-02 | 13618. | 24513. | 5.31E+04 | 1.74E+05 | 3.63 | 1.04E+01 | 5419. | 5769. |
| DOWNSTREAM | 1.00E-03 | 11043. | 19878. | 5.95E+04 | 1.95E+05 | 4.83 | 6.74E+01 | 6068. | 6295. |
| DOWNSTREAM | 1.00E-04 | 9271. | 16689. | 6.38E+04 | 2.09E+05 | 5.99 | 4.77E+02 | 6508. | 6669. |

Stagnation temperature, $T_t$: 50 000 K; 90 000° R
Sonic flow factor, $\psi$: 5.69E-03 (kg)($K^{1/2}$)/(sec)(N); 1.58E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 2.58E+01 kg/(sec)($m^2$); 5.28E+00 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 50000. | 90000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.88E-01 | 37621. | 67718. | 3.19E+04 | 1.05E+05 | 1.00 | 1.00E+00 | 3256. | 5212. |
| DOWNSTREAM | 1.00E-01 | 21236. | 38224. | 4.97E+04 | 1.63E+05 | 2.24 | 1.73E+00 | 5070. | 5765. |
| DOWNSTREAM | 1.00E-02 | 14302. | 25744. | 6.06E+04 | 1.99E+05 | 3.86 | 8.62E+00 | 6179. | 6524. |
| DOWNSTREAM | 1.00E-03 | 11418. | 20552. | 6.69E+04 | 2.19E+05 | 5.15 | 5.58E+01 | 6818. | 7042. |
| DOWNSTREAM | 1.00E-04 | 9554. | 17196. | 7.11E+04 | 2.33E+05 | 6.36 | 3.96E+02 | 7252. | 7411. |

Stagnation temperature, $T_t$: 75 000 K; 135 000° R
Sonic flow factor, $\psi$: 5.68E-03 (kg)($K^{1/2}$)/(sec)(N); 1.58E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 2.10E+01 kg/(sec)($m^2$); 4.30E+00 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 75000. | 135000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.87E-01 | 55306. | 101352. | 3.93E+04 | 1.29E+05 | 1.00 | 1.00E+00 | 4004. | 6402. |
| DOWNSTREAM | 1.00E-01 | 30025. | 54045. | 6.09E+04 | 2.00E+05 | 2.14 | 1.67E+00 | 6210. | 7030. |
| DOWNSTREAM | 1.00E-02 | 15454. | 27817. | 7.25E+04 | 2.38E+05 | 4.20 | 6.81E+00 | 7390. | 7725. |
| DOWNSTREAM | 1.00E-03 | 11871. | 21367. | 7.85E+04 | 2.57E+05 | 5.69 | 4.33E+01 | 8002. | 8215. |
| DOWNSTREAM | 1.00E-04 | 9850. | 17729. | 8.25E+04 | 2.71E+05 | 7.01 | 3.08E+02 | 8416. | 8567. |

Stagnation temperature, $T_t$: 100 000 K; 180 000° R
Sonic flow factor, $\psi$: 5.67E-03 (kg)($K^{1/2}$)/(sec)(N); 1.58E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 1.82E+01 kg/(sec)($m^2$); 3.72E+00 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 100000. | 180000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.87E-01 | 75049. | 135088. | 4.54E+04 | 1.49E+05 | 1.00 | 1.00E+00 | 4627. | 7400. |
| DOWNSTREAM | 1.00E-01 | 39897. | 71814. | 7.04E+04 | 2.31E+05 | 2.13 | 1.67E+00 | 7177. | 8125. |
| DOWNSTREAM | 1.00E-02 | 17162. | 30892. | 8.33E+04 | 2.73E+05 | 4.26 | 5.93E+00 | 8494. | 8831. |
| DOWNSTREAM | 1.00E-03 | 12252. | 22053. | 8.91E+04 | 2.92E+05 | 6.18 | 3.57E+01 | 9088. | 9292. |
| DOWNSTREAM | 1.00E-04 | 10061. | 18110. | 9.30E+04 | 3.05E+05 | 7.62 | 2.53E+02 | 9482. | 9626. |

TABLE III. - Continued. CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(c) Stagnation pressure, $1.01325 \times 10^{7}$ (100 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^{o}R$ | m/sec | ft/sec | | | Ideal, $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 2500 K; 4500$^{o}$ R<br>Sonic flow factor, $\psi$: 1.04E-02 (kg)($K^{1/2}$)/(sec)(N); 2.89E+02 (lb)($^{o}R^{1/2}$)/(sec)($ft^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 2.10E+03 kg/(sec)($m^2$); 4.31E+02 lb/(sec)($ft^2$) | | | | | | | | | |
| CHAMBER | 1. | 2500. | 4500. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.44E-01 | 2178. | 3920. | 3.43E+03 | 1.12E+04 | 1.00 | 1.00E+00 | 349. | 617. |
| DOWNSTREAM | 1.00E-01 | 1432. | 2577. | 6.05E+03 | 1.99E+04 | 2.14 | 2.02E+00 | 618. | 717. |
| DOWNSTREAM | 1.00E-02 | 764. | 1376. | 7.55E+03 | 2.48E+04 | 3.60 | 8.57E+00 | 770. | 812. |
| DOWNSTREAM | 1.00E-03 | 398. | 716. | 8.22E+03 | 2.70E+04 | 5.43 | 4.14E+01 | 839. | 859. |
| Stagnation temperature, $T_t$: 3500 K; 6300$^{o}$ R<br>Sonic flow factor, $\psi$: 9.99E-03 (kg)($K^{1/2}$)/(sec)(N); 2.78E+02 (lb)($^{o}R^{1/2}$)/(sec)($ft^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.71E+03 kg/(sec)($m^2$); 3.50E+02 lb/(sec)($ft^2$) | | | | | | | | | |
| CHAMBER | 1. | 3500. | 6300. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.61E-01 | 3197. | 5755. | 4.04E+03 | 1.33E+04 | 1.00 | 1.00E+00 | 412. | 751. |
| DOWNSTREAM | 1.00E-01 | 2318. | 4172. | 7.48E+03 | 2.45E+04 | 2.13 | 2.16E+00 | 762. | 893. |
| DOWNSTREAM | 1.00E-02 | 1320. | 2375. | 9.48E+03 | 3.11E+04 | 3.49 | 9.70E+00 | 957. | 1025. |
| DOWNSTREAM | 1.00E-03 | 700. | 1260. | 1.04E+04 | 3.42E+04 | 5.19 | 4.68E+01 | 1052. | 1090. |
| DOWNSTREAM | 1.00E-04 | 364. | 655. | 1.09E+04 | 3.57E+04 | 7.50 | 2.33E+02 | 1109. | 1123. |
| Stagnation temperature, $T_t$: 5000 K; 9000$^{o}$ R<br>Sonic flow factor, $\psi$: 8.85E-03 (kg)($K^{1/2}$)/(sec)(N); 2.46E+02 (lb)($^{o}R^{1/2}$)/(sec)($ft^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.27E+03 kg/(sec)($m^2$); 2.60E+02 lb/(sec)($ft^2$) | | | | | | | | | |
| CHAMBER | 1. | 5000. | 9000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.65E-01 | 4657. | 8382. | 5.41E+03 | 1.78E+04 | 1.00 | 1.00E+00 | 552. | 1012. |
| DOWNSTREAM | 1.00E-01 | 3832. | 6897. | 1.02E+04 | 3.33E+04 | 2.17 | 2.30E+00 | 1036. | 1224. |
| DOWNSTREAM | 1.00E-02 | 3036. | 5465. | 1.33E+04 | 4.36E+04 | 3.36 | 1.28E+01 | 1355. | 1460. |
| DOWNSTREAM | 1.00E-03 | 2370. | 4266. | 1.52E+04 | 4.98E+04 | 4.44 | 8.23E+01 | 1549. | 1616. |
| DOWNSTREAM | 1.00E-04 | 1540. | 2771. | 1.64E+04 | 5.38E+04 | 5.63 | 4.85E+02 | 1672. | 1711. |
| DOWNSTREAM | 3.00E-05 | 1122. | 2020. | 1.68E+04 | 5.51E+04 | 6.66 | 1.15E+03 | 1712. | 1740. |
| DOWNSTREAM | 1.00E-05 | 829. | 1491. | 1.70E+04 | 5.59E+04 | 7.82 | 2.51E+03 | 1738. | 1759. |

Stagnation temperature, $T_t$: 6000 K; 10 800$^{o}$ R
Sonic flow factor, $\psi$: 8.04E-03 (kg)($K^{1/2}$)/(sec)(N); 2.24E+02 (lb)($^{o}R^{1/2}$)/(sec)(ft$^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 1.05E+03 kg/(sec)(m$^2$); 2.15E+02 lb/(sec)(ft$^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 6000. | 10800. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.57E-01 | 5496. | 9893. | 6.67E+03 | 2.19E+04 | 1.00 | 1.00E+00 | 680. | 1228. |
| DOWNSTREAM | 1.00E-01 | 4434. | 7981. | 1.22E+04 | 4.02E+04 | 2.18 | 2.24E+00 | 1249. | 1469. |
| DOWNSTREAM | 1.00E-02 | 3528. | 6350. | 1.59E+04 | 5.22E+04 | 3.41 | 1.23E+01 | 1621. | 1743. |
| DOWNSTREAM | 1.00E-03 | 2912. | 5241. | 1.81E+04 | 5.95E+04 | 4.52 | 8.15E+01 | 1848. | 1928. |
| DOWNSTREAM | 1.00E-04 | 2442. | 4395. | 1.97E+04 | 6.45E+04 | 5.59 | 5.83E+02 | 2004. | 2061. |
| DOWNSTREAM | 3.00E-05 | 2222. | 4000. | 2.03E+04 | 6.65E+04 | 6.15 | 1.65E+03 | 2057. | 2116. |
| DOWNSTREAM | 1.00E-05 | 2019. | 3634. | 2.08E+04 | 6.81E+04 | 6.65 | 4.28E+03 | 2117. | 2159. |

Stagnation temperature, $T_t$: 7000 K; 12 600$^{o}$ R
Sonic flow factor, $\psi$: 7.72E-03 (kg)($K^{1/2}$)/(sec)(N); 2.15E+02 (lb)($^{o}R^{1/2}$)/(sec)(ft$^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 9.35E+02 kg/(sec)(m$^2$); 1.91E+02 lb/(sec)(ft$^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 7000. | 12600. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.45E-01 | 6198. | 11156. | 7.74E+03 | 2.54E+04 | 1.00 | 1.00E+00 | 789. | 1391. |
| DOWNSTREAM | 1.00E-01 | 4809. | 8656. | 1.38E+04 | 4.52E+04 | 2.20 | 2.17E+00 | 1405. | 1644. |
| DOWNSTREAM | 1.00E-02 | 3758. | 6764. | 1.77E+04 | 5.81E+04 | 3.46 | 1.17E+01 | 1806. | 1936. |
| DOWNSTREAM | 1.00E-03 | 3095. | 5571. | 2.01E+04 | 6.59E+04 | 4.61 | 7.70E+01 | 2048. | 2133. |
| DOWNSTREAM | 1.00E-04 | 2620. | 4717. | 2.17E+04 | 7.12E+04 | 5.70 | 5.53E+02 | 2213. | 2275. |
| DOWNSTREAM | 3.00E-05 | 2417. | 4350. | 2.24E+04 | 7.34E+04 | 6.26 | 1.58E+03 | 2282. | 2334. |
| DOWNSTREAM | 1.00E-05 | 2248. | 4047. | 2.29E+04 | 7.51E+04 | 6.77 | 4.17E+03 | 2335. | 2382. |

Stagnation temperature, $T_t$: 8000 K; 14 400$^{o}$ R
Sonic flow factor, $\psi$: 7.72E-03 (kg)($K^{1/2}$)/(sec)(N); 2.15E+02 (lb)($^{o}R^{1/2}$)/(sec)(ft$^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 8.74E+02 kg/(sec)(m$^2$); 1.79E+02 lb/(sec)(ft$^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 8000. | 14400. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.32E-01 | 6781. | 12205. | 8.55E+03 | 2.80E+04 | 1.00 | 1.00E+00 | 872. | 1501. |
| DOWNSTREAM | 1.00E-01 | 5041. | 9075. | 1.48E+04 | 4.84E+04 | 2.21 | 2.10E+00 | 1505. | 1753. |
| DOWNSTREAM | 1.00E-02 | 3873. | 6972. | 1.88E+04 | 6.17E+04 | 3.51 | 1.12E+01 | 1919. | 2051. |
| DOWNSTREAM | 1.00E-03 | 3176. | 5716. | 2.12E+04 | 6.97E+04 | 4.68 | 7.36E+01 | 2155. | 2252. |
| DOWNSTREAM | 1.00E-04 | 2689. | 4841. | 2.29E+04 | 7.51E+04 | 5.79 | 5.28E+02 | 2335. | 2397. |
| DOWNSTREAM | 3.00E-05 | 2485. | 4473. | 2.36E+04 | 7.74E+04 | 6.36 | 1.51E+03 | 2404. | 2458. |
| DOWNSTREAM | 1.00E-05 | 2319. | 4173. | 2.41E+04 | 7.91E+04 | 6.87 | 3.99E+03 | 2460. | 2507. |

Stagnation temperature, $T_t$: 10 000 K; 18 000$^{o}$ R
Sonic flow factor, $\psi$: 7.83E-03 (kg)($K^{1/2}$)/(sec)(N); 2.18E+02 (lb)($^{o}R^{1/2}$)/(sec)(ft$^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 7.93E+02 kg/(sec)(m$^2$); 1.62E+02 lb/(sec)(ft$^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 10000. | 18000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.09E-01 | 7969. | 14345. | 9.93E+03 | 3.26E+04 | 1.00 | 1.00E+00 | 1013. | 1676. |
| DOWNSTREAM | 1.00E-01 | 5396. | 9713. | 1.63E+04 | 5.33E+04 | 2.24 | 1.97E+00 | 1657. | 1914. |
| DOWNSTREAM | 1.00E-02 | 4012. | 7221. | 2.04E+04 | 6.69E+04 | 3.62 | 1.03E+01 | 2080. | 2215. |
| DOWNSTREAM | 1.00E-03 | 3262. | 5872. | 2.28E+04 | 7.50E+04 | 4.82 | 6.74E+01 | 2330. | 2418. |
| DOWNSTREAM | 1.00E-04 | 2758. | 4965. | 2.45E+04 | 8.05E+04 | 5.95 | 4.83E+02 | 2501. | 2564. |
| DOWNSTREAM | 3.00E-05 | 2550. | 4590. | 2.52E+04 | 8.27E+04 | 6.54 | 1.39E+03 | 2571. | 2626. |
| DOWNSTREAM | 1.00E-05 | 2383. | 4289. | 2.58E+04 | 8.45E+04 | 7.07 | 3.66E+03 | 2627. | 2675. |

Stagnation temperature, $T_t$: 12 000 K; 21 600$^{o}$ R
Sonic flow factor, $\psi$: 7.66E-03 (kg)($K^{1/2}$)/(sec)(N); 2.13E+02 (lb)($^{o}R^{1/2}$)/(sec)(ft$^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 7.08E+02 kg/(sec)(m$^2$); 1.45E+02 lb/(sec)(ft$^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 12000. | 21600. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.05E-01 | 9732. | 17518. | 1.11E+04 | 3.63E+04 | 1.00 | 1.00E+00 | 1129. | 1866. |
| DOWNSTREAM | 1.00E-01 | 5887. | 10596. | 1.79E+04 | 5.88E+04 | 2.24 | 1.82E+00 | 1825. | 2092. |
| DOWNSTREAM | 1.00E-02 | 4144. | 7459. | 2.21E+04 | 7.25E+04 | 3.74 | 9.24E+00 | 2255. | 2389. |
| DOWNSTREAM | 1.00E-03 | 3335. | 6004. | 2.46E+04 | 8.06E+04 | 5.00 | 6.00E+01 | 2534. | 2591. |
| DOWNSTREAM | 1.00E-04 | 2812. | 5061. | 2.62E+04 | 8.60E+04 | 6.17 | 4.30E+02 | 2674. | 2737. |
| DOWNSTREAM | 3.00E-05 | 2599. | 4678. | 2.69E+04 | 8.83E+04 | 6.75 | 1.23E+03 | 2744. | 2798. |
| DOWNSTREAM | 1.00E-05 | 2430. | 4373. | 2.75E+04 | 9.01E+04 | 7.30 | 3.26E+03 | 2800. | 2848. |

TABLE III. - Continued. CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(c) Concluded. Stagnation pressure, $1.01325 \times 10^{7}$ (100 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^{o}R$ | m/sec | ft/sec | | | Ideal, $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 14 000 K; 25 200$^{o}$ R<br>Sonic flow factor, $\psi$: 7.31E-03 (kg)$(K^{1/2})$/(sec)(N); 2.03E+02 (lb)$(^{o}R^{1/2})$/(sec)$(ft^2)$(atm)<br>Mass flow per unit throat area, $W/A^*$: 6.26E+02 kg/(sec)$(m^2)$; 1.28E+02 lb/(sec)$(ft^2)$ | | | | | | | | | |
| CHAMBER | 1. | 14000. | 25200. | 0 | 0 | 0 | INFINITY | 1202. | 2082. |
| THROAT | 5.33E-01 | 12159. | 21886. | 1.18E+04 | 3.87E+04 | 1.00 | 1.00E+00 | 2050. | 2346. |
| DOWNSTREAM | 1.00E-01 | 7134. | 12841. | 2.01E+04 | 6.60E+04 | 2.10 | 1.79E+00 | 2498. | 2633. |
| DOWNSTREAM | 1.00E-02 | 4344. | 7819. | 2.45E+04 | 8.04E+04 | 3.90 | 8.17E+00 | 2745. | 2832. |
| DOWNSTREAM | 1.00E-03 | 3428. | 6170. | 2.69E+04 | 8.83E+04 | 5.25 | 5.25E+01 | 2914. | 2976. |
| DOWNSTREAM | 1.00E-04 | 2874. | 5173. | 2.86E+04 | 9.37E+04 | 6.47 | 3.75E+02 | 2983. | 3036. |
| DOWNSTREAM | 3.00E-05 | 2654. | 4776. | 2.93E+04 | 9.60E+04 | 7.09 | 1.08E+03 | 3038. | 3085. |
| DOWNSTREAM | 1.00E-05 | 2480. | 4464. | 2.98E+04 | 9.77E+04 | 7.65 | 2.84E+03 | | |
| Stagnation temperature, $T_t$: 16 000 K; 28 800$^{o}$ R<br>Sonic flow factor, $\psi$: 7.01E-03 (kg)$(K^{1/2})$/(sec)(N); 1.95E+02 (lb)$(^{o}R^{1/2})$/(sec)$(ft^2)$(atm)<br>Mass flow per unit throat area, $W/A^*$: 5.62E+02 kg/(sec)$(m^2)$; 1.15E+02 lb/(sec)$(ft^2)$ | | | | | | | | | |
| CHAMBER | 1. | 16000. | 28800. | 0 | 0 | 0 | INFINITY | 1284. | 2302. |
| THROAT | 5.53E-01 | 14474. | 26052. | 1.26E+04 | 4.13E+04 | 1.00 | 1.00E+00 | 2314. | 2687. |
| DOWNSTREAM | 1.00E-01 | 9987. | 17977. | 2.27E+04 | 7.45E+04 | 2.08 | 2.02E+00 | 2845. | 2986. |
| DOWNSTREAM | 1.00E-02 | 4826. | 8686. | 2.79E+04 | 9.15E+04 | 3.91 | 7.65E+00 | 3095. | 3181. |
| DOWNSTREAM | 1.00E-03 | 3570. | 6426. | 3.04E+04 | 9.96E+04 | 5.56 | 4.65E+01 | 3261. | 3322. |
| DOWNSTREAM | 1.00E-04 | 2957. | 5322. | 3.20E+04 | 1.05E+05 | 6.89 | 3.31E+02 | 3329. | 3382. |
| DOWNSTREAM | 3.00E-05 | 2724. | 4903. | 3.26E+04 | 1.07E+05 | 7.55 | 9.48E+02 | 3383. | 3429. |
| DOWNSTREAM | 1.00E-05 | 2543. | 4577. | 3.32E+04 | 1.09E+05 | 8.14 | 2.50E+03 | | |
| Stagnation temperature, $T_t$: 18 000 K; 32 400$^{o}$ R<br>Sonic flow factor, $\psi$: 6.74E-03 (kg)$(K^{1/2})$/(sec)(N); 1.88E+02 (lb)$(^{o}R^{1/2})$/(sec)$(ft^2)$(atm)<br>Mass flow per unit throat area, $W/A^*$: 5.09E+02 kg/(sec)$(m^2)$; 1.04E+02 lb/(sec)$(ft^2)$ | | | | | | | | | |
| CHAMBER | 1. | 18000. | 32400. | 0 | 0 | 0 | INFINITY | 1399. | 2536. |
| THROAT | 5.60E-01 | 16519. | 29733. | 1.37E+04 | 4.50E+04 | 1.00 | 1.00E+00 | 2577. | 3020. |
| DOWNSTREAM | 1.00E-01 | 12684. | 22832. | 2.53E+04 | 8.29E+04 | 2.16 | 2.18E+00 | 3270. | 3458. |
| DOWNSTREAM | 1.00E-02 | 7148. | 12866. | 3.21E+04 | 1.05E+05 | 3.30 | 9.24E+00 | 3557. | 3645. |
| DOWNSTREAM | 1.00E-03 | 3855. | 6938. | 3.49E+04 | 1.14E+05 | 5.77 | 4.32E+01 | 3723. | 3784. |
| DOWNSTREAM | 1.00E-04 | 3076. | 5536. | 3.65E+04 | 1.20E+05 | 7.36 | 2.97E+02 | 3790. | 3842. |
| DOWNSTREAM | 3.00E-05 | 2816. | 5069. | 3.72E+04 | 1.22E+05 | 8.09 | 8.47E+02 | 3844. | 3889. |
| DOWNSTREAM | 1.00E-05 | 2621. | 4717. | 3.77E+04 | 1.24E+05 | 8.73 | 2.23E+03 | | |

Stagnation temperature, $T_t$: 25 000 K; 45 000° R
Sonic flow factor, $\psi$: 5.86E-03 (kg)($K^{1/2}$)/(sec)(N); 1.63E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 3.75E+02 kg/(sec)($m^2$); 7.69E+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 25000. | 45000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.56E-01 | 22627. | 40729. | 1.90E+04 | 6.23E+04 | 1.00 | 1.00E+00 | 1935. | 3464. |
| DOWNSTREAM | 1.00E-01 | 17727. | 31908. | 3.45E+04 | 1.13E+05 | 2.20 | 2.19E+00 | 3521. | 4123. |
| DOWNSTREAM | 1.00E-02 | 13564. | 24415. | 4.44E+04 | 1.46E+05 | 3.47 | 1.16E+01 | 4529. | 4848. |
| DOWNSTREAM | 1.00E-03 | 10681. | 19226. | 5.01E+04 | 1.65E+05 | 4.67 | 7.30E+01 | 5113. | 5314. |
| DOWNSTREAM | 1.00E-04 | 8217. | 14791. | 5.39E+04 | 1.77E+05 | 5.87 | 4.80E+02 | 5492. | 5624. |
| DOWNSTREAM | 3.00E-05 | 6516. | 11729. | 5.52E+04 | 1.81E+05 | 6.32 | 1.21E+03 | 5632. | 5731. |
| DOWNSTREAM | 1.00E-05 | 4367. | 7860. | 5.61E+04 | 1.84E+05 | 7.26 | 2.38E+03 | 5722. | 5787. |

Stagnation temperature, $T_t$: 35 000 K; 63 000° R
Sonic flow factor, $\psi$: 5.65E-03 (kg)($K^{1/2}$)/(sec)(N); 1.57E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 3.06E+02 kg/(sec)($m^2$); 6.27E+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 35000. | 63000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.25E-01 | 28976. | 52157. | 2.50E+04 | 8.21E+04 | 1.00 | 1.00E+00 | 2553. | 4327. |
| DOWNSTREAM | 1.00E-01 | 20699. | 37257. | 4.24E+04 | 1.39E+05 | 2.23 | 2.04E+00 | 4325. | 5014. |
| DOWNSTREAM | 1.00E-02 | 15296. | 27532. | 5.36E+04 | 1.76E+05 | 3.59 | 1.06E+01 | 5463. | 5819. |
| DOWNSTREAM | 1.00E-03 | 12125. | 21825. | 6.00E+04 | 1.97E+05 | 4.84 | 6.67E+01 | 6117. | 6342. |
| DOWNSTREAM | 1.00E-04 | 9919. | 17854. | 6.42E+04 | 2.11E+05 | 6.07 | 4.60E+02 | 6548. | 6703. |
| DOWNSTREAM | 3.00E-05 | 8979. | 16161. | 6.59E+04 | 2.16E+05 | 6.73 | 1.29E+03 | 6720. | 6850. |
| DOWNSTREAM | 1.00E-05 | 8191. | 14744. | 6.72E+04 | 2.20E+05 | 7.33 | 3.32E+03 | 6853. | 6965. |

Stagnation temperature, $T_t$: 50 000 K; 90 000° R
Sonic flow factor, $\psi$: 5.72E-03 (kg)($K^{1/2}$)/(sec)(N); 1.59E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 2.59E+02 kg/(sec)($m^2$); 5.31E+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 50000. | 90000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.94E-01 | 38228. | 68811. | 3.15E+04 | 1.03E+05 | 1.00 | 1.00E+00 | 3207. | 5178. |
| DOWNSTREAM | 1.00E-01 | 23555. | 42399. | 4.97E+04 | 1.63E+05 | 2.26 | 1.83E+00 | 5073. | 5803. |
| DOWNSTREAM | 1.00E-02 | 15298. | 29337. | 6.13E+04 | 2.01E+05 | 3.77 | 9.13E+00 | 6252. | 6616. |
| DOWNSTREAM | 1.00E-03 | 12753. | 22955. | 6.78E+04 | 2.23E+05 | 5.09 | 5.75E+01 | 6918. | 7147. |
| DOWNSTREAM | 1.00E-04 | 10444. | 18800. | 7.22E+04 | 2.37E+05 | 6.37 | 3.98E+02 | 7357. | 7516. |
| DOWNSTREAM | 3.00E-05 | 9503. | 17105. | 7.39E+04 | 2.42E+05 | 7.05 | 1.12E+03 | 7533. | 7667. |
| DOWNSTREAM | 1.00E-05 | 8748. | 15746. | 7.52E+04 | 2.47E+05 | 7.66 | 2.90E+03 | 7670. | 7785. |

Stagnation temperature, $T_t$: 75 000 K; 135 000° R
Sonic flow factor, $\psi$: 5.70E-03 (kg)($K^{1/2}$)/(sec)(N); 1.59E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 2.11E+02 kg/(sec)($m^2$); 4.32E+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 75000. | 135000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.88E-01 | 55406. | 101531. | 3.91E+04 | 1.28E+05 | 1.00 | 1.00E+00 | 3985. | 6373. |
| DOWNSTREAM | 1.00E-01 | 30610. | 55099. | 6.07E+04 | 1.99E+05 | 2.16 | 1.68E+00 | 6186. | 7010. |
| DOWNSTREAM | 1.00E-02 | 17610. | 31698. | 7.27E+04 | 2.39E+05 | 4.06 | 7.38E+00 | 7418. | 7780. |
| DOWNSTREAM | 1.00E-03 | 13379. | 24082. | 7.92E+04 | 2.60E+05 | 5.54 | 4.58E+01 | 8074. | 8298. |
| DOWNSTREAM | 1.00E-04 | 10891. | 19604. | 8.34E+04 | 2.74E+05 | 6.92 | 3.17E+02 | 8504. | 8659. |
| DOWNSTREAM | 3.00E-05 | 9914. | 17845. | 8.51E+04 | 2.79E+05 | 7.63 | 8.94E+02 | 8676. | 8808. |
| DOWNSTREAM | 1.00E-05 | 9147. | 16465. | 8.64E+04 | 2.83E+05 | 8.28 | 2.33E+03 | 8811. | 8925. |

Stagnation temperature, $T_t$: 100 000 K; 180 000° R
Sonic flow factor, $\psi$: 5.69E-03 (kg)($K^{1/2}$)/(sec)(N); 1.58E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 1.82E+02 kg/(sec)($m^2$); 3.73+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 100000. | 180000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.87E-01 | 75106. | 135190. | 4.52E+04 | 1.48E+05 | 1.00 | 1.00E+00 | 4614. | 7377. |
| DOWNSTREAM | 1.00E-01 | 40076. | 72137. | 7.02E+04 | 2.30E+05 | 2.13 | 1.67E+00 | 7156. | 8101. |
| DOWNSTREAM | 1.00E-02 | 19094. | 34369. | 8.33E+04 | 2.73E+05 | 4.22 | 6.37E+00 | 8492. | 8853. |
| DOWNSTREAM | 1.00E-03 | 13861. | 24951. | 8.96E+04 | 2.94E+05 | 5.96 | 3.83E+01 | 9135. | 9352. |
| DOWNSTREAM | 1.00E-04 | 11187. | 20136. | 9.37E+04 | 3.07E+05 | 7.45 | 2.65E+02 | 9551. | 9701. |
| DOWNSTREAM | 3.00E-05 | 10169. | 18305. | 9.53E+04 | 3.13E+05 | 8.21 | 7.47E+02 | 9717. | 9844. |
| DOWNSTREAM | 1.00E-05 | 9383. | 16890. | 9.66E+04 | 3.17E+05 | 8.90 | 1.95E+03 | 9847. | 9958. |

TABLE III. - Continued. CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(d) Stagnation pressure, 2.02650E×10$^{7}$ N/m$^{2}$ (200 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^{o}$R | m/sec | ft/sec | | | Ideal, $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 2500 K; 4500$^{o}$ R<br>Sonic flow factor, $\psi$: 1.04E-02 (kg)(K$^{1/2}$)/(sec)(N); 2.89E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^{2}$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 4.21E+03 kg/(sec)(m$^{2}$); 8.62E+02 lb/(sec)(ft$^{2}$) | | | | | | | | | |
| CHAMBER | 1. | 2500. | 4500. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.44E-01 | 2174. | 3913. | 3.43E+03 | 1.12E+04 | 1.00 | 1.00E+00 | 349. | 616. |
| DOWNSTREAM | 1.00E-01 | 1428. | 2571. | 6.05E+03 | 1.99E+04 | 2.14 | 2.02E+00 | 617. | 716. |
| DOWNSTREAM | 1.00E-02 | 763. | 1373. | 7.54E+03 | 2.47E+04 | 3.60 | 8.67E+00 | 759. | 811. |
| DOWNSTREAM | 1.00E-03 | 397. | 714. | 8.22E+03 | 2.70E+04 | 5.43 | 4.14E+01 | 838. | 858. |
| Stagnation temperature, $T_t$: 3500 K; 6300$^{o}$ R<br>Sonic flow factor, $\psi$: 1.01E-02 (kg)(K$^{1/2}$)/(sec)(N); 2.80E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^{2}$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 3.45E+03 kg/(sec)(m$^{2}$); 7.07E+02 lb/(sec)(ft$^{2}$) | | | | | | | | | |
| CHAMBER | 1. | 3500. | 6300. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.58E-01 | 3170. | 5707. | 4.04E+03 | 1.32E+04 | 1.00 | 1.00E+00 | 412. | 746. |
| DOWNSTREAM | 1.00E-01 | 2246. | 4044. | 7.40E+03 | 2.43E+04 | 2.14 | 2.13E+00 | 755. | 883. |
| DOWNSTREAM | 1.00E-02 | 1267. | 2281. | 9.36E+03 | 3.07E+04 | 3.51 | 9.51E+00 | 954. | 1011. |
| DOWNSTREAM | 1.00E-03 | 671. | 1207. | 1.03E+04 | 3.37E+04 | 5.23 | 4.59E+01 | 1047. | 1074. |
| DOWNSTREAM | 1.00E-04 | 348. | 627. | 1.07E+04 | 3.51E+04 | 7.55 | 2.28E+02 | 1092. | 1106. |
| Stagnation temperature, $T_t$: 5000 K; 9000$^{o}$ R<br>Sonic flow factor, $\psi$: 9.15E-03 (kg)(K$^{1/2}$)/(sec)(N); 2.55E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^{2}$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 2.62E+03 kg/(sec)(m$^{2}$); 5.37E+02 lb/(sec)(ft$^{2}$) | | | | | | | | | |
| CHAMBER | 1. | 5000. | 9000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.65E-01 | 4644. | 8359. | 5.24E+03 | 1.72E+04 | 1.00 | 1.00E+00 | 534. | 979. |
| DOWNSTREAM | 1.00E-01 | 3777. | 6798. | 9.82E+03 | 3.22E+04 | 2.17 | 2.29E+00 | 1002. | 1182. |
| DOWNSTREAM | 1.00E-02 | 2900. | 5220. | 1.28E+04 | 4.21E+04 | 3.36 | 1.26E+01 | 1308. | 1407. |
| DOWNSTREAM | 1.00E-03 | 2035. | 3662. | 1.46E+04 | 4.78E+04 | 4.46 | 7.47E+01 | 1487. | 1545. |
| DOWNSTREAM | 1.00E-04 | 1148. | 2066. | 1.56E+04 | 5.11E+04 | 5.11 | 3.94E+02 | 1587. | 1618. |
| DOWNSTREAM | 3.00E-05 | 824. | 1482. | 1.59E+04 | 5.21E+04 | 7.31 | 9.23E+02 | 1619. | 1641. |
| DOWNSTREAM | 1.00E-05 | 604. | 1087. | 1.61E+04 | 5.27E+04 | 8.62 | 2.01E+03 | 1639. | 1655. |

Stagnation temperature, $T_t$: 6000 K; 10 800$^{o}$ R

Sonic flow factor, $\psi$: 8.36E-03 (kg)($K^{1/2}$)/(sec)(N); 2.33E+02 (lb)($^{o}R^{1/2}$)/(sec)(ft$^2$)(atm)

Mass flow per unit throat area, $\dot{W}/A^*$: 2.19E+03 kg/(sec)(m$^2$); 4.48E+02 lb/(sec)(ft$^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 6000. | 10800. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.59E-01 | 5511. | 9920. | 6.39E+03 | 2.10E+04 | 1.00 | 1.00E+00 | 652. | 1179. |
| DOWNSTREAM | 1.00E-01 | 4445. | 8001. | 1.18E+04 | 3.88E+04 | 2.18 | 2.24E+00 | 1200. | 1413. |
| DOWNSTREAM | 1.00E-02 | 3510. | 6319. | 1.53E+04 | 5.02E+04 | 3.40 | 1.23E+01 | 1559. | 1676. |
| DOWNSTREAM | 1.00E-03 | 2856. | 5141. | 1.74E+04 | 5.72E+04 | 4.52 | 8.10E+01 | 1777. | 1853. |
| DOWNSTREAM | 1.00E-04 | 2316. | 4169. | 1.89E+04 | 6.19E+04 | 5.61 | 5.66E+02 | 1925. | 1978. |
| DOWNSTREAM | 3.00E-05 | 2013. | 3623. | 1.94E+04 | 6.38E+04 | 6.17 | 1.55E+03 | 1983. | 2027. |
| DOWNSTREAM | 1.00E-05 | 1650. | 2971. | 1.99E+04 | 6.52E+04 | 6.69 | 3.70E+03 | 2027. | 2062. |

Stagnation temperature, $T_t$: 7000 K; 12 600$^{o}$ R

Sonic flow factor, $\psi$: 7.88E-03 (kg)($K^{1/2}$)/(sec)(N); 2.20E+02 (lb)($^{o}R^{1/2}$)/(sec)(ft$^2$)(atm)

Mass flow per unit throat area, $\dot{W}/A^*$: 1.91E+03 kg (sec)(m$^2$); 3.91E+02 lb/(sec)(ft$^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 7000. | 12600. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.49E-01 | 5271. | 11287. | 7.51E+03 | 2.46E+04 | 1.00 | 1.00E+00 | 766. | 1359. |
| DOWNSTREAM | 1.00E-01 | 4902. | 8824. | 1.35E+04 | 4.42E+04 | 2.19 | 2.18E+00 | 1374. | 1610. |
| DOWNSTREAM | 1.00E-02 | 3817. | 6875. | 1.73E+04 | 5.69E+04 | 3.45 | 1.18E+01 | 1759. | 1896. |
| DOWNSTREAM | 1.00E-03 | 3124. | 5623. | 1.97E+04 | 6.45E+04 | 4.60 | 7.69E+01 | 2005. | 2089. |
| DOWNSTREAM | 1.00E-04 | 2619. | 4715. | 2.13E+04 | 6.97E+04 | 5.71 | 5.48E+02 | 2167. | 2227. |
| DOWNSTREAM | 3.00E-05 | 2398. | 4316. | 2.19E+04 | 7.19E+04 | 6.28 | 1.56E+03 | 2233. | 2284. |
| DOWNSTREAM | 1.00E-05 | 2209. | 3975. | 2.24E+04 | 7.35E+04 | 6.80 | 4.08E+03 | 2285. | 2329. |

Stagnation temperature, $T_t$: 8000 K; 14 400$^{o}$ R

Sonic flow factor, $\psi$: 7.76E-03 (kg)($K^{1/2}$)/(sec)(N); 2.16E+02 (lb)($^{o}R^{1/2}$)/(sec)(ft$^2$)(atm)

Mass flow per unit throat area, $\dot{W}$ $A^*$: 1.76E+03 kg/(sec)(m$^2$); 3.60E+02 lb/(sec)(ft$^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 8000. | 14400. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.37E-01 | 5914. | 12443. | 8.40E+03 | 2.76E+04 | 1.00 | 1.00E+00 | 857. | 1488. |
| DOWNSTREAM | 1.00E-01 | 5201. | 9362. | 1.47E+04 | 4.81E+04 | 2.20 | 2.11E+00 | 1495. | 1743. |
| DOWNSTREAM | 1.00E-02 | 3942. | 7158. | 1.87E+04 | 6.14E+04 | 3.51 | 1.13E+01 | 1908. | 2040. |
| DOWNSTREAM | 1.00E-03 | 3244. | 5840. | 2.11E+04 | 6.93E+04 | 4.68 | 7.32E+01 | 2153. | 2239. |
| DOWNSTREAM | 1.00E-04 | 2729. | 4911. | 2.28E+04 | 7.47E+04 | 5.81 | 5.22E+02 | 2320. | 2382. |
| DOWNSTREAM | 3.00E-05 | 2510. | 4519. | 2.34E+04 | 7.69E+04 | 6.39 | 1.49E+03 | 2389. | 2441. |
| DOWNSTREAM | 1.00E-05 | 2331. | 4197. | 2.40E+04 | 7.86E+04 | 6.91 | 3.92E+03 | 2443. | 2489. |

Stagnation temperature, $T_t$: 10 000 K; 18 000$^{o}$ R

Sonic flow factor, $\psi$: 7.82E-03 (kg)($K^{1/2}$)/(sec)(N); 2.18E+02 (lb)($^{o}R^{1/2}$)/(sec)(ft$^2$)(atm)

Mass flow per unit throat area, $\dot{W}$ $A^*$: 1.58E+03 kg (sec)(m$^2$); 3.24E+02 lb/(sec)(ft$^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 10000. | 18000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.15E-01 | 8042. | 14565. | 9.82E+03 | 3.22E+04 | 1.00 | 1.00E+00 | 1001. | 1672. |
| DOWNSTREAM | 1.00E-01 | 5606. | 10071. | 1.63E+04 | 5.34E+04 | 2.23 | 1.99E+00 | 1660. | 1920. |
| DOWNSTREAM | 1.00E-02 | 4156. | 7492. | 2.05E+04 | 6.72E+04 | 3.60 | 1.04E+01 | 2087. | 2223. |
| DOWNSTREAM | 1.00E-03 | 3358. | 6044. | 2.29E+04 | 7.52E+04 | 4.82 | 6.73E+01 | 2338. | 2426. |
| DOWNSTREAM | 1.00E-04 | 2822. | 5079. | 2.46E+04 | 8.07E+04 | 5.98 | 4.80E+02 | 2509. | 2571. |
| DOWNSTREAM | 3.00E-05 | 2600. | 4681. | 2.53E+04 | 8.30E+04 | 6.57 | 1.37E+03 | 2578. | 2632. |
| DOWNSTREAM | 1.00E-05 | 2423. | 4361. | 2.58E+04 | 8.47E+04 | 7.11 | 3.61E+03 | 2633. | 2681. |

Stagnation temperature, $T_t$: 12 000 K; 21 600$^{o}$ R

Sonic flow factor, $\psi$: 7.73E-03 (kg)($K^{1/2}$) (sec)(N); 2.15E+02 (lb)($^{o}R^{1/2}$) (sec)(ft$^2$)(atm)

Mass flow per unit throat area, $\dot{W}$ $A^*$: 1.43E+03 kg (sec)(m$^2$); 2.93E+02 lb/(sec)(ft$^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 12000. | 21600. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.04E-01 | 9637. | 17347. | 1.10E+04 | 3.62E+04 | 1.00 | 1.00E+00 | 1125. | 1853. |
| DOWNSTREAM | 1.00E-01 | 6051. | 10892. | 1.78E+04 | 5.85E+04 | 2.24 | 1.86E+00 | 1818. | 2087. |
| DOWNSTREAM | 1.00E-02 | 4295. | 7730. | 2.21E+04 | 7.25E+04 | 3.71 | 9.45E+00 | 2253. | 2390. |
| DOWNSTREAM | 1.00E-03 | 3438. | 6188. | 2.46E+04 | 8.06E+04 | 4.98 | 6.09E+01 | 2505. | 2593. |
| DOWNSTREAM | 1.00E-04 | 2881. | 5187. | 2.62E+04 | 8.61E+04 | 6.17 | 4.33E+02 | 2675. | 2738. |
| DOWNSTREAM | 3.00E-05 | 2656. | 4780. | 2.69E+04 | 8.83E+04 | 6.77 | 1.24E+03 | 2745. | 2799. |
| DOWNSTREAM | 1.00E-05 | 2476. | 4457. | 2.75E+04 | 9.01E+04 | 7.32 | 3.27E+03 | 2801. | 2848. |

TABLE III. - Continued. CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(d) Concluded. Stagnation pressure, 2.02650E+$10^{7}$ N/$m^2$ (200 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^{o}$R | m/sec | ft/sec | | | Ideal, $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 14 000 K; 25 200$^{o}$ R<br>Sonic flow factor, $\psi$: 7.43E-03 (kg)($K^{1/2}$)/(sec)(N); 2.07E+02 (lb)($^{o}R^{1/2}$)/(sec)($ft^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.27E+03 kg/(sec)($m^2$); 2.61E+02 lb/(sec)($ft^2$) | | | | | | | | | |
| CHAMBER | 1. | 14000. | 25200. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.23E-01 | 11882. | 21388. | 1.18E+04 | 3.89E+04 | 1.00 | 1.00E+00 | 1208. | 2056. |
| DOWNSTREAM | 1.00E-01 | 5938. | 12488. | 1.98E+04 | 6.49E+04 | 2.15 | 1.78E+00 | 2016. | 2305. |
| DOWNSTREAM | 1.00E-02 | 4473. | 8051. | 2.42E+04 | 7.93E+04 | 3.85 | 8.44E+00 | 2455. | 2602. |
| DOWNSTREAM | 1.00E-03 | 3526. | 6347. | 2.66E+04 | 8.74E+04 | 5.18 | 5.39E+01 | 2716. | 2803. |
| DOWNSTREAM | 1.00E-04 | 2943. | 5297. | 2.83E+04 | 9.28E+04 | 6.42 | 3.33E+02 | 2885. | 2948. |
| DOWNSTREAM | 3.00E-05 | 2711. | 4879. | 2.90E+04 | 9.51E+04 | 7.05 | 1.10E+03 | 2955. | 3008. |
| DOWNSTREAM | 1.00E-05 | 2528. | 4550. | 2.95E+04 | 9.68E+04 | 7.61 | 2.89E+03 | 3010. | 3056. |
| Stagnation temperature, $T_t$: 16 000 K; 28 800$^{o}$ R<br>Sonic flow factor, $\psi$: 7.14E-03 (kg)($K^{1/2}$)/(sec)(N); 1.99E+02 (lb)($^{o}R^{1/2}$)/(sec)($ft^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.14E+03 kg/(sec)($m^2$); 2.34E+02 lb/(sec)($ft^2$) | | | | | | | | | |
| CHAMBER | 1. | 16000. | 28800. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.44E-01 | 14255. | 25659. | 1.26E+04 | 4.12E+04 | 1.00 | 1.00E+00 | 1281. | 2267. |
| DOWNSTREAM | 1.00E-01 | 9111. | 16399. | 2.22E+04 | 7.27E+04 | 2.06 | 1.91E+00 | 2259. | 2605. |
| DOWNSTREAM | 1.00E-02 | 4798. | 8636. | 2.70E+04 | 8.87E+04 | 3.95 | 7.74E+00 | 2757. | 2897. |
| DOWNSTREAM | 1.00E-03 | 3647. | 6565. | 2.95E+04 | 9.68E+04 | 5.45 | 4.81E+01 | 3009. | 3096. |
| DOWNSTREAM | 1.00E-04 | 3019. | 5434. | 3.12E+04 | 1.02E+05 | 6.75 | 3.40E+02 | 3177. | 3238. |
| DOWNSTREAM | 3.00E-05 | 2776. | 4997. | 3.18E+04 | 1.04E+05 | 7.42 | 9.71E+02 | 3245. | 3298. |
| DOWNSTREAM | 1.00E-05 | 2587. | 4656. | 3.24E+04 | 1.06E+05 | 8.02 | 2.55E+03 | 3299. | 3346. |
| Stagnation temperature, $T_t$: 18 000 K; 32 400$^{o}$ R<br>Sonic flow factor, $\psi$: 6.90E-03 (kg)($K^{1/2}$)/(sec)(N); 1.92E+02 (lb)($^{o}R^{1/2}$)/(sec)($ft^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.04E+03 kg/(sec)($m^2$); 2.13E+02 lb/(sec)($ft^2$) | | | | | | | | | |
| CHAMBER | 1. | 18000. | 32400. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.57E-01 | 16372. | 29469. | 1.35E+04 | 4.43E+04 | 1.00 | 1.00E+00 | 1378. | 2482. |
| DOWNSTREAM | 1.00E-01 | 11998. | 21596. | 2.46E+04 | 8.07E+04 | 2.13 | 2.11E+00 | 2509. | 2928. |
| DOWNSTREAM | 1.00E-02 | 5846. | 10522. | 3.07E+04 | 1.01E+05 | 3.51 | 8.00E+00 | 3130. | 3289. |
| DOWNSTREAM | 1.00E-03 | 3841. | 6914. | 3.33E+04 | 1.09E+05 | 5.72 | 4.41E+01 | 3395. | 3482. |
| DOWNSTREAM | 1.00E-04 | 3118. | 5612. | 3.49E+04 | 1.15E+05 | 7.18 | 3.07E+02 | 3562. | 3622. |
| DOWNSTREAM | 3.00E-05 | 2856. | 5142. | 3.56E+04 | 1.17E+05 | 7.89 | 8.73E+02 | 3629. | 3681. |
| DOWNSTREAM | 1.00E-05 | 2657. | 4783. | 3.61E+04 | 1.18E+05 | 8.52 | 2.30E+03 | 3683. | 3728. |

Stagnation temperature, $T_t$: 25 000 K; 45 000° R

Sonic flow factor, $\psi$: 6.08E-03 (kg)($K^{1/2}$)/(sec)(N); 1.69E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)

Mass flow per unit throat area, $\dot{W}/A^*$: 7.79E+02 kg/(sec)($m^2$); 1.60E+02 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 25000. | 45000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.58E-01 | 22701. | 40861. | 1.82E+04 | 5.98E+04 | 1.00 | 1.00E+00 | 1859. | 3339. |
| DOWNSTREAM | 1.00E-01 | 17758. | 31964. | 3.33E+04 | 1.09E+05 | 2.19 | 2.19E+00 | 3396. | 3977. |
| DOWNSTREAM | 1.00E-02 | 13401. | 24121. | 4.28E+04 | 1.40E+05 | 3.46 | 1.15E+01 | 4366. | 4671. |
| DOWNSTREAM | 1.00E-03 | 10159. | 18286. | 4.82E+04 | 1.58E+05 | 4.68 | 7.05E+01 | 4919. | 5106. |
| DOWNSTREAM | 1.00E-04 | 6278. | 11301. | 5.15E+04 | 1.69E+05 | 5.72 | 3.87E+02 | 5254. | 5356. |
| DOWNSTREAM | 3.00E-05 | 3972. | 7149. | 5.25E+04 | 1.72E+05 | 7.41 | 7.98E+02 | 5352. | 5415. |
| DOWNSTREAM | 1.00E-05 | 3135. | 5642. | 5.31E+04 | 1.74E+05 | 9.70 | 1.81E+03 | 5412. | 5460. |

Stagnation temperature, $T_t$: 35 000 K; 63 000° R

Sonic flow factor, $\psi$: 5.70E-03 (kg)($K^{1/2}$)/(sec)(N); 1.59E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)

Mass flow per unit throat area, $\dot{W}/A^*$: 6.17E+02 kg/(sec)($m^2$); 1.26E+02 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 35000. | 63000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.31E-01 | 29533. | 53160. | 2.45E+04 | 8.05E+04 | 1.00 | 1.00E+00 | 2501. | 4281. |
| DOWNSTREAM | 1.00E-01 | 21366. | 38459. | 4.21E+04 | 1.38E+05 | 2.22 | 2.05E+00 | 4290. | 4978. |
| DOWNSTREAM | 1.00E-02 | 15738. | 28328. | 5.32E+04 | 1.75E+05 | 3.58 | 1.06E+01 | 5426. | 5780. |
| DOWNSTREAM | 1.00E-03 | 12371. | 22268. | 5.96E+04 | 1.95E+05 | 4.84 | 6.64E+01 | 6074. | 6297. |
| DOWNSTREAM | 1.00E-04 | 9997. | 17994. | 6.37E+04 | 2.09E+05 | 6.10 | 4.53E+02 | 6498. | 6650. |
| DOWNSTREAM | 3.00E-05 | 8958. | 16125. | 6.54E+04 | 2.14E+05 | 6.77 | 1.26E+03 | 6665. | 6791. |
| DOWNSTREAM | 1.00E-05 | 8049. | 14488. | 6.66E+04 | 2.19E+05 | 7.40 | 3.20E+03 | 6793. | 6900. |

Stagnation temperature, $T_t$: 50 000 K; 90 000° R

Sonic flow factor, $\psi$: 5.73E-03 (kg)($K^{1/2}$)/(sec)(N); 1.60E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)

Mass flow per unit throat area, $\dot{W}/A^*$: 5.19E+02 kg/(sec)($m^2$); 1.06E+02 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 50000. | 90000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.98E-01 | 38627. | 69528. | 3.12E+04 | 1.02E+05 | 1.00 | 1.00E+00 | 3178. | 5159. |
| DOWNSTREAM | 1.00E-01 | 24437. | 43987. | 4.97E+04 | 1.63E+05 | 2.25 | 1.86E+00 | 5069. | 5809. |
| DOWNSTREAM | 1.00E-02 | 16943. | 30498. | 6.14E+04 | 2.02E+05 | 3.75 | 9.25E+00 | 6264. | 6632. |
| DOWNSTREAM | 1.00E-03 | 13165. | 23696. | 6.80E+04 | 2.23E+05 | 5.08 | 5.77E+01 | 6935. | 7165. |
| DOWNSTREAM | 1.00E-04 | 10696. | 19253. | 7.23E+04 | 2.37E+05 | 6.39 | 3.96E+02 | 7374. | 7531. |
| DOWNSTREAM | 3.00E-05 | 9685. | 17434. | 7.40E+04 | 2.43E+05 | 7.07 | 1.11E+03 | 7547. | 7680. |
| DOWNSTREAM | 1.00E-05 | 8870. | 15966. | 7.53E+04 | 2.47E+05 | 7.71 | 2.86E+03 | 7682. | 7796. |

Stagnation temperature, $T_t$: 75 000 K; 135 000° R

Sonic flow factor, $\psi$: 5.71E-03 (kg)($K^{1/2}$)/(sec)(N); 1.59E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)

Mass flow per unit throat area, $\dot{W}/A^*$: 4.23E+02 kg/(sec)($m^2$); 8.66E+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 75000. | 135000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.88E-01 | 55481. | 101665. | 3.90E+04 | 1.28E+05 | 1.00 | 1.00E+00 | 3975. | 6359. |
| DOWNSTREAM | 1.00E-01 | 31051. | 55892. | 6.06E+04 | 1.99E+05 | 2.18 | 1.69E+00 | 6177. | 7004. |
| DOWNSTREAM | 1.00E-02 | 18353. | 33035. | 7.28E+04 | 2.39E+05 | 4.02 | 7.54E+00 | 7428. | 7797. |
| DOWNSTREAM | 1.00E-03 | 13875. | 24976. | 7.94E+04 | 2.60E+05 | 5.50 | 4.64E+01 | 8095. | 8322. |
| DOWNSTREAM | 1.00E-04 | 11220. | 20195. | 8.36E+04 | 2.74E+05 | 5.90 | 3.19E+02 | 8528. | 8684. |
| DOWNSTREAM | 3.00E-05 | 10175. | 18316. | 8.53E+04 | 2.80E+05 | 7.63 | 8.95E+02 | 8701. | 8832. |
| DOWNSTREAM | 1.00E-05 | 9357. | 16843. | 8.66E+04 | 2.84E+05 | 8.30 | 2.32E+03 | 8835. | 8949. |

Stagnation temperature, $T_t$: 100 000 K; 180 000° R

Sonic flow factor, $\psi$: 5.70E-03 (kg)($K^{1/2}$)/(sec)(N); 1.59E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)

Mass flow per unit throat area, $\dot{W}/A^*$: 3.65E+02 kg/(sec)($m^2$); 7.49E+01 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 100000. | 180000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.88E-01 | 75196. | 135354. | 4.52E+04 | 1.48E+05 | 1.00 | 1.00E+00 | 4609. | 7370. |
| DOWNSTREAM | 1.00E-01 | 40210. | 72378. | 7.01E+04 | 2.30E+05 | 2.14 | 1.67E+00 | 7152. | 8097. |
| DOWNSTREAM | 1.00E-02 | 19838. | 35709. | 8.33E+04 | 2.73E+05 | 4.20 | 6.52E+00 | 8499. | 8867. |
| DOWNSTREAM | 1.00E-03 | 14404. | 25928. | 8.98E+04 | 2.95E+05 | 5.90 | 3.91E+01 | 9154. | 9375. |
| DOWNSTREAM | 1.00E-04 | 11552. | 20794. | 9.39E+04 | 3.08E+05 | 7.41 | 2.68E+02 | 9575. | 9728. |
| DOWNSTREAM | 3.00E-05 | 10468. | 18842. | 9.56E+04 | 3.13E+05 | 8.18 | 7.53E+02 | 9744. | 9871. |
| DOWNSTREAM | 1.00E-05 | 9630. | 17334. | 9.68E+04 | 3.18E+05 | 8.89 | 1.95E+03 | 9874. | 9985. |

TABLE III. - Continued. CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(e) Stagnation pressure, 5.06625E×10$^{7}$ N/m$^{2}$ (500 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^{o}$R | m/sec | ft/sec | | | Idea., $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 2500 K; 4500$^{o}$ R<br>Sonic flow factor, $\psi$: 1.04E-02 (kg)(K$^{1/2}$)/(sec)(N); 2.89E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^{2}$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.05E+04 kg/(sec)(m$^{2}$); 2.16E+03 lb/(sec)(ft$^{2}$) | | | | | | | | | |
| CHAMBER | 1. | 2500. | 4500. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.44E-01 | 2171. | 3908. | 3.43E+03 | 1.12E+04 | 1.00 | 1.00E+00 | 349. | 616. |
| DOWNSTREAM | 1.00E-01 | 1426. | 2566. | 6.05E+03 | 1.98E+04 | 2.15 | 2.02E+00 | 617. | 716. |
| DOWNSTREAM | 1.00E-02 | 761. | 1370. | 7.53E+03 | 2.47E+04 | 3.61 | 8.66E+00 | 768. | 811. |
| DOWNSTREAM | 1.00E-03 | 396. | 713. | 8.21E+03 | 2.69E+04 | 5.43 | 4.14E+01 | 837. | 857. |
| Stagnation temperature, $T_t$: 3500 K; 6300$^{o}$ R<br>Sonic flow factor, $\psi$: 1.02E-02 (kg)(K$^{1/2}$)/(sec)(N); 2.83E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^{2}$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 8.70E+03 kg/(sec)(m$^{2}$); 1.78E+03 lb/(sec)(ft$^{2}$) | | | | | | | | | |
| CHAMBER | 1. | 3500. | 6300. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.55E-01 | 3139. | 5651. | 4.04E+03 | 1.32E+04 | 1.00 | 1.00E+00 | 412. | 741. |
| DOWNSTREAM | 1.00E-01 | 2181. | 3926. | 7.34E+03 | 2.41E+04 | 2.14 | 2.11E+00 | 748. | 873. |
| DOWNSTREAM | 1.00E-02 | 1222. | 2199. | 9.24E+03 | 3.03E+04 | 3.52 | 9.36E+00 | 943. | 998. |
| DOWNSTREAM | 1.00E-03 | 645. | 1161. | 1.01E+04 | 3.32E+04 | 5.25 | 4.51E+01 | 1033. | 1060. |
| DOWNSTREAM | 1.00E-04 | 335. | 603. | 1.06E+04 | 3.47E+04 | 7.59 | 2.25E+02 | 1078. | 1091. |
| Stagnation temperature, $T_t$: 5000 K; 9000$^{o}$ R<br>Sonic flow factor, $\psi$: 9.48E-03 (kg)(K$^{1/2}$)/(sec)(N); 2.64E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^{2}$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 6.79E+03 kg/(sec)(m$^{2}$); 1.39E+03 lb/(sec)(ft$^{2}$) | | | | | | | | | |
| CHAMBER | 1. | 5000. | 9000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.64E-01 | 4618. | 8313. | 5.07E+03 | 1.66E+04 | 1.00 | 1.00E+00 | 517. | 946. |
| DOWNSTREAM | 1.00E-01 | 3674. | 6613. | 9.48E+03 | 3.11E+04 | 2.17 | 2.27E+00 | 956. | 1139. |
| DOWNSTREAM | 1.00E-02 | 2635. | 4742. | 1.23E+04 | 4.04E+04 | 3.36 | 1.19E+01 | 1255. | 1346. |
| DOWNSTREAM | 1.00E-03 | 1595. | 2872. | 1.38E+04 | 4.54E+04 | 4.66 | 6.37E+01 | 1412. | 1460. |
| DOWNSTREAM | 1.00E-04 | 861. | 1549. | 1.46E+04 | 4.80E+04 | 6.60 | 3.25E+02 | 1493. | 1518. |
| DOWNSTREAM | 3.00E-05 | 613. | 1103. | 1.49E+04 | 4.89E+04 | 7.93 | 7.58E+02 | 1518. | 1536. |
| DOWNSTREAM | 1.00E-05 | 449. | 808. | 1.50E+04 | 4.94E+04 | 9.35 | 1.65E+03 | 1535. | 1547. |
| DOWNSTREAM | 3.00E-06 | 318. | 573. | 1.52E+04 | 4.98E+04 | 11.18 | 3.86E+03 | 1547. | 1556. |

Stagnation temperature, $T_t$: 6000 K; 10 800° R
Sonic flow factor, $\psi$: 8.81E-03 (kg)($K^{1/2}$)/(sec)(N); 2.45E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 5.76E+03 kg/(sec)($m^2$); 1.18E+03 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 5000. | 10800. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.59E-01 | 5512. | 9922. | 6.04E+03 | 1.98E+04 | 1.00 | 1.00E+00 | 616. | 1117. |
| DOWNSTREAM | 1.00E-01 | 4416. | 7949. | 1.12E+04 | 3.66E+04 | 2.18 | 2.25E+00 | 1138. | 1340. |
| DOWNSTREAM | 1.00E-02 | 3423. | 6161. | 1.45E+04 | 4.76E+04 | 3.40 | 1.23E+01 | 1479. | 1589. |
| DOWNSTREAM | 1.00E-03 | 2668. | 4802. | 1.65E+04 | 5.41E+04 | 4.53 | 7.86E+01 | 1682. | 1753. |
| DOWNSTREAM | 1.00E-04 | 1851. | 3332. | 1.78E+04 | 5.83E+04 | 5.66 | 4.89E+02 | 1813. | 1857. |
| DOWNSTREAM | 3.00E-05 | 1376. | 2477. | 1.82E+04 | 5.98E+04 | 6.57 | 1.18E+03 | 1858. | 1890. |
| DOWNSTREAM | 1.00E-05 | 1025. | 1845. | 1.85E+04 | 6.08E+04 | 7.67 | 2.63E+03 | 1888. | 1912. |
| DOWNSTREAM | 3.00E-06 | 733. | 1319. | 1.87E+04 | 6.15E+04 | 9.14 | 6.11E+03 | 1912. | 1928. |

Stagnation temperature, $T_t$: 7000 K; 12 600° R
Sonic flow factor, $\psi$: 8.24E-03 (kg)($K^{1/2}$)/(sec)(N); 2.29E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 4.99E+03 kg/(sec)($m^2$); 1.02E+03 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 7000. | 12600. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.51E-01 | 6325. | 11384. | 7.12E+03 | 2.34E+04 | 1.00 | 1.00E+00 | 726. | 1297. |
| DOWNSTREAM | 1.00E-01 | 4966. | 8939. | 1.29E+04 | 4.23E+04 | 2.19 | 2.19E+00 | 1314. | 1541. |
| DOWNSTREAM | 1.00E-02 | 3843. | 6917. | 1.66E+04 | 5.45E+04 | 3.44 | 1.18E+01 | 1694. | 1817. |
| DOWNSTREAM | 1.00E-03 | 3100. | 5581. | 1.88E+04 | 6.18E+04 | 4.60 | 7.68E+01 | 1921. | 2000. |
| DOWNSTREAM | 1.00E-04 | 2533. | 4560. | 2.03E+04 | 6.67E+04 | 5.72 | 5.39E+02 | 2075. | 2130. |
| DOWNSTREAM | 3.00E-05 | 2256. | 4062. | 2.09E+04 | 6.87E+04 | 6.31 | 1.50E+03 | 2136. | 2183. |
| DOWNSTREAM | 1.00E-05 | 1973. | 3551. | 2.14E+04 | 7.02E+04 | 6.84 | 3.78E+03 | 2183. | 2222. |
| DOWNSTREAM | 3.00E-06 | 1562. | 2811. | 2.18E+04 | 7.16E+04 | 7.48 | 9.70E+03 | 2225. | 2255. |

Stagnation temperature, $T_t$: 8000 K; 14 400° R
Sonic flow factor, $\psi$: 7.94E-03 (kg)($K^{1/2}$)/(sec)(N); 2.21E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 4.50E+03 kg/(sec)($m^2$); 9.21E+02 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 8000. | 14400. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.42E-01 | 7045. | 12682. | 8.10E+03 | 2.66E+04 | 1.00 | 1.00E+00 | 826. | 1449. |
| DOWNSTREAM | 1.00E-01 | 5364. | 9654. | 1.43E+04 | 4.69E+04 | 2.20 | 2.13E+00 | 1458. | 1703. |
| DOWNSTREAM | 1.00E-02 | 4089. | 7359. | 1.83E+04 | 6.00E+04 | 3.49 | 1.13E+01 | 1865. | 1995. |
| DOWNSTREAM | 1.00E-03 | 3300. | 5939. | 2.06E+04 | 6.77E+04 | 4.68 | 7.31E+01 | 2105. | 2189. |
| DOWNSTREAM | 1.00E-04 | 2740. | 4932. | 2.22E+04 | 7.30E+04 | 5.82 | 5.17E+02 | 2268. | 2327. |
| DOWNSTREAM | 3.00E-05 | 2498. | 4496. | 2.29E+04 | 7.51E+04 | 6.42 | 1.47E+03 | 2334. | 2384. |
| DOWNSTREAM | 1.00E-05 | 2291. | 4124. | 2.34E+04 | 7.67E+04 | 6.96 | 3.82E+03 | 2385. | 2429. |
| DOWNSTREAM | 3.00E-06 | 2066. | 3718. | 2.39E+04 | 7.83E+04 | 7.56 | 1.09E+04 | 2434. | 2472. |

Stagnation temperature, $T_t$: 10 000 K; 18 000° R
Sonic flow factor, $\psi$: 7.83E-03 (kg)($K^{1/2}$)/(sec)(N); 2.18E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 3.97E+03 kg/(sec)($m^2$); 8.13E+02 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 10000. | 18000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.22E-01 | 8295. | 14931. | 9.63E+03 | 3.16E+04 | 1.00 | 1.00E+00 | 982. | 1662. |
| DOWNSTREAM | 1.00E-01 | 5884. | 10592. | 1.62E+04 | 5.32E+04 | 2.22 | 2.02E+00 | 1554. | 1917. |
| DOWNSTREAM | 1.00E-02 | 4343. | 7818. | 2.05E+04 | 6.71E+04 | 3.59 | 1.05E+01 | 2096. | 2222. |
| DOWNSTREAM | 1.00E-03 | 3477. | 6258. | 2.29E+04 | 7.52E+04 | 4.83 | 6.70E+01 | 2336. | 2423. |
| DOWNSTREAM | 1.00E-04 | 2895. | 5211. | 2.46E+04 | 8.06E+04 | 5.00 | 4.74E+02 | 2505. | 2566. |
| DOWNSTREAM | 3.00E-05 | 2654. | 4777. | 2.52E+04 | 8.28E+04 | 6.61 | 1.35E+03 | 2573. | 2626. |
| DOWNSTREAM | 1.00E-05 | 2460. | 4427. | 2.58E+04 | 8.45E+04 | 7.15 | 3.54E+03 | 2627. | 2673. |
| DOWNSTREAM | 3.00E-06 | 2266. | 4078. | 2.63E+04 | 8.62E+04 | 7.77 | 1.03E+04 | 2679. | 2719. |

Stagnation temperature, $T_t$: 12 000 K; 21 600° R
Sonic flow factor, $\psi$: 7.80E-03 (kg)($K^{1/2}$)/(sec)(N); 2.17E+02 (lb)($^oR^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 3.61E+03 kg/(sec)($m^2$); 7.39E+02 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 12000. | 21600. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.08E-01 | 9663. | 17394. | 1.09E+04 | 3.57E+04 | 1.00 | 1.00E+00 | 1110. | 1838. |
| DOWNSTREAM | 1.00E-01 | 6327. | 11389. | 1.78E+04 | 5.83E+04 | 2.23 | 1.91E+00 | 1811. | 2085. |
| DOWNSTREAM | 1.00E-02 | 4506. | 8110. | 2.21E+04 | 7.25E+04 | 3.68 | 9.66E+00 | 2253. | 2392. |
| DOWNSTREAM | 1.00E-03 | 3576. | 6436. | 2.46E+04 | 8.07E+04 | 4.96 | 6.16E+01 | 2507. | 2595. |
| DOWNSTREAM | 1.00E-04 | 2972. | 5349. | 2.63E+04 | 8.61E+04 | 6.18 | 4.34E+02 | 2677. | 2740. |
| DOWNSTREAM | 3.00E-05 | 2727. | 4909. | 2.69E+04 | 8.84E+04 | 6.80 | 1.24E+03 | 2747. | 2800. |
| DOWNSTREAM | 1.00E-05 | 2532. | 4558. | 2.75E+04 | 9.01E+04 | 7.36 | 3.25E+03 | 2801. | 2848. |
| DOWNSTREAM | 3.00E-06 | 2342. | 4215. | 2.80E+04 | 9.18E+04 | 7.97 | 9.44E+03 | 2854. | 2894. |

TABLE III. - Continued. CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(e) Concluded. Stagnation pressure, $5.06625E{\times}10^{7}$ N/m$^2$ (500 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^{o}$R | m/sec | ft/sec | | | Ideal, $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 14 000 K; 25 200$^{o}$ R<br>Sonic flow factor, $\psi$: 7.59E-03 (kg)(K$^{1/2}$)/(sec)(N); 2.11E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 3.25E+03 kg/(sec)(m$^2$); 6.65E+02 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 14000. | 25200. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.13E-01 | 11577. | 20838. | 1.19E+04 | 3.89E+04 | 1.00 | 1.00E+00 | 1210. | 2026. |
| DOWNSTREAM | 1.00E-01 | 6975. | 12554. | 1.95E+04 | 6.39E+04 | 2.21 | 1.81E+00 | 1985. | 2273. |
| DOWNSTREAM | 1.00E-02 | 4676. | 8417. | 2.39E+04 | 7.85E+04 | 3.79 | 8.77E+00 | 2439. | 2579. |
| DOWNSTREAM | 1.00E-03 | 3667. | 6600. | 2.64E+04 | 8.67E+04 | 5.13 | 5.55E+01 | 2694. | 2782. |
| DOWNSTREAM | 1.00E-04 | 3038. | 5468. | 2.81E+04 | 9.22E+04 | 6.38 | 3.91E+02 | 2854. | 2927. |
| DOWNSTREAM | 3.00E-05 | 2787. | 5017. | 2.88E+04 | 9.44E+04 | 7.02 | 1.11E+03 | 2934. | 2987. |
| DOWNSTREAM | 1.00E-05 | 2590. | 4662. | 2.93E+04 | 9.61E+04 | 7.60 | 2.92E+03 | 2988. | 3035. |
| DOWNSTREAM | 3.00E-06 | 2399. | 4318. | 2.98E+04 | 9.78E+04 | 8.23 | 8.51E+03 | 3041. | 3081. |
| Stagnation temperature, $T_t$: 16 000 K; 28 800$^{o}$ R<br>Sonic flow factor, $\psi$: 7.30E-03 (kg)(K$^{1/2}$)/(sec)(N); 2.03E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 2.92E+03 kg/(sec)(m$^2$); 5.99E+02 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 16000. | 28800. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.35E-01 | 13922. | 25059. | 1.26E+04 | 4.12E+04 | 1.00 | 1.00E+00 | 1281. | 2227. |
| DOWNSTREAM | 1.00E-01 | 8356. | 15041. | 2.16E+04 | 7.07E+04 | 2.10 | 1.82E+00 | 2138. | 2520. |
| DOWNSTREAM | 1.00E-02 | 4922. | 8860. | 2.63E+04 | 8.62E+04 | 3.90 | 8.01E+00 | 2679. | 2820. |
| DOWNSTREAM | 1.00E-03 | 3776. | 6797. | 2.88E+04 | 9.44E+04 | 5.34 | 4.99E+01 | 2935. | 3023. |
| DOWNSTREAM | 1.00E-04 | 3110. | 5599. | 3.04E+04 | 9.99E+04 | 6.66 | 3.50E+02 | 3104. | 3166. |
| DOWNSTREAM | 3.00E-05 | 2851. | 5132. | 3.11E+04 | 1.02E+05 | 7.32 | 9.96E+02 | 3173. | 3226. |
| DOWNSTREAM | 1.00E-05 | 2649. | 4768. | 3.16E+04 | 1.04E+05 | 7.92 | 2.62E+03 | 3227. | 3273. |
| DOWNSTREAM | 3.00E-06 | 2456. | 4421. | 3.22E+04 | 1.06E+05 | 8.57 | 7.62E+03 | 3279. | 3320. |
| Stagnation temperature, $T_t$: 18 000 K; 32 400$^{o}$ R<br>Sonic flow factor, $\psi$: 7.08E-03 (kg)(K$^{1/2}$)/(sec)(N); 1.97E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 2.67E+03 kg/(sec)(m$^2$); 5.48E+02 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 18000. | 32400. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.50E-01 | 15121. | 29018. | 1.33E+04 | 4.38E+04 | 1.00 | 1.00E+00 | 1351. | 2424. |
| DOWNSTREAM | 1.00E-01 | 10863. | 19554. | 2.38E+04 | 7.82E+04 | 2.08 | 1.99E+00 | 2430. | 2815. |
| DOWNSTREAM | 1.00E-02 | 5392. | 9706. | 2.92E+04 | 9.59E+04 | 3.90 | 7.66E+00 | 2982. | 3130. |
| DOWNSTREAM | 1.00E-03 | 3923. | 7061. | 3.18E+04 | 1.04E+05 | 5.58 | 4.57E+01 | 3242. | 3330. |
| DOWNSTREAM | 1.00E-04 | 3196. | 5753. | 3.34E+04 | 1.10E+05 | 6.99 | 3.18E+02 | 3411. | 3472. |
| DOWNSTREAM | 3.00E-05 | 2924. | 5263. | 3.41E+04 | 1.12E+05 | 7.69 | 9.02E+02 | 3479. | 3531. |
| DOWNSTREAM | 1.00E-05 | 2714. | 4885. | 3.46E+04 | 1.14E+05 | 8.32 | 2.37E+03 | 3533. | 3579. |
| DOWNSTREAM | 3.00E-06 | 2516. | 4528. | 3.52E+04 | 1.15E+05 | 9.00 | 6.90E+03 | 3584. | 3624. |

Stagnation temperature, $T_t$: 25 000 K; 45 000° R
Sonic flow factor, $\psi$: 6.38E-03 (kg)($K^{1/2}$)/(sec)(N); 1.78E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 2.04E+03 kg/(sec)($m^2$); 4.18E+02 lb/(sec)($ft^2$)

| CHAMBER | 1. | 25000. | 45000. | 0 | 0 | 0 | INFINITY | | |
|---|---|---|---|---|---|---|---|---|---|
| THROAT | 5.59E-01 | 22702. | 40864. | 1.73E+04 | 5.68E+04 | 1.00 | 1.00E+00 | 1757. | 3181. |
| DOWNSTREAM | 1.00E-01 | 17583. | 31650. | 3.17E+04 | 1.04E+05 | 2.19 | 2.19E+00 | 3234. | 3787. |
| DOWNSTREAM | 1.00E-02 | 12775. | 22995. | 4.07E+04 | 1.33E+05 | 3.46 | 1.12E+01 | 4147. | 4431. |
| DOWNSTREAM | 1.00E-03 | 8183. | 14729. | 4.55E+04 | 1.49E+05 | 4.59 | 6.01E+01 | 4640. | 4792. |
| DOWNSTREAM | 1.00E-04 | 3897. | 7014. | 4.78E+04 | 1.57E+05 | 7.57 | 2.64E+02 | 4873. | 4940. |
| DOWNSTREAM | 3.00E-05 | 3334. | 6000. | 4.85E+04 | 1.59E+05 | 8.89 | 7.05E+02 | 4945. | 4999. |
| DOWNSTREAM | 1.00E-05 | 3021. | 5438. | 4.90E+04 | 1.61E+05 | 9.79 | 1.81E+03 | 4999. | 5045. |
| DOWNSTREAM | 3.00E-06 | 2763. | 4974. | 4.95E+04 | 1.62E+05 | 10.69 | 5.19E+03 | 5050. | 5090. |

Stagnation temperature, $T_t$: 35 000 K; 63 000° R
Sonic flow factor, $\psi$: 5.83E-03 (kg)($K^{1/2}$)/(sec)(N); 1.62E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 1.58E+03 kg/(sec)($m^2$); 3.23E+02 lb/(sec)($ft^2$)

| CHAMBER | 1. | 35000. | 63000. | 0 | 0 | 0 | INFINITY | | |
|---|---|---|---|---|---|---|---|---|---|
| THROAT | 5.38E-01 | 30123. | 54222. | 2.37E+04 | 7.76E+04 | 1.00 | 1.00E+00 | 2413. | 4173. |
| DOWNSTREAM | 1.00E-01 | 22073. | 39731. | 4.11E+04 | 1.35E+05 | 2.22 | 2.07E+00 | 4195. | 4873. |
| DOWNSTREAM | 1.00E-02 | 16171. | 29108. | 5.21E+04 | 1.71E+05 | 3.56 | 1.06E+01 | 5314. | 5663. |
| DOWNSTREAM | 1.00E-03 | 12527. | 22548. | 5.83E+04 | 1.91E+05 | 4.84 | 6.59E+01 | 5948. | 6164. |
| DOWNSTREAM | 1.00E-04 | 9845. | 17721. | 6.23E+04 | 2.04E+05 | 6.14 | 4.40E+02 | 6355. | 6499. |
| DOWNSTREAM | 3.00E-05 | 8548. | 15386. | 6.39E+04 | 2.10E+05 | 6.83 | 1.19E+03 | 6512. | 6629. |
| DOWNSTREAM | 1.00E-05 | 7127. | 12828. | 6.50E+04 | 2.13E+05 | 7.35 | 2.84E+03 | 6627. | 6720. |
| DOWNSTREAM | 3.00E-06 | 4812. | 8662. | 6.59E+04 | 2.16E+05 | 8.11 | 6.25E+03 | 6721. | 6782. |

Stagnation temperature, $T_t$: 50 000 K; 90 000° R
Sonic flow factor, $\psi$: 5.77E-03 (kg)($K^{1/2}$)/(sec)(N); 1.61E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 1.31E+03 kg/(sec)($m^2$); 2.68E+02 lb/(sec)($ft^2$)

| CHAMBER | 1. | 50000. | 90000. | 0 | 0 | 0 | INFINITY | | |
|---|---|---|---|---|---|---|---|---|---|
| THROAT | 5.05E-01 | 39372. | 70870. | 3.06E+04 | 1.01E+05 | 1.00 | 1.00E+00 | 3125. | 5120. |
| DOWNSTREAM | 1.00E-01 | 25654. | 46177. | 4.95E+04 | 1.62E+05 | 2.25 | 1.89E+00 | 5050. | 5799. |
| DOWNSTREAM | 1.00E-02 | 17793. | 32027. | 6.14E+04 | 2.01E+05 | 3.72 | 9.38E+00 | 6260. | 6631. |
| DOWNSTREAM | 1.00E-03 | 13684. | 24631. | 6.80E+04 | 2.23E+05 | 5.08 | 5.79E+01 | 6933. | 7162. |
| DOWNSTREAM | 1.00E-04 | 10981. | 19765. | 7.23E+04 | 2.37E+05 | 6.41 | 3.93E+02 | 7368. | 7523. |
| DOWNSTREAM | 3.00E-05 | 9861. | 17750. | 7.39E+04 | 2.43E+05 | 7.12 | 1.09E+03 | 7538. | 7668. |
| DOWNSTREAM | 1.00E-05 | 8941. | 16094. | 7.52E+04 | 2.47E+05 | 7.78 | 2.79E+03 | 7670. | 7780. |
| DOWNSTREAM | 3.00E-06 | 7978. | 14361. | 7.64E+04 | 2.51E+05 | 8.52 | 7.83E+03 | 7792. | 7885. |

Stagnation temperature, $T_t$: 75 000 K; 135 000° R
Sonic flow factor, $\psi$: 5.74E-03 (kg)($K^{1/2}$)/(sec)(N); 1.60E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 1.06E+03 kg/(sec)($m^2$); 2.17E+02 lb/(sec)($ft^2$)

| CHAMBER | 1. | 75000. | 135000. | 0 | 0 | 0 | INFINITY | | |
|---|---|---|---|---|---|---|---|---|---|
| THROAT | 4.88E-01 | 55684. | 102030. | 3.88E+04 | 1.27E+05 | 1.00 | 1.00E+00 | 3956. | 6334. |
| DOWNSTREAM | 1.00E-01 | 31903. | 57425. | 6.04E+04 | 1.98E+05 | 2.20 | 1.71E+00 | 6160. | 6994. |
| DOWNSTREAM | 1.00E-02 | 19397. | 34915. | 7.29E+04 | 2.39E+05 | 3.97 | 7.74E+00 | 7436. | 7813. |
| DOWNSTREAM | 1.00E-03 | 14552. | 26193. | 7.95E+04 | 2.61E+05 | 5.46 | 4.72E+01 | 8115. | 8345. |
| DOWNSTREAM | 1.00E-04 | 11651. | 20971. | 8.33E+04 | 2.75E+05 | 6.89 | 3.20E+02 | 8552. | 8708. |
| DOWNSTREAM | 3.00E-05 | 10509. | 18916. | 8.56E+04 | 2.81E+05 | 7.64 | 8.94E+02 | 8724. | 8855. |
| DOWNSTREAM | 1.00E-05 | 9611. | 17300. | 8.69E+04 | 2.85E+05 | 8.33 | 2.31E+03 | 8857. | 8969. |
| DOWNSTREAM | 3.00E-06 | 8739. | 15731. | 8.81E+04 | 2.89E+05 | 9.09 | 6.56E+03 | 8982. | 9078. |

Stagnation temperature, $T_t$: 100 000 K; 180 000° R
Sonic flow factor, $\psi$: 5.72E-03 (kg)($K^{1/2}$)/(sec)(N); 1.59E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 9.17E+02 kg/(sec)($m^2$); 1.88E+02 lb/(sec)($ft^2$)

| CHAMBER | 1. | 100000. | 180000. | 0 | 0 | 0 | INFINITY | | |
|---|---|---|---|---|---|---|---|---|---|
| THROAT | 4.89E-01 | 75305. | 135549. | 4.51E+04 | 1.48E+05 | 1.00 | 1.00E+00 | 4599. | 7353. |
| DOWNSTREAM | 1.00E-01 | 40536. | 72965. | 7.00E+04 | 2.30E+05 | 2.15 | 1.67E+00 | 7137. | 8081. |
| DOWNSTREAM | 1.00E-02 | 20926. | 37667. | 8.34E+04 | 2.73E+05 | 4.15 | 6.73E+00 | 8500. | 8879. |
| DOWNSTREAM | 1.00E-03 | 15160. | 27287. | 9.00E+04 | 2.95E+05 | 5.84 | 4.00E+01 | 9173. | 9398. |
| DOWNSTREAM | 1.00E-04 | 12049. | 21688. | 9.42E+04 | 3.09E+05 | 7.37 | 2.71E+02 | 9601. | 9754. |
| DOWNSTREAM | 3.00E-05 | 10866. | 19559. | 9.58E+04 | 3.14E+05 | 8.16 | 7.58E+02 | 9770. | 9898. |
| DOWNSTREAM | 1.00E-05 | 9951. | 17912. | 9.71E+04 | 3.19E+05 | 8.89 | 1.96E+03 | 9901. | 10011. |
| DOWNSTREAM | 3.00E-06 | 9081. | 16346. | 9.83E+04 | 3.23E+05 | 9.69 | 5.59E+03 | 10024. | 10118. |

TABLE III. - Continued. CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(f) Stagnation pressure, $1.01325 \times 10^{8}$ N/m$^2$ (1000 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^{o}$R | m/sec | ft/sec | | | Ideal, $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 3500 K; 6300$^{o}$ R<br>Sonic flow factor, $\psi$: 1.02E-02 (kg)(K$^{1/2}$)/(sec)(N); 2.84E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.75E+04 kg/(sec)(m$^2$); 3.58E+03 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 3500. | 6300. | 0 | 0 | 0 | INFINITY | 411. | 738. |
| THROAT | 5.53E-01 | 3121. | 5617. | 4.04E+03 | 1.32E+04 | 1.00 | 1.00E+00 | 744. | 868. |
| DOWNSTREAM | 1.00E-01 | 2148. | 3866. | 7.30E+03 | 2.39E+04 | 2.14 | 2.09E+00 | 937. | 992. |
| DOWNSTREAM | 1.00E-02 | 1200. | 2159. | 9.19E+03 | 3.01E+04 | 3.53 | 9.29E+00 | 1026. | 1053. |
| DOWNSTREAM | 1.00E-03 | 633. | 1139. | 1.01E+04 | 3.30E+04 | 5.27 | 4.47E+01 | 1070. | 1083. |
| DOWNSTREAM | 1.00E-04 | 329. | 591. | 1.05E+04 | 3.44E+04 | 7.61 | 2.23E+02 | | |
| Stagnation temperature, $T_t$: 5000 K; 9000$^{o}$ R<br>Sonic flow factor, $\psi$: 9.66E-03 (kg)(K$^{1/2}$)/(sec)(N); 2.69E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.38E+04 kg/(sec)(m$^2$); 2.84E+03 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 5000. | 9000. | 0 | 0 | 0 | INFINITY | 508. | 928. |
| THROAT | 5.63E-01 | 4595. | 8271. | 4.98E+03 | 1.63E+04 | 1.00 | 1.00E+00 | 947. | 1114. |
| DOWNSTREAM | 1.00E-01 | 3579. | 6443. | 9.28E+03 | 3.05E+04 | 2.15 | 2.25E+00 | 1223. | 1308. |
| DOWNSTREAM | 1.00E-02 | 2412. | 4341. | 1.20E+04 | 3.94E+04 | 3.37 | 1.14E+01 | 1366. | 1410. |
| DOWNSTREAM | 1.00E-03 | 1388. | 2498. | 1.34E+04 | 4.40E+04 | 4.81 | 5.84E+01 | 1439. | 1461. |
| DOWNSTREAM | 1.00E-04 | 739. | 1331. | 1.41E+04 | 4.63E+04 | 6.85 | 2.95E+02 | 1461. | 1477. |
| DOWNSTREAM | 3.00E-05 | 526. | 946. | 1.43E+04 | 4.70E+04 | 8.23 | 6.89E+02 | 1476. | 1487. |
| DOWNSTREAM | 1.00E-05 | 385. | 692. | 1.45E+04 | 4.75E+04 | 9.72 | 1.50E+03 | | |
| Stagnation temperature, $T_t$: 6000 K; 10 800$^{o}$ R<br>Sonic flow factor, $\psi$: 9.12E-03 (kg)(K$^{1/2}$)/(sec)(N); 2.54E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.19E+04 kg/(sec)(m$^2$); 2.44E+03 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 6000. | 10800. | 0 | 0 | 0 | INFINITY | 594. | 1079. |
| THROAT | 5.60E-01 | 5502. | 9904. | 5.83E+03 | 1.91E+04 | 1.00 | 1.00E+00 | 1099. | 1294. |
| DOWNSTREAM | 1.00E-01 | 4368. | 7862. | 1.08E+04 | 3.54E+04 | 2.18 | 2.25E+00 | 1426. | 1531. |
| DOWNSTREAM | 1.00E-02 | 3303. | 5945. | 1.40E+04 | 4.59E+04 | 3.40 | 1.21E+01 | 1617. | 1681. |
| DOWNSTREAM | 1.00E-03 | 2398. | 4316. | 1.59E+04 | 5.20E+04 | 4.54 | 7.40E+01 | 1730. | 1765. |
| DOWNSTREAM | 1.00E-04 | 1426. | 2568. | 1.70E+04 | 5.57E+04 | 6.02 | 4.09E+02 | 1766. | 1791. |
| DOWNSTREAM | 3.00E-05 | 1034. | 1861. | 1.73E+04 | 5.68E+04 | 7.14 | 9.67E+02 | 1789. | 1808. |
| DOWNSTREAM | 1.00E-05 | 761. | 1371. | 1.75E+04 | 5.76E+04 | 8.39 | 2.11E+03 | 1808. | 1821. |
| DOWNSTREAM | 3.00E-06 | 542. | 975. | 1.77E+04 | 5.82E+04 | 10.04 | 4.95E+03 | 1820. | 1829. |
| DOWNSTREAM | 1.00E-06 | 396. | 713. | 1.78E+04 | 5.86E+04 | 11.81 | 1.08E+04 | | |
| Stagnation temperature, $T_t$: 7000 K; 12 600$^{o}$ R<br>Sonic flow factor, $\psi$: 8.57E-03 (kg)(K$^{1/2}$)/(sec)(N); 2.39E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 1.04E+04 kg/(sec)(m$^2$); 2.13E+03 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 7000. | 12600. | 0 | 0 | 0 | INFINITY | 695. | 1245. |
| THROAT | 5.53E-01 | 5341. | 11414. | 6.81E+03 | 2.24E+04 | 1.00 | 1.00E+00 | 1263. | 1482. |
| DOWNSTREAM | 1.00E-01 | 4972. | 8950. | 1.24E+04 | 4.06E+04 | 2.18 | 2.20E+00 | 1630. | 1748. |
| DOWNSTREAM | 1.00E-02 | 3811. | 6861. | 1.60E+04 | 5.24E+04 | 3.44 | 1.18E+01 | 1847. | 1923. |
| DOWNSTREAM | 1.00E-03 | 3016. | 5429. | 1.81E+04 | 5.94E+04 | 4.60 | 7.62E+01 | 1992. | 2043. |
| DOWNSTREAM | 1.00E-04 | 2341. | 4213. | 1.95E+04 | 6.41E+04 | 5.74 | 5.16E+02 | 2067. | 2088. |
| DOWNSTREAM | 3.00E-05 | 1927. | 3469. | 2.01E+04 | 6.59E+04 | 6.33 | 1.36E+03 | 2086. | 2117. |
| DOWNSTREAM | 1.00E-05 | 1493. | 2687. | 2.05E+04 | 6.71E+04 | 7.12 | 3.09E+03 | 2118. | 2140. |
| DOWNSTREAM | 3.00E-06 | 1086. | 1954. | 2.08E+04 | 6.81E+04 | 8.37 | 7.37E+03 | 2138. | 2154. |
| DOWNSTREAM | 1.00E-06 | 801. | 1441. | 2.10E+04 | 6.88E+04 | 9.79 | 1.61E+04 | | |

Stagnation temperature, $T_t$: 8000 K; 14 400° R

Sonic flow factor, $\psi$: 8.18E-03 (kg)($K^{1/2}$)/(sec)(N); 2.28E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)

Mass flow per unit throat area, $\dot{W}/A^*$: 9.27E+03 kg/(sec)($m^2$); 1.90E+03 lb/(sec)($ft^2$)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 8000. | 14400. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.45E-01 | 7107. | 12793. | 7.80E+03 | 2.56E+04 | 1.00 | 1.00E+00 | 795. | 1402. |
| DOWNSTREAM | 1.00E-01 | 5438. | 9788. | 1.39E+04 | 4.55E+04 | 2.19 | 2.14E+00 | 1414. | 1653. |
| DOWNSTREAM | 1.00E-02 | 4126. | 7427. | 1.78E+04 | 5.83E+04 | 3.48 | 1.14E+01 | 1811. | 1938. |
| DOWNSTREAM | 1.00E-03 | 3298. | 5936. | 2.01E+04 | 6.58E+04 | 4.57 | 7.31E+01 | 2045. | 2126. |
| DOWNSTREAM | 1.00E-04 | 2693. | 4847. | 2.16E+04 | 7.08E+04 | 5.83 | 5.12E+02 | 2202. | 2259. |
| DOWNSTREAM | 3.00E-05 | 2416. | 4348. | 2.22E+04 | 7.29E+04 | 6.44 | 1.44E+03 | 2265. | 2313. |
| DOWNSTREAM | 1.00E-05 | 2157. | 3882. | 2.27E+04 | 7.44E+04 | 6.99 | 3.67E+03 | 2314. | 2354. |
| DOWNSTREAM | 3.00E-06 | 1811. | 3259. | 2.31E+04 | 7.59E+04 | 7.58 | 9.88E+03 | 2358. | 2391. |
| DOWNSTREAM | 1.00E-06 | 1409. | 2535. | 2.34E+04 | 7.69E+04 | 8.38 | 2.27E+04 | 2390. | 2415. |

Stagnation temperature, $T_t$: 10 000 K; 18 000° R

Sonic flow factor, $\psi$: 7.90E-03 (kg)($K^{1/2}$)/(sec)(N); 2.20E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)

Mass flow per unit throat area, $\dot{W}/A^*$: 8.01E+03 kg/(sec)($m^2$); 1.64E+03 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 10000. | 18000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.27E-01 | 8443. | 15197. | 9.43E+03 | 3.09E+04 | 1.00 | 1.00E+00 | 961. | 1641. |
| DOWNSTREAM | 1.00E-01 | 6074. | 10934. | 1.61E+04 | 5.27E+04 | 2.21 | 2.04E+00 | 1638. | 1901. |
| DOWNSTREAM | 1.00E-02 | 4469. | 8044. | 2.03E+04 | 6.65E+04 | 3.58 | 1.05E+01 | 2068. | 2204. |
| DOWNSTREAM | 1.00E-03 | 3551. | 6393. | 2.27E+04 | 7.45E+04 | 4.82 | 6.69E+01 | 2317. | 2403. |
| DOWNSTREAM | 1.00E-04 | 2932. | 5278. | 2.44E+04 | 7.99E+04 | 6.02 | 4.70E+02 | 2483. | 2544. |
| DOWNSTREAM | 3.00E-05 | 2674. | 4814. | 2.50E+04 | 8.21E+04 | 6.64 | 1.33E+03 | 2550. | 2602. |
| DOWNSTREAM | 1.00E-05 | 2463. | 4434. | 2.55E+04 | 8.38E+04 | 7.20 | 3.48E+03 | 2603. | 2648. |
| DOWNSTREAM | 3.00E-06 | 2248. | 4046. | 2.60E+04 | 8.54E+04 | 7.82 | 1.00E+04 | 2654. | 2692. |
| DOWNSTREAM | 1.00E-06 | 2053. | 3695. | 2.64E+04 | 8.67E+04 | 8.40 | 2.63E+04 | 2693. | 2727. |

Stagnation temperature, $T_t$: 12 000 K; 21 600° R

Sonic flow factor, $\psi$: 7.84E-03 (kg)($K^{1/2}$)/(sec)(N); 2.18E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)

Mass flow per unit throat area, $\dot{W}/A^*$: 7.26E+03 kg/(sec)($m^2$); 1.49E+03 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 12000. | 21600. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.13E-01 | 9760. | 17568. | 1.07E+04 | 3.52E+04 | 1.00 | 1.00E+00 | 1094. | 1824. |
| DOWNSTREAM | 1.00E-01 | 6557. | 11803. | 1.77E+04 | 5.80E+04 | 2.22 | 1.94E+00 | 1803. | 2079. |
| DOWNSTREAM | 1.00E-02 | 4667. | 8400. | 2.21E+04 | 7.24E+04 | 3.66 | 9.76E+00 | 2249. | 2388. |
| DOWNSTREAM | 1.00E-03 | 3677. | 6618. | 2.45E+04 | 8.05E+04 | 4.96 | 6.17E+01 | 2503. | 2591. |
| DOWNSTREAM | 1.00E-04 | 3034. | 5461. | 2.62E+04 | 8.60E+04 | 6.19 | 4.33E+02 | 2672. | 2734. |
| DOWNSTREAM | 3.00E-05 | 2773. | 4992. | 2.69E+04 | 8.82E+04 | 6.82 | 1.23E+03 | 2741. | 2793. |
| DOWNSTREAM | 1.00E-05 | 2565. | 4616. | 2.74E+04 | 8.99E+04 | 7.40 | 3.21E+03 | 2795. | 2841. |
| DOWNSTREAM | 3.00E-06 | 2359. | 4247. | 2.79E+04 | 9.16E+04 | 8.03 | 9.31E+03 | 2846. | 2886. |
| DOWNSTREAM | 1.00E-06 | 2186. | 3935. | 2.83E+04 | 9.29E+04 | 8.60 | 2.47E+04 | 2887. | 2922. |

Stagnation temperature, $T_t$: 14 000 K; 25 200° R

Sonic flow factor, $\psi$: 7.68E-03 (kg)($K^{1/2}$)/(sec)(N); 2.14E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)

Mass flow per unit throat area, $\dot{W}/A^*$: 6.58E+03 kg/(sec)($m^2$); 1.35E+03 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 14000. | 25200. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.10E-01 | 11459. | 20626. | 1.18E+04 | 3.87E+04 | 1.00 | 1.00E+00 | 1204. | 2006. |
| DOWNSTREAM | 1.00E-01 | 7133. | 12839. | 1.93E+04 | 6.33E+04 | 2.21 | 1.94E+00 | 1968. | 2258. |
| DOWNSTREAM | 1.00E-02 | 4846. | 8722. | 2.38E+04 | 7.81E+04 | 3.76 | 8.98E+00 | 2427. | 2568. |
| DOWNSTREAM | 1.00E-03 | 3778. | 6800. | 2.63E+04 | 8.63E+04 | 5.10 | 5.54E+01 | 2634. | 2772. |
| DOWNSTREAM | 1.00E-04 | 3109. | 5597. | 2.80E+04 | 9.18E+04 | 6.38 | 3.94E+02 | 2854. | 2916. |
| DOWNSTREAM | 3.00E-05 | 2843. | 5117. | 2.87E+04 | 9.40E+04 | 7.03 | 1.12E+03 | 2923. | 2975. |
| DOWNSTREAM | 1.00E-05 | 2633. | 4739. | 2.92E+04 | 9.58E+04 | 7.61 | 2.93E+03 | 2977. | 3023. |
| DOWNSTREAM | 3.00E-06 | 2429. | 4373. | 2.97E+04 | 9.74E+04 | 8.26 | 8.50E+03 | 3029. | 3069. |
| DOWNSTREAM | 1.00E-06 | 2261. | 4071. | 3.01E+04 | 9.88E+04 | 8.84 | 2.26E+04 | 3070. | 3105. |

TABLE III. - Concluded. CHOKED NOZZLE FLOW OF HYDROGEN IN CHEMICAL EQUILIBRIUM IN DEBYE-HÜCKEL APPROXIMATION

[E-02, E-03, E+02, E+03, etc., after numbers signify that numbers are to be multiplied by $10^{-2}$, $10^{-3}$, $10^{2}$, $10^{3}$, etc.]

(f) Concluded. Stagnation pressure, $1.01325\times10^{8}$ N/m$^2$ (1000 atm)

| Location | Pressure ratio, $p/p_t$ | Temperature, T | | Velocity, v | | Mach number, M | Area ratio, $A/A^*$ | Specific impulse, sec | |
|---|---|---|---|---|---|---|---|---|---|
| | | K | $^{o}$R | m/sec | ft/sec | | | Ideal, $I_{sp,i}$ | Vacuum, $I_{sp,v}$ |
| Stagnation temperature, $T_t$: 16 000 K; 28 800$^{o}$ R<br>Sonic flow factor, $\psi$: 7.42E-03 (kg)(K$^{1/2}$)/(sec)(N); 2.07E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 5.95E+03 kg/(sec)(m$^2$); 1.22E+03 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 16000. | 28800. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.27E-01 | 13665. | 24598. | 1.26E+04 | 4.13E+04 | 1.00 | 1.00E+00 | 1283. | 2198. |
| DOWNSTREAM | 1.00E-01 | 8141. | 14655. | 2.12E+04 | 6.95E+04 | 2.15 | 1.80E+00 | 2161. | 2475. |
| DOWNSTREAM | 1.00E-02 | 5069. | 9123. | 2.59E+04 | 8.50E+04 | 3.85 | 8.23E+00 | 2640. | 2783. |
| DOWNSTREAM | 1.00E-03 | 3886. | 6994. | 2.84E+04 | 9.33E+04 | 5.28 | 5.10E+01 | 2899. | 2987. |
| DOWNSTREAM | 1.00E-04 | 3184. | 5731. | 3.01E+04 | 9.87E+04 | 6.61 | 3.56E+02 | 3069. | 3131. |
| DOWNSTREAM | 3.00E-05 | 2910. | 5238. | 3.08E+04 | 1.01E+05 | 7.28 | 1.01E+03 | 3138. | 3190. |
| DOWNSTREAM | 1.00E-05 | 2696. | 4853. | 3.13E+04 | 1.03E+05 | 7.89 | 2.54E+03 | 3192. | 3238. |
| DOWNSTREAM | 3.00E-06 | 2491. | 4484. | 3.18E+04 | 1.04E+05 | 8.55 | 7.68E+03 | 3243. | 3283. |
| DOWNSTREAM | 1.00E-06 | 2325. | 4185. | 3.22E+04 | 1.06E+05 | 9.15 | 2.05E+04 | 3285. | 3320. |
| Stagnation temperature, $T_t$: 18 000 K; 32 400$^{o}$ R<br>Sonic flow factor, $\psi$: 7.21E-03 (kg)(K$^{1/2}$)/(sec)(N); 2.01E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 5.44E+03 kg/(sec)(m$^2$); 1.11E+03 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 18000. | 32400. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.45E-01 | 15906. | 28630. | 1.33E+04 | 4.35E+04 | 1.00 | 1.00E+00 | 1353. | 2388. |
| DOWNSTREAM | 1.00E-01 | 10093. | 18168. | 2.33E+04 | 7.65E+04 | 2.07 | 1.91E+00 | 2378. | 2740. |
| DOWNSTREAM | 1.00E-02 | 5414. | 9745. | 2.85E+04 | 9.34E+04 | 3.91 | 7.76E+00 | 2902. | 3050. |
| DOWNSTREAM | 1.00E-03 | 4017. | 7231. | 3.10E+04 | 1.02E+05 | 5.49 | 4.68E+01 | 3164. | 3253. |
| DOWNSTREAM | 1.00E-04 | 3266. | 5879. | 3.27E+04 | 1.07E+05 | 6.89 | 3.24E+02 | 3334. | 3396. |
| DOWNSTREAM | 3.00E-05 | 2981. | 5366. | 3.34E+04 | 1.09E+05 | 7.59 | 9.19E+02 | 3403. | 3455. |
| DOWNSTREAM | 1.00E-05 | 2761. | 4969. | 3.39E+04 | 1.11E+05 | 8.22 | 2.41E+03 | 3456. | 3502. |
| DOWNSTREAM | 3.00E-06 | 2552. | 4594. | 3.44E+04 | 1.13E+05 | 8.91 | 6.99E+03 | 3508. | 3547. |
| DOWNSTREAM | 1.00E-06 | 2385. | 4294. | 3.48E+04 | 1.14E+05 | 9.53 | 1.85E+04 | 3549. | 3584. |
| Stagnation temperature, $T_t$: 25 000 K; 45 000$^{o}$ R<br>Sonic flow factor, $\psi$: 6.59E-03 (kg)(K$^{1/2}$)/(sec)(N); 1.84E+02 (lb)($^{o}$R$^{1/2}$)/(sec)(ft$^2$)(atm)<br>Mass flow per unit throat area, $\dot{W}/A^*$: 4.23E+03 kg/(sec)(m$^2$); 8.65E+02 lb/(sec)(ft$^2$) | | | | | | | | | |
| CHAMBER | 1. | 25000. | 45000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.59E-01 | 22641. | 40754. | 1.68E+04 | 5.50E+04 | 1.00 | 1.00E+00 | 1710. | 3077. |
| DOWNSTREAM | 1.00E-01 | 17285. | 31112. | 3.07E+04 | 1.01E+05 | 2.18 | 2.17E+00 | 3127. | 3658. |
| DOWNSTREAM | 1.00E-02 | 11835. | 21304. | 3.92E+04 | 1.28E+05 | 3.44 | 1.07E+01 | 3992. | 4254. |
| DOWNSTREAM | 1.00E-03 | 5923. | 10661. | 4.33E+04 | 1.42E+05 | 4.93 | 4.69E+01 | 4414. | 4529. |
| DOWNSTREAM | 1.00E-04 | 3721. | 6698. | 4.52E+04 | 1.48E+05 | 7.82 | 2.59E+02 | 4605. | 4668. |
| DOWNSTREAM | 3.00E-05 | 3309. | 5956. | 4.58E+04 | 1.50E+05 | 8.79 | 7.17E+02 | 4674. | 4726. |
| DOWNSTREAM | 1.00E-05 | 3027. | 5449. | 4.64E+04 | 1.52E+05 | 9.59 | 1.85E+03 | 4727. | 4773. |
| DOWNSTREAM | 3.00E-06 | 2780. | 5003. | 4.69E+04 | 1.54E+05 | 10.44 | 5.34E+03 | 4778. | 4817. |
| DOWNSTREAM | 1.00E-06 | 2591. | 4663. | 4.73E+04 | 1.55E+05 | 11.19 | 1.42E+04 | 4819. | 4853. |

Stagnation temperature, $T_t$: 35 000 K; 63 000° R
Sonic flow factor, $\psi$: 6.00E-03 (kg)($K^{1/2}$)/(sec)(N); 1.67E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 3.25E+03 kg/(sec)($m^2$); 6.65E+02 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 35000. | 63000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.42E-01 | 30434. | 54782. | 2.29E+04 | 7.50E+04 | 1.00 | 1.00E+00 | 2332. | 4057. |
| DOWNSTREAM | 1.00E-01 | 22415. | 40347. | 4.01E+04 | 1.32E+05 | 2.22 | 2.09E+00 | 4088. | 4752. |
| DOWNSTREAM | 1.00E-02 | 15316. | 29370. | 5.08E+04 | 1.67E+05 | 3.55 | 1.07E+01 | 5183. | 5523. |
| DOWNSTREAM | 1.00E-03 | 12420. | 22356. | 5.69E+04 | 1.87E+05 | 4.85 | 6.53E+01 | 5798. | 6005. |
| DOWNSTREAM | 1.00E-04 | 9296. | 16732. | 6.06E+04 | 1.99E+05 | 6.16 | 4.19E+02 | 6184. | 6318. |
| DOWNSTREAM | 3.00E-05 | 7339. | 13211. | 6.20E+04 | 2.04E+05 | 6.72 | 1.05E+03 | 6325. | 6425. |
| DOWNSTREAM | 1.00E-05 | 4976. | 8957. | 6.29E+04 | 2.06E+05 | 7.64 | 2.09E+03 | 6415. | 6483. |
| DOWNSTREAM | 3.00E-06 | 3371. | 6069. | 6.36E+04 | 2.09E+05 | 10.71 | 4.61E+03 | 6481. | 6525. |
| DOWNSTREAM | 1.00E-06 | 2924. | 5263. | 6.40E+04 | 2.10E+05 | 12.46 | 1.14E+04 | 6524. | 6561. |

Stagnation temperature, $T_t$: 50 000 K; 90 000° R
Sonic flow factor, $\psi$: 5.82E-03 (kg)($K^{1/2}$)/(sec)(N); 1.62E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 2.64E+03 kg/(sec)($m^2$); 5.40E+02 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 50000. | 90000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 5.10E-01 | 39986. | 71975. | 3.01E+04 | 9.88E+04 | 1.00 | 1.00E+00 | 3070. | 5068. |
| DOWNSTREAM | 1.00E-01 | 25547. | 47785. | 4.92E+04 | 1.61E+05 | 2.24 | 1.91E+00 | 5013. | 5764. |
| DOWNSTREAM | 1.00E-02 | 18396. | 33112. | 6.11E+04 | 2.00E+05 | 3.71 | 9.45E+00 | 6227. | 6598. |
| DOWNSTREAM | 1.00E-03 | 14026. | 25247. | 6.76E+04 | 2.22E+05 | 5.07 | 5.79E+01 | 6898. | 7125. |
| DOWNSTREAM | 1.00E-04 | 11120. | 20017. | 7.19E+04 | 2.36E+05 | 6.43 | 3.88E+02 | 7327. | 7480. |
| DOWNSTREAM | 3.00E-05 | 9894. | 17809. | 7.35E+04 | 2.41E+05 | 7.16 | 1.07E+03 | 7494. | 7620. |
| DOWNSTREAM | 1.00E-05 | 8853. | 15935. | 7.47E+04 | 2.45E+05 | 7.85 | 2.71E+03 | 7621. | 7728. |
| DOWNSTREAM | 3.00E-06 | 7667. | 13800. | 7.59E+04 | 2.49E+05 | 8.59 | 7.41E+03 | 7738. | 7825. |
| DOWNSTREAM | 1.00E-06 | 6171. | 11108. | 7.67E+04 | 2.52E+05 | 8.99 | 1.73E+04 | 7823. | 7891. |

Stagnation temperature, $T_t$: 75 000 K; 135 000° R
Sonic flow factor, $\psi$: 5.76E-03 (kg)($K^{1/2}$)/(sec)(N); 1.60E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 2.13E+03 kg/(sec)($m^2$); 4.37E+02 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 75000. | 135000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.90E-01 | 56941. | 102494. | 3.86E+04 | 1.27E+05 | 1.00 | 1.00E+00 | 3932. | 6305. |
| DOWNSTREAM | 1.00E-01 | 32734. | 58922. | 6.02E+04 | 1.98E+05 | 2.21 | 1.73E+00 | 6141. | 6980. |
| DOWNSTREAM | 1.00E-02 | 20218. | 36392. | 7.29E+04 | 2.39E+05 | 3.94 | 7.88E+00 | 7435. | 7817. |
| DOWNSTREAM | 1.00E-03 | 15070. | 27125. | 7.96E+04 | 2.61E+05 | 5.44 | 4.76E+01 | 8121. | 8352. |
| DOWNSTREAM | 1.00E-04 | 11964. | 21536. | 8.39E+04 | 2.75E+05 | 6.89 | 3.21E+02 | 8558. | 8714. |
| DOWNSTREAM | 3.00E-05 | 10739. | 19330. | 8.56E+04 | 2.81E+05 | 7.65 | 8.91E+02 | 8729. | 8859. |
| DOWNSTREAM | 1.00E-05 | 9770. | 17586. | 8.69E+04 | 2.85E+05 | 8.36 | 2.28E+03 | 8861. | 8972. |
| DOWNSTREAM | 3.00E-06 | 8820. | 15876. | 8.81E+04 | 2.89E+05 | 9.15 | 6.46E+03 | 8984. | 9078. |
| DOWNSTREAM | 1.00E-06 | 8007. | 14413. | 8.90E+04 | 2.92E+05 | 9.89 | 1.67E+04 | 9080. | 9161. |

Stagnation temperature, $T_t$: 100 000 K; 180 000° R
Sonic flow factor, $\psi$: 5.73E-03 (kg)($K^{1/2}$)/(sec)(N); 1.59E+02 (lb)($^{\circ}R^{1/2}$)/(sec)($ft^2$)(atm)
Mass flow per unit throat area, $\dot{W}/A^*$: 1.83E+03 kg/(sec)($m^2$); 3.76E+02 lb/(sec)($ft^2$)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CHAMBER | 1. | 100000. | 180000. | 0 | 0 | 0 | INFINITY | | |
| THROAT | 4.87E-01 | 75314. | 135565. | 4.50E+04 | 1.48E+05 | 1.00 | 1.00E+00 | 4585. | 7329. |
| DOWNSTREAM | 1.00E-01 | 40947. | 73704. | 6.98E+04 | 2.29E+05 | 2.15 | 1.68E+00 | 7114. | 8059. |
| DOWNSTREAM | 1.00E-02 | 21820. | 39276. | 8.33E+04 | 2.73E+05 | 4.11 | 6.85E+00 | 8492. | 8878. |
| DOWNSTREAM | 1.00E-03 | 15752. | 28354. | 9.00E+04 | 2.95E+05 | 5.79 | 4.06E+01 | 9177. | 9406. |
| DOWNSTREAM | 1.00E-04 | 12428. | 22371. | 9.42E+04 | 3.09E+05 | 7.34 | 2.73E+02 | 9610. | 9763. |
| DOWNSTREAM | 3.00E-05 | 11163. | 20093. | 9.59E+04 | 3.15E+05 | 8.15 | 7.58E+02 | 9779. | 9907. |
| DOWNSTREAM | 1.00E-05 | 10182. | 18328. | 9.72E+04 | 3.19E+05 | 8.89 | 1.95E+03 | 9909. | 10019. |
| DOWNSTREAM | 3.00E-06 | 9248. | 16646. | 9.84E+04 | 3.23E+05 | 9.71 | 5.54E+03 | 10031. | 10125. |
| DOWNSTREAM | 1.00E-06 | 8485. | 15274. | 9.93E+04 | 3.26E+05 | 10.48 | 1.45E+04 | 10127. | 10209. |

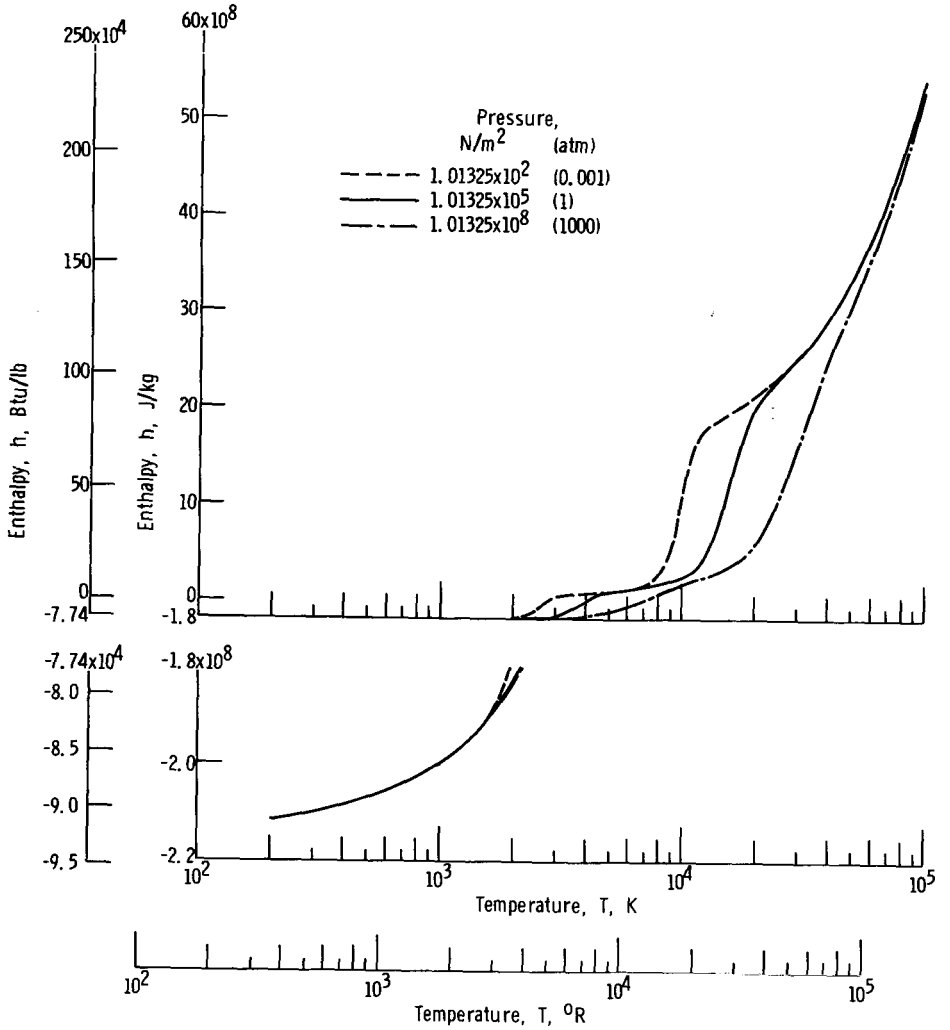


Figure 1. - Enthalpy of spin-equilibrated hydrogen in chemical equilibrium in Debye-Hückel approximation.

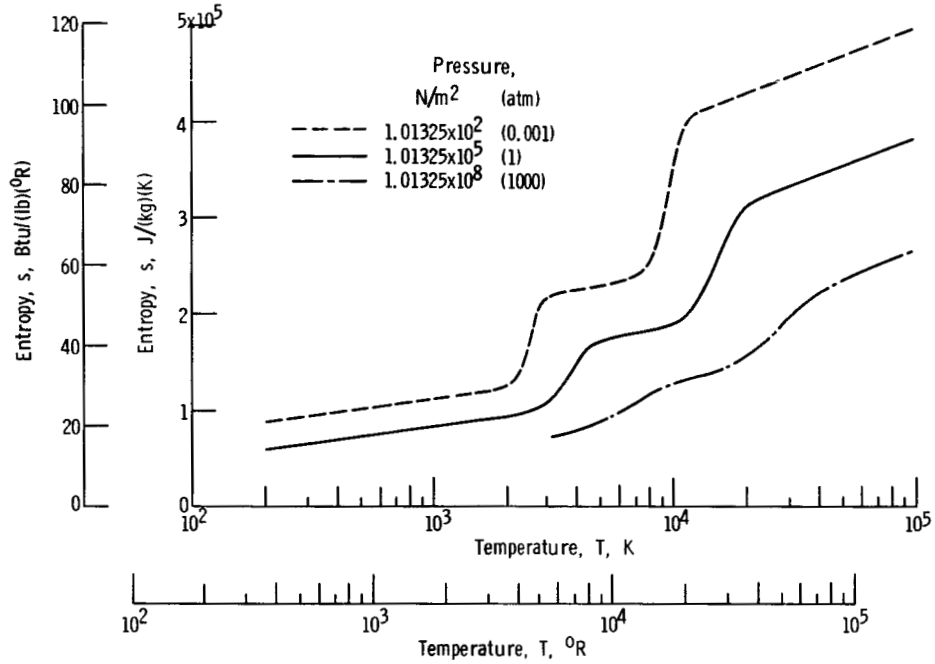


Figure 2. - Entropy of spin-equilibrated hydrogen in chemical equilibrium in Debye-Hückel approximation.

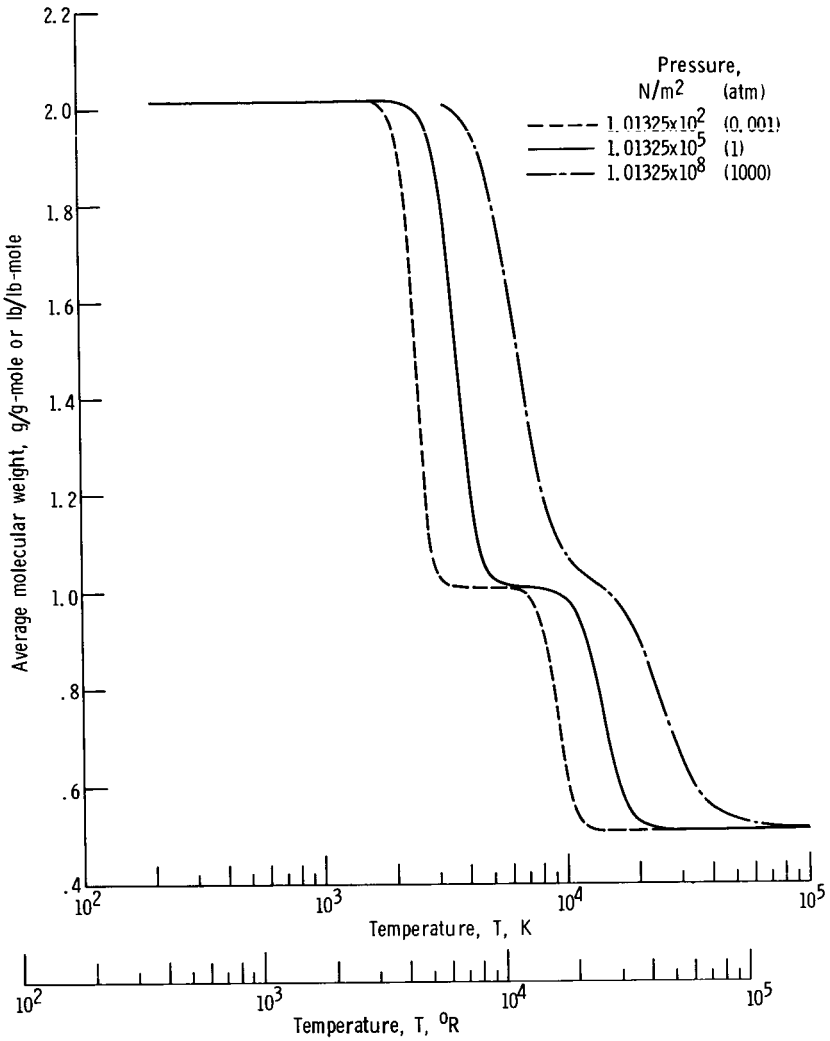


Figure 3. - Average molecular weight of spin-equilibrated hydrogen in chemical equilibrium in Debye-Hückel approximation.

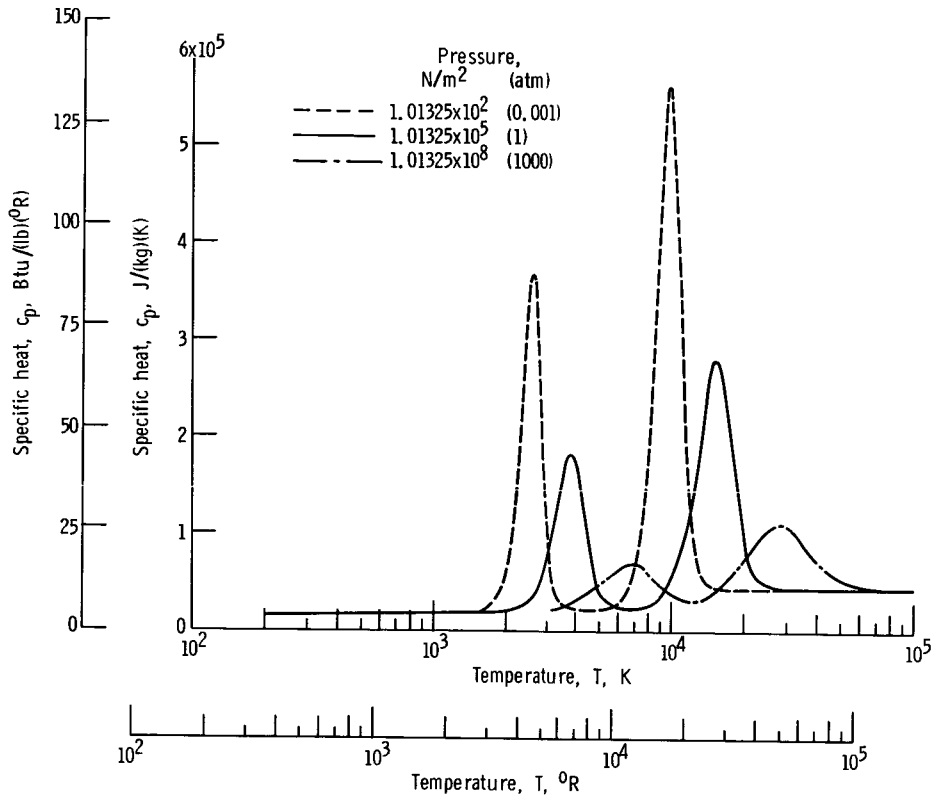


Figure 4. - Specific heat at constant pressure of spin-equilibrated hydrogen in chemical equilibrium in Debye-Hückel approximation.

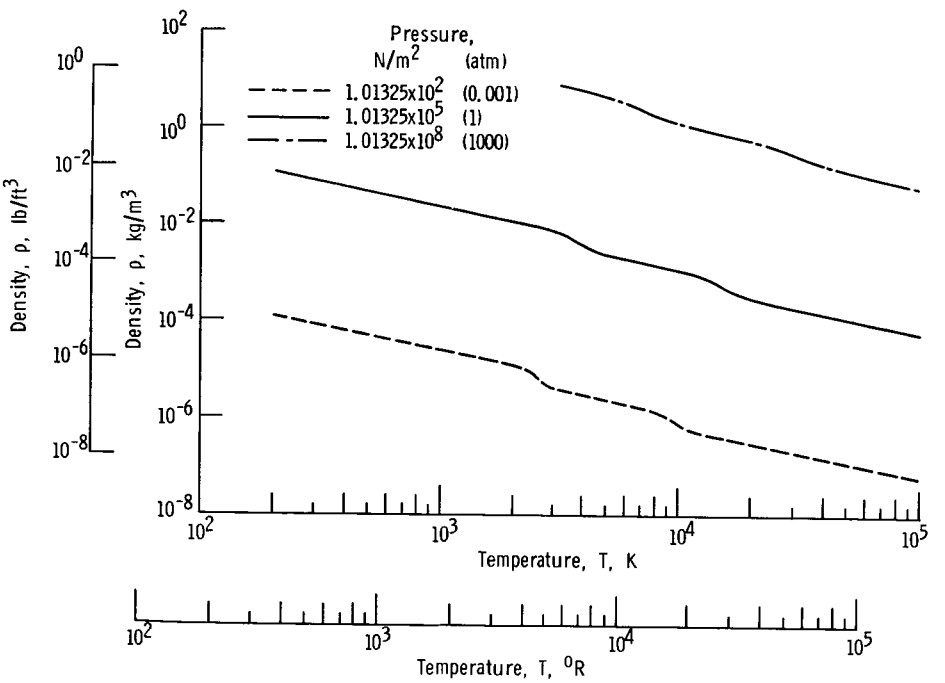


Figure 5. - Density of spin-equilibrated hydrogen in chemical equilibrium in Debye-Hückel approximation.

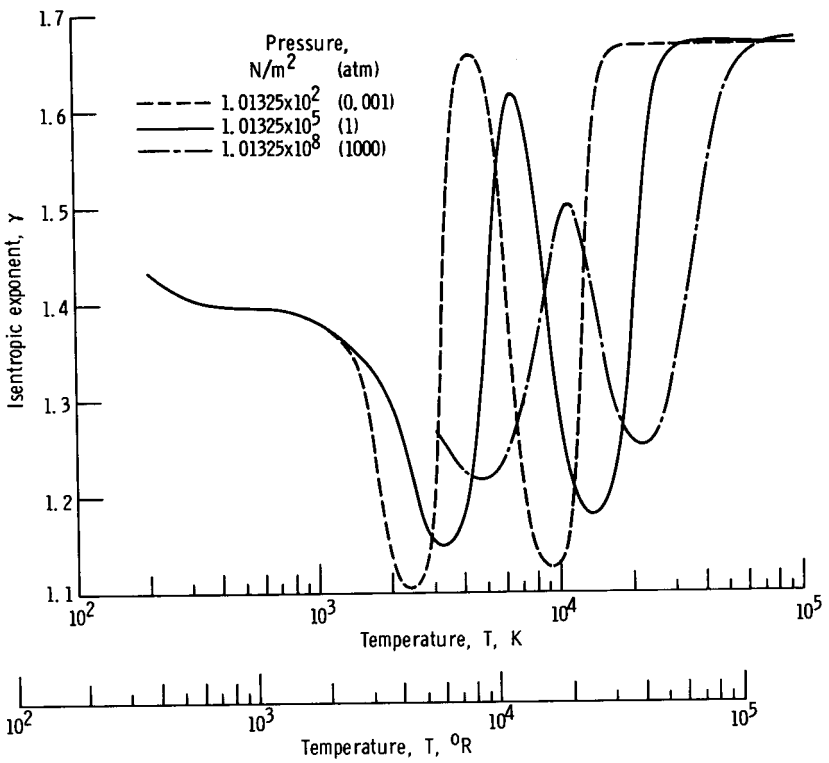


Figure 6. - Isentropic exponent of spin-equilibrated hydrogen in chemical equilibrium in Debye-Hückel approximation.

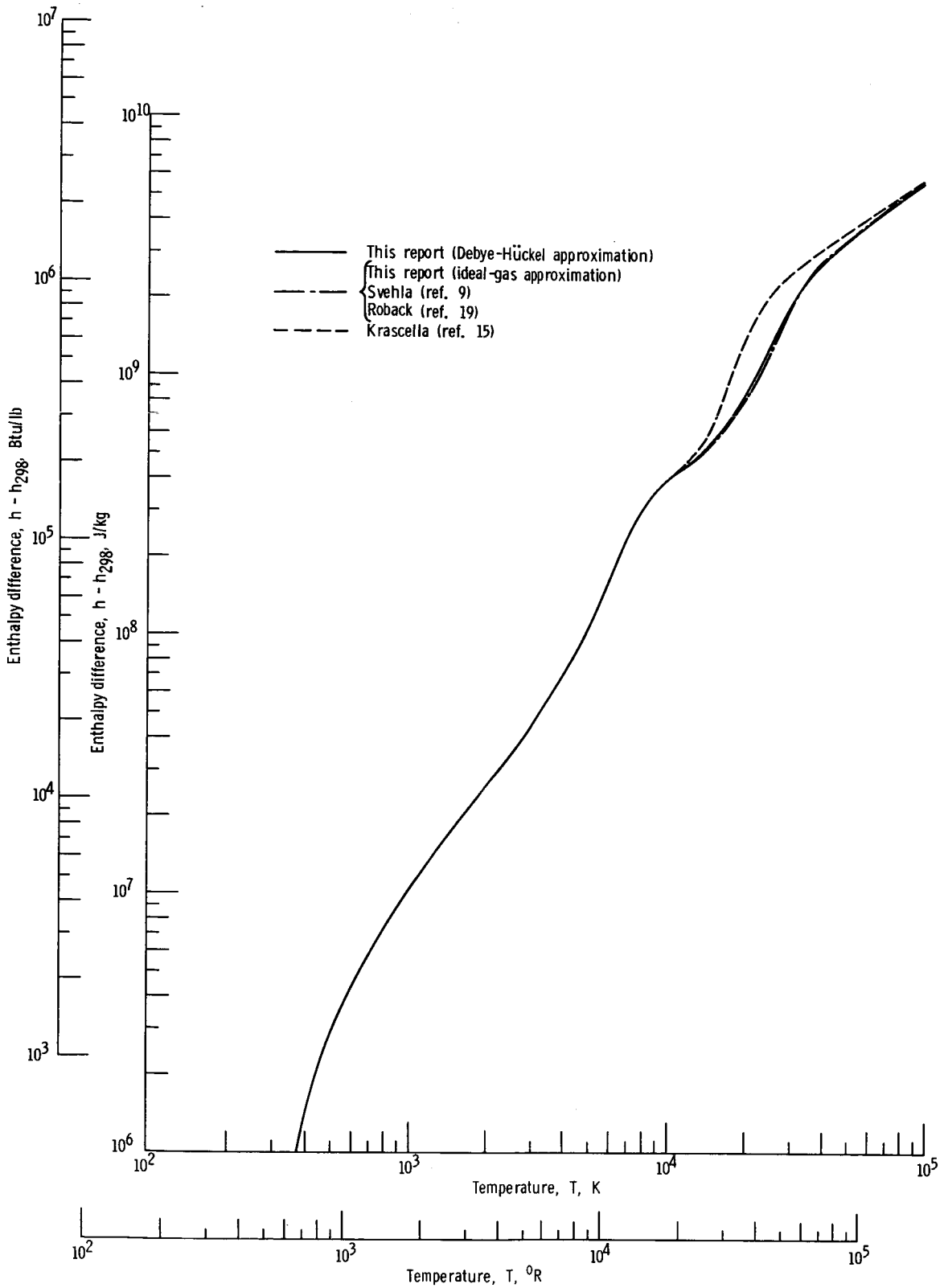


Figure 7. - Comparison of enthalpy differences of hydrogen in chemical equilibrium according to the Debye-Hückel and ideal-gas approximations of this report and the results of three other investigators for a pressure of $1.01325 \times 10^8$ N/m$^2$ (1000 atm).

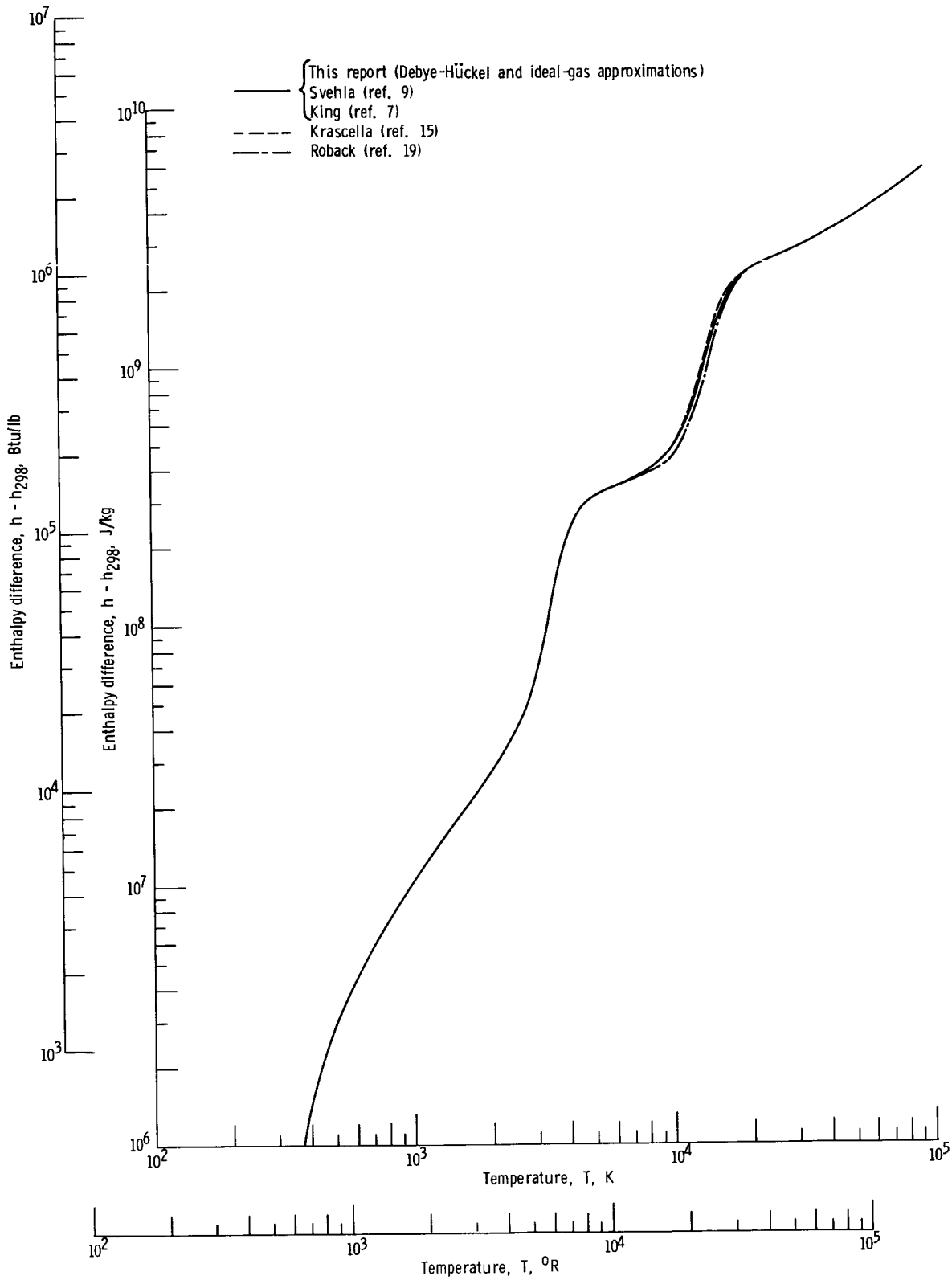


Figure 8. - Comparison of enthalpy differences of hydrogen in chemical equilibrium according to the Debye-Hückel and ideal-gas approximations of this report and the results of four other investigators for a pressure of $1.01325 \times 10^5$ N/m$^2$ (1 atm).

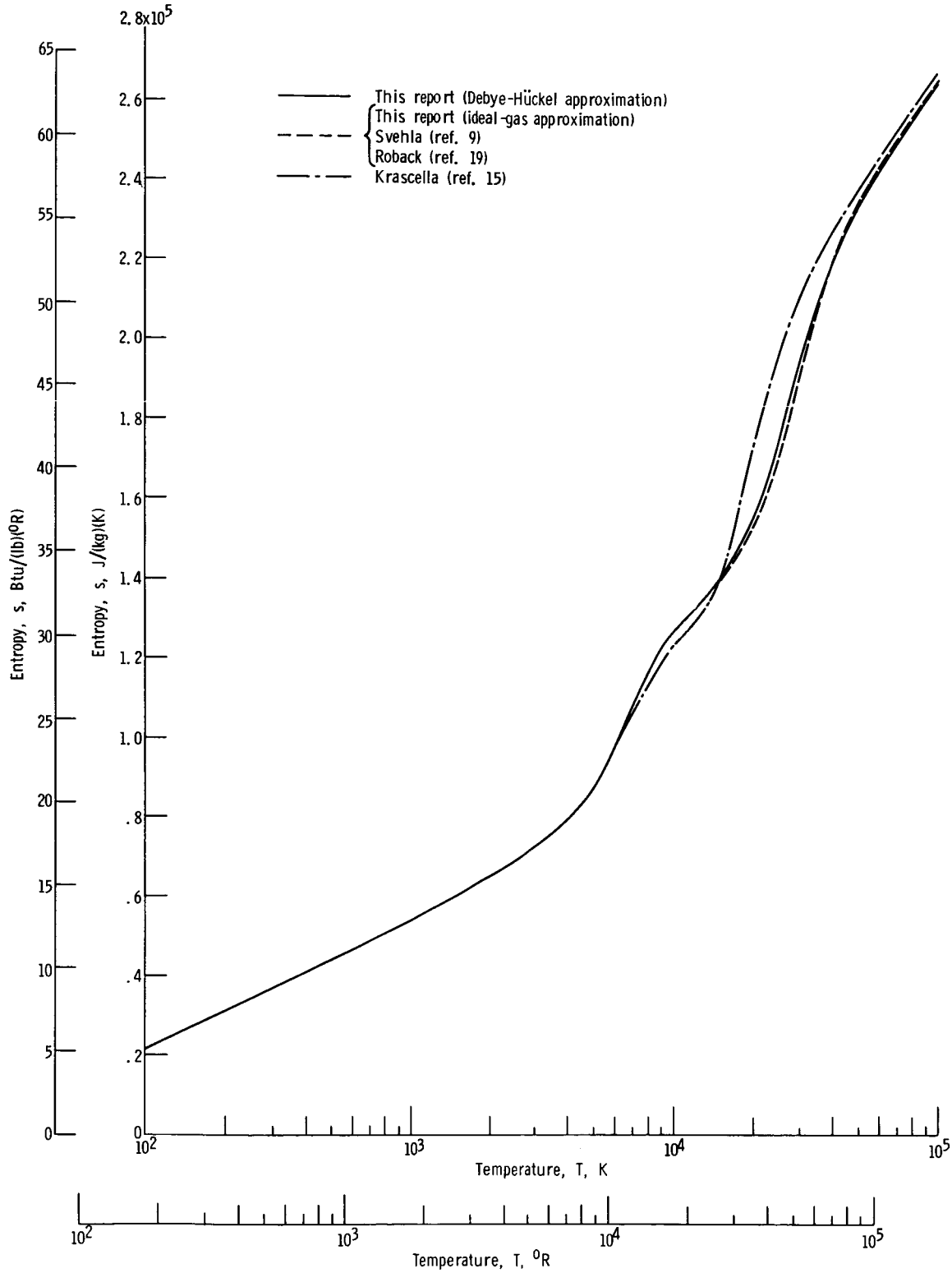


Figure 9. - Comparison of entropy of hydrogen in chemical equilibrium according to the Debye-Hückel and ideal-gas approximations of this report and the results of three other investigators for a pressure of $1.01325 \times 10^8$ N/m$^2$ (1000 atm).

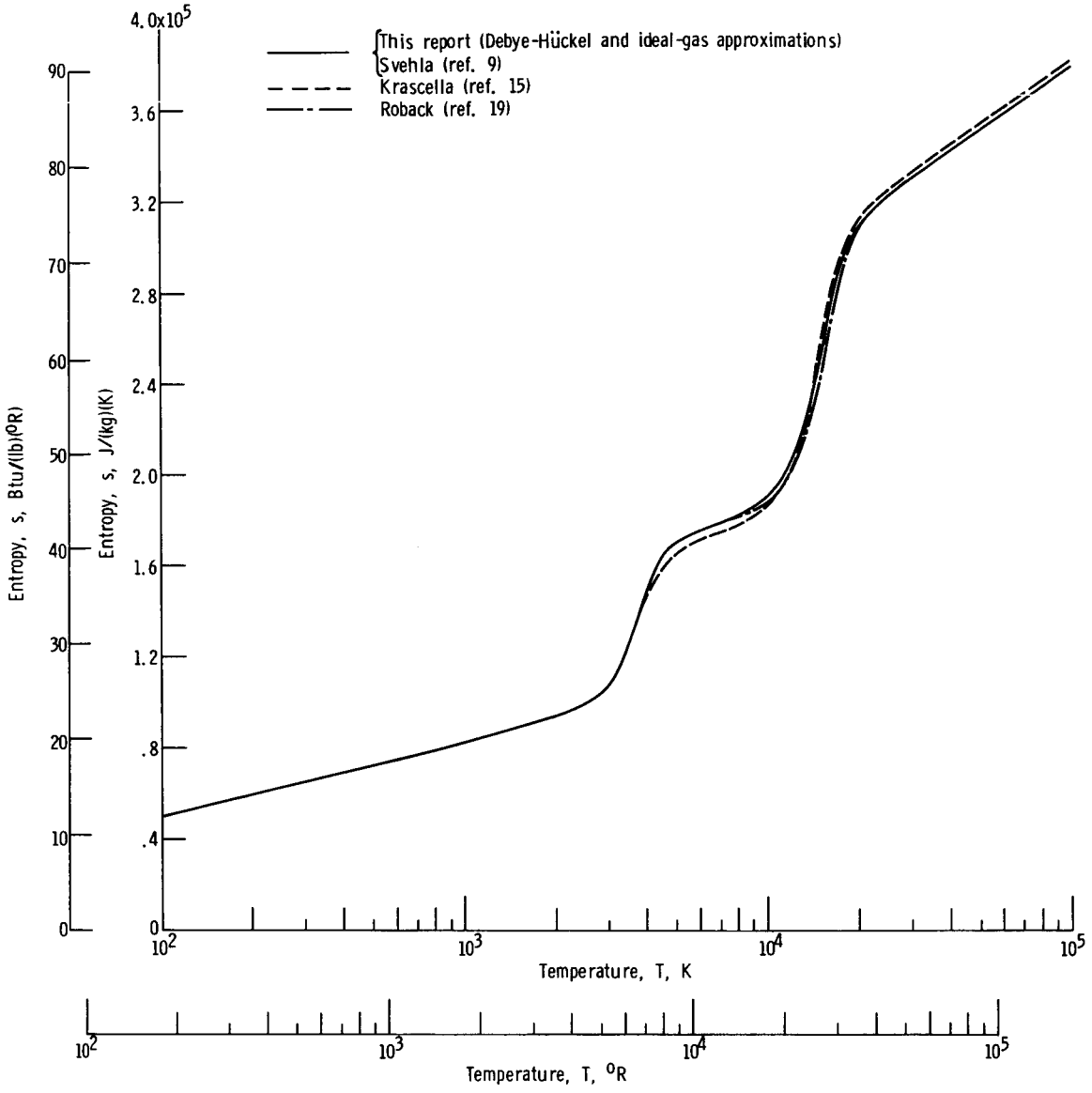


Figure 10. - Comparison of entropy of hydrogen in chemical equilibrium according to the Debye-Hückel and ideal-gas approximations of this report and the results of three other investigators for a pressure of $1.01325 \times 10^5$ N/m$^2$ (1 atm).

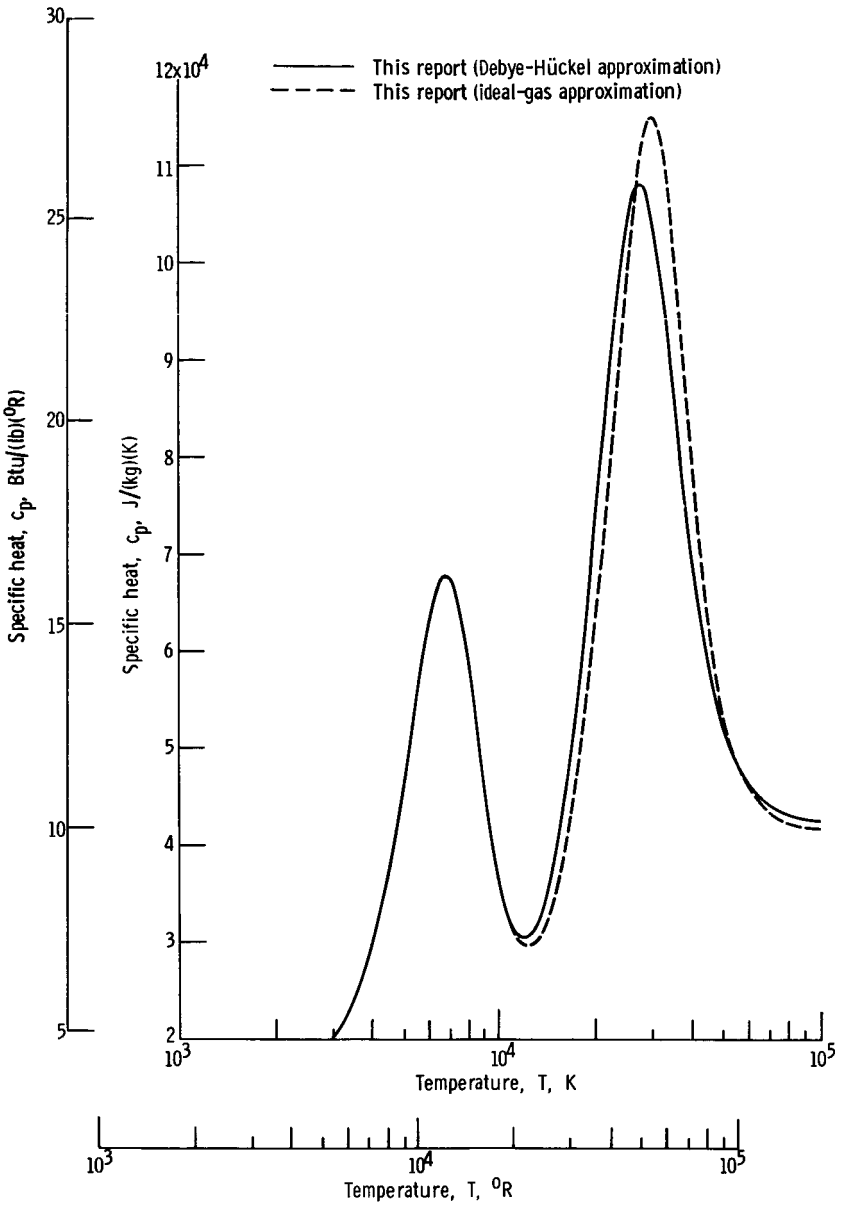


Figure 11. - Comparison of specific heat at constant pressure according to the Debye-Hückel and ideal-gas approximations of this report. Pressure, $1.01325x10^8$ N/m$^2$ (1000 atm).

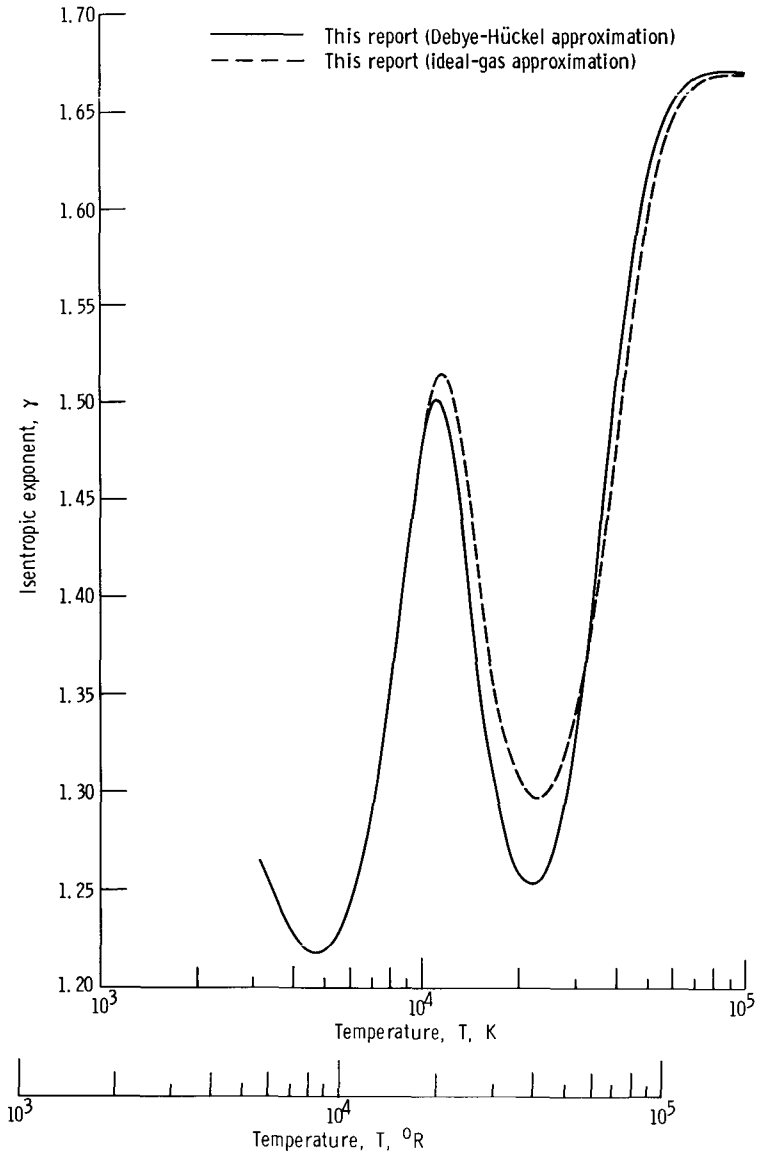


Figure 12. - Comparison of isentropic exponent according to the Debye-Hückel and ideal-gas approximations of this report. Pressure, $1.01325 \times 10^8$ N/m$^2$ (1000 atm).

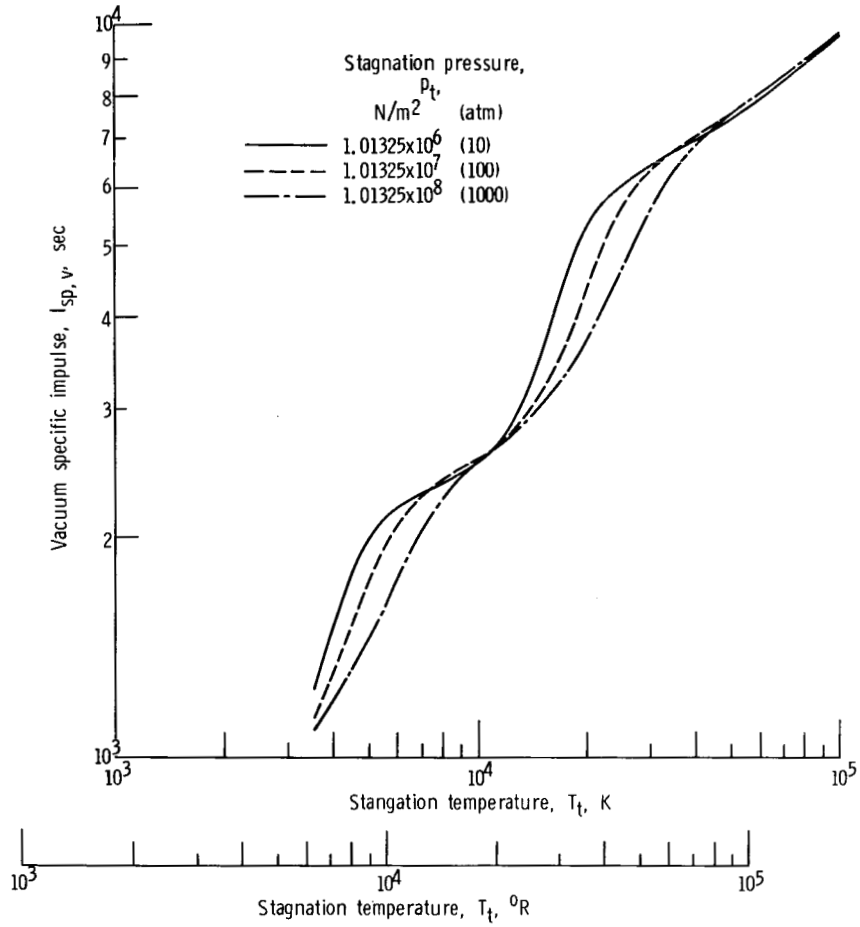


Figure 13. - Vacuum specific impulse for choked nozzle flow with shifting chemical equilibrium in Debye-Hückel approximation. Ratio of nozzle-exit pressure to stagnation pressure of $10^{-4}$

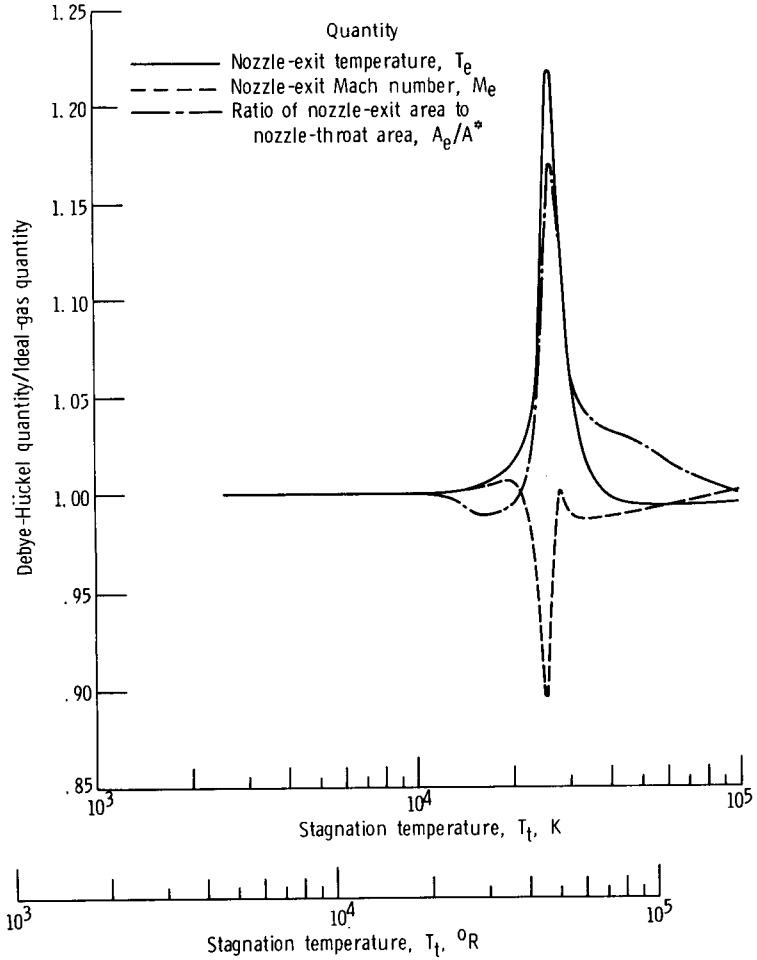


Figure 14. - Ratio of nozzle-exit quantities calculated by two approximations with shifting chemical equilibrium at a stagnation pressure of $1.01325 \times 10^8$ N/m$^2$ (1000 atm). Ratio of nozzle-exit pressure to stagnation pressure of $10^{-3}$.

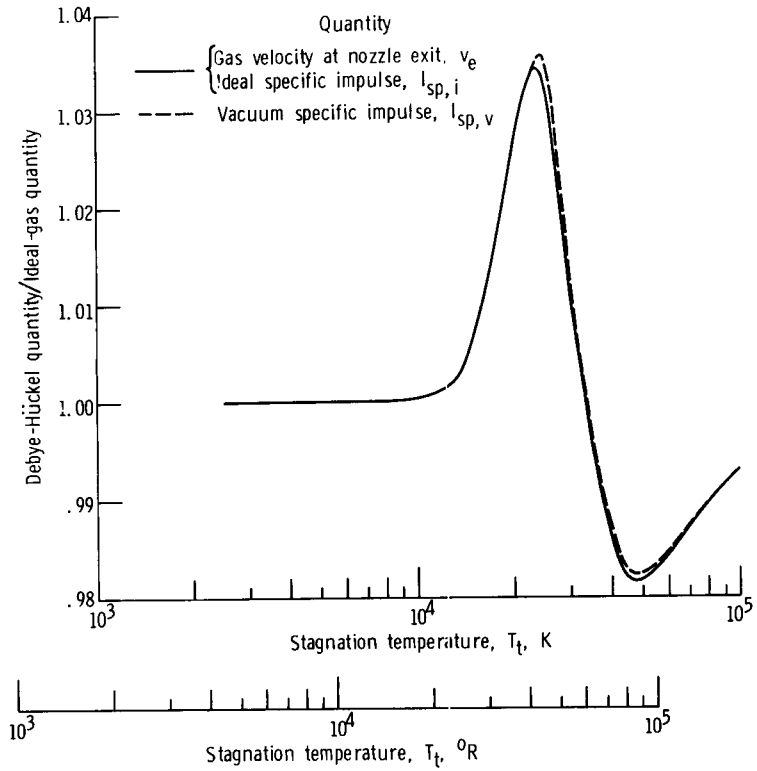


Figure 15. - Ratio of nozzle-exit quantities calculated by two approximations with shifting chemical equilibrium at a stagnation pressure of $1.01325 \times 10^8$ N/m$^2$ (1000 atm). Ratio of nozzle-exit pressure to stagnation pressure of $10^{-3}$.

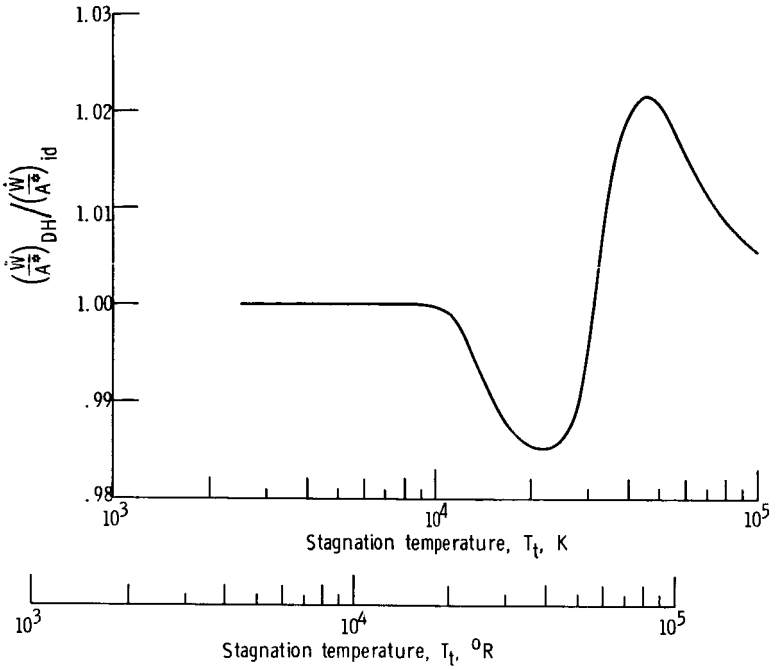


Figure 16. - Ratio of mass flows per unit throat area according to the Debye-Hückel and ideal-gas approximations with shifting chemical equilibrium at a stagnation pressure of $1.01325 \times 10^8$ N/m$^2$ (1000 atm). Choked flow assumed.

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