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MEMORANDUM

THEORETICAL PERFORMANCE OF LIQUID HYDROGEN WITH LIQUID OXYGEN AS A ROCKET PROPELLANT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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Tables II(a) through II(h): Add 10,000 to the enthalpy values for R = 0.150 and 0.200 for pressure ratios of 1.00 to 4000.00.

Tables II(a), (c), (d), (e), (g), and (h): Add 10,000 to the enthalpy values for R = 0.250 for pressure ratios of 1.00 to 10.00.

Tables II(b) and (f): Add 10,000 to the enthalpy values for R = 0.250 for pressure ratios of 1.00 to 10.21.

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SUMMARY

Theoretical rocket performance for both equilibrium and frozen composition during expansion was calculated for the propellant combination liquid hydrogen and liquid oxygen at four chamber pressures (60, 150, 300, and 600 lb/sq in. abs) and a wide range of pressure ratios (1 to 4000) and oxidant-fuel ratios (1.190 to 39.683). Data are given to estimate performance parameters at chamber pressures other than those for which data are tabulated. The parameters included are specific impulse, specific impulse in vacuum, combustion-chamber temperature, nozzle-exit temperature, molecular weight, molecular-weight derivatives, characteristic velocity, coefficient of thrust, ratio of nozzle-exit area to throat area, specific heat at constant pressure, isentropic exponent, viscosity, thermal conductivity, Mach number, and equilibrium gas compositions.

The maximum value of specific impulse for expansion to 1 atmosphere is given in the following table:

Combustion-chamber pressure, P_c, lb/sq in. abs	Ratio of chamber pressure to exit pressure, P_c/P	Specific impulse, I, (lb)(sec)/(lb)	
		Assuming frozen composition	Assuming equilibrium composition
60	4.083	254.6	255.4
150	10.207	313.1	315.0
300	20.414	345.8	348.1
600	40.827	371.8	374.5

INTRODUCTION

The performance of hydrogen and oxygen as a rocket propellant has been reported in the literature. However, additional performance calculations are needed for a wider range of conditions than were heretofore available. Calculations were therefore made at the NASA Lewis Research Center to provide rocket performance data for liquid hydrogen and liquid oxygen for the following conditions:

(1) Four chamber pressures (60, 150, 300, and 600 lb/sq in. abs)

(2) A wide range of oxidant-fuel weight ratios (1.190 to 39.683)

(3) A wide range of pressure ratios (1 to 4000)

(4) Equilibrium and frozen composition during expansion

Data are given to permit estimates of performance parameters at chamber pressures other than those given in this report.

SYMBOLS

The following symbols are used in this report:

A	nozzle area, sq in.
$\mathcal{A}$	number of formula weights (defined as A in ref. 1)
a	local velocity of sound, ft/sec
C_F	coefficient of thrust, $C_F = g_c I/c^* = F/P_c A_t$
C_p^o	molar specific heat at constant pressure, cal/(mole)(^oK)
c_p	specific heat at constant pressure, $(\partial h/\partial T)_p$, cal/(g)($^oK$)
c_v	specific heat at constant volume, cal/(g)(^oK)
c^*	characteristic velocity, $g_c P_c A_t/w$, ft/sec
F	thrust, lb
$f_\mu^{(k)}$	function of T^*
g_c	gravitational conversion factor, 32.174 $\left(\frac{\text{lb mass}}{\text{lb force}}\right)\left(\frac{\text{ft}}{\text{sec}^2}\right)$

H_T^o sum of sensible enthalpy and chemical energy at temperature T, cal/mole

h sum of sensible enthalpy and chemical energy per unit mass, $\frac{\sum_i x_i (H_T^o)_i}{\mathcal{M}}$, cal/g

I specific impulse with ambient and exit pressures equal, (lb force)(sec)/lb mass

I_{vac} specific impulse in vacuum, (lb force)(sec)/lb mass

k coefficient of thermal conductivity, cal/(sec)(cm)(^oK)

M Mach number

$\mathcal{M}$ molecular weight, $\sum_i x_i \mathcal{M}_i$, g/g-mole or lb/lb-mole

n_{c^*} characteristic-velocity exponent, $\partial \ln c^* / \partial \ln P_c$

n_I specific-impulse exponent for fixed pressure ratio, $\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{P_c/P}$

$n_{I_{vac}}$ specific-impulse in vacuum exponent for fixed pressure ratio, $\left(\frac{\partial \ln I_{vac}}{\partial \ln P_c}\right)_{P_c/P}$

n_T temperature exponent for fixed pressure ratio, $\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{P_c/P}$

n_ϵ area-ratio exponent for fixed pressure ratio, $\left(\frac{\partial \ln \epsilon}{\partial \ln P_c}\right)_{P_c/P}$

O/F oxidant-fuel weight ratio

P static pressure (sum of partial pressures), lb/sq in. abs

p partial pressure, lb/sq in. abs

Q heat of formation or dissociation

R	equivalence ratio, ratio of two times the number of oxygen atoms to the number of hydrogen atoms, 2(O)/(H)
$\mathscr{R}$	universal gas constant (consistent units)
S_T°	entropy at a pressure of 1 atmosphere, cal/(mole)($^\circ$K)
s	entropy per unit mass, $\dfrac{\sum_i x_i \left[(S_T^\circ)_i - \mathscr{R} \ln(p_i/14.696)\right]}{\mathscr{M}}$, cal/(g)($^\circ$K)
T	temperature $^\circ$K
T^*	reduced temperature for viscosity calculations (temperature divided by force constant (ϵ/k), kT/ϵ
V	velocity, ft/sec
v	specific volume
w	mass-flow rate, lb/sec
x	mole fraction
γ	isentropic exponent, $\left(\dfrac{\partial \ln P}{\partial \ln \rho}\right)_s$
δ	correction term for polarity for viscosity calculations
ϵ	ratio of nozzle area to throat area
ϵ/k	force constant for viscosity calculation
μ	absolute viscosity, g/(cm)(sec) or poises
ρ	density, lb/cu in.
σ	collision diameter for viscosity calculation
$\Omega(2,2)^*$	function of T^*

Subscripts:

c	combustion chamber
e	nozzle exit

i	product of combustion
in	injector
P	constant pressure
P_c/P	constant pressure ratio
s	constant entropy
T	constant temperature
t	nozzle throat
1	reference point

Superscript:

o	thermodynamic standard reference state

CALCULATION OF PERFORMANCE DATA

Theoretical rocket performance data were obtained for liquid hydrogen with liquid oxygen for four chamber pressures over a wide range of oxidant-fuel ratios and pressure ratios assuming both equilibrium and frozen composition during expansion.

The computations were carried out by the method of reference 1 with modifications to adapt it for use with an IBM 650 Magnetic Drum Data-Processing Machine, with index accumulators, high-speed core, and floating-point attachments. The successive approximation process used in the calculations was continued until seven-figure accuracy was reached in the desired values of the assigned parameters (mass balance, pressure, and enthalpy or entropy).

Assumptions

The calculations were based on the following usual assumptions: perfect gas law, adiabatic combustion at constant pressure, isentropic expansion, no friction, homogeneous mixing, and one-dimensional flow. The products of combustion were assumed to be the following ideal gases: atomic hydrogen, H; hydrogen, H_2; water, H_2O; atomic oxygen, O; oxygen, O_2; and the hydroxyl radical, OH.

Initial Data

Thermodynamic data. - The ideal gas thermodynamic properties for atomic hydrogen, hydrogen, atomic oxygen, and oxygen were taken from reference 2. Data for water are also given in reference 2, however, the same data are given to more decimal places in reference 3, and therefore reference 3 data were used. The hydroxyl radical data were taken from reference 4. The values of entropy used in the present report do not include nuclear spin.

Heats of formation or dissociation. - The heats of formation or dissociation for the molecules considered in this report are given in the following table:

Reaction (all substances in gas phase)	Heat of formation or dissociation, Q		Temperature of reaction, °K	Reference
	cm^{-1}	cal/mole		
$Q + H_2 \rightarrow 2H$	36,116	103,263	0	5
$Q + O_2 \rightarrow 2O$	41,260	117,971	0	6
$H_2 + \frac{1}{2} O_2 \rightarrow H_2O + Q$	------	57,797.9	298.16	7
$Q + OH \rightarrow O + H$	35,450	101,359	0	8

Where values are given in centimeter^{-1}, they are converted by taking 1 centimeter^{-1} equivalent to 2.85921 calories per mole, calculated from data given in reference 9. The base used in this report for assigning absolute values to enthalpy is the same as in reference 1.

Viscosity data. - Viscosity data are needed for heat-transfer calculations; however, accurate data for gases at high temperatures are unavailable in the literature. Theoretical considerations of force fields lead to theoretical expressions for viscosity that fit available experimental data fairly well and therefore provide a basis upon which experimental data may be extrapolated into the higher temperature regions.

A detailed treatment of the derivation of various theoretical equations for viscosity is given in references 10 and 11. The use of these equations to obtain a refined numerical calculation of viscosity involves the selection of a force-field potential and considerable numerical work. Much of this numerical work can be saved by using tables of collision integrals such as those based on the Lennard-Jones 6-12 potential and the following equation (ref. 11):

$$\mu \times 10^7 = \frac{266.93\sqrt{MT}\, f_\mu^{(k)}}{\sigma^2 \Omega^{(2,2)*}} \tag{1}$$

The parameters $\Omega^{(2,2)*}$ and $f_\mu^{(k)}$ for nonpolar gases are tabulated in reference 11 as a function of reduced temperature T^* while $\Omega^{(2,2)*}$ for polar gases ($f_\mu^{(k)}$ assumed to be unity) is tabulated in reference 12 as a function of T^* and δ.

The force constants ϵ/k and σ for H_2, O_2, and H and ϵ/k, σ, and δ for H_2O were calculated from experimental viscosity data. No experimental viscosity data were found for O and OH. The value of σ for O was estimated from equations in reference 13, and the value of ϵ/k was taken to be equal to that of O_2. The values of σ and ϵ/k for OH were estimated from the following equations:

$$\sigma_{OH} = \frac{\sigma_{O_2} + \sigma_{H_2}}{2} \tag{2}$$

$$(\epsilon/k)_{OH} = \sqrt{(\epsilon/k)_{O_2}(\epsilon/k)_{H_2}} \tag{3}$$

The force constants selected are summarized in the following table:

Substance	σ, Å	ϵ/k, °K	δ	Reference
H	2.497	99.8		[a]14
H_2	2.729	86.1		[a]2
H_2O	3.487	126.3	2.409	[a]15
O	3.068	102.2		[b]13
O_2	3.490	102.2		[a]2
OH	3.110	93.8		(c)

[a]Calculated from data in reference given.

[b]σ Estimated from equations in reference given and ϵ/k assumed equal to that of O_2.

[c]Estimated by means of equations (2) and (3).

Physical and thermochemical data. - Several physical and thermochemical properties of the propellants are listed in table I. Additional properties of hydrogen may be found in references 16 and 17 while properties of oxygen may be found in reference 18.

FORMULAS

The formulas used in computing the various performance parameters are as follows:

Specific impulse with ambient and exit pressures equal, (lb force)(sec)/lb mass:

$$I = 294.98\sqrt{\frac{h_c - h_e}{1000}} \tag{4}$$

Specific impulse in vacuum, (lb force)(sec)/lb mass:

$$I_{vac} = I + P\left(\frac{A}{w}\right) \tag{5}$$

Nozzle area per unit mass-flow rate, (sq in.)(sec)/lb:

$$\frac{A}{w} = \frac{86.4554\ T}{P\mathcal{M}I} \tag{6}$$

Throat area per unit mass-flow rate, (sq in.)(sec)/lb:

$$\frac{A_t}{w} = \frac{2781.6\ T_t}{P_t \mathcal{M}_t a} \tag{7}$$

This equation is derived from the continuity equation and the fact that velocity of flow equals velocity of sound at the throat.

Velocity of sound, ft/sec:

$$a = \sqrt{\left(\frac{\partial P}{\partial \rho}\right)_s} = \sqrt{\frac{P}{\rho}\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s} = 299.16\sqrt{\left(\frac{T}{\mathcal{M}}\right)\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s} \tag{8}$$

Characteristic velocity, ft/sec:

$$c^* = g_c P_c \frac{A_t}{w} = 32.174\ P_c \frac{A_t}{w} \tag{9}$$

Coefficient of thrust:

$$C_F = \frac{g_c I}{c^*} = \frac{32.174\ I}{c^*} \tag{10}$$

Ratio of nozzle area to throat area

$$\epsilon = \frac{A/w}{A_t/w} \tag{11}$$

Partial Derivatives

The derivatives of the fundamental thermodynamic quantities have many useful applications. Equations (24) to (27) are examples of these applications.

All the relations between first derivatives may be expressed in terms of three arbitrary first derivatives in addition to the fundamental quantities. The three derivatives selected for this report are $(\partial h/\partial T)_P = c_p$, $(\partial \ln \mathscr{M}/\partial \ln T)_P$, and $(\partial \ln \mathscr{M}/\partial \ln P)_T$. Specific heat c_p is needed in heat-transfer calculations and the other two derivatives are a useful indication of the extent of dissociation.

These derivatives were obtained by means of the following equations:

$$c_p = \frac{1}{P\mathscr{M}T}\left[\sum_i p_i (H_T^o)_i \left(\frac{\partial \ln p_i}{\partial \ln T}\right)_P - \mathscr{A}h\left(\frac{\partial \ln \mathscr{A}}{\partial \ln T}\right)_P + T\sum_i p_i (C_P^o)_i\right] \tag{12}$$

$$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln P}\right)_T = \frac{P}{\sum_i p_i \left(\frac{\partial \ln p_i}{\partial \ln \mathscr{A}}\right)_T} - 1 \tag{13}$$

$$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_P = \left(\frac{\partial \ln \mathscr{A}}{\partial \ln T}\right)_P \tag{14}$$

where $(\partial \ln p_i/\partial \ln T)_P$, $(\partial \ln \mathscr{A}/\partial \ln T)_P$, and $(\partial \ln p_i/\partial \ln \mathscr{A})_T$ are found by matrix methods similar to those described for obtaining $(\partial \ln p_i/\partial \ln T)_s$ in reference 1, and where $\mathscr{A}$ is A in reference 1.

Reference 19 presents a convenient scheme for expressing all first derivatives in terms of $(\partial v/\partial T)_P$, $(\partial v/\partial P)_T$, and $(\partial h/\partial T)_P = c_p$. By means

of the following equations, $(\partial v/\partial T)_P$ and $(\partial v/\partial P)_T$ can be obtained from the derivatives given in this report:

$$\left(\frac{\partial v}{\partial T}\right)_P = -\frac{v}{T}\left[\left(\frac{\partial \ln \mathcal{M}}{\partial \ln T}\right)_P - 1\right] \tag{15}$$

$$\left(\frac{\partial v}{\partial P}\right)_T = -\frac{v}{P}\left[\left(\frac{\partial \ln \mathcal{M}}{\partial \ln P}\right)_T + 1\right] \tag{16}$$

With the aid of the tables in reference 19 and equations (15) and (16), other first derivatives can be expressed in terms of c_p, $(\partial \ln \mathcal{M}/\partial \ln T)_P$, and $(\partial \ln \mathcal{M}/\partial \ln P)_T$. Some examples are,

$$c_v = c_p - \frac{\mathcal{R}}{\mathcal{M}} \frac{\left[1 - \left(\frac{\partial \ln \mathcal{M}}{\partial \ln T}\right)_P\right]^2}{1 + \left(\frac{\partial \ln \mathcal{M}}{\partial \ln P}\right)_T} \tag{17}$$

$$\gamma = \left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s = \frac{c_p}{c_p\left[1 + \left(\frac{\partial \ln \mathcal{M}}{\partial \ln P}\right)_T\right] - \frac{\mathcal{R}}{\mathcal{M}}\left[1 - \left(\frac{\partial \ln \mathcal{M}}{\partial \ln T}\right)_P\right]^2} \tag{18}$$

or

$$\gamma = \frac{c_p}{c_v}\left[\frac{1}{1 + \left(\frac{\partial \ln \mathcal{M}}{\partial \ln P}\right)_T}\right] \tag{19}$$

When composition is frozen,

$$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln P}\right)_T = \left(\frac{\partial \ln \mathcal{M}}{\partial \ln T}\right)_P = 0 \tag{20}$$

and equations (17) and (18) reduce to

$$c_v = c_p - \frac{\mathcal{R}}{\mathcal{M}}$$

and

$$\gamma = \frac{c_p}{c_p - \frac{\mathcal{R}}{\mathcal{M}}} = \frac{c_p}{c_v} \tag{21}$$

Viscosity of Mixtures

Viscosities of multicomponent mixtures calculated by rigorous methods (refs. 11 and 20) show excellent agreement with experimental data. However, these calculations involve considerable effort and become increasingly more difficult with increasing number of components. Simpler techniques, but which still involve considerable calculations, are given in references 21 and 22.

The following equation, based on averaging kinematic viscosities, gives approximate results, which are often sufficiently accurate for engineering purposes:

$$\mu = \frac{\mathscr{M}}{\sum_i \frac{x_i \mathscr{M}_i}{\mu_i}} \tag{22}$$

The equation appears adequate until better high-temperature data for the individual components become available.

Conductivity

Thermal conductivities as well as viscosities are needed in heat-transfer calculations. However, experimental conductivity data are generally even less available than experimental viscosity data. Therefore, the Eucken relation

$$k = \mu\left(c_p + \frac{5}{4}\frac{\mathscr{R}}{\mathscr{M}}\right) \tag{23}$$

which often gives satisfactory values of conductivity for individual components, is used in this report to estimate the conductivity of gaseous mixtures.

THEORETICAL PERFORMANCE DATA

Tables

The calculated values of the various performance parameters for combustion pressures of 60, 150, 300, and 600 pounds per square inch absolute and for a range of equivalence ratios and exit conditions are given in tables II to V. Table II presents performance data at assigned pressure ratios from 1 to 4000 for equivalence ratios from 0.15 to 5.00 (oxidant-fuel weight ratios from 1.190 to 39.683). Properties at the throat may be found where $\epsilon = 1.00$. Table III gives various thermodynamic partial

derivatives. Equilibrium composition in the combustion chamber and at the assigned exit conditions is given in table IV. Characteristic velocity and summary of the performance parameters at an exit pressure of 1 atmosphere are presented in table V.

Curves

The performance parameters are plotted in figures 1 to 8. Curves of specific impulse are presented in figure 1 for assigned pressure ratios as functions of percent by weight of fuel. Combustion temperature and exit temperature for assigned pressure ratios are plotted in figure 2 as functions of percent by weight of fuel. Curves of the ratio of nozzle area to throat area are plotted in figure 3 as functions of percent by weight of fuel for assigned pressure ratios. Figure 4 gives the curves for coefficient of thrust for assigned pressure ratios as functions of percent by weight of fuel; figure 5 presents curves of molecular weight for assigned pressure ratios; and figure 6 presents curves of characteristic velocity as functions of percent by weight of fuel. Figure 7 gives curves of specific impulse in vacuum for assigned area ratios as functions of percent by weight of fuel. The curves of figure 7 were obtained by interpolation of the data at assigned pressure ratios.

Effect of Assuming Frozen or Equilibrium Composition During Expansion

A comparison of specific impulse data based on equilibrium and frozen composition during expansion to an exit pressure of 1 atmosphere is given in figure 8. A comparison of maximum calculated values of specific impulse based on equilibrium and frozen composition during expansion is shown in the following table for expansion to 1 atmosphere and to pressure ratios of 100 and 4000 (taken from table II):

Chamber pressure, P_c, lb/sq in. abs	Pressure ratio, P_c/P	Equivalence ratio, R, at which I is maximum	Oxidant-fuel weight ratio, O/F	Composition during expansion	Maximum specific impulse, I, $\frac{(lb)(sec)}{lb}$	Difference in I, percent
60	4.083	0.35 .35	2.778 2.778	Equilibrium Frozen	255.4 254.6	0.31
	100	0.45 .40	3.571 3.175	Equilibrium Frozen	400.8 394.2	1.67
	4000	0.70 .40	5.556 3.175	Equilibrium Frozen	465.9 448.8	3.81
150	10.207	0.40 .35	3.175 2.778	Equilibrium Frozen	315.0 313.1	0.61
	100	0.50 .40	3.968 3.175	Equilibrium Frozen	401.3 395.7	1.42
	4000	0.70 .45	5.556 3.571	Equilibrium Frozen	466.6 451.4	3.37
300	20.414	0.45 .40	3.571 3.175	Equilibrium Frozen	348.1 345.8	0.67
	100	0.50 .40	3.968 3.175	Equilibrium Frozen	401.5 396.6	1.24
	4000	0.70 .45	5.556 3.571	Equilibrium Frozen	467.0 453.3	3.02
600	40.827	0.50 .40	3.968 3.175	Equilibrium Frozen	374.5 371.8	0.73
	100	0.50 .45	3.968 3.571	Equilibrium Frozen	401.7 397.5	1.06
	4000	0.70 .50	5.556 3.968	Equilibrium Frozen	467.4 454.9	2.75

The preceding table shows that for pressure ratios up to 100, the difference in maximum specific impulse due to equilibrium or frozen composition during expansion is less than 2 percent. For a pressure ratio of 4000 the difference increases to 3 to 4 percent. However, the maximum specific impulse occurs in general at a higher oxidant-fuel ratio O/F for equilibrium composition than for frozen composition.

A comparison of values specific impulse for frozen and equilibrium composition at the same O/F ould show larger differences. For example, from data in table II, for amber pressure of 60 pounds per square inch

absolute, a pressure ratio of 4000, an O/F of 5.556 (where equilibrium specific impulse is maximum) the difference in specific impulse for frozen and equilibrium composition is 9.6 percent. For the same conditions but for the stoichiometric O/F of 7.937, the difference is 15.8 percent. This is the largest difference between frozen and equilibrium specific impulse at constant O/F for any of the conditions in this report.

The O/F for maximum specific impulse increases with increasing pressure ratio. For fixed pressure ratios and frozen composition the O/F for maximum specific impulse increases with increasing chamber pressure.

Effect of Chamber Pressure

By use of suitable exponents, performance parameters can be estimated with good accuracy at chamber pressures other than those given in this report. The logarithmic values of the parameters I, I_{vac}, T, ϵ, and c^* are very nearly linear with the logarithm of chamber pressure for a fixed equivalence ratio and pressure ratio or fixed equivalence ratio and area ratio. This linearity permits the data to be extended by means of exponential equations.

In the case of equilibrium composition, the following analytic expressions were derived that permit the exponents to be computed from data at a single chamber pressure:

$$n_I = \left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{P_c/P} = 86.4554 \frac{T}{I^2}\left(\frac{1}{\mathscr{M}_c} - \frac{1}{\mathscr{M}}\right) \tag{24}$$

$$n_T = \left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{P_c/P} = \frac{\mathscr{R}}{\mathscr{M} c_p}\left[1 - \left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_P\right] - \frac{\mathscr{R}}{c_p \mathscr{M}_c} \tag{25}$$

$$n_\epsilon = \left(\frac{\partial \ln \epsilon}{\partial \ln P_c}\right)_{P_c/P} = (n_{A/w})_e - (n_{A/w})_t \tag{26}$$

where

$$n_{A/w} = \left(\frac{\partial \ln A/w}{\partial \ln P_c}\right)_{P_c/P} = -\frac{\mathscr{R}}{c_p \mathscr{M}_c}\left[1 - \left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_P\right] - \frac{1}{\gamma} - n_I$$

$$n_{c^*} = \frac{\partial \ln c^*}{\partial \ln P_c} = 1 + (n_{A/w})_t \tag{27}$$

$$n_{I_{vac}} = \left(\frac{\partial \ln I_{vac}}{\partial \ln P_c}\right)_{P_c/P} = \frac{I(n_I - n_{c^*} - n_\epsilon)}{I_{vac}} + n_{c^*} + n_\epsilon \qquad (28)$$

Equations (24) to (28) may be written in the approximate form:

$$I = I_1\left(\frac{P_c}{P_{c,1}}\right)^{n_{I,1}} \qquad (29)$$

$$T = T_1\left(\frac{P_c}{P_{c,1}}\right)^{n_{T,1}} \qquad (30)$$

$$\epsilon = \epsilon_1\left(\frac{P_c}{P_{c,1}}\right)^{n_{\epsilon,1}} \qquad (31)$$

$$c^* = c_1^*\left(\frac{P_c}{P_{c,1}}\right)^{n_{c^*,1}} \qquad (32)$$

$$I_{vac} = I_{vac,1}\left(\frac{P_c}{P_{c,1}}\right)^{n_{I_{vac},1}} \qquad (33)$$

where $P_{c,1}$ may be either 60, 150, 300, or 600 pounds per square inch absolute provided that I_1, T_1, ϵ_1, c_1^*, $I_{vac,1}$, and their derivatives are the corresponding values for the chamber pressure selected.

The exponents obtained by means of equations (24) to (28) are shown in table III.

In order to illustrate the use of these derivatives, suppose it is desired to obtain the value of equilibrium specific impulse for a chamber pressure of 1200 pounds per square inch absolute and a pressure ratio of 81.65 (exit pressure, 1 atm) for an equivalence ratio R of 0.90 (O/F = 7.143): From table III, the value of I at this pressure ratio and equivalence ratio (but for a chamber pressure of 600 lb/sq in. abs) is 376.8 and the value of n_I is 0.0079. From equation (29),

$$I = 376.8\left(\frac{1200}{600}\right)^{0.0079}$$

$$= 376.8(1.0055)$$

$$= 378.9$$

A comparison of the parameters obtained by means of the chamber-pressure correlation and by a direct calculation is given in the following table (R = 0.90, equilibrium composition during expansion):

Parameter	Chamber pressure, P_c, 1200 lb/sq in. abs; Exit pressure, P, 1 atm		
	Estimated by correlation	Direct calculation	Error
I	378.93	378.86	0.07
T_c	3623.3	3622.0	1.3
T_e	2338.4	2338.6	.2
ϵ	11.769	11.755	.014
c^*	7306.1	7304.7	1.4

It is expected that values estimated for other equivalence ratios and pressure ratios for chamber pressures from about 30 to 1200 pounds per square inch absolute will have small errors of the order of magnitude shown in the previous table.

The following analytic expressions were derived for equilibrium composition which permit exponents to be computed similar to those in equations (24) to (28) but for constant area ratio rather than constant pressure ratio (eqs. 34, 37, 38, 40):

$$\left(\frac{\partial \ln P_c/P}{\partial \ln P_c}\right)_\epsilon = n_\epsilon \Big/ \left(\frac{\partial \ln \epsilon}{\partial \ln P}\right)_s \tag{34}$$

where

$$\left(\frac{\partial \ln \epsilon}{\partial \ln P}\right)_s = -\frac{1}{\gamma} - \left(\frac{\partial \ln I}{\partial \ln P}\right)_s \tag{35}$$

and

$$\left(\frac{\partial \ln I}{\partial \ln P}\right)_s = -86.4554 \frac{T}{I^2 \mathcal{M}} \quad \text{or} \quad 1 - \frac{I_{vac}}{I} \tag{36}$$

$$\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_\epsilon = n_I - \left(\frac{\partial \ln I}{\partial \ln P}\right)_s \left(\frac{\partial \ln P_c/P}{\partial \ln P_c}\right)_\epsilon \tag{37}$$

$$\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_\epsilon = n_T - \left(\frac{\partial \ln T}{\partial \ln P}\right)_s \left(\frac{\partial \ln P_c/P}{\partial \ln P_c}\right)_\epsilon \tag{38}$$

where

$$\left(\frac{\partial \ln T}{\partial \ln P}\right)_s = \frac{\mathcal{R}}{\mathcal{M} c_p} \left[1 - \left(\frac{\partial \ln \mathcal{M}}{\partial \ln T}\right)_P\right] \tag{39}$$

$$\left(\frac{\partial \ln I_{vac}}{\partial \ln P_c}\right)_\epsilon = n_{I_{vac}} - \left(\frac{\partial \ln I_{vac}}{\partial \ln P}\right)_s \left(\frac{\partial \ln P_c/P}{\partial \ln P_c}\right)_\epsilon \tag{40}$$

$$= \frac{I(n_I - n_c*)}{I_{vac}} + n_c*$$

where

$$\left(\frac{\partial \ln I_{vac}}{\partial \ln P}\right)_s = \left(\frac{\partial \ln \epsilon}{\partial \ln P}\right)_s \left(1 - \frac{I}{I_{vac}}\right) \tag{41}$$

Data for constant area ratios for chamber pressures other than those given in this report may be obtained in a manner similar to the previous example by interpolating the data in table II (see, for example, fig. 7) together with exponents obtained from equations (34) to (41).

Effect of Finite Chamber Area

The use of a combustion chamber of finite cross-sectional area leads to a pressure change during the combustion process. For a cylindrical

chamber, the injector face pressure P_{in} may be found from the following equation derived from the conservation of the momentum

$$P_{in} = P_l + \frac{w}{A_l g_c} (V_l - V_{in}) \tag{42}$$

where P_l and V_l are the static pressure and velocity at the nozzle entrance, respectively, and V_{in} is the average velocity of propellant (liquid or gas) in the axial direction when injected. Equation (42) may be written

$$P_{in} = P_c \left(\frac{P_l}{P_c}\right)(I_l g_c - V_{in}) \tag{43}$$

where P_c is the stagnation pressure in the nozzle.

In order to illustrate this, consider a rocket operating at an equivalence ratio of 1.00, a nozzle stagnation pressure of 600 pounds per square inch absolute, a ratio of chamber area to throat area ϵ of 2.122, and V_{in} = 100 feet per second. From table II, corresponding to an area ratio of 2.122, P_c/P_l is 1.05 and I is 43.3. From table V, c^* is 7039. Therefore, for these conditions, using equation (43),

$$P_{in} = 600\left(\frac{1}{1.05}\right) + \frac{600}{7039(2.122)} [(43.3)(32.17) - 100]$$

$$= 571.4 + 51.9$$

$$= 623.3 \text{ lb/sq in. abs}$$

SUMMARY OF RESULTS

A theoretical investigation of the performance of liquid hydrogen with liquid oxygen was made for the following conditions: (1) equilibrium and frozen composition during expansion, (2) four chamber pressures (60, 150, 300, and 600 lb/sq in. abs), (3) wide range of oxidant-fuel weight ratios (1.190 to 39.683), and (4) wide range of pressure ratios (1 to 4000).

1. The maximum values of specific impulse for expansion to 1 atmosphere are summarized in the following table:

Chamber pressure, P_c, lb/sq in. abs	Ratio of chamber pressure to exit pressure, P_c/P	Specific impulse, I, (lb)(sec)/lb	
		Equilibrium composition	Frozen composition
60	4.083	255.4	254.6
150	10.207	315.0	313.1
300	20.414	348.1	345.8
600	40.827	374.5	371.8

The maximum value of specific impulse for a chamber pressure of 600 pounds per square inch absolute and a pressure ratio of 4000 is 467.4 and 454.9 assuming equilibrium and frozen composition, respectively.

2. The difference between maximum values of specific impulse due to the assumption of equilibrium or frozen composition during expansion is less than 2 percent for pressure ratios up to 100 and about 3 to 4 percent for a pressure ratio of 4000.

3. For the same oxidant-fuel ratios, the difference between values of specific impulse due to the assumption of equilibrium or frozen composition during expansion may be as high as 15.8 percent for the conditions in this report.

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio, March 2, 1959

REFERENCES

1. Huff, Vearl N., Gordon, Sanford, and Morrell, Virginia E.: General Method and Thermodynamic Tables for Computation of Equilibrium Composition and Temperature of Chemical Reactions. NACA Rep. 1037, 1951. (Supersedes NACA TN's 2113 and 2161.)

2. Hilsenrath, Joseph, et al: Tables of Thermal Properties of Gases. Cir. 564, NBS, Nov. 1, 1955.

3. Friedman, Abraham S., and Haar, Lester: High Speed Machine Computations of Ideal Gas Thermodynamic Functions. I. The Isotopic Water Molecules. Jour. Chem. Phys. vol. 22, no. 12, Dec. 1954, pp. 2051-2058.

4. Haar, Lester, and Friedman, A. S.: High-Speed Machine Computations of Ideal Gas Thermodynamic Functions. II. The Diatomic Free Radicals of the Isotopic Hydrides of Oxygen and Sulfur. Jour. Chem. Phys., vol. 23, no. 5, May 1955, pp. 869-875.

5. Beutler, H., and Jünger, H. O.: Die Bindungsfestigkeiten im H_2-Molekül. Zs. f. Phys., Bd. 101, Heft 56, July 1936, pp. 304-310.

6. Brix, P., and Herzberg, G.: Fine Structure of the Schumann-Runge Bands Near the Convergence Limit and the Dissociation Energy of the Oxygen Molecule. Canadian Jour. Phys., vol. 32, no. 2, Feb. 1954, pp. 110-135.

7. Rossini, Frederick D., et al: Selected Values of Chemical Thermodynamic Properties. Cir. 500, NBS, Feb. 1952.

8. Barrow, R. F.: The $B^2\Sigma^+ - A^2\Sigma^+$ Band-Systems of OH and OD. Arkiv f. Phys., Bd. 11, Nr. 19, 1956, pp. 281-290.

9. DuMond, Jesse W. M., and Cohen, E. Richard: Least-Squares Adjustment of the Atomic Constants, 1952. Rev. Modern Phys., vol. 25, no. 3, July 1953, pp. 691-708.

10. Chapman, Sydney, and Cowling, T. G.: The Mathematical Theory of Non-Uniform Gases. Second ed., Cambridge Univ. Press, 1952.

11. Hirschfelder, Joseph O., Curtiss, Charles F., and Bird, R. Byron: Molecular Theory of Gases and Liquids. John Wiley & Sons, Inc., 1954.

12. Krieger, F. J.: The Viscosity of Polar Gases. RM-646, The RAND Corp., July 1, 1951.

13. Hirschfelder, Joseph O., and Eliason, Morton A.: The Estimation of the Transport Properties for Electronically Excited Atoms and Molecules. Tech. Rep. WIS-AF-1, Naval Res. Lab., Univ. Wisconsin, May 14, 1956. (Contract AF-33(616)-3414.)

14. Amdur, I.: Viscosity and Diffusion Coefficients of Atomic Hydrogen and Atomic Deuterium. Jour. Chem. Phys., vol. 4, no. 6, June 1936, pp. 339-343.

15. Bonilla, Charles F., Brooks, Robert D., and Walker, Philip L., Jr.: The Viscosity of Steam and of Nitrogen at Atmospheric Pressure and High Temperatures. Paper presented at General Discussion on Heat Transfer Conf. (London), Sept. 11-13, 1951.

16. Woolley, Harold W., Scott, Russell B., and Brickwedde, F. G.: Compilation of Thermal Properties of Hydrogen in Its Various Isotopic and Ortho-Para Modifications. Jour. Res. Nat. Bur. Standards, vol. 41, no. 5, Nov. 1948, pp. 379-475.

17. Anon.: Physical Properties and Thermodynamic Functions of Fuels, Oxidizers, and Products of Combustion. I - Fuels. R-127, The Rand Corp., Jan. 1949.

18. Anon.: Physical Properties and Thermodynamic Functions of Fuels, Oxidizers, and Products of Combustion. II - Oxidizers. R-129, The Rand Corp., Feb. 1949.

19. Bridgman, P. W.: A Complete Collection of Thermodynamic Formulas. Phys. Rev., 2nd. ser., vol. III, no. 4, Apr. 1914, pp. 273-281.

20. Hirschfelder, Joseph O., Bird, R. Byron, and Spotz, Ellen L.: The Transport Properties of Gases and Gaseous Mixtures, II. Chem. Rev., vol. 44, no. 1, Feb. 1949, pp. 205-231.

21. Bromley, L. A., and Wilke, C. R.: Viscosity Behavior of Gases. Ind. and Eng. Chem., vol. 43, no. 7, July 1951, pp. 1641-1648.

22. Brokaw, Richard S.: Approximate Formulas for the Viscosity and Thermal Conductivity of Gas Mixtures. Jour. Chem. Phys., vol. 29, no. 2, Aug. 1958, pp. 391-397.

23. Washburn, Edward W., ed.: International Critical Tables. Vol. I. McGraw-Hill Book Co., Inc., 1926.

24. Washburn, Edward W., ed.: International Critical Tables. Vol. III. McGraw-Hill Book Co., Inc., 1928.

25. Hodgman, Charles D., ed.: Handbook of Chemistry and Physics. Thirty-Eighth ed., Chem. Rubber Pub. Co., 1956-1957.

TABLE I. - PROPERTIES OF LIQUID PROPELLANTS

Properties	Hydrogen	Oxygen
Molecular weight, M	2.016	32.00
Density, g/cc	[a]0.0709 (at -252.7° C)	[b]1.1414 (at -182.0° C)
Freezing point, °C	[c]-259.20	[c]-218.76
Boiling point, °C	[c]-252.77	[c]-182.97
Enthalpy required to convert liquid at boiling point to gaseous elements at 25° C, kcal/mole	[d]1.894	[d]3.081
Enthalpy of vaporization, kcal/mole	[c]0.216 (at -252.77° C)	[c]1.630 (at -182.97° C)
Enthalpy of fusion, kcal/mole	[c]0.028 (at -259.20° C)	[c]0.106 (at -218.76° C)

[a]Ref. 23.

[b]Ref. 24.

[c]Ref. 7.

[d]Ref. 1.

TABLE II. - THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Combustion-chamber pressure, 60 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/lb
R = 0.150, PERCENT FUEL = 45.65, O/F = 1.190													
1.00	60.00	1183	9313.5	4.416	1.3395	1.7753	314	0.00073	0.000			0.000	0.0
1.05	57.14	1166	9287.7	4.416	1.3408	1.7711	311	.00073	.271	550.1	2.250	.210	47.4
1.20	50.00	1129	9216.6	4.416	1.3436	1.7597	303	.00070	.527	534.2	1.297	.403	90.8
1.40	42.86	1085	9141.8	4.416	1.3469	1.7472	293	.00068	.722	496.1	1.081	.543	122.2
1.60	37.50	1049	9077.7	4.416	1.3497	1.7369	285	.00066	.860	486.6	1.018	.636	143.2
1.87	32.17	1008	9006.6	4.416	1.3527	1.7257	276	.00063	1.000	484.1	1.000	.725	163.4
2.00	30.00	989	8975.4	4.416	1.3540	1.7210	272	.00062	1.059	484.4	1.003	.761	171.5
4.00	15.00	824	8693.4	4.416	1.3631	1.6865	234	.00052	1.566	501.7	1.233	1.031	232.3
4.08	14.70	819	8683.8	4.416	1.3634	1.6856	232	.00052	1.579	502.3	1.244	1.038	233.7
10.00	6.00	643	8392.5	4.416	1.3748	1.6507	188	.00042	2.152	527.5	1.974	1.257	283.1
20.00	3.00	532	8209.8	4.416	1.3800	1.6343	159	.00035	2.586	543.5	2.983	1.376	309.9
40.00	1.50	439	8058.9	4.416	1.3824	1.6206	133	.00029	3.031	556.4	4.620	1.467	330.4
100.00	.60	340	7899.0	4.416	1.3800	1.6099	104	.00023	3.648	569.8	8.432	1.558	350.8
200.00	.30	280	7802.6	4.416	1.3930	1.5951	85	.00018	4.148	577.7	13.431	1.610	362.6
400.00	.15	230	7723.2	4.416	1.4064	1.5573	70	.00015	4.675	584.1	21.488	1.652	372.0
1000.00	.06	175	7640.1	4.416	1.4339	1.4871	55	.00011	5.440	590.6	39.928	1.694	381.6
2000.00	.03	142	7590.9	4.416	1.4544	1.4402	45	.00009	6.098	594.3	63.572	1.719	387.2
4000.00	.02	114	7551.2	4.416	1.4680	1.4116	36	.00007	6.851	597.3	100.939	1.739	391.6
R = 0.200, PERCENT FUEL = 38.65, O/F = 1.587													
1.00	60.00	1514	2969.7	5.216	1.3077	1.6194	404	0.00084	0.000			0.000	0.0
1.05	57.14	1497	2941.7	5.216	1.3088	1.6149	399	.00083	.274	552.1	2.233	.209	49.3
1.20	50.00	1450	2866.8	5.216	1.3119	1.6028	384	.00081	.533	548.6	1.289	.400	94.6
1.40	42.86	1398	2783.1	5.216	1.3154	1.5891	368	.00078	.730	509.3	1.077	.539	127.4
1.60	37.50	1354	2713.2	5.216	1.3184	1.5774	354	.00076	.869	499.6	1.016	.632	149.4
1.85	32.49	1307	2640.5	5.216	1.3217	1.5653	339	.00073	1.000	497.3	1.000	.716	169.2
2.00	30.00	1282	2601.1	5.216	1.3235	1.5585	333	.00072	1.068	497.8	1.004	.757	179.1
4.00	15.00	1079	2290.0	5.216	1.3391	1.5046	307	.00061	1.572	516.7	1.244	1.029	243.2
4.08	14.70	1073	2281.6	5.216	1.3395	1.5031	306	.00061	1.585	517.4	1.256	1.035	244.7
10.00	6.00	852	1954.3	5.216	1.3559	1.4516	251	.00048	2.148	544.7	2.009	1.257	297.2
20.00	3.00	709	1748.8	5.216	1.3686	1.4232	213	.00040	2.573	562.0	3.049	1.379	325.9
40.00	1.50	588	1578.0	5.216	1.3814	1.4067	179	.00034	3.010	576.0	4.739	1.472	348.0
100.00	.60	458	1396.3	5.216	1.3970	1.3918	142	.00026	3.619	590.5	8.679	1.565	370.0
200.00	.30	379	1280.1	5.216	1.4081	1.3807	117	.00022	4.111	599.1	13.870	1.619	382.7
400.00	.15	312	1179.2	5.216	1.4209	1.3681	96	.00018	4.658	608.1	22.296	1.662	393.0
1000.00	.06	242	1068.9	5.216	1.3973	1.3398	74	.00013	5.394	618.4	41.979	1.706	403.5
2000.00	.03	198	1041.1	5.216	1.4148	1.2794	61	.00011	6.015	617.7	67.667	1.733	409.7
4000.00	.02	161	993.9	5.216	1.4392	1.2384	50	.00009	6.704	621.1	108.755	1.754	414.6
R = 0.250, PERCENT FUEL = 33.51, O/F = 1.984													
1.00	60.00	1816	1249.3	6.015	1.2812	1.5088	481	0.00092	0.000			0.000	0.0
1.05	57.14	1797	1220.2	6.016	1.2824	1.5036	477	.00091	.277	563.4	2.218	.207	50.3
1.20	50.00	1744	1142.1	6.016	1.2855	1.4898	467	.00089	.538	550.2	1.283	.398	96.6
1.40	42.86	1686	1059.8	6.016	1.2889	1.4751	456	.00086	.736	516.3	1.073	.536	130.1
1.60	37.50	1636	981.5	6.016	1.2919	1.4630	446	.00084	.878	506.0	1.015	.629	152.6
1.83	32.78	1587	910.0	6.016	1.2948	1.4513	436	.00081	1.000	504.5	1.000	.708	171.8
2.00	30.00	1555	864.0	6.016	1.2968	1.4436	429	.00080	1.076	505.1	1.005	.754	182.1
4.00	15.00	1322	535.1	6.016	1.3125	1.3875	378	.00066	1.578	525.5	1.236	1.026	249.3
4.08	14.70	1316	526.2	6.016	1.3129	1.3860	377	.00066	1.592	526.2	1.248	1.033	250.8
10.00	6.00	1057	176.1	6.016	1.3329	1.3226	314	.00054	2.147	553.3	2.048	1.258	305.6
20.00	3.00	887	9954.0	6.016	1.3461	1.2848	269	.00046	2.563	573.7	3.127	1.382	335.7
40.00	1.50	741	9766.1	6.016	1.3569	1.2559	228	.00038	2.987	588.7	4.883	1.478	359.0
100.00	.60	581	9569.1	6.016	1.3663	1.2321	191	.00030	3.581	604.2	8.985	1.574	382.4
200.00	.30	482	9447.8	6.016	1.3717	1.2190	171	.00025	4.063	613.4	14.296	1.630	395.9
400.00	.15	399	9347.3	6.016	1.3759	1.2100	155	.00020	4.581	620.9	23.208	1.675	406.8
1000.00	.06	310	9240.5	6.016	1.3823	1.1943	93	.00015	5.327	628.7	43.894	1.721	418.1
2000.00	.03	256	9175.9	6.016	1.3866	1.1803	78	.00012	5.945	633.4	71.279	1.749	424.7
4000.00	.02	210	9122.7	6.016	1.3903	1.1687	64	.00010	6.606	637.2	115.650	1.771	430.2
R = 0.300, PERCENT FUEL = 29.57, O/F = 2.381													
1.00	60.00	2089	9932.7	6.812	1.2550	1.4578	550	0.00100	0.000			0.000	0.0
1.05	57.14	2069	9903.2	6.812	1.2564	1.4493	546	.00099	.279	568.2	2.204	.206	50.7
1.20	50.00	2015	9823.7	6.813	1.2602	1.4278	536	.00096	.543	559.6	1.277	.395	97.4
1.40	42.86	1950	9734.6	6.814	1.2644	1.4052	525	.00093	.742	519.7	1.070	.533	131.3
1.60	37.50	1896	9659.7	6.815	1.2679	1.3879	515	.00090	.883	510.2	1.013	.629	154.1
1.82	33.04	1846	9590.7	6.815	1.2711	1.3729	505	.00088	1.000	508.3	1.000	.700	172.5
2.00	30.00	1808	9539.6	6.815	1.2734	1.3623	498	.00086	1.083	509.0	1.006	.751	185.1
4.00	15.00	1533	9200.0	6.816	1.2870	1.3006	443	.00074	1.585	530.5	1.256	1.024	252.5
4.08	14.70	1526	9190.8	6.816	1.2879	1.2992	443	.00074	1.598	531.3	1.278	1.031	254.1
10.00	6.00	1228	8822.6	6.818	1.3074	1.2537	373	.00060	2.148	561.8	2.085	1.259	310.4
20.00	3.00	1064	8591.4	6.818	1.3248	1.2191	323	.00051	2.555	581.2	3.207	1.386	341.6
40.00	1.50	896	8393.8	6.818	1.3384	1.1931	279	.00042	2.968	597.0	5.038	1.485	365.9
100.00	.60	708	8180.5	6.818	1.3530	1.1674	233	.00033	3.545	613.5	9.326	1.584	390.5
200.00	.30	590	8049.6	6.818	1.3604	1.1006	207	.00027	4.013	623.3	14.995	1.642	404.8
400.00	.15	490	7940.9	6.818	1.3667	1.0867	186	.00023	4.516	631.2	24.237	1.689	416.3
1000.00	.06	383	7824.9	6.818	1.3725	1.0745	120	.00017	5.246	639.6	46.005	1.738	428.3
2000.00	.03	317	7754.4	6.818	1.3773	1.0643	98	.00014	5.851	644.6	74.922	1.766	435.4
4000.00	.02	262	7696.1	6.818	1.3831	1.0526	80	.00011	6.509	648.7	122.202	1.790	441.2

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Continued. Combustion-chamber pressure, 60 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/(lb)
R = 0.350, PERCENT FUEL = 26.47, O/F = 2.778													
1.00	60.00	2329	8892.8	7.597	1.2267	1.4897	608	0.00010	0.000			0.000	0.0
1.05	57.14	2309	8863.2	7.599	1.2284	1.4752	605	.00009	.282	568.4	2.189	.204	50.7
1.20	50.00	2253	8783.6	7.602	1.2330	1.4362	595	.00005	.548	560.3	1.270	.393	97.5
1.40	42.86	2189	8694.1	7.606	1.2382	1.3999	585	.00001	.749	520.7	1.067	.530	131.5
1.60	37.50	2133	8618.7	7.608	1.2425	1.3707	575	.00098	.890	511.4	1.012	.622	154.4
1.80	33.32	2085	8553.6	7.610	1.2462	1.3475	566	.00095	1.000	509.7	1.000	.692	171.8
2.00	30.00	2042	8497.1	7.611	1.2494	1.3289	559	.00092	1.090	510.6	1.007	.747	185.6
4.00	15.00	1772	8152.4	7.615	1.2679	1.2391	506	.00079	1.589	533.1	1.277	1.022	253.8
4.08	14.70	1764	8143.0	7.615	1.2684	1.2371	504	.00079	1.603	533.8	1.289	1.029	255.4
10.00	6.00	1452	7768.0	7.616	1.2882	1.1665	434	.00065	2.147	565.5	2.121	1.260	312.8
20.00	3.00	1239	7520.0	7.616	1.3035	1.1208	381	.00055	2.648	585.8	3.285	1.389	345.0
40.00	1.50	1051	7316.3	7.616	1.3187	1.0795	330	.00046	2.951	602.4	5.194	1.491	370.1
100.00	.60	838	7093.2	7.616	1.3364	1.0366	268	.00036	3.309	619.8	9.687	1.594	395.7
200.00	.30	703	6954.1	7.616	1.3474	1.0120	226	.00030	3.962	630.1	15.643	1.654	410.7
400.00	.15	587	6837.8	7.616	1.3552	.9934	189	.00025	4.451	638.6	25.377	1.703	422.9
1000.00	.06	460	6713.2	7.616	1.3634	.9790	148	.00019	5.159	647.5	48.339	1.754	435.5
2000.00	.03	382	6637.2	7.616	1.3683	.9694	121	.00016	5.748	652.8	78.934	1.784	443.0
4000.00	.02	317	6574.1	7.616	1.3733	.9600	98	.00013	6.389	657.2	129.082	1.809	449.2
R = 0.400, PERCENT FUEL = 23.95, O/F = 3.175													
1.00	60.00	2531	8050.5	8.363	1.1996	1.6075	656	0.00025	0.000			0.000	0.0
1.05	57.14	2512	8021.3	8.366	1.2011	1.5870	653	.00023	.286	565.1	2.173	.203	50.4
1.20	50.00	2458	7942.5	8.374	1.2055	1.5334	645	.00018	.554	558.7	1.263	.390	96.9
1.40	42.86	2396	7855.8	8.383	1.2107	1.4758	635	.00013	.756	519.7	1.063	.526	130.8
1.60	37.50	2342	7778.8	8.389	1.2153	1.4300	626	.00008	.898	510.8	1.010	.618	153.8
1.78	33.62	2298	7716.8	8.393	1.2192	1.3954	619	.00005	1.000	509.2	1.000	.683	169.9
2.00	30.00	2252	7657.4	8.397	1.2232	1.3620	611	.00001	1.098	510.3	1.008	.744	184.9
4.00	15.00	1978	7311.0	8.411	1.2458	1.2147	561	.00085	1.594	533.8	1.289	1.020	253.7
4.08	14.70	1970	7301.4	8.411	1.2464	1.2116	559	.00084	1.607	534.6	1.302	1.027	255.3
10.00	6.00	1640	6920.2	8.416	1.2689	1.1161	490	.00069	2.145	567.3	2.160	1.261	313.6
20.00	3.00	1411	6670.9	8.416	1.2839	1.0681	435	.00059	2.640	588.3	3.365	1.393	346.5
40.00	1.50	1207	6457.0	8.416	1.2990	1.0259	381	.00050	2.934	605.7	5.356	1.497	372.4
100.00	.60	972	6222.0	8.416	1.3166	.9772	313	.00040	3.476	623.9	10.068	1.604	398.9
200.00	.30	820	6075.6	8.416	1.3316	.9481	266	.00033	3.914	634.9	16.345	1.667	414.5
400.00	.15	689	5952.4	8.416	1.3426	.9252	224	.00027	4.384	643.8	26.628	1.718	427.3
1000.00	.06	543	5819.7	8.416	1.3555	.9041	176	.00021	5.068	653.3	50.955	1.772	440.6
2000.00	.03	453	5736.3	8.416	1.3595	.8930	146	.00017	5.640	658.9	83.421	1.804	448.5
4000.00	.02	377	5670.6	8.416	1.3648	.8834	119	.00014	6.262	663.6	136.777	1.830	455.1
R = 0.450, PERCENT FUEL = 21.87, O/F = 3.571													
1.00	60.00	2696	7354.5	9.102	1.1774	1.7899	696	0.00044	0.000			0.000	0.0
1.05	57.14	2678	7325.9	9.107	1.1785	1.7649	693	.00041	.288	559.4	2.159	.201	49.9
1.20	50.00	2628	7248.6	9.121	1.1819	1.6982	686	.00035	.559	555.5	1.257	.387	96.0
1.40	42.86	2570	7161.4	9.136	1.1862	1.6247	677	.00028	.763	517.2	1.060	.523	129.6
1.60	37.50	2519	7087.6	9.148	1.1901	1.5642	669	.00023	.905	508.6	1.009	.615	152.4
1.77	33.93	2481	7033.2	9.156	1.1932	1.5208	663	.00019	1.000	507.3	1.000	.675	167.2
2.00	30.00	2434	6967.6	9.164	1.1972	1.4702	655	.00014	1.107	508.6	1.010	.740	183.5
4.00	15.00	2167	6622.5	9.199	1.2215	1.2440	609	.00092	1.600	533.1	1.303	1.018	252.4
4.08	14.70	2159	6613.0	9.199	1.2222	1.2389	608	.00092	1.613	533.9	1.316	1.025	254.0
10.00	6.00	1822	6228.5	9.214	1.2498	1.0871	541	.00073	2.141	567.6	2.204	1.263	313.0
20.00	3.00	1581	5974.4	9.216	1.2658	1.0282	486	.00063	2.629	589.3	3.454	1.398	346.5
40.00	1.50	1362	5754.8	9.216	1.2806	.9843	431	.00054	2.916	607.3	5.529	1.506	373.1
100.00	.60	1109	5511.3	9.216	1.3004	.9335	360	.00043	3.444	626.4	10.479	1.616	400.5
200.00	.30	942	5358.4	9.216	1.3148	.9005	309	.00036	3.867	638.0	17.107	1.682	416.8
400.00	.15	796	5228.8	9.216	1.3278	.8733	262	.00030	4.320	647.4	28.011	1.735	430.1
1000.00	.06	632	5088.3	9.216	1.3415	.8469	208	.00023	4.979	657.4	53.887	1.792	444.1
2000.00	.03	529	5001.7	9.216	1.3500	.8317	173	.00019	5.528	663.4	88.516	1.826	452.5
4000.00	.02	441	4929.4	9.216	1.3561	.8212	143	.00016	6.130	668.4	145.512	1.854	459.4
R = 0.500, PERCENT FUEL = 20.12, O/F = 3.968													
1.00	60.00	2828	6769.6	9.811	1.1605	2.0170	728	0.00065	0.000			0.000	0.0
1.05	57.14	2811	6741.8	9.819	1.1613	1.9891	725	.00063	.290	552.0	2.147	.200	49.2
1.20	50.00	2765	6666.5	9.839	1.1636	1.9138	719	.00056	.563	551.2	1.251	.385	94.7
1.40	42.86	2711	6581.4	9.861	1.1667	1.8287	711	.00048	.769	513.7	1.057	.520	128.0
1.60	37.50	2664	6509.1	9.879	1.1695	1.7571	704	.00041	.912	505.4	1.008	.612	150.6
1.76	34.19	2632	6459.9	9.890	1.1717	1.7087	699	.00037	1.000	504.3	1.000	.668	164.2
2.00	30.00	2585	6391.4	9.906	1.1750	1.6426	692	.00031	1.114	505.8	1.012	.738	181.4
4.00	15.00	2335	6050.4	9.969	1.1964	1.3401	651	.00003	1.607	531.1	1.317	1.017	250.2
4.08	14.70	2327	6040.9	9.970	1.1971	1.3326	650	.00003	1.620	532.0	1.331	1.024	251.8
10.00	6.00	1996	5655.8	10.006	1.2285	1.0939	588	.00079	2.139	566.7	2.252	1.266	311.3
20.00	3.00	1748	5398.4	10.014	1.2481	1.0036	535	.00067	2.617	589.1	3.552	1.405	345.4
40.00	1.50	1518	5174.1	10.016	1.2654	.9563	479	.00058	2.896	607.8	5.719	1.515	372.6
100.00	.60	1247	4923.4	10.016	1.2827	.9083	406	.00047	3.411	627.7	10.920	1.630	400.8
200.00	.30	1067	4764.5	10.016	1.2936	.8830	352	.00039	3.821	639.7	17.932	1.698	417.7
400.00	.15	907	4629.0	10.016	1.3118	.8547	304	.00033	4.258	649.7	29.520	1.755	431.6
1000.00	.06	727	4481.0	10.016	1.3285	.8023	242	.00025	4.889	660.3	57.146	1.815	446.3
2000.00	.03	611	4389.2	10.016	1.3383	.7848	203	.00021	5.418	666.7	94.228	1.851	455.1
4000.00	.02	512	4312.2	10.016	1.3469	.7703	168	.00017	5.994	672.0	155.405	1.880	462.4

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Continued. Combustion-chamber pressure, 60 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ϵ	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/(lb)
R = 0.600, PERCENT FUEL = 17.35, O/F = 4.762													
1.00	60.00	3015	5841.6	11.142	1.1386	2.5641	777	0.00216	0.000			0.000	0.0
1.05	57.14	3001	5815.4	11.154	1.1389	2.5343	775	.00214	.293	335.2	2.131	.199	47.7
1.20	50.00	2961	5744.6	11.186	1.1396	2.4522	769	.00206	.569	341.0	1.244	.386	91.9
1.40	42.86	2914	5664.3	11.221	1.1407	2.3566	762	.00197	.776	305.0	1.054	.517	124.2
1.60	37.50	2874	5596.0	11.251	1.1419	2.2736	757	.00189	.921	297.3	1.006	.609	146.2
1.74	34.55	2849	5554.5	11.269	1.1427	2.2225	753	.00184	1.000	296.4	1.000	.658	158.0
2.00	30.00	2807	5484.3	11.299	1.1442	2.1350	747	.00176	1.125	298.1	1.014	.734	176.3
4.00	15.00	2595	5156.9	11.429	1.1533	1.7214	715	.00139	1.621	324.5	1.339	1.016	244.1
4.08	14.70	2588	5147.7	11.432	1.1538	1.7099	714	.00138	1.634	325.4	1.354	1.023	245.7
10.00	6.00	2299	4768.9	11.547	1.1811	1.2736	665	.00099	2.143	361.9	2.346	1.272	305.5
20.00	3.00	2063	4509.2	11.593	1.2063	1.0527	620	.00079	2.499	385.7	3.762	1.417	340.5
40.00	1.50	1825	4278.5	11.610	1.2290	.9310	569	.00065	2.854	402.6	6.136	1.535	368.8
100.00	.60	1529	4016.0	11.616	1.2505	.8551	496	.00053	3.341	427.1	11.885	1.659	398.6
200.00	.30	1326	3846.9	11.616	1.2647	.8176	440	.00045	3.728	440.3	19.729	1.734	416.6
400.00	.15	1144	3700.6	11.616	1.2790	.7842	385	.00038	4.136	451.3	32.844	1.797	431.6
1000.00	.06	932	3538.3	11.616	1.2981	.7449	317	.00030	4.719	463.2	64.475	1.864	447.7
2000.00	.03	792	3436.3	11.616	1.3116	.7201	269	.00025	5.202	470.4	107.316	1.904	457.5
4000.00	.02	670	3349.8	11.616	1.3234	.7001	226	.00021	5.730	476.4	178.419	1.938	465.6
R = 0.700, PERCENT FUEL = 15.25, O/F = 5.556													
1.00	60.00	3128	5138.3	12.360	1.1266	3.1609	811	0.00273	0.000			0.000	0.0
1.05	57.14	3114	5113.6	12.375	1.1266	3.1356	809	.00270	.295	317.7	2.122	.198	46.1
1.20	50.00	3076	5047.5	12.417	1.1264	3.0646	804	.00262	.572	330.1	1.240	.381	88.9
1.40	42.86	3037	4972.3	12.464	1.1264	2.9793	798	.00254	.780	295.5	1.051	.515	120.2
1.60	37.50	3001	4908.1	12.504	1.1265	2.9028	793	.00248	.926	288.2	1.005	.607	141.5
1.73	34.75	2981	4871.9	12.527	1.1266	2.8581	790	.00241	1.000	287.4	1.000	.652	152.2
2.00	30.00	2943	4803.0	12.570	1.1268	2.7698	784	.00233	1.131	289.3	1.015	.732	170.8
4.00	15.00	2761	4492.8	12.762	1.1301	2.3662	756	.00191	1.630	315.9	1.353	1.016	237.0
4.08	14.70	2756	4484.0	12.767	1.1303	2.3526	757	.00190	1.643	316.8	1.369	1.022	238.6
10.00	6.00	2517	4119.3	12.975	1.1422	1.7290	719	.00138	2.151	354.1	2.414	1.276	297.8
20.00	3.00	2320	3863.7	13.094	1.1599	1.3390	685	.00105	2.498	379.0	3.943	1.427	333.0
40.00	1.50	2108	3631.4	13.168	1.1847	1.0359	644	.00080	2.828	400.3	6.551	1.554	362.1
100.00	.60	1813	3360.7	13.208	1.2172	.8583	579	.00061	3.272	423.5	12.932	1.685	393.3
200.00	.30	1596	3183.1	13.215	1.2346	.7942	529	.00052	3.633	437.8	21.899	1.768	412.5
400.00	.15	1395	3027.4	13.216	1.2487	.7553	470	.00044	4.015	449.9	36.494	1.837	428.6
1000.00	.06	1156	2852.1	13.216	1.2670	.7136	397	.00036	4.557	463.0	72.680	1.911	446.0
2000.00	.03	998	2740.1	13.216	1.2814	.6848	344	.00030	5.000	471.1	122.229	1.958	456.8
4000.00	.02	853	2643.9	13.216	1.2952	.6596	294	.00025	5.481	477.9	205.254	1.998	465.9
R = 0.800, PERCENT FUEL = 13.60, O/F = 6.349													
1.00	60.00	3188	4586.9	13.470	1.1207	3.6135	835	0.00317	0.000			0.000	0.0
1.05	57.14	3175	4564.0	13.488	1.1205	3.5978	833	.00315	.296	300.7	2.117	.197	44.6
1.20	50.00	3141	4502.0	13.536	1.1199	3.5527	828	.00309	.573	319.4	1.238	.380	86.0
1.40	42.86	3103	4431.5	13.593	1.1193	3.4973	823	.00303	.782	286.0	1.050	.514	116.3
1.60	37.50	3070	4371.3	13.641	1.1188	3.4461	818	.00297	.928	279.0	1.005	.606	137.0
1.72	34.85	3052	4338.7	13.667	1.1186	3.4169	815	.00293	1.000	278.3	1.000	.650	147.0
2.00	30.00	3016	4272.7	13.721	1.1181	3.3544	810	.00286	1.134	280.3	1.016	.731	165.3
4.00	15.00	2853	3980.7	13.961	1.1170	3.0181	786	.00251	1.635	306.6	1.361	1.015	229.7
4.08	14.70	2848	3972.4	13.968	1.1170	3.0070	785	.00250	1.648	307.5	1.376	1.022	231.2
10.00	6.00	2645	3625.9	14.254	1.1190	2.4611	754	.00199	2.158	344.6	2.453	1.278	289.2
20.00	3.00	2467	3379.6	14.450	1.1252	1.9810	727	.00157	2.505	370.0	4.060	1.433	324.1
40.00	1.50	2321	3151.6	14.611	1.1386	1.5084	698	.00117	2.826	392.2	6.873	1.562	353.4
100.00	.60	2074	2878.8	14.750	1.1705	1.0340	649	.00078	3.232	417.1	13.944	1.704	385.5
200.00	.30	1868	2695.0	14.797	1.1982	.8417	604	.00061	3.548	432.6	23.785	1.794	405.7
400.00	.15	1658	2531.0	14.812	1.2191	.7527	552	.00051	3.894	445.8	40.475	1.870	422.9
1000.00	.06	1398	2343.4	14.816	1.2383	.6975	479	.00041	4.395	460.3	81.660	1.953	441.8
2000.00	.03	1220	2221.8	14.816	1.2515	.6676	424	.00035	4.806	469.3	138.794	2.008	453.6
4000.00	.02	1058	2116.0	14.816	1.2654	.6395	370	.00030	5.245	477.0	235.555	2.050	463.7
R = 0.900, PERCENT FUEL = 12.28, O/F = 7.143													
1.00	60.00	3213	4142.9	14.479	1.1182	3.7568	854	0.00335	0.000			0.000	0.0
1.05	57.14	3201	4121.5	14.499	1.1179	3.7501	850	.00333	.296	484.9	2.115	.197	43.2
1.20	50.00	3168	4063.3	14.553	1.1172	3.7293	843	.00329	.574	309.3	1.238	.380	83.2
1.40	42.86	3131	3997.2	14.616	1.1163	3.6942	840	.00325	.783	277.1	1.050	.514	112.6
1.60	37.50	3099	3940.7	14.669	1.1157	3.6652	835	.00320	.929	270.3	1.005	.605	132.7
1.72	34.89	3082	3910.6	14.698	1.1153	3.6487	833	.00318	1.000	269.7	1.000	.649	142.2
2.00	30.00	3047	3848.1	14.759	1.1146	3.6123	828	.00313	1.136	271.6	1.017	.731	160.2
4.00	15.00	2892	3573.5	15.031	1.1118	3.4127	804	.00288	1.637	297.3	1.364	1.015	222.6
4.08	14.70	2888	3565.7	15.039	1.1117	3.4059	804	.00287	1.650	298.2	1.379	1.022	224.1
10.00	6.00	2701	3238.7	15.377	1.1095	3.0640	774	.00250	2.161	334.6	2.470	1.279	280.5
20.00	3.00	2564	3004.8	15.625	1.1093	2.7328	752	.00217	2.509	359.8	4.112	1.433	314.7
40.00	1.50	2429	2786.4	15.856	1.1113	2.3991	728	.00186	2.852	382.1	7.032	1.567	343.6
100.00	.60	2246	2520.2	16.124	1.1212	1.7259	695	.00131	3.234	407.8	14.621	1.714	375.8
200.00	.30	2093	2330.5	16.278	1.1403	1.2476	664	.00093	3.521	424.6	25.591	1.803	395.6
400.00	.15	1919	2166.1	16.370	1.1721	.8760	623	.00066	3.805	439.2	44.382	1.882	414.7
1000.00	.06	1660	1967.2	16.410	1.2081	.7114	560	.00048	4.233	455.2	91.675	1.955	433.1
2000.00	.03	1468	1836.1	16.415	1.2258	.6631	507	.00041	4.606	465.3	157.405	2.004	448.0
4000.00	.02	1289	1720.5	16.416	1.2367	.6325	452	.00035	5.010	473.9	269.819	2.044	459.1

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Continued. Combustion-chamber pressure, 60 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/(lb)
R = 1.000, PERCENT FUEL = 11.19, O/F = 7.937													
1.00	60.00	3217	3777.9	15.399	1.1174	3.6327	864	0.00328	0.000			0.000	0.0
1.05	57.14	3205	3757.7	15.420	1.1171	3.6262	862	.00327	.296	470.6	2.115	.197	41.9
1.20	50.00	3173	3702.9	15.478	1.1163	3.6075	856	.00323	.574	300.2	1.237	.380	80.8
1.40	42.86	3136	3640.6	15.545	1.1154	3.5859	852	.00319	.784	268.9	1.050	.514	109.3
1.60	37.50	3104	3587.4	15.602	1.1147	3.5718	847	.00315	.930	262.4	1.005	.605	128.7
1.72	34.91	3088	3559.2	15.633	1.1143	3.5493	845	.00313	1.000	261.7	1.000	.648	137.9
2.00	30.00	3053	3500.2	15.698	1.1136	3.5214	840	.00309	1.136	263.6	1.017	.730	155.4
4.00	15.00	2900	3241.5	15.990	1.1104	3.3883	816	.00288	1.637	288.6	1.364	1.015	216.0
4.08	14.70	2896	3234.1	15.998	1.1103	3.3831	816	.00287	1.650	289.5	1.380	1.022	217.5
10.00	6.00	2713	2925.7	16.363	1.1074	3.1047	786	.00256	2.161	324.9	2.474	1.280	272.3
20.00	3.00	2579	2704.9	16.634	1.1060	2.8827	764	.00230	2.509	349.4	4.124	1.436	305.6
40.00	1.50	2452	2498.2	16.894	1.1057	2.6882	742	.00203	2.833	371.3	7.068	1.568	333.7
100.00	.60	2287	2245.2	17.213	1.1075	2.4850	711	.00166	3.237	396.6	14.785	1.716	365.2
200.00	.30	2164	2068.3	17.431	1.1113	2.3612	687	.00138	3.532	413.5	26.152	1.813	385.7
400.00	.15	2037	1903.2	17.624	1.1167	2.2363	660	.00111	3.820	428.6	46.510	1.898	403.9
1000.00	.06	1859	1703.0	17.826	1.1309	1.1590	619	.00079	4.197	446.1	99.697	1.997	424.9
2000.00	.03	1710	1565.5	17.928	1.1594	.8974	581	.00080	4.487	457.6	176.636	2.062	438.8
4000.00	.02	1549	1440.4	17.985	1.1869	.7318	537	.00047	4.798	467.5	310.311	2.119	451.0
R = 1.500, PERCENT FUEL = 7.749, O/F =11.905													
1.00	60.00	3118	2626.1	18.987	1.1200	2.2973	889	0.00216	0.000			0.000	0.0
1.05	57.14	3103	2610.2	19.010	1.1198	2.2869	887	.00214	.296	417.0	2.117	.197	37.2
1.20	50.00	3070	2567.2	19.074	1.1193	2.2574	881	.00210	.574	266.0	1.238	.380	71.6
1.40	42.86	3031	2518.3	19.147	1.1187	2.2216	875	.00206	.783	238.2	1.050	.514	96.8
1.60	37.50	2999	2478.6	19.210	1.1183	2.1892	869	.00202	.928	232.4	1.005	.605	114.1
1.72	34.88	2981	2459.0	19.244	1.1181	2.1710	867	.00199	1.000	231.8	1.000	.650	122.4
2.00	30.00	2945	2408.2	19.313	1.1177	2.1323	861	.00195	1.134	233.4	1.016	.731	137.7
4.00	15.00	2786	2209.6	19.623	1.1167	1.9340	833	.00172	1.635	255.4	1.361	1.015	191.3
4.08	14.70	2777	2199.9	19.632	1.1167	1.9277	832	.00171	1.648	256.1	1.377	1.022	192.6
10.00	6.00	2578	1959.5	19.999	1.1183	1.6300	796	.00140	2.158	287.1	2.454	1.278	240.8
20.00	3.00	2421	1786.5	20.250	1.1227	1.3799	767	.00115	2.506	308.3	4.065	1.433	270.0
40.00	1.50	2263	1630.0	20.463	1.1317	1.1285	736	.00092	2.830	326.9	6.896	1.563	294.4
100.00	.60	2040	1439.4	20.667	1.1538	.8344	688	.00066	3.238	347.9	14.098	1.706	321.3
200.00	.30	1856	1309.8	20.755	1.1784	.6739	645	.00051	3.545	361.3	24.259	1.796	338.4
400.00	.15	1684	1193.0	20.795	1.2033	.5774	595	.00041	3.870	372.7	41.606	1.874	353.1
1000.00	.06	1415	1026.4	20.810	1.2262	.5156	524	.00033	4.347	385.2	84.484	1.961	369.3
2000.00	.03	1240	910.6	20.812	1.2423	.4890	489	.00029	4.745	393.1	144.082	2.015	379.5
4000.00	.02	1080	803.9	20.813	1.2550	.4690	466	.00024	5.173	399.8	245.360	2.061	388.2
R = 2.000, PERCENT FUEL = 5.927, O/F =15.873													
1.00	60.00	2966	2016.0	21.453	1.1264	1.5209	886	0.00145	0.000			0.000	0.0
1.05	57.14	2953	2002.7	21.476	1.1263	1.5098	884	.00144	.295	382.7	2.122	.198	34.1
1.20	50.00	2917	1966.4	21.537	1.1264	1.4788	878	.00140	.572	244.0	1.240	.381	65.7
1.40	42.86	2877	1925.3	21.606	1.1265	1.4419	870	.00135	.780	218.4	1.052	.515	88.8
1.60	37.50	2841	1890.2	21.665	1.1267	1.4091	864	.00132	.926	213.0	1.005	.607	104.6
1.73	34.75	2821	1870.4	21.698	1.1268	1.3901	861	.00129	1.000	212.4	1.000	.653	112.6
2.00	30.00	2783	1832.8	21.761	1.1272	1.3529	854	.00125	1.131	213.8	1.015	.732	126.3
4.00	15.00	2604	1663.4	22.033	1.1309	1.1868	821	.00103	1.630	233.5	1.353	1.016	175.2
4.08	14.70	2597	1658.6	22.043	1.1310	1.1832	820	.00103	1.642	234.2	1.368	1.022	176.4
10.00	6.00	2385	1459.5	22.333	1.1424	.9205	774	.00080	2.152	261.7	2.412	1.276	220.1
20.00	3.00	2177	1319.9	22.496	1.1565	.7701	734	.00063	2.500	280.1	3.941	1.427	246.1
40.00	1.50	1978	1192.9	22.600	1.1808	.6166	689	.00050	2.831	295.9	6.557	1.552	267.6
100.00	.60	1706	1044.7	22.660	1.2122	.5100	621	.00038	3.273	313.1	12.980	1.685	290.7
200.00	.30	1503	947.2	22.673	1.2308	.4699	566	.00033	3.629	323.8	21.822	1.768	305.0
400.00	.15	1318	861.6	22.677	1.2450	.4457	510	.00028	4.008	332.8	36.754	1.838	316.9
1000.00	.06	1095	764.9	22.677	1.2620	.4221	438	.00023	4.546	342.6	73.335	1.913	329.9
2000.00	.03	945	703.1	22.677	1.2749	.4064	386	.00020	4.986	348.7	123.637	1.960	338.0
4000.00	.02	812	649.8	22.677	1.2862	.3916	337	.00017	5.460	353.8	208.163	1.999	344.8
R = 3.000, PERCENT FUEL = 4.031, O/F =23.810													
1.00	60.00	2655	1381.4	24.532	1.1503	0.8140	851	0.00078	0.000			0.000	0.0
1.05	57.14	2640	1370.9	24.548	1.1510	.8048	848	.00077	.292	336.4	2.140	.199	30.2
1.20	50.00	2599	1342.7	24.591	1.1529	.7795	840	.00074	.566	215.4	1.248	.384	58.1
1.40	42.86	2550	1310.6	24.638	1.1554	.7506	831	.00071	.772	192.5	1.056	.519	78.5
1.60	37.50	2509	1283.4	24.676	1.1579	.7260	822	.00068	.915	187.5	1.007	.611	92.3
1.75	34.33	2481	1265.7	24.700	1.1596	.7099	816	.00066	1.000	186.9	1.000	.664	100.3
2.00	30.00	2438	1239.0	24.735	1.1624	.6838	808	.00063	1.118	187.9	1.013	.736	111.3
4.00	15.00	2216	1109.8	24.876	1.1809	.5739	760	.00051	1.612	203.8	1.325	1.017	153.7
4.08	14.70	2209	1106.2	24.879	1.1815	.5710	759	.00051	1.625	204.4	1.339	1.023	154.8
10.00	6.00	1915	958.9	24.972	1.2107	.4712	690	.00039	2.140	226.3	2.286	1.268	191.7
20.00	3.00	1691	859.6	24.998	1.2309	.4277	633	.00033	2.512	240.5	3.629	1.409	213.1
40.00	1.50	1480	772.3	25.006	1.2463	.4030	575	.00029	2.883	252.4	5.877	1.522	230.2
100.00	.60	1229	673.9	25.008	1.2627	.3820	500	.00024	3.388	265.2	11.319	1.641	248.1
200.00	.30	1061	611.0	25.008	1.2749	.3666	446	.00021	3.787	273.1	18.732	1.712	258.9
400.00	.15	911	556.7	25.008	1.2872	.3561	395	.00018	4.207	279.6	31.103	1.771	267.9
1000.00	.06	739	496.6	25.008	1.3046	.3403	331	.00015	4.805	286.6	60.907	1.835	277.4
2000.00	.03	627	459.3	25.008	1.3178	.3295	287	.00012	5.300	290.9	101.211	1.873	283.3
4000.00	.02	529	427.5	25.008	1.3306	.3198	247	.00010	5.839	294.5	167.951	1.902	288.1

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Concluded. Combustion-chamber pressure, 60 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 4.000, PERCENT FUEL = 3.054, O/F =31.746													
1.00	60.00	2347	1054.4	26.257	1.1871	0.5285	798	0.00050	0.000			0.000	0.0
1.05	57.14	2330	1049.8	26.265	1.1885	.5227	795	.00049	.287	307.2	2.165	.202	27.4
1.20	50.00	2282	1022.5	26.286	1.1925	.5073	784	.00047	.557	195.1	1.260	.388	52.7
1.40	42.86	2228	996.2	26.307	1.1972	.4906	772	.00045	.760	174.0	1.061	.524	71.2
1.60	37.50	2180	974.0	26.323	1.2013	.4772	761	.00044	.902	169.2	1.009	.616	83.6
1.78	33.79	2143	957.0	26.334	1.2046	.4674	753	.00042	1.000	168.5	1.000	.678	92.1
2.00	30.00	2101	937.9	26.345	1.2084	.4569	743	.00041	1.103	169.1	1.009	.742	100.7
4.00	15.00	1858	834.6	26.387	1.2292	.4102	685	.00035	1.599	182.3	1.297	1.019	138.3
4.08	14.70	1851	831.7	26.388	1.2298	.4092	683	.00034	1.612	182.8	1.311	1.026	139.2
10.00	6.00	1556	717.0	26.403	1.2503	.3769	606	.00029	2.146	201.1	2.192	1.263	171.3
20.00	3.00	1351	641.3	26.406	1.2627	.3619	547	.00025	2.537	212.9	3.439	1.397	189.6
40.00	1.50	1167	575.7	26.406	1.2738	.3501	491	.00022	2.926	222.8	5.518	1.504	204.1
100.00	.60	954	502.8	26.406	1.2893	.3354	422	.00018	3.452	233.3	10.507	1.615	219.1
200.00	.30	815	456.7	26.406	1.3020	.3244	372	.00016	3.870	239.7	17.236	1.681	228.0
400.00	.15	692	417.5	26.406	1.3151	.3141	326	.00013	4.314	245.0	28.358	1.735	235.4
1000.00	.06	553	374.8	26.406	1.3329	.3013	270	.00011	4.951	250.6	54.842	1.792	243.2
2000.00	.03	464	348.3	26.406	1.3438	.2929	232	.00009	5.484	254.0	90.278	1.827	247.9
4000.00	.02	387	326.2	26.406	1.3563	.2865	197	.00008	6.070	256.8	148.471	1.855	251.7
R = 5.000, PERCENT FUEL = 2.458, O/F =39.683													
1.00	60.00	2062	855.0	27.299	1.2228	0.4109	740	0.00037	0.000			0.000	0.0
1.05	57.14	2044	847.7	27.302	1.2242	.4079	736	.00037	.283	282.2	2.186	.204	25.2
1.20	50.00	1995	826.1	27.309	1.2280	.4004	724	.00036	.550	178.9	1.269	.392	48.4
1.40	42.86	1938	806.0	27.316	1.2323	.3925	710	.00034	.751	159.3	1.066	.529	65.3
1.60	37.50	1890	787.4	27.321	1.2358	.3864	698	.00033	.892	154.7	1.011	.621	76.7
1.80	33.40	1849	771.7	27.324	1.2387	.3816	688	.00033	1.000	153.9	1.000	.690	85.1
2.00	30.00	1811	757.4	27.327	1.2414	.3775	679	.00032	1.093	154.3	1.007	.747	92.2
4.00	15.00	1576	672.1	27.336	1.2590	.3579	617	.00026	1.594	165.7	1.282	1.022	126.2
4.08	14.70	1571	669.7	27.336	1.2600	.3575	615	.00026	1.607	166.1	1.295	1.029	127.0
10.00	6.00	1304	576.3	27.338	1.2707	.3413	559	.00023	2.151	182.2	2.145	1.261	155.7
20.00	3.00	1122	515.3	27.339	1.2815	.3309	484	.00020	2.549	192.6	3.345	1.393	171.9
40.00	1.50	961	462.9	27.339	1.2928	.3209	432	.00018	2.946	201.2	5.334	1.496	184.7
100.00	.60	778	405.1	27.339	1.3094	.3076	367	.00015	3.486	210.3	10.072	1.603	197.8
200.00	.30	659	369.0	27.339	1.3227	.2979	321	.00012	3.918	215.8	16.410	1.666	205.6
400.00	.15	555	338.5	27.339	1.3364	.2888	279	.00011	4.379	220.3	26.810	1.717	212.0
1000.00	.06	438	305.6	27.339	1.3536	.2783	230	.00008	5.047	225.0	51.370	1.771	218.6
2000.00	.03	365	283.4	27.339	1.3632	.2728	195	.00007	5.611	227.8	84.029	1.804	222.6
4000.00	.02	303	268.6	27.339	1.3697	.2693	164	.00006	6.234	230.1	137.526	1.830	225.9

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Combustion-chamber pressure, 150 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.150, PERCENT FUEL = 45.65, O/F = 1.190													
1.00	150.00	1183	5313.5	4.416	1.3396	1.7752	314	0.00073	0.000			0.000	0.0
1.05	142.86	1168	5287.7	4.416	1.3406	1.7711	311	.00073	.271	530.0	2.250	.210	47.4
1.20	125.00	1129	5218.7	4.416	1.3436	1.7597	303	.00070	.527	334.2	1.297	.403	90.8
1.40	107.14	1085	5141.8	4.416	1.3469	1.7473	293	.00068	.722	296.1	1.081	.543	122.2
1.60	93.75	1049	5077.7	4.416	1.3497	1.7368	285	.00066	.860	286.6	1.018	.636	143.2
1.87	80.42	1008	5006.8	4.416	1.3527	1.7257	276	.00063	1.000	284.1	1.000	.725	163.4
2.00	75.00	989	4975.4	4.416	1.3541	1.7210	272	.00062	1.059	284.4	1.003	.761	171.5
4.00	37.50	824	4693.4	4.416	1.3651	1.6825	234	.00052	1.566	301.7	1.233	1.031	232.3
10.00	15.00	643	4392.5	4.416	1.3748	1.6505	188	.00042	2.152	327.5	1.974	1.257	283.1
10.21	14.70	639	4386.6	4.416	1.3750	1.6591	187	.00041	2.165	328.1	1.997	1.261	284.0
20.00	7.50	532	4209.6	4.416	1.3800	1.6343	159	.00035	2.586	343.5	2.982	1.376	309.9
40.00	3.75	439	4058.9	4.416	1.3824	1.6269	133	.00029	3.031	356.4	4.620	1.467	330.4
100.00	1.50	340	3899.0	4.416	1.3882	1.6091	104	.00023	3.648	369.8	8.432	1.558	350.8
200.00	.75	280	3802.6	4.416	1.3923	1.5971	85	.00018	4.149	377.7	13.431	1.610	362.6
400.00	.38	230	3723.2	4.416	1.4070	1.5556	70	.00015	4.674	384.1	21.488	1.652	372.0
1000.00	.15	175	3640.1	4.416	1.4350	1.4845	55	.00011	5.438	390.6	39.928	1.694	381.6
2000.00	.08	142	3590.9	4.416	1.4552	1.4387	45	.00009	6.096	394.3	63.572	1.719	387.2
4000.00	.04	114	3551.2	4.416	1.4710	1.4054	36	.00007	6.844	397.3	100.938	1.739	391.6
R = 0.200, PERCENT FUEL = 38.65, O/F = 1.587													
1.00	150.00	1514	2969.7	5.216	1.3078	1.6191	402	0.00084	0.000			0.000	0.0
1.05	142.86	1497	2941.7	5.216	1.3089	1.6146	399	.00083	.274	552.1	2.233	.209	49.3
1.20	125.00	1450	2866.8	5.216	1.3119	1.6026	389	.00081	.533	348.6	1.289	.400	94.6
1.40	107.14	1398	2783.1	5.216	1.3154	1.5889	378	.00078	.730	309.3	1.077	.539	127.4
1.60	93.75	1354	2713.2	5.216	1.3185	1.5773	369	.00076	.869	299.6	1.016	.632	149.4
1.85	81.24	1307	2640.5	5.216	1.3217	1.5652	359	.00073	1.000	297.3	1.000	.716	169.2
2.00	75.00	1282	2601.1	5.216	1.3236	1.5585	353	.00072	1.068	297.8	1.004	.757	179.1
4.00	37.50	1079	2290.0	5.216	1.3391	1.5045	307	.00061	1.572	316.7	1.244	1.029	243.2
10.00	15.00	852	1954.3	5.216	1.3558	1.4516	251	.00048	2.148	344.7	2.009	1.257	297.2
10.21	14.70	847	1947.7	5.216	1.3562	1.4506	250	.00048	2.161	345.3	2.033	1.261	298.2
20.00	7.50	709	1748.8	5.216	1.3655	1.4232	213	.00040	2.573	362.0	3.049	1.379	325.9
40.00	3.75	588	1578.0	5.216	1.3714	1.4067	179	.00034	3.010	376.0	4.739	1.472	348.0
100.00	1.50	458	1396.3	5.216	1.3770	1.3914	142	.00026	3.619	390.5	8.679	1.565	370.0
200.00	.75	379	1286.1	5.216	1.3811	1.3607	117	.00022	4.111	399.1	13.670	1.619	382.7
400.00	.38	312	1195.2	5.216	1.3861	1.3677	96	.00018	4.638	406.1	22.295	1.662	393.0
1000.00	.15	242	1098.9	5.216	1.3972	1.3402	74	.00013	5.394	413.4	41.979	1.706	403.5
2000.00	.08	198	1041.1	5.216	1.4164	1.2958	61	.00011	6.012	417.7	67.687	1.733	409.7
4000.00	.04	161	993.9	5.216	1.4344	1.2580	50	.00009	6.706	421.1	108.754	1.754	414.6
R = 0.250, PERCENT FUEL = 33.51, O/F = 1.984													
1.00	150.00	1816	1249.3	6.016	1.2820	1.5040	481	0.00092	0.000			0.000	0.0
1.05	142.86	1797	1220.2	6.016	1.2831	1.4992	477	.00091	.277	563.4	2.218	.207	50.3
1.20	125.00	1745	1142.1	6.016	1.2860	1.4867	467	.00089	.538	356.2	1.283	.398	96.6
1.40	107.14	1686	1054.7	6.016	1.2893	1.4730	456	.00086	.736	316.3	1.073	.536	130.1
1.60	93.75	1636	981.5	6.016	1.2921	1.4616	446	.00084	.876	306.6	1.015	.629	152.7
1.83	81.96	1587	910.0	6.016	1.2950	1.4503	436	.00081	1.000	304.5	1.000	.708	171.8
2.00	75.00	1555	863.9	6.016	1.2970	1.4429	429	.00080	1.076	305.1	1.005	.754	183.1
4.00	37.50	1322	535.1	6.016	1.3125	1.3875	378	.00068	1.578	325.5	1.256	1.027	249.3
10.00	15.00	1057	176.1	6.016	1.3329	1.3225	314	.00054	2.147	355.3	2.048	1.258	305.6
10.21	14.70	1052	169.0	6.016	1.3333	1.3213	312	.00054	2.159	355.9	2.073	1.262	306.6
20.00	7.50	887	9954.0	6.016	1.3461	1.2847	269	.00046	2.563	373.7	3.127	1.382	335.7
40.00	3.75	741	9768.1	6.016	1.3569	1.2559	228	.00038	2.987	388.7	4.883	1.478	359.0
100.00	1.50	581	9569.1	6.016	1.3663	1.2320	181	.00030	3.581	404.2	8.985	1.574	382.4
200.00	.75	482	9447.8	6.016	1.3717	1.2190	151	.00025	4.064	413.4	14.396	1.630	395.9
400.00	.38	399	9347.3	6.016	1.3755	1.2100	125	.00020	4.582	420.9	23.208	1.675	406.8
1000.00	.15	310	9240.5	6.016	1.3819	1.1955	95	.00015	5.327	426.7	43.694	1.722	418.1
2000.00	.08	256	9175.9	6.016	1.3866	1.1603	78	.00012	5.945	433.4	71.260	1.749	424.7
4000.00	.04	210	9122.7	6.016	1.4039	1.1461	64	.00010	6.606	437.2	115.651	1.771	430.2
R = 0.300, PERCENT FUEL = 29.57, O/F = 2.381													
1.00	150.00	2092	9932.7	6.813	1.2583	1.4348	550	0.00099	0.000			0.000	0.0
1.05	142.86	2071	9903.1	6.814	1.2595	1.4282	547	.00098	.279	560.4	2.205	.206	50.8
1.20	125.00	2015	9823.6	6.814	1.2627	1.4111	537	.00095	.542	359.7	1.277	.395	97.5
1.40	107.14	1951	9734.4	6.815	1.2663	1.3931	525	.00092	.742	319.8	1.070	.533	131.4
1.60	93.75	1897	9659.5	6.815	1.2694	1.3786	515	.00090	.882	310.3	1.013	.626	154.2
1.82	82.58	1846	9590.3	6.815	1.2723	1.3659	505	.00087	1.000	306.3	1.000	.700	172.6
2.00	75.00	1809	9539.0	6.816	1.2744	1.3567	498	.00086	1.082	309.0	1.006	.751	185.1
4.00	37.50	1553	9199.8	6.816	1.2892	1.2999	445	.00074	1.585	330.5	1.266	1.025	252.5
10.00	15.00	1256	8825.4	6.816	1.3095	1.2337	375	.00060	2.146	361.8	2.085	1.259	310.4
10.21	14.70	1251	8817.9	6.816	1.3099	1.2322	374	.00060	2.160	362.4	2.111	1.264	311.5
20.00	7.50	1064	8591.3	6.816	1.3246	1.1891	325	.00051	2.555	381.2	3.206	1.386	341.7
40.00	3.75	895	8393.7	6.816	1.3384	1.1551	279	.00042	2.966	397.0	5.037	1.465	366.0
100.00	1.50	706	8180.4	6.816	1.3530	1.1175	225	.00033	3.544	413.5	9.325	1.584	390.5
200.00	.75	590	8049.7	6.816	1.3602	1.1008	187	.00027	4.013	423.3	14.994	1.642	404.8
400.00	.38	490	7940.9	6.816	1.3666	1.0668	156	.00023	4.517	431.2	24.235	1.689	416.3
1000.00	.15	383	7624.8	6.816	1.3724	1.0745	120	.00017	5.246	439.6	46.002	1.738	428.3
2000.00	.08	317	7754.3	6.816	1.3776	1.0637	98	.00014	5.851	444.6	74.917	1.767	435.4
4000.00	.04	262	7696.0	6.816	1.3827	1.0533	80	.00011	6.510	448.7	122.193	1.790	441.2

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Continued. Combustion-chamber pressure, 150 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.350, PERCENT FUEL = 26.47, O/F = 2.778													
1.00	150.00	2339	8892.8	7.604	1.2338	1.4271	610	0.00107	0.000			0.000	0.0
1.05	142.86	2317	8863.1	7.605	1.2352	1.4164	606	.00106	.282	569.2	2.192	.205	50.8
1.20	125.00	2259	8783.3	7.607	1.2391	1.3889	597	.00102	.547	560.7	1.271	.393	97.6
1.40	107.14	2193	8693.6	7.609	1.2434	1.3604	585	.00099	.748	321.0	1.067	.530	131.6
1.60	93.75	2137	8618.1	7.611	1.2471	1.3385	576	.00096	.889	311.6	1.012	.623	154.6
1.80	83.19	2087	8552.2	7.612	1.2502	1.3209	567	.00093	1.000	309.8	1.000	.693	172.1
2.00	75.00	2044	8496.3	7.613	1.2528	1.3068	559	.00091	1.089	310.7	1.007	.748	185.7
4.00	37.50	1772	8151.6	7.615	1.2690	1.2337	506	.00079	1.590	333.1	1.276	1.023	254.0
10.00	15.00	1451	7767.3	7.616	1.2884	1.1659	434	.00065	2.148	365.6	2.120	1.260	312.9
10.21	14.70	1444	7759.5	7.616	1.2888	1.1645	433	.00065	2.160	366.2	2.147	1.265	314.0
20.00	7.50	1239	7524.4	7.616	1.3035	1.1206	381	.00055	2.549	385.8	3.282	1.390	345.1
40.00	3.75	1051	7317.8	7.616	1.3188	1.0794	330	.00046	2.952	402.4	5.191	1.491	370.2
100.00	1.50	838	7092.8	7.616	1.3364	1.0366	267	.00036	3.510	419.8	9.681	1.594	395.8
200.00	.75	702	6953.8	7.616	1.3475	1.0119	226	.00030	3.963	430.2	15.634	1.654	410.8
400.00	.38	586	6837.5	7.616	1.3553	.9953	189	.00025	4.452	438.6	25.362	1.703	422.9
1000.00	.15	460	6713.0	7.616	1.3634	.9789	148	.00019	5.160	447.5	48.312	1.754	435.5
2000.00	.08	382	6637.0	7.616	1.3683	.9694	121	.00016	5.750	452.8	78.890	1.784	443.0
4000.00	.04	317	6574.0	7.616	1.3739	.9587	98	.00013	6.390	457.2	129.010	1.809	449.2
R = 0.400, PERCENT FUEL = 23.95, O/F = 3.175													
1.00	150.00	2553	8050.5	8.379	1.2094	1.4879	660	0.00118	0.000			0.000	0.0
1.05	142.86	2532	8021.1	8.382	1.2108	1.4725	657	.00116	.284	566.8	2.178	.203	50.6
1.20	125.00	2475	7941.9	8.388	1.2148	1.4323	648	.00112	.552	559.6	1.265	.391	97.2
1.40	107.14	2410	7852.7	8.393	1.2194	1.3894	637	.00107	.754	320.4	1.064	.527	131.2
1.60	93.75	2353	7777.5	8.398	1.2235	1.3555	628	.00104	.895	311.3	1.011	.619	154.1
1.79	83.84	2308	7715.9	8.401	1.2269	1.3293	620	.00101	1.000	309.7	1.000	.686	170.6
2.00	75.00	2260	7655.7	8.404	1.2302	1.3052	612	.00098	1.096	310.8	1.008	.745	185.3
4.00	37.50	1978	7308.9	8.413	1.2491	1.1954	561	.00084	1.594	334.1	1.286	1.021	254.0
10.00	15.00	1638	6918.4	8.416	1.2695	1.1133	489	.00069	2.147	367.5	2.155	1.261	313.9
10.21	14.70	1631	6910.5	8.416	1.2699	1.1119	488	.00069	2.159	368.2	2.182	1.266	315.0
20.00	7.50	1410	6669.3	8.416	1.2841	1.0674	435	.00059	2.542	388.5	3.358	1.393	346.7
40.00	3.75	1206	6455.6	8.416	1.2991	1.0256	380	.00050	2.931	405.8	5.344	1.497	372.5
100.00	1.50	971	6220.8	8.416	1.3187	.9769	313	.00040	3.479	424.0	10.047	1.604	399.0
200.00	.75	819	6074.6	8.416	1.3317	.9479	266	.00033	3.917	434.9	16.311	1.666	414.6
400.00	.38	688	5951.6	8.416	1.3427	.9251	224	.00027	4.388	443.9	26.573	1.717	427.4
1000.00	.15	543	5819.0	8.416	1.3536	.9040	176	.00021	5.072	453.3	50.851	1.771	440.6
2000.00	.08	452	5737.8	8.416	1.3595	.8930	146	.00017	5.644	458.9	83.253	1.803	448.6
4000.00	.04	376	5670.2	8.416	1.3649	.8832	119	.00014	6.266	463.6	136.502	1.829	455.1
R = 0.450, PERCENT FUEL = 21.87, O/F = 3.571													
1.00	150.00	2733	7354.5	9.133	1.1879	1.6077	701	0.00132	0.000			0.000	0.0
1.05	142.86	2713	7325.6	9.137	1.1891	1.5861	698	.00130	.287	562.0	2.165	.202	50.1
1.20	125.00	2659	7247.6	9.148	1.1925	1.5361	690	.00125	.557	357.0	1.259	.388	96.4
1.40	107.14	2596	7159.7	9.159	1.1966	1.4792	681	.00119	.760	318.4	1.061	.524	130.2
1.60	93.75	2542	7085.3	9.168	1.2004	1.4330	672	.00115	.902	309.6	1.009	.616	153.0
1.77	84.52	2499	7028.7	9.174	1.2034	1.3991	666	.00111	1.000	308.3	1.000	.678	168.4
2.00	75.00	2451	6964.7	9.181	1.2070	1.3621	658	.00107	1.103	309.5	1.009	.742	184.2
4.00	37.50	2171	6618.6	9.209	1.2282	1.1951	610	.00089	1.599	333.6	1.298	1.019	253.0
10.00	15.00	1819	6224.7	9.215	1.2519	1.0788	541	.00073	2.145	368.0	2.193	1.263	313.5
10.21	14.70	1812	6216.7	9.215	1.2523	1.0750	539	.00072	2.156	368.7	2.221	1.267	314.7
20.00	7.50	1578	5971.1	9.216	1.2664	1.0258	486	.00063	2.634	389.6	3.436	1.397	346.9
40.00	3.75	1359	5751.9	9.216	1.2808	.9835	430	.00054	2.922	407.6	5.502	1.504	373.4
100.00	1.50	1106	5509.0	9.216	1.3006	.9330	359	.00043	3.450	426.6	10.428	1.614	400.7
200.00	.75	939	5356.4	9.216	1.3150	.9001	308	.00036	3.873	438.1	17.026	1.679	417.0
400.00	.38	794	5227.1	9.216	1.3280	.8730	262	.00030	4.327	447.5	27.879	1.733	430.2
1000.00	.15	631	5086.9	9.216	1.3417	.8467	207	.00023	4.986	457.5	53.635	1.789	444.2
2000.00	.08	528	5000.6	9.216	1.3501	.8316	172	.00019	5.536	463.5	88.103	1.823	452.6
4000.00	.04	440	4928.4	9.216	1.3561	.8211	143	.00016	6.139	468.4	144.834	1.851	459.5
R = 0.500, PERCENT FUEL = 20.12, O/F = 3.968													
1.00	150.00	2881	6769.6	9.859	1.1704	1.7727	736	0.00149	0.000			0.000	0.0
1.05	142.86	2862	6741.4	9.866	1.1713	1.7501	733	.00147	.289	555.6	2.153	.201	49.6
1.20	125.00	2811	6665.2	9.883	1.1739	1.6893	726	.00141	.561	353.3	1.254	.386	95.3
1.40	107.14	2752	6579.0	9.901	1.1771	1.6211	717	.00134	.766	315.4	1.059	.522	128.8
1.60	93.75	2701	6506.0	9.915	1.1802	1.5642	710	.00129	.908	307.0	1.008	.614	151.5
1.76	85.15	2664	6454.3	9.925	1.1825	1.5246	704	.00125	1.000	305.7	1.000	.671	165.6
2.00	75.00	2615	6387.3	9.937	1.1858	1.4743	697	.00120	1.110	307.1	1.011	.739	182.4
4.00	37.50	2346	6044.3	9.984	1.2061	1.2448	653	.00098	1.605	332.1	1.311	1.018	251.2
10.00	15.00	1994	5649.4	10.010	1.2334	1.0652	587	.00077	2.142	367.4	2.235	1.265	312.2
10.21	14.70	1986	5641.3	10.010	1.2339	1.0625	586	.00077	2.154	368.1	2.264	1.270	313.3
20.00	7.50	1743	5392.6	10.015	1.2495	.9956	533	.00066	2.624	389.6	3.522	1.403	346.1
40.00	3.75	1512	5169.1	10.016	1.2641	.9502	478	.00057	2.905	408.2	5.670	1.512	373.2
100.00	1.50	1242	4919.2	10.016	1.2830	.8994	405	.00046	3.421	428.0	10.829	1.626	401.3
200.00	.75	1063	4761.0	10.016	1.2960	.8642	351	.00039	3.831	440.0	17.784	1.694	418.1
400.00	.38	904	4626.0	10.016	1.3121	.8340	301	.00033	4.269	450.0	29.278	1.750	431.9
1000.00	.15	724	4478.5	10.016	1.3288	.8019	241	.00025	4.901	460.5	56.678	1.809	446.5
2000.00	.08	608	4387.2	10.016	1.3386	.7843	204	.00021	5.431	466.8	93.457	1.845	455.3
4000.00	.04	510	4310.5	10.016	1.3471	.7700	167	.00017	6.009	472.1	154.133	1.874	462.6

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OX'GEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Continued. Combustion-chamber pressure, 150 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/(lb)
R = 0.600, PERCENT FUEL = 17.35, O/F = 4.762													
1.00	150.00	3097	5841.6	11.228	1.1465	2.2005	788	0.00191	0.000			0.000	0.0
1.05	142.86	3081	5815.0	11.239	1.1469	2.1752	786	.00188	.292	540.2	2.136	.199	48.2
1.20	125.00	3036	5742.8	11.268	1.1479	2.1055	780	.00181	.567	544.0	1.247	.383	92.7
1.40	107.14	2985	5661.1	11.300	1.1493	2.0248	773	.00173	.774	307.5	1.055	.518	125.3
1.60	93.75	2940	5591.6	11.326	1.1507	1.9551	766	.00167	.918	299.6	1.007	.610	147.5
1.74	86.09	2911	5547.9	11.343	1.1517	1.9107	762	.00162	1.000	298.7	1.000	.661	159.9
2.00	75.00	2865	5478.2	11.368	1.1535	1.8396	756	.00155	1.122	300.4	1.013	.735	177.8
4.00	37.50	2630	5146.9	11.479	1.1662	1.5032	720	.00121	1.618	326.4	1.333	1.017	245.9
10.00	15.00	2308	4756.8	11.570	1.1922	1.1596	666	.00092	2.143	363.4	2.321	1.270	307.2
10.21	14.70	2300	4748.7	11.572	1.1928	1.1536	665	.00091	2.154	364.1	2.352	1.275	308.4
20.00	7.50	2058	4497.3	11.602	1.2142	1.0010	619	.00075	2.506	386.9	3.708	1.414	342.0
40.00	3.75	1815	4267.6	11.613	1.2327	.9136	586	.00064	2.867	406.6	6.038	1.530	370.1
100.00	1.50	1518	4006.8	11.616	1.2517	.8215	493	.00053	3.360	427.8	11.693	1.652	399.6
200.00	.75	1317	3838.9	11.616	1.2654	.8157	437	.00045	3.749	440.9	19.413	1.726	417.4
400.00	.38	1135	3693.7	11.616	1.2798	.7825	385	.00038	4.158	451.9	32.319	1.787	432.3
1000.00	.15	924	3532.7	11.616	1.2988	.7435	314	.00030	4.742	463.6	63.444	1.853	448.2
2000.00	.08	786	3431.6	11.616	1.3122	.7189	267	.00025	5.228	470.7	105.595	1.893	457.9
4000.00	.04	665	3345.7	11.616	1.3238	.6994	224	.00020	5.759	476.6	175.548	1.927	466.0
R = 0.700, PERCENT FUEL = 15.25, O/F = 5.556													
1.00	150.00	3231	5138.3	12.482	1.1328	2.7036	825	0.00240	0.000			0.000	0.0
1.05	142.86	3216	5113.3	12.497	1.1328	2.6809	823	.00237	.294	523.5	2.126	.198	46.7
1.20	125.00	3176	5045.5	12.536	1.1328	2.6171	818	.00230	.570	333.6	1.242	.382	89.8
1.40	107.14	3130	4968.6	12.580	1.1329	2.5409	811	.00222	.778	298.5	1.052	.516	121.5
1.60	93.75	3091	4903.1	12.618	1.1331	2.4728	806	.00215	.923	291.1	1.006	.607	143.1
1.73	86.66	3068	4865.0	12.640	1.1333	2.4318	803	.00211	1.000	290.3	1.000	.655	154.2
2.00	75.00	3025	4795.9	12.680	1.1338	2.3550	797	.00203	1.129	292.1	1.015	.733	172.6
4.00	37.50	2823	4480.4	12.855	1.1366	1.9694	767	.00166	1.627	318.6	1.348	1.016	239.3
10.00	15.00	2550	4102.6	13.040	1.1534	1.4750	724	.00111	2.150	356.5	2.391	1.275	300.2
10.21	14.70	2544	4094.6	13.044	1.1539	1.4650	723	.00110	2.161	357.3	2.425	1.280	301.4
20.00	7.50	2331	3845.6	13.134	1.1725	1.1743	687	.00074	2.500	381.1	3.886	1.424	335.4
40.00	3.75	2102	3613.6	13.187	1.1957	.9713	643	.00045	2.838	402.1	6.425	1.547	364.2
100.00	1.50	1797	3344.9	13.211	1.2221	.8356	596	.00029	3.296	424.8	12.637	1.677	395.0
200.00	.75	1579	3169.2	13.215	1.2367	.7871	521	.00021	3.662	438.9	21.191	1.758	413.9
400.00	.38	1379	3015.2	13.216	1.2500	.7520	465	.00044	4.048	450.8	35.638	1.825	429.8
1000.00	.15	1142	2841.9	13.216	1.2682	.7111	392	.00035	4.593	463.7	70.952	1.898	447.0
2000.00	.08	983	2731.3	13.216	1.2825	.6825	340	.00030	5.039	471.7	119.341	1.943	457.6
4000.00	.04	841	2636.4	13.216	1.2964	.6576	290	.00025	5.523	478.4	200.371	1.981	466.6
R = 0.800, PERCENT FUEL = 13.60, O/F = 6.349													
1.00	150.00	3304	4586.9	13.622	1.1257	3.1245	851	0.00222	0.000			0.000	0.0
1.05	142.86	3290	4563.4	13.639	1.1255	3.1098	849	.00220	.295	506.9	2.121	.198	45.2
1.20	125.00	3253	4499.9	13.687	1.1249	3.0677	844	.00214	.572	323.2	1.240	.381	87.0
1.40	107.14	3211	4427.7	13.741	1.1244	3.0158	838	.00208	.781	289.3	1.051	.515	117.7
1.60	93.75	3174	4366.2	13.788	1.1240	2.9681	833	.00202	.927	282.2	1.005	.606	138.6
1.72	86.97	3154	4331.9	13.814	1.1237	2.9401	830	.00199	1.000	281.5	1.000	.652	148.9
2.00	75.00	3115	4265.3	13.865	1.1234	2.8824	824	.00192	1.132	283.4	1.016	.732	167.3
4.00	37.50	2935	3967.3	14.095	1.1228	2.5693	796	.00159	1.633	309.7	1.357	1.016	232.2
10.00	15.00	2704	3606.7	14.369	1.1267	2.0604	763	.00110	2.157	347.8	2.437	1.278	292.0
10.21	14.70	2699	3599.0	14.375	1.1269	2.0482	762	.00109	2.168	348.5	2.472	1.284	293.2
20.00	7.50	2526	3357.5	14.544	1.1354	1.6945	734	.00073	2.505	373.0	4.017	1.431	327.1
40.00	3.75	2338	3128.1	14.677	1.1540	1.2665	701	.00043	2.829	394.9	6.763	1.558	356.3
100.00	1.50	2064	2853.8	14.778	1.1840	.9242	647	.00071	3.246	419.2	13.610	1.698	388.1
200.00	.75	1846	2673.8	14.808	1.2005	.7993	598	.00038	3.578	434.4	23.116	1.785	408.0
400.00	.38	1634	2512.1	14.814	1.2228	.7393	545	.00049	3.935	447.3	39.267	1.859	424.9
1000.00	.15	1375	2327.4	14.816	1.2401	.6930	472	.00041	4.444	461.5	79.186	1.940	443.4
2000.00	.08	1199	2207.9	14.816	1.2552	.6639	417	.00035	4.858	470.4	134.569	1.990	455.0
4000.00	.04	1039	2103.9	14.816	1.2672	.6361	364	.00029	5.302	477.9	228.324	2.033	464.8
R = 0.900, PERCENT FUEL = 12.28, O/F = 7.143													
1.00	150.00	3336	4142.9	14.653	1.1226	3.2851	870	0.00230	0.000			0.000	0.0
1.05	142.86	3322	4120.9	14.672	1.1224	3.2773	868	.00229	.295	491.1	2.118	.197	43.8
1.20	125.00	3286	4061.3	14.726	1.1216	3.2547	862	.00225	.573	313.2	1.239	.380	84.3
1.40	107.14	3246	3993.5	14.787	1.1208	3.2263	857	.00221	.782	280.4	1.051	.514	114.0
1.60	93.75	3211	3935.7	14.840	1.1201	3.1997	852	.00217	.928	273.6	1.005	.606	134.3
1.72	87.09	3192	3904.1	14.869	1.1197	3.1843	849	.00214	1.000	272.9	1.000	.650	144.2
2.00	75.00	3154	3840.9	14.927	1.1190	3.1513	843	.00208	1.134	274.8	1.016	.731	162.1
4.00	37.50	2964	3560.2	15.193	1.1163	2.9688	818	.00176	1.636	300.6	1.360	1.016	225.2
10.00	15.00	2775	3219.0	15.529	1.1144	2.6406	786	.00120	2.161	338.0	2.457	1.279	283.5
10.21	14.70	2770	3211.8	15.536	1.1144	2.6322	786	.00119	2.172	338.8	2.493	1.284	284.6
20.00	7.50	2623	2981.5	15.765	1.1151	2.3678	764	.00089	2.510	363.2	4.082	1.434	317.9
40.00	3.75	2474	2760.3	15.981	1.1187	1.9960	737	.00056	2.835	385.4	6.960	1.564	346.9
100.00	1.50	2267	2492.1	16.217	1.1536	1.3985	699	.00028	3.238	410.9	14.385	1.709	379.0
200.00	.75	2092	2307.5	16.335	1.1578	1.0228	663	.00018	3.529	427.3	24.996	1.802	399.6
400.00	.38	1896	2139.6	16.393	1.1671	.8018	620	.00009	3.832	441.5	43.209	1.883	417.5
1000.00	.15	1628	1944.1	16.415	1.2133	.6963	552	.00047	4.288	457.0	88.419	1.973	437.4
2000.00	.08	1427	1815.6	16.416	1.2260	.6560	498	.00040	4.671	466.8	151.688	2.030	450.0
4000.00	.04	1261	1706.5	16.416	1.2369	.6277	443	.00034	5.081	475.2	259.928	2.078	460.8

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Continued. Combustion-chamber pressure, 150 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, $I_{vac.}$, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 1.000, PERCENT FUEL = 11.19, O/F = 7.937													
1.00	150.00	3341	3777.9	15.586	1.1217	3.1852	882	0.00295	0.000			0.000	0.0
1.05	142.86	3328	3757.1	15.607	1.1214	3.1796	880	.00294	.295	476.5	2.118	.197	42.5
1.20	125.00	3292	3701.0	15.664	1.1206	3.1630	875	.00291	.573	303.9	1.238	.380	81.8
1.40	107.14	3252	3637.1	15.730	1.1197	3.1421	869	.00287	.782	272.2	1.050	.514	110.7
1.60	93.75	3217	3582.7	15.786	1.1190	3.1265	864	.00283	.928	265.5	1.005	.606	130.3
1.72	87.13	3199	3555.1	15.817	1.1186	3.1111	861	.00282	1.000	264.9	1.000	.650	139.8
2.00	75.00	3161	3493.4	15.880	1.1178	3.0866	856	.00278	1.134	266.7	1.016	.731	157.3
4.00	37.50	2994	3228.9	16.167	1.1146	2.9493	831	.00258	1.636	291.8	1.361	1.016	218.6
10.00	15.00	2789	2907.0	16.532	1.1117	2.7109	799	.00229	2.162	328.3	2.462	1.279	275.3
10.21	14.70	2785	2900.1	16.539	1.1116	2.7049	798	.00228	2.172	329.0	2.498	1.284	276.4
20.00	7.50	2644	2682.4	16.795	1.1106	2.4914	775	.00205	2.511	352.8	4.097	1.434	308.7
40.00	3.75	2505	2472.8	17.043	1.1107	2.2430	752	.00180	2.837	374.7	7.007	1.566	337.0
100.00	1.50	2325	2217.2	17.345	1.1135	1.8808	719	.00145	3.244	400.0	14.608	1.712	368.5
200.00	.75	2188	2039.0	17.547	1.1188	1.5942	692	.00120	3.542	416.7	25.757	1.807	389.0
400.00	.38	2048	1873.6	17.718	1.1262	1.3134	662	.00096	3.834	431.6	45.624	1.891	407.1
1000.00	.15	1850	1674.1	17.886	1.1497	.9862	617	.00069	4.220	448.7	97.111	1.988	427.8
2000.00	.08	1686	1538.1	17.962	1.1732	.8016	575	.00054	4.522	459.9	170.978	2.051	441.5
4000.00	.04	1517	1415.4	17.999	1.1980	.6640	527	.00043	4.853	469.5	298.702	2.107	453.4
R = 1.500, PERCENT FUEL = 7.749, O/F =11.905													
1.00	150.00	3219	2626.1	19.176	1.1249	1.9992	905	0.00193	0.000			0.000	0.0
1.05	142.86	3206	2609.8	19.199	1.1247	1.9899	903	.00191	.295	421.7	2.120	.198	37.6
1.20	125.00	3169	2565.9	19.260	1.1242	1.9637	897	.00188	.572	268.9	1.240	.381	72.4
1.40	107.14	3127	2515.9	19.330	1.1237	1.9320	891	.00183	.781	240.7	1.051	.515	97.9
1.60	93.75	3091	2473.3	19.390	1.1233	1.9032	885	.00180	.927	234.8	1.005	.606	115.3
1.72	86.98	3071	2449.6	19.424	1.1232	1.8866	881	.00178	1.000	234.2	1.000	.651	123.9
2.00	75.00	3031	2403.5	19.489	1.1228	1.8526	875	.00173	1.133	235.8	1.016	.732	139.2
4.00	37.50	2853	2197.1	19.783	1.1223	1.6765	845	.00152	1.633	257.7	1.357	1.016	193.2
10.00	15.00	2626	1947.2	20.134	1.1249	1.4088	806	.00123	2.158	289.4	2.439	1.278	243.0
10.21	14.70	2621	1942.0	20.141	1.1250	1.4026	805	.00123	2.169	290.1	2.474	1.283	244.0
20.00	7.50	2455	1774.4	20.361	1.1306	1.1951	774	.00102	2.507	310.5	4.027	1.431	272.2
40.00	3.75	2281	1614.9	20.545	1.1413	.9827	740	.00082	2.834	329.0	6.805	1.559	296.6
100.00	1.50	2037	1424.2	20.710	1.1651	.7495	687	.00060	3.249	349.7	13.824	1.700	323.4
200.00	.75	1842	1295.4	20.774	1.1881	.6298	641	.00048	3.566	362.8	23.681	1.789	340.3
400.00	.38	1644	1180.0	20.802	1.2093	.5593	589	.00040	3.903	374.0	40.495	1.865	354.7
1000.00	.15	1393	1047.3	20.811	1.2308	.5103	517	.00033	4.391	386.3	82.105	1.948	370.6
2000.00	.08	1220	960.9	20.813	1.2441	.4869	463	.00028	4.794	394.0	139.978	2.001	380.6
4000.00	.04	1062	885.4	20.813	1.2573	.4666	409	.00024	5.226	400.5	238.311	2.046	389.2
R = 2.000, PERCENT FUEL = 5.927, O/F =15.873													
1.00	150.00	3045	2016.0	21.610	1.1322	1.3351	900	0.00130	0.000			0.000	0.0
1.05	142.86	3031	2002.4	21.631	1.1322	1.3254	898	.00129	.294	386.3	2.126	.198	34.4
1.20	125.00	2992	1965.5	21.688	1.1323	1.2984	891	.00126	.571	246.2	1.242	.381	66.3
1.40	107.14	2947	1923.6	21.752	1.1326	1.2665	883	.00122	.778	220.3	1.052	.516	89.7
1.60	93.75	2909	1888.0	21.807	1.1329	1.2381	876	.00118	.924	214.8	1.006	.607	105.6
1.73	86.67	2886	1867.2	21.838	1.1331	1.2211	872	.00116	1.000	214.2	1.000	.655	113.8
2.00	75.00	2845	1829.6	21.895	1.1336	1.1894	865	.00113	1.129	215.6	1.015	.733	127.4
4.00	37.50	2649	1657.8	22.145	1.1382	1.0314	829	.00095	1.627	235.1	1.348	1.016	176.6
10.00	15.00	2388	1451.9	22.405	1.1514	.8231	778	.00073	2.151	263.1	2.393	1.275	221.6
10.21	14.70	2382	1447.6	22.410	1.1518	.8187	777	.00072	2.162	263.7	2.427	1.280	222.4
20.00	7.50	2184	1311.8	22.540	1.1681	.6852	736	.00059	2.502	281.4	3.895	1.424	247.5
40.00	3.75	1974	1185.0	22.621	1.1892	.5809	688	.00048	2.839	297.0	6.456	1.547	268.9
100.00	1.50	1694	1037.6	22.665	1.2166	.4985	618	.00038	3.291	313.9	12.741	1.679	291.8
200.00	.75	1492	940.9	22.675	1.2328	.4656	562	.00032	3.652	324.5	21.403	1.760	305.9
400.00	.38	1305	856.0	22.677	1.2462	.4438	506	.00028	4.035	333.4	36.042	1.828	317.7
1000.00	.15	1084	760.3	22.677	1.2629	.4209	434	.00023	4.576	343.1	71.914	1.902	330.6
2000.00	.08	935	699.0	22.677	1.2758	.4053	382	.00020	5.01	349.1	121.231	1.948	338.5
4000.00	.04	803	646.3	22.677	1.2892	.3906	334	.00017	5.495	354.1	204.087	1.988	345.2
R = 3.000, PERCENT FUEL = 4.031, O/F =23.810													
1.00	150.00	2695	1381.4	24.614	1.1581	0.7383	859	0.00072	0.000			0.000	0.0
1.05	142.86	2679	1370.8	24.628	1.1588	.7306	856	.00071	.291	340.3	2.145	.200	30.3
1.20	125.00	2634	1342.2	24.666	1.1609	.7094	847	.00069	.564	216.5	1.251	.385	58.4
1.40	107.14	2582	1309.9	24.706	1.1635	.6854	837	.00066	.769	193.4	1.057	.520	78.9
1.60	93.75	2537	1282.4	24.739	1.1661	.6650	828	.00063	.913	188.4	1.007	.612	92.8
1.75	85.58	2507	1263.9	24.760	1.1679	.6513	822	.00062	1.000	187.7	1.000	.666	101.1
2.00	75.00	2462	1237.6	24.789	1.1707	.6319	813	.00059	1.116	188.6	1.012	.737	111.9
4.00	37.50	2226	1107.7	24.905	1.1886	.5411	762	.00049	1.610	204.4	1.320	1.017	154.3
10.00	15.00	1914	956.6	24.980	1.2156	.4589	690	.00039	2.142	226.7	2.271	1.267	192.3
10.21	14.70	1907	953.5	24.981	1.2161	.4575	688	.00038	2.154	227.2	2.301	1.272	193.0
20.00	7.50	1687	857.4	25.000	1.2333	.4232	632	.00033	2.517	240.8	3.601	1.407	213.5
40.00	3.75	1475	770.4	25.006	1.2473	.4015	574	.00029	2.891	252.7	5.831	1.520	230.6
100.00	1.50	1224	672.4	25.006	1.2631	.3816	499	.00024	3.397	265.4	11.232	1.637	248.4
200.00	.75	1057	609.6	25.008	1.2752	.3682	445	.00021	3.796	273.2	18.588	1.708	259.1
400.00	.38	908	555.6	25.008	1.2875	.3559	394	.00018	4.217	279.8	30.867	1.767	268.1
1000.00	.15	736	495.9	25.008	1.3049	.3401	330	.00015	4.816	286.8	60.444	1.829	277.6
2000.00	.08	625	458.5	25.008	1.3181	.3292	286	.00012	5.312	291.0	100.439	1.868	283.4
4000.00	.04	527	426.8	25.008	1.3309	.3196	246	.00010	5.853	294.5	166.664	1.899	288.2

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Concluded. Combustion-chamber pressure, 150 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/(lb)
R = 4.000, PERCENT FUEL = 3.054, O/F =31.746													
1.00	150.00	2363	1054.4	26.287	1.1944	0.5005	802	0.00041	0.000			0.000	0.0
1.05	142.86	2344	1045.7	26.294	1.1957	.4958	798	.00041	.286	308.0	2.169	.202	27.5
1.20	125.00	2295	1022.3	26.311	1.1994	.4833	787	.00041	.556	195.6	1.261	.389	52.8
1.40	107.14	2238	995.9	26.328	1.2037	.4699	774	.00044	.758	174.4	1.062	.525	71.3
1.60	93.75	2188	973.6	26.341	1.2075	.4590	763	.00042	.900	169.5	1.010	.617	83.8
1.78	84.31	2149	956.3	26.350	1.2105	.4509	754	.00040	1.000	168.7	1.000	.680	92.4
2.00	75.00	2107	937.5	26.359	1.2138	.4426	745	.00040	1.101	169.4	1.009	.743	100.9
4.00	37.50	1859	834.0	26.391	1.2362	.4044	685	.00034	1.599	182.4	1.295	1.020	138.5
10.00	15.00	1555	716.5	26.404	1.2512	.3757	605	.00028	2.148	201.2	2.187	1.263	171.5
10.21	14.70	1549	714.1	26.404	1.2515	.3752	604	.00028	2.160	201.5	2.215	1.267	172.1
20.00	7.50	1350	640.8	26.406	1.2629	.3616	547	.00025	2.539	213.0	3.431	1.397	189.7
40.00	3.75	1166	575.3	26.406	1.2739	.3500	491	.00022	2.928	222.9	5.506	1.504	204.2
100.00	1.50	953	502.5	26.406	1.2894	.3353	421	.00018	3.455	233.4	10.485	1.614	219.2
200.00	.75	814	456.5	26.406	1.3021	.3244	372	.00016	3.873	239.8	17.201	1.680	228.1
400.00	.38	691	417.3	26.406	1.3152	.3140	326	.00013	4.317	245.1	28.301	1.734	235.5
1000.00	.15	552	374.6	26.406	1.3330	.3012	270	.00011	4.955	250.6	54.731	1.791	243.2
2000.00	.08	463	348.1	26.406	1.3459	.2928	232	.00009	5.487	254.0	90.095	1.826	247.9
4000.00	.04	387	326.0	26.406	1.3563	.2864	197	.00007	6.075	256.8	148.169	1.854	251.7
R = 5.000, PERCENT FUEL = 2.458, O/F =39.683													
1.00	150.00	2066	855.0	27.307	1.2269	0.4020	741	0.00037	0.000			0.000	0.0
1.05	142.86	2048	847.7	27.310	1.2282	.3996	737	.00036	.283	282.4	2.188	.204	25.2
1.20	125.00	1998	828.0	27.315	1.2315	.3934	725	.00035	.549	179.0	1.269	.392	48.4
1.40	107.14	1941	805.9	27.321	1.2353	.3869	711	.00034	.750	159.3	1.066	.529	65.3
1.60	93.75	1892	787.3	27.325	1.2384	.3818	699	.00033	.891	154.8	1.011	.622	76.7
1.80	83.45	1850	771.5	27.327	1.2410	.3777	688	.00032	1.000	153.9	1.000	.690	85.2
2.00	75.00	1812	757.3	27.329	1.2433	.3742	679	.00032	1.092	154.4	1.007	.747	92.2
4.00	37.50	1578	672.0	27.337	1.2563	.3570	617	.00028	1.594	165.7	1.281	1.022	126.2
10.00	15.00	1303	576.2	27.338	1.2708	.3411	539	.00023	2.152	182.2	2.144	1.262	155.7
10.21	14.70	1298	574.3	27.338	1.2711	.3408	538	.00023	2.164	182.5	2.171	1.266	156.3
20.00	7.50	1122	515.2	27.339	1.2815	.3309	484	.00020	2.550	192.6	3.343	1.393	171.9
40.00	3.75	961	462.8	27.339	1.2929	.3209	432	.00018	2.947	201.2	5.332	1.496	184.7
100.00	1.50	778	405.1	27.339	1.3094	.3076	367	.00015	3.487	210.3	10.068	1.603	197.9
200.00	.75	658	369.0	27.339	1.3227	.2979	321	.00012	3.919	215.8	16.403	1.666	205.6
400.00	.38	554	338.5	27.339	1.3364	.2887	279	.00011	4.380	220.3	26.799	1.717	212.0
1000.00	.15	438	305.6	27.339	1.3536	.2782	229	.00008	5.048	225.0	51.350	1.771	218.7
2000.00	.08	365	285.4	27.339	1.3652	.2728	195	.00007	5.612	227.8	83.996	1.803	222.6
4000.00	.04	303	268.6	27.339	1.3697	.2693	164	.00006	6.235	230.1	137.472	1.830	225.9

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Combustion-chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, (cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.150, PERCENT FUEL = 45.65, O/F = 1.190													
1.00	300.00	1183	5313.5	4.416	1.3396	1.7752	314	0.00073	0.000			0.000	0.0
1.05	285.71	1168	5287.7	4.416	1.3408	1.7710	311	.00073	.271	330.1	2.250	.210	47.4
1.20	250.00	1129	5218.6	4.416	1.3436	1.7597	303	.00070	.527	334.2	1.497	.403	90.8
1.40	214.29	1085	5141.9	4.416	1.3469	1.7472	293	.00068	.722	296.1	1.081	.543	122.2
1.60	187.50	1049	5077.7	4.416	1.3497	1.7369	285	.00066	.860	286.6	1.018	.636	143.2
1.87	160.64	1008	5006.8	4.416	1.3527	1.7257	276	.00063	1.000	284.1	1.000	.725	163.4
2.00	150.00	989	4975.4	4.416	1.3540	1.7210	272	.00062	1.059	284.4	1.003	.761	171.5
4.00	75.00	824	4693.4	4.416	1.3651	1.6825	234	.00052	1.566	301.7	1.233	1.031	232.3
10.00	30.00	643	4392.5	4.416	1.3748	1.6505	188	.00042	2.152	327.5	1.974	1.257	283.1
20.00	15.00	532	4209.8	4.416	1.3799	1.6344	159	.00035	2.586	343.5	2.982	1.376	309.9
20.41	14.70	529	4204.9	4.416	1.3801	1.6339	158	.00035	2.599	343.9	3.020	1.379	310.6
40.00	7.50	439	4058.9	4.416	1.3824	1.6267	133	.00029	3.031	356.4	4.620	1.467	330.4
100.00	3.00	340	3899.0	4.416	1.3880	1.6099	104	.00023	3.648	369.8	8.432	1.558	350.8
200.00	1.50	280	3802.5	4.416	1.3923	1.5970	85	.00018	4.149	377.7	13.431	1.610	362.6
400.00	.75	230	3723.2	4.416	1.4004	1.5771	70	.00015	4.675	384.1	21.488	1.652	372.0
1000.00	.30	175	3640.1	4.416	1.4332	1.4840	55	.00011	5.437	390.6	39.928	1.694	381.6
2000.00	.15	142	3590.9	4.416	1.4551	1.4367	45	.00009	6.096	394.3	63.572	1.719	387.2
4000.00	.08	114	3551.2	4.416	1.4713	1.4046	36	.00007	6.843	397.3	100.938	1.739	391.6
R = 0.200, PERCENT FUEL = 38.65, O/F = 1.587													
1.00	300.00	1514	2969.7	5.216	1.3078	1.6188	402	0.00084	0.000			0.000	0.0
1.05	285.71	1497	2941.7	5.216	1.3089	1.6144	399	.00083	.274	552.2	2.233	.209	49.3
1.20	250.00	1450	2866.8	5.216	1.3119	1.6025	389	.00081	.533	348.6	1.289	.400	94.6
1.40	214.29	1398	2783.2	5.216	1.3154	1.5889	378	.00078	.730	309.3	1.077	.539	127.4
1.60	187.50	1354	2713.2	5.216	1.3185	1.5773	369	.00076	.869	299.6	1.016	.632	149.4
1.85	162.47	1307	2640.5	5.216	1.3217	1.5652	359	.00073	1.000	297.3	1.000	.716	169.2
2.00	150.00	1282	2601.1	5.216	1.3235	1.5585	353	.00072	1.068	297.8	1.004	.757	179.1
4.00	75.00	1079	2290.0	5.216	1.3391	1.5046	307	.00061	1.572	316.7	1.244	1.029	243.2
10.00	30.00	852	1954.3	5.216	1.3559	1.4516	261	.00048	2.148	344.7	2.009	1.257	297.2
20.00	15.00	709	1746.8	5.216	1.3696	1.4232	233	.00040	2.573	362.0	3.049	1.379	325.9
20.41	14.70	705	1743.2	5.216	1.3698	1.4225	232	.00040	2.586	362.4	3.088	1.382	326.7
40.00	7.50	588	1578.0	5.216	1.3715	1.4065	179	.00034	3.010	376.0	4.739	1.472	348.0
100.00	3.00	458	1396.3	5.216	1.3771	1.3913	142	.00026	3.619	390.5	8.679	1.565	370.0
200.00	1.50	379	1286.1	5.216	1.3811	1.3807	117	.00022	4.111	399.1	13.870	1.619	382.7
400.00	.75	312	1195.2	5.216	1.3861	1.3677	96	.00018	4.638	406.1	22.296	1.662	393.0
1000.00	.30	242	1098.9	5.216	1.3972	1.3402	74	.00013	5.394	413.4	41.979	1.706	403.5
2000.00	.15	198	1041.1	5.216	1.4106	1.2977	61	.00011	6.014	417.7	67.687	1.733	409.7
4000.00	.08	161	993.9	5.216	1.4349	1.2571	50	.00009	6.705	421.1	108.755	1.754	414.6
R = 0.250, PERCENT FUEL = 33.51, O/F = 1.984													
1.00	300.00	1817	1249.3	6.016	1.2824	1.5015	481	0.00092	0.000			0.000	0.0
1.05	285.71	1797	1220.2	6.016	1.2835	1.4971	477	.00091	.276	563.4	2.218	.207	50.3
1.20	250.00	1745	1142.1	6.016	1.2862	1.4852	467	.00089	.538	356.2	1.283	.398	96.6
1.40	214.29	1686	1054.7	6.016	1.2895	1.4719	456	.00086	.736	316.3	1.073	.536	130.1
1.60	187.50	1636	981.5	6.016	1.2923	1.4609	446	.00084	.876	306.6	1.015	.629	152.7
1.83	163.91	1587	909.9	6.016	1.2951	1.4498	436	.00081	1.000	304.5	1.000	.708	171.8
2.00	150.00	1555	863.9	6.016	1.2971	1.4425	429	.00080	1.076	305.1	1.005	.754	183.1
4.00	75.00	1322	535.1	6.016	1.3125	1.3875	378	.00068	1.578	325.5	1.256	1.027	249.3
10.00	30.00	1057	176.1	6.016	1.3329	1.3226	314	.00054	2.147	355.3	2.048	1.258	305.6
20.00	15.00	887	9954.0	6.016	1.3460	1.2849	269	.00046	2.563	373.7	3.127	1.382	335.7
20.41	14.70	882	9948.0	6.016	1.3464	1.2838	268	.00045	2.575	374.2	3.168	1.386	336.5
40.00	7.50	741	9768.1	6.016	1.3568	1.2560	228	.00038	2.987	388.7	4.883	1.478	359.0
100.00	3.00	581	9569.0	6.016	1.3663	1.2321	191	.00030	3.581	404.2	8.985	1.574	382.4
200.00	1.50	482	9447.8	6.016	1.3718	1.2192	171	.00025	4.064	413.4	14.396	1.630	395.9
400.00	.75	399	9347.3	6.016	1.3755	1.2099	155	.00020	4.581	420.9	23.208	1.675	406.8
1000.00	.30	310	9240.5	6.016	1.3820	1.1949	95	.00015	5.327	428.7	43.894	1.722	418.1
2000.00	.15	256	9175.9	6.016	1.3867	1.1801	78	.00012	5.945	433.4	71.280	1.749	424.7
4000.00	.08	210	9122.7	6.016	1.4042	1.1475	64	.00010	6.605	437.2	115.650	1.771	430.2
R = 0.300, PERCENT FUEL = 29.57, O/F = 2.381													
1.00	300.00	2093	9932.7	6.814	1.2600	1.4230	550	0.00098	0.000			0.000	0.0
1.05	285.71	2072	9903.1	6.814	1.2611	1.4174	547	.00097	.279	568.5	2.206	.206	50.8
1.20	250.00	2016	9823.5	6.815	1.2640	1.4027	537	.00095	.542	359.8	1.277	.396	97.5
1.40	214.29	1952	9734.4	6.815	1.2674	1.3869	525	.00092	.742	319.8	1.070	.533	131.4
1.60	187.50	1897	9659.4	6.815	1.2702	1.3740	515	.00090	.882	310.3	1.013	.626	154.2
1.82	165.12	1846	9590.1	6.816	1.2729	1.3623	505	.00087	1.000	308.3	1.000	.701	172.7
2.00	150.00	1809	9538.9	6.816	1.2750	1.3539	498	.00086	1.082	309.1	1.006	.751	185.1
4.00	75.00	1553	9199.7	6.816	1.2893	1.2994	445	.00074	1.585	330.6	1.266	1.025	252.6
10.00	30.00	1257	8825.3	6.816	1.3095	1.2336	379	.00060	2.148	361.8	2.085	1.260	310.4
20.00	15.00	1054	8591.2	6.816	1.3248	1.1891	325	.00051	2.555	381.2	3.206	1.386	341.7
20.41	14.70	1059	8584.9	6.816	1.3253	1.1878	324	.00050	2.567	381.7	3.248	1.390	342.5
40.00	7.50	895	8393.6	6.816	1.3384	1.1531	279	.00042	2.968	397.0	5.037	1.485	366.0
100.00	3.00	707	8180.4	6.816	1.3531	1.1173	223	.00033	3.544	413.5	9.325	1.584	390.5
200.00	1.50	590	8049.6	6.816	1.3603	1.1006	187	.00027	4.013	423.3	14.993	1.642	404.8
400.00	.75	490	7940.8	6.816	1.3667	1.0865	156	.00023	4.517	431.3	24.234	1.689	416.3
1000.00	.30	383	7824.8	6.816	1.3724	1.0745	120	.00017	5.247	439.6	46.000	1.738	428.3
2000.00	.15	317	7754.3	6.816	1.3776	1.0657	98	.00014	5.851	444.6	74.914	1.767	435.4
4000.00	.08	262	7696.0	6.816	1.3832	1.0565	80	.00011	6.509	448.7	122.189	1.790	441.2

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.350, PERCENT FUEL = 26.47, O/F = 2.778													
1.00	300.00	2344	8892.8	7.607	1.2379	1.3936	610	0.00105	0.000			0.000	0.0
1.05	285.71	2322	8863.0	7.608	1.2391	1.3850	607	.00104	.281	369.6	2.194	.203	50.9
1.20	250.00	2263	8783.1	7.610	1.2425	1.3629	597	.00101	.547	360.9	1.272	.393	97.7
1.40	214.29	2196	8693.4	7.611	1.2463	1.3398	586	.00098	.747	321.1	1.068	.531	131.7
1.60	187.50	2139	8617.8	7.612	1.2495	1.3219	576	.00095	.888	311.7	1.012	.623	154.7
1.80	166.26	2088	8551.5	7.613	1.2523	1.3072	567	.00093	1.000	309.9	1.000	.694	172.3
2.00	150.00	2045	8496.0	7.614	1.2546	1.2955	559	.00091	1.089	310.8	1.007	.748	185.8
4.00	75.00	1771	8151.2	7.616	1.2695	1.2310	506	.00079	1.590	333.2	1.275	1.023	254.0
10.00	30.00	1451	7766.9	7.616	1.2884	1.1657	434	.00065	2.149	365.6	2.119	1.261	313.0
20.00	15.00	1238	7524.1	7.616	1.3035	1.1205	381	.00055	2.549	385.8	3.261	1.390	345.1
20.41	14.70	1232	7517.5	7.616	1.3040	1.1192	379	.00055	2.561	386.4	3.325	1.393	345.9
40.00	7.50	1051	7317.5	7.616	1.3188	1.0794	330	.00046	2.952	402.4	5.189	1.491	370.2
100.00	3.00	838	7092.6	7.616	1.3364	1.0365	267	.00036	3.511	419.8	9.678	1.594	395.8
200.00	1.50	702	6953.6	7.616	1.3474	1.0119	225	.00030	3.964	430.2	15.630	1.654	410.8
400.00	.75	586	6837.4	7.616	1.3563	.9954	189	.00025	4.453	438.6	25.355	1.703	422.9
1000.00	.30	460	6712.9	7.616	1.3653	.9791	148	.00019	5.161	447.5	48.298	1.754	435.5
2000.00	.15	382	6636.9	7.616	1.3704	.9692	121	.00016	5.751	452.8	78.868	1.784	443.0
4000.00	.08	317	6573.9	7.616	1.3753	.9598	98	.00013	6.392	457.2	128.975	1.809	449.2
R = 0.400, PERCENT FUEL = 23.95, O/F = 3.175													
1.00	300.00	2565	8050.5	8.389	1.2157	1.4207	662	0.00114	0.000			0.000	0.0
1.05	285.71	2543	8021.0	8.390	1.2170	1.4084	658	.00112	.284	367.8	2.181	.204	50.7
1.20	250.00	2484	7941.5	8.395	1.2205	1.3764	649	.00109	.551	360.1	1.267	.391	97.4
1.40	214.29	2417	7852.1	8.399	1.2247	1.3423	638	.00105	.753	320.7	1.065	.528	131.4
1.60	187.50	2359	7776.7	8.403	1.2283	1.3153	629	.00101	.894	311.6	1.011	.620	154.4
1.79	167.44	2310	7714.6	8.405	1.2313	1.2941	621	.00099	1.000	310.0	1.000	.687	171.1
2.00	150.00	2263	7654.8	8.407	1.2342	1.2752	613	.00096	1.095	311.0	1.008	.746	185.6
4.00	75.00	1978	7307.8	8.414	1.2508	1.1857	561	.00083	1.594	334.2	1.285	1.021	254.2
10.00	30.00	1637	6917.4	8.416	1.2698	1.1119	489	.00069	2.148	367.6	2.152	1.262	314.0
20.00	15.00	1409	6668.4	8.416	1.2842	1.0671	434	.00059	2.544	388.5	3.354	1.393	346.8
20.41	14.70	1403	6661.6	8.416	1.2846	1.0658	433	.00059	2.555	389.1	3.399	1.397	347.6
40.00	7.50	1205	6454.8	8.416	1.2991	1.0255	380	.00050	2.939	405.8	5.338	1.497	372.6
100.00	3.00	970	6220.2	8.416	1.3188	.9768	313	.00040	3.480	424.1	10.036	1.603	399.1
200.00	1.50	819	6074.1	8.416	1.3318	.9478	266	.00033	3.919	435.0	16.294	1.666	414.7
400.00	.75	687	5951.2	8.416	1.3428	.9250	224	.00027	4.390	443.9	26.545	1.717	427.4
1000.00	.30	542	5818.7	8.416	1.3537	.9038	176	.00021	5.074	453.3	50.799	1.770	440.7
2000.00	.15	452	5737.5	8.416	1.3595	.8929	146	.00017	5.646	459.0	83.167	1.802	448.6
4000.00	.08	376	5670.0	8.416	1.3650	.8831	119	.00014	6.269	463.6	136.362	1.829	455.1
R = 0.450, PERCENT FUEL = 21.87, O/F = 3.571													
1.00	300.00	2755	7354.5	9.152	1.1952	1.5003	705	0.00125	0.000			0.000	0.0
1.05	285.71	2734	7325.4	9.155	1.1964	1.4843	704	.00123	.286	363.6	2.169	.202	50.3
1.20	250.00	2677	7247.0	9.164	1.1997	1.4419	693	.00119	.556	357.9	1.261	.389	96.7
1.40	214.29	2611	7158.7	9.173	1.2036	1.3959	683	.00114	.758	319.1	1.062	.525	130.5
1.60	187.50	2555	7084.0	9.180	1.2072	1.3588	675	.00110	.900	310.2	1.010	.617	153.4
1.78	168.67	2510	7026.0	9.185	1.2100	1.3312	668	.00107	1.000	308.8	1.000	.680	169.1
2.00	150.00	2460	6962.9	9.190	1.2132	1.3023	660	.00104	1.102	310.0	1.009	.743	184.6
4.00	75.00	2173	6616.3	9.208	1.2319	1.1697	610	.00088	1.599	333.9	1.295	1.020	253.4
10.00	30.00	1818	6222.5	9.215	1.2529	1.0717	540	.00072	2.147	366.2	2.187	1.263	313.8
20.00	15.00	1576	5969.2	9.216	1.2667	1.0246	485	.00063	2.537	389.8	3.427	1.397	347.2
20.41	14.70	1569	5962.2	9.216	1.2671	1.0233	483	.00063	2.548	390.3	3.474	1.401	348.1
40.00	7.50	1358	5750.2	9.216	1.2810	.9831	430	.00054	2.925	407.7	5.487	1.503	373.6
100.00	3.00	1105	5507.6	9.216	1.3007	.9327	358	.00043	3.453	426.7	10.401	1.613	400.9
200.00	1.50	938	5355.2	9.216	1.3151	.8999	308	.00036	3.877	438.2	16.963	1.678	417.1
400.00	.75	793	5226.1	9.216	1.3281	.8728	261	.00030	4.331	447.6	27.808	1.732	430.3
1000.00	.30	630	5086.2	9.216	1.3418	.8465	207	.00023	4.990	457.6	53.499	1.788	444.3
2000.00	.15	527	5000.0	9.216	1.3501	.8315	172	.00019	5.541	463.6	87.879	1.821	452.6
4000.00	.08	440	4927.9	9.216	1.3561	.8211	142	.00016	6.144	468.5	144.468	1.849	459.5
R = 0.500, PERCENT FUEL = 20.12, O/F = 3.968													
1.00	300.00	2915	6769.6	9.891	1.1779	1.6231	741	0.00139	0.000			0.000	0.0
1.05	285.71	2895	6741.2	9.897	1.1788	1.6042	738	.00137	.288	357.9	2.158	.201	49.8
1.20	250.00	2841	6664.3	9.911	1.1814	1.5535	730	.00132	.559	354.6	1.256	.387	95.7
1.40	214.29	2778	6577.6	9.926	1.1847	1.4970	721	.00126	.764	316.4	1.060	.523	129.3
1.60	187.50	2724	6504.1	9.938	1.1878	1.4502	713	.00121	.906	307.9	1.009	.615	152.0
1.77	169.85	2684	6450.6	9.946	1.1901	1.4168	707	.00118	1.000	306.6	1.000	.674	166.6
2.00	150.00	2633	6384.7	9.956	1.1932	1.3760	699	.00114	1.108	307.9	1.010	.740	183.0
4.00	75.00	2352	6040.6	9.993	1.2121	1.1932	654	.00094	1.604	332.6	1.307	1.019	251.9
10.00	30.00	1992	5645.6	10.012	1.2339	1.0900	587	.00076	2.145	367.7	2.224	1.265	312.7
20.00	15.00	1740	5389.3	10.015	1.2509	.9916	533	.00066	2.529	389.9	3.504	1.401	346.6
20.41	14.70	1732	5382.2	10.015	1.2513	.9902	531	.00066	2.540	390.5	3.553	1.403	347.5
40.00	7.50	1509	5166.1	10.016	1.2644	.9491	477	.00057	2.910	408.4	5.642	1.511	373.5
100.00	3.00	1240	4916.8	10.016	1.2833	.8988	404	.00046	3.427	428.2	10.777	1.624	401.5
200.00	1.50	1060	4758.9	10.016	1.2982	.8638	350	.00039	3.837	440.2	17.699	1.691	418.3
400.00	.75	902	4624.2	10.016	1.3123	.8336	300	.00032	4.275	450.1	29.139	1.747	432.1
1000.00	.30	722	4477.1	10.016	1.3289	.8015	240	.00025	4.908	460.6	56.410	1.806	446.6
2000.00	.15	607	4386.0	10.016	1.3387	.7842	201	.00021	5.439	466.9	93.015	1.842	455.4
4000.00	.08	508	4309.5	10.016	1.3472	.7696	167	.00017	6.018	472.2	153.404	1.871	462.7

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.600, PERCENT FUEL = 17.35, O/F = 4.762													
1.00	300.00	3155	5841.6	11.290	1.1529	1.9667	796	0.00174	0.000			0.000	0.0
1.05	285.71	3137	5814.6	11.300	1.1532	1.9446	794	.00172	.291	543.6	2.140	.200	48.5
1.20	250.00	3089	5741.6	11.326	1.1544	1.8842	787	.00166	.565	346.0	1.248	.384	93.3
1.40	214.29	3033	5658.9	11.354	1.1560	1.8145	780	.00159	.772	309.3	1.056	.519	126.1
1.60	187.50	2985	5588.7	11.378	1.1576	1.7545	773	.00152	.916	301.2	1.007	.611	148.4
1.75	171.73	2953	5543.1	11.393	1.1588	1.7154	768	.00149	1.000	300.2	1.000	.663	161.2
2.00	150.00	2904	5474.1	11.415	1.1608	1.6559	761	.00143	1.119	301.8	1.013	.736	178.8
4.00	75.00	2652	5140.3	11.510	1.1743	1.3741	724	.00115	1.615	327.7	1.328	1.017	247.0
10.00	30.00	2311	4749.0	11.583	1.1992	1.0984	667	.00088	2.144	364.3	2.303	1.269	308.3
20.00	15.00	2054	4489.8	11.606	1.2185	.9752	618	.00073	2.512	387.6	3.673	1.412	343.0
20.41	14.70	2047	4482.6	11.607	1.2190	.9726	616	.00073	2.522	388.2	3.726	1.416	343.9
40.00	7.50	1808	4260.9	11.614	1.2346	.9053	565	.00063	2.877	407.2	5.977	1.527	370.9
100.00	3.00	1512	4001.1	11.616	1.2523	.8496	496	.00052	3.371	428.3	11.578	1.647	400.2
200.00	1.50	1311	3834.0	11.616	1.2659	.8145	436	.00045	3.761	441.3	19.216	1.721	418.0
400.00	.75	1130	3689.5	11.616	1.2802	.7815	381	.00038	4.171	452.2	31.993	1.781	432.7
1000.00	.30	919	3529.3	11.616	1.2993	.7427	312	.00030	4.757	463.8	62.803	1.847	448.6
2000.00	.15	782	3428.6	11.616	1.3126	.7183	265	.00025	5.244	470.9	104.524	1.886	458.2
4000.00	.08	661	3343.2	11.616	1.3242	.6988	223	.00020	5.776	476.8	173.763	1.919	466.3
R = 0.700, PERCENT FUEL = 15.25, O/F = 5.556													
1.00	300.00	3307	5138.3	12.574	1.1378	2.3992	836	0.00217	0.000			0.000	0.0
1.05	285.71	3291	5112.9	12.588	1.1378	2.3785	834	.00215	.293	527.6	2.129	.198	47.0
1.20	250.00	3248	5044.0	12.625	1.1379	2.3404	828	.00208	.569	336.2	1.244	.382	90.6
1.40	214.29	3198	4966.0	12.667	1.1382	2.2912	821	.00201	.777	300.7	1.053	.517	122.4
1.60	187.50	3156	4899.5	12.702	1.1386	2.1898	815	.00194	.922	293.1	1.006	.608	144.1
1.73	172.98	3130	4859.9	12.723	1.1389	2.1520	811	.00190	1.000	292.3	1.000	.657	155.6
2.00	150.00	3085	4790.8	12.759	1.1395	2.0841	805	.00183	1.127	294.1	1.014	.734	173.9
4.00	75.00	2865	4471.7	12.920	1.1454	1.7441	774	.00150	1.625	320.4	1.344	1.016	240.8
10.00	30.00	2569	4091.1	13.081	1.1620	1.3258	728	.00110	2.149	358.1	2.374	1.274	301.9
20.00	15.00	2335	3833.6	13.157	1.1711	1.0849	687	.00088	2.503	382.5	3.843	1.422	336.9
20.41	14.70	2328	3826.4	13.159	1.1717	1.0791	686	.00087	2.513	383.1	3.900	1.426	337.9
40.00	7.50	2095	3602.0	13.196	1.2020	.9294	641	.00072	2.846	403.2	6.337	1.543	365.6
100.00	3.00	1785	3334.7	13.213	1.2246	.8253	573	.00058	3.312	425.6	12.441	1.672	396.1
200.00	1.50	1566	3160.2	13.216	1.2378	.7835	518	.00050	3.682	439.6	20.858	1.751	414.9
400.00	.75	1368	3007.3	13.216	1.2508	.7500	462	.00043	4.070	451.4	35.080	1.817	430.6
1000.00	.30	1133	2835.4	13.216	1.2690	.7094	389	.00035	4.616	464.2	69.841	1.889	447.6
2000.00	.15	975	2725.7	13.216	1.2833	.6811	337	.00029	5.065	472.1	117.461	1.933	458.2
4000.00	.08	834	2631.6	13.216	1.2972	.6564	288	.00024	5.551	478.7	197.192	1.971	467.0
R = 0.800, PERCENT FUEL = 13.60, O/F = 6.349													
1.00	300.00	3393	4586.9	13.740	1.1296	2.7921	864	0.00257	0.000			0.000	0.0
1.05	285.71	3378	4563.0	13.757	1.1294	2.7781	861	.00255	.294	511.3	2.123	.198	45.6
1.20	250.00	3338	4498.3	13.803	1.1289	2.7382	856	.00250	.571	326.0	1.241	.381	87.8
1.40	214.29	3292	4424.9	13.855	1.1284	2.6891	850	.00244	.780	291.8	1.052	.515	118.7
1.60	187.50	3253	4362.3	13.900	1.1281	2.6439	844	.00238	.925	284.5	1.005	.607	139.8
1.73	173.68	3231	4326.9	13.926	1.1279	2.6168	841	.00235	1.000	283.8	1.000	.653	150.4
2.00	150.00	3189	4259.9	13.974	1.1276	2.5628	835	.00229	1.131	285.6	1.015	.732	168.7
4.00	75.00	2995	3957.6	14.193	1.1277	2.2689	807	.00197	1.632	312.0	1.354	1.016	234.0
10.00	30.00	2744	3592.8	14.449	1.1332	1.8019	770	.00152	2.156	349.9	2.423	1.277	294.1
20.00	15.00	2550	3341.8	14.605	1.1439	1.4368	738	.00119	2.505	375.0	3.982	1.429	329.1
20.41	14.70	2544	3334.7	14.609	1.1443	1.4265	737	.00118	2.515	375.7	4.042	1.433	330.1
40.00	7.50	2344	3111.8	14.716	1.1620	1.1265	704	.00091	2.832	396.7	6.676	1.555	358.3
100.00	3.00	2053	2840.4	14.791	1.1918	.8717	645	.00067	3.260	420.6	13.365	1.692	389.8
200.00	1.50	1830	2659.7	14.810	1.2106	.7805	595	.00056	3.601	435.6	22.652	1.778	409.5
400.00	.75	1617	2499.6	14.815	1.2246	.7331	541	.00049	3.964	448.3	38.453	1.850	426.2
1000.00	.30	1360	2316.9	14.816	1.2412	.6903	488	.00040	4.478	462.3	77.533	1.929	444.4
2000.00	.15	1185	2198.7	14.816	1.2543	.6615	413	.00034	4.894	471.0	131.747	1.979	455.9
4000.00	.08	1027	2096.0	14.816	1.2683	.6339	359	.00029	5.340	478.4	223.495	2.021	465.6
R = 0.900, PERCENT FUEL = 12.28, O/F = 7.143													
1.00	300.00	3430	4142.9	14.789	1.1261	2.9626	883	0.00276	0.000			0.000	0.0
1.05	285.71	3416	4120.5	14.809	1.1258	2.9553	881	.00275	.295	495.7	2.121	.198	44.2
1.20	250.00	3377	4059.8	14.861	1.1250	2.9343	875	.00271	.572	316.0	1.240	.381	85.1
1.40	214.29	3334	3990.7	14.921	1.1242	2.9078	869	.00267	.781	282.9	1.051	.515	115.1
1.60	187.50	3296	3931.9	14.972	1.1235	2.8830	864	.00263	.927	276.0	1.005	.606	135.5
1.72	173.98	3276	3899.3	15.001	1.1232	2.8682	861	.00261	1.000	275.3	1.000	.651	145.6
2.00	150.00	3235	3835.4	15.058	1.1225	2.8374	855	.00257	1.133	277.1	1.016	.732	163.6
4.00	75.00	3054	3550.3	15.317	1.1198	2.6636	829	.00234	1.635	303.0	1.358	1.016	227.1
10.00	30.00	2829	3204.5	15.641	1.1185	2.3536	795	.00200	2.161	340.5	2.448	1.278	285.8
20.00	15.00	2666	2964.3	15.867	1.1199	2.0547	769	.00170	2.511	365.6	4.058	1.432	320.2
20.41	14.70	2661	2957.5	15.873	1.1200	2.0490	768	.00169	2.521	366.3	4.121	1.437	321.2
40.00	7.50	2503	2741.4	16.068	1.1253	1.7023	742	.00138	2.837	387.8	6.901	1.562	349.2
100.00	3.00	2276	2472.2	16.273	1.1443	1.2030	700	.00095	3.241	413.0	14.187	1.706	381.3
200.00	1.50	2084	2288.0	16.364	1.1699	.9165	662	.00070	3.540	429.2	24.518	1.797	401.7
400.00	.75	1877	2121.5	16.403	1.1947	.7617	615	.00056	3.858	443.0	42.200	1.876	419.4
1000.00	.30	1606	1928.5	16.415	1.2158	.6840	546	.00046	4.329	458.2	86.184	1.964	439.0
2000.00	.15	1416	1801.8	16.416	1.2281	.6520	491	.00039	4.716	467.9	147.806	2.019	451.3
4000.00	.08	1241	1690.4	16.416	1.2404	.6246	437	.00034	5.130	476.1	253.224	2.066	462.0

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 1.000, PERCENT FUEL = 11.19, O/F = 7.937													
1.00	300.00	3437	3777.9	15.734	1.1250	2.8811	896	0.00272	0.000			0.000	0.0
1.05	285.71	3423	3756.8	15.755	1.1247	2.8760	894	.00271	.295	481.0	2.120	.198	62.9
1.20	250.00	3384	3699.5	15.811	1.1239	2.8611	888	.00268	.572	306.7	1.239	.380	82.6
1.40	214.29	3341	3634.5	15.875	1.1230	2.8421	882	.00265	.781	274.6	1.051	.515	111.7
1.60	187.50	3304	3579.1	15.930	1.1222	2.8243	877	.00261	.927	267.9	1.003	.606	131.5
1.76	170.08	3284	3548.5	15.961	1.1218	2.8138	874	.00259	1.000	267.2	1.000	.651	141.3
2.00	150.00	3244	3488.2	16.023	1.1211	2.7914	868	.00256	1.133	269.0	1.016	.732	158.8
4.00	75.00	3065	3219.4	16.303	1.1179	2.6657	842	.00237	1.635	294.2	1.359	1.016	220.4
10.00	30.00	2847	2893.0	16.659	1.1131	2.4459	808	.00210	2.162	330.7	2.453	1.279	277.5
20.00	15.00	2692	2665.8	16.914	1.1142	2.2431	783	.00177	2.812	355.3	4.076	1.453	311.1
20.41	14.70	2687	2659.3	16.921	1.1142	2.2367	783	.00177	2.822	356.0	4.140	1.458	312.0
40.00	7.50	2542	2454.2	17.153	1.1148	2.0143	758	.00144	3.440	377.1	6.959	1.564	339.4
100.00	3.00	2349	2196.7	17.439	1.1186	1.8681	724	.00122	3.950	402.3	14.469	1.709	370.9
200.00	1.50	2203	2017.9	17.625	1.1220	1.4246	695	.00119	3.549	418.9	25.445	1.803	391.3
400.00	.75	2052	1852.3	17.779	1.1330	1.1770	663	.00007	3.845	433.7	44.925	1.886	409.3
1000.00	.30	1839	1653.8	17.920	1.1572	.8997	614	.00004	4.239	450.6	95.113	1.981	429.9
2000.00	.15	1668	1519.2	17.979	1.1821	.7520	570	.00001	4.553	461.4	166.780	2.043	443.3
4000.00	.08	1493	1398.2	18.005	1.2043	.6606	520	.00002	4.897	470.8	290.406	2.097	455.0
R = 1.500, PERCENT FUEL = 7.749, O/F = 11.905													
1.00	300.00	3297	2626.1	19.320	1.1288	1.8003	918	0.00177	0.000			0.000	0.0
1.05	285.71	3282	2609.6	19.342	1.1286	1.7919	915	.00176	.294	425.1	2.123	.198	37.9
1.20	250.00	3243	2564.9	19.401	1.1281	1.7680	909	.00172	.571	271.0	1.241	.381	73.0
1.40	214.29	3198	2514.1	19.468	1.1277	1.7391	902	.00168	.780	242.6	1.052	.515	98.7
1.60	187.50	3159	2470.9	19.526	1.1273	1.7131	896	.00165	.925	236.6	1.005	.607	116.2
1.73	173.72	3137	2446.4	19.558	1.1271	1.6977	892	.00163	1.000	235.9	1.000	.653	125.0
2.00	150.00	3096	2400.0	19.620	1.1269	1.6672	886	.00159	1.131	237.5	1.015	.732	140.2
4.00	75.00	2904	2190.9	19.900	1.1267	1.5076	854	.00139	1.632	259.4	1.354	1.016	194.6
10.00	30.00	2661	1938.5	20.228	1.1302	1.2677	812	.00113	2.158	291.1	2.427	1.277	244.6
20.00	15.00	2478	1764.5	20.435	1.1369	1.0774	779	.00093	2.708	312.1	3.997	1.429	273.8
20.41	14.70	2472	1759.5	20.440	1.1372	1.0719	778	.00093	2.718	312.7	4.056	1.434	274.6
40.00	7.50	2291	1604.4	20.597	1.1487	.8963	742	.00055	2.837	330.4	6.734	1.557	298.2
100.00	3.00	2032	1413.9	20.734	1.1726	.7030	686	.00036	3.258	350.9	13.621	1.695	324.8
200.00	1.50	1830	1285.8	20.784	1.1938	.6070	638	.00036	3.582	363.8	23.271	1.783	341.5
400.00	.75	1629	1171.3	20.805	1.2126	.5300	595	.00019	3.927	374.8	39.732	1.857	355.8
1000.00	.30	1379	1039.8	20.812	1.2363	.4572	543	.00012	4.422	386.9	80.499	1.940	371.5
2000.00	.15	1207	954.3	20.813	1.2492	.4230	508	.00008	4.828	394.5	137.214	1.991	381.4
4000.00	.08	1050	879.8	20.812	1.2584	.4030	483	.00004	5.263	401.0	233.567	2.035	389.8
R = 2.000, PERCENT FUEL = 5.927, O/F = 15.873													
1.00	300.00	3103	2016.0	21.723	1.1368	1.2138	910	0.00111	0.000			0.000	0.0
1.05	285.71	3088	2002.2	21.743	1.1368	1.2052	907	.00110	.293	388.8	2.129	.198	34.7
1.20	250.00	3046	1964.8	21.797	1.1370	1.1812	900	.00107	.569	247.8	1.243	.382	66.7
1.40	214.29	2998	1922.4	21.857	1.1373	1.1528	892	.00103	.777	221.6	1.053	.517	90.2
1.60	187.50	2957	1886.3	21.908	1.1377	1.1276	885	.00100	.922	216.1	1.006	.608	106.2
1.73	173.03	2932	1864.9	21.936	1.1380	1.1122	881	.00098	1.000	215.4	1.000	.656	114.7
2.00	150.00	2889	1827.3	21.990	1.1387	1.0844	873	.00095	1.127	216.8	1.014	.734	128.2
4.00	75.00	2679	1653.8	22.219	1.1439	.9449	835	.00068	1.626	236.2	1.344	1.018	177.5
10.00	30.00	2402	1446.7	22.451	1.1579	.7644	781	.00048	2.151	264.1	2.379	1.274	222.6
20.00	15.00	2188	1308.3	22.567	1.1748	.6477	736	.00036	2.705	282.2	3.881	1.422	248.5
20.41	14.70	2181	1302.4	22.569	1.1751	.6447	735	.00035	2.715	282.7	3.918	1.426	249.2
40.00	7.50	1970	1179.6	22.633	1.1945	.5611	687	.00036	2.846	297.7	6.385	1.544	269.8
100.00	3.00	1686	1032.8	22.668	1.2192	.4923	636	.00027	3.304	314.5	12.580	1.674	292.5
200.00	1.50	1483	938.7	22.675	1.2341	.4632	559	.00022	3.666	324.9	21.125	1.754	306.5
400.00	.75	1297	852.3	22.677	1.2470	.4427	503	.00018	4.053	333.7	35.672	1.821	318.2
1000.00	.30	1076	757.2	22.677	1.2636	.4201	432	.00013	4.596	343.4	70.973	1.894	331.0
2000.00	.15	929	696.4	22.677	1.2765	.4046	380	.00010	5.040	349.3	119.641	1.940	338.9
4000.00	.08	797	644.1	22.677	1.2898	.3900	331	.00007	5.518	354.3	201.392	1.978	345.5
R = 3.000, PERCENT FUEL = 4.031, O/F = 23.810													
1.00	300.00	2723	1381.4	24.669	1.1639	0.6909	865	0.00038	0.000			0.000	0.0
1.05	285.71	2705	1370.7	24.682	1.1646	.6842	861	.00038	.290	341.6	2.148	.200	30.5
1.20	250.00	2658	1341.9	24.715	1.1667	.6659	852	.00035	.563	217.3	1.252	.385	58.6
1.40	214.29	2604	1309.3	24.751	1.1694	.6451	841	.00033	.768	194.0	1.058	.521	79.2
1.60	187.50	2556	1281.7	24.780	1.1719	.6275	832	.00031	.911	188.9	1.008	.613	93.1
1.76	170.82	2523	1262.7	24.798	1.1738	.6155	825	.00029	1.000	188.2	1.000	.668	101.6
2.00	150.00	2477	1236.7	24.823	1.1766	.5991	816	.00027	1.114	189.1	1.012	.738	112.2
4.00	75.00	2232	1106.3	24.922	1.1938	.5216	764	.00017	1.609	204.8	1.317	1.018	154.7
10.00	30.00	1914	955.2	24.985	1.2185	.4317	690	.00008	2.144	227.0	2.261	1.267	192.6
20.00	15.00	1684	856.1	25.002	1.2347	.4206	632	.00033	2.521	241.0	3.584	1.406	213.8
20.41	14.70	1678	853.3	25.002	1.2351	.4199	630	.00033	2.532	241.4	3.634	1.410	214.4
40.00	7.50	1472	769.2	25.007	1.2478	.4007	573	.00029	2.896	252.9	5.802	1.510	230.8
100.00	3.00	1222	671.4	25.008	1.2633	.3813	498	.00024	3.403	265.6	11.177	1.635	248.6
200.00	1.50	1055	608.7	25.008	1.2754	.3680	444	.00021	3.802	273.4	18.498	1.709	259.3
400.00	.75	906	554.8	25.008	1.2877	.3557	393	.00018	4.223	279.9	30.718	1.764	268.2
1000.00	.30	735	495.3	25.008	1.3021	.3399	330	.00014	4.823	286.8	60.154	1.826	277.7
2000.00	.15	623	458.0	25.008	1.3103	.3291	286	.00012	5.319	291.1	99.956	1.864	283.5
4000.00	.08	526	426.4	25.008	1.3311	.3195	245	.00010	5.861	294.6	165.857	1.896	288.3

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Concluded. Combustion-chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, $I_{vac.}$, (lb)(sec)/lb	Area ratio, ϵ	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/lb
R = 4.000, PERCENT FUEL = 3.054, O/F =31.746													
1.00	300.00	2372	1054.4	26.307	1.1993	0.4836	804	0.00046	0.000			0.000	0.0
1.05	285.71	2354	1045.7	26.312	1.2005	.4796	800	.00046	.286	308.5	1.172	.203	67.5
1.20	250.00	2303	1022.2	26.327	1.2040	.4689	789	.00044	.555	195.8	1.062	.390	52.9
1.40	214.29	2244	995.8	26.341	1.2080	.4574	776	.00043	.757	174.5	1.033	.526	71.4
1.60	187.50	2194	973.4	26.352	1.2115	.4481	765	.00041	.899	169.7	1.010	.618	83.9
1.78	168.42	2153	955.8	26.360	1.2143	.4412	755	.00040	1.000	168.9	1.000	.682	92.6
2.00	150.00	2110	937.2	26.367	1.2173	.4341	745	.00039	1.100	169.5	1.009	.743	101.0
4.00	75.00	1859	833.7	26.394	1.2340	.4010	685	.00034	1.599	182.5	1.294	1.040	138.6
10.00	30.00	1555	716.2	26.404	1.2517	.3749	605	.00028	2.149	201.2	2.184	1.263	171.6
20.00	15.00	1349	640.5	26.406	1.2631	.3614	547	.00025	2.541	213.0	3.426	1.397	189.8
20.41	14.70	1343	638.5	26.406	1.2634	.3611	545	.00025	2.552	213.4	3.474	1.400	190.2
40.00	7.50	1165	575.1	26.406	1.2740	.3499	491	.00022	2.930	222.9	5.499	1.503	204.2
100.00	3.00	952	502.2	26.406	1.2895	.3352	421	.00018	3.457	233.4	10.472	1.614	219.2
200.00	1.50	813	456.3	26.406	1.3021	.3243	372	.00016	3.875	239.8	17.179	1.679	228.1
400.00	.75	690	417.1	26.406	1.3153	.3139	329	.00013	4.319	245.1	28.266	1.733	235.5
1000.00	.30	552	374.5	26.406	1.3331	.3012	270	.00011	4.957	250.7	54.663	1.791	243.2
2000.00	.15	463	348.0	26.406	1.3459	.2928	232	.00009	5.490	254.0	89.984	1.825	247.9
4000.00	.08	386	326.0	26.406	1.3564	.2864	197	.00007	6.077	256.8	147.985	1.853	251.8
R = 5.000, PERCENT FUEL = 2.458, O/F =39.683													
1.00	300.00	2069	855.0	27.313	1.2295	0.3968	742	0.00036	0.000			0.000	0.0
1.05	285.71	2051	847.7	27.315	1.2306	.3947	737	.00036	.282	282.5	1.189	.204	65.2
1.20	250.00	2000	828.0	27.319	1.2337	.3893	725	.00035	.548	179.1	1.270	.393	48.5
1.40	214.29	1942	805.9	27.324	1.2371	.3835	711	.00034	.749	159.4	1.066	.529	65.4
1.60	187.50	1893	787.3	27.327	1.2400	.3790	699	.00033	.891	154.8	1.011	.622	76.8
1.80	166.83	1851	771.4	27.329	1.2424	.3753	689	.00032	1.000	153.9	1.000	.691	85.3
2.00	150.00	1813	757.2	27.331	1.2445	.3722	679	.00031	1.092	154.4	1.007	.747	92.2
4.00	75.00	1578	671.9	27.337	1.2567	.3564	617	.00028	1.594	165.8	1.281	1.044	128.2
10.00	30.00	1303	576.1	27.339	1.2709	.3411	539	.00023	2.152	182.2	2.143	1.262	155.8
20.00	15.00	1142	515.1	27.339	1.2815	.3309	484	.00020	2.550	192.6	3.342	1.393	172.0
20.41	14.70	1117	513.5	27.339	1.2819	.3308	482	.00020	2.562	192.9	3.388	1.396	172.4
40.00	7.50	961	462.8	27.339	1.2949	.3209	436	.00018	2.947	201.2	5.330	1.496	184.7
100.00	3.00	777	405.0	27.339	1.3095	.3076	387	.00015	3.487	210.3	10.066	1.603	197.9
200.00	1.50	658	368.9	27.339	1.3227	.2979	321	.00012	3.919	215.8	16.399	1.666	205.7
400.00	.75	554	338.5	27.339	1.3364	.2887	279	.00011	4.380	220.3	26.792	1.717	212.0
1000.00	.30	438	305.5	27.339	1.3536	.2782	229	.00008	5.049	225.0	51.338	1.771	218.7
2000.00	.15	365	285.3	27.339	1.3653	.2726	195	.00007	5.613	227.8	83.976	1.803	222.6
4000.00	.08	303	268.6	27.339	1.3767	.2693	164	.00006	6.235	230.1	137.439	1.830	225.9

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Combustion-chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.150, PERCENT FUEL = 45.65, O/F = 1.190													
1.00	600.00	1183	5313.5	4.416	1.3396	1.7753	314	0.00073	0.000			0.000	0.0
1.05	571.43	1168	5287.7	4.416	1.3406	1.7710	311	.00073	.271	530.0	2.250	.210	47.4
1.20	500.00	1129	5218.6	4.416	1.3436	1.7597	303	.00070	.527	334.2	1.297	.403	90.8
1.40	428.57	1085	5141.8	4.416	1.3469	1.7472	293	.00068	.722	296.1	1.081	.543	122.2
1.60	375.00	1049	5077.7	4.416	1.3497	1.7370	285	.00066	.860	286.6	1.018	.636	143.2
1.87	321.68	1008	5006.8	4.416	1.3528	1.7256	276	.00063	1.000	284.1	1.000	.725	163.4
2.00	300.00	989	4975.4	4.416	1.3541	1.7210	272	.00062	1.059	284.4	1.003	.761	171.5
4.00	150.00	824	4693.4	4.416	1.3651	1.6824	234	.00052	1.566	301.7	1.233	1.031	232.3
10.00	60.00	643	4392.5	4.416	1.3748	1.6506	188	.00042	2.152	327.5	1.974	1.257	283.1
20.00	30.00	532	4209.8	4.416	1.3799	1.6345	159	.00035	2.586	343.5	2.983	1.376	309.9
40.00	15.00	439	4058.9	4.416	1.3824	1.6269	133	.00029	3.031	356.4	4.620	1.467	330.4
40.83	14.70	437	4054.8	4.416	1.3824	1.6267	132	.00029	3.044	356.8	4.682	1.469	330.9
100.00	6.00	340	3899.0	4.416	1.3883	1.6089	104	.00023	3.648	369.8	8.432	1.558	350.8
200.00	3.00	280	3802.6	4.416	1.3930	1.5951	85	.00018	4.148	377.7	13.431	1.619	362.6
400.00	1.50	230	3723.2	4.416	1.4069	1.5558	70	.00015	4.674	384.1	21.488	1.652	372.0
1000.00	.60	175	3640.1	4.416	1.4347	1.4852	55	.00011	5.438	390.6	39.928	1.694	381.6
2000.00	.30	142	3590.9	4.416	1.4552	1.4387	45	.00009	6.096	394.3	63.572	1.719	387.2
4000.00	.15	114	3551.2	4.416	1.4717	1.4039	36	.00007	6.842	397.3	100.938	1.739	391.6
R = 0.200, PERCENT FUEL = 38.65, O/F = 1.587													
1.00	600.00	1514	2969.7	5.216	1.3078	1.6187	402	0.00084	0.000			0.000	0.0
1.05	571.43	1497	2941.7	5.216	1.3089	1.6143	399	.00083	.274	552.1	2.233	.209	49.3
1.20	500.00	1450	2866.8	5.216	1.3119	1.6024	389	.00081	.533	348.6	1.289	.400	94.6
1.40	428.57	1398	2783.1	5.216	1.3154	1.5888	378	.00078	.730	309.3	1.077	.539	127.4
1.60	375.00	1354	2713.2	5.216	1.3185	1.5773	369	.00076	.869	299.6	1.016	.632	149.4
1.85	324.94	1307	2640.5	5.216	1.3217	1.5651	359	.00073	1.000	297.3	1.000	.716	169.2
2.00	300.00	1282	2601.1	5.216	1.3236	1.5584	353	.00072	1.068	297.8	1.004	.757	179.1
4.00	150.00	1079	2290.0	5.216	1.3391	1.5048	307	.00061	1.572	316.7	1.244	1.029	243.2
10.00	60.00	852	1954.3	5.216	1.3558	1.4516	251	.00048	2.148	344.7	2.009	1.257	297.2
20.00	30.00	709	1748.8	5.216	1.3656	1.4232	213	.00040	2.573	362.0	3.049	1.379	325.9
40.00	15.00	588	1578.0	5.216	1.3715	1.4066	179	.00034	3.010	376.0	4.739	1.472	348.0
40.83	14.70	585	1573.4	5.216	1.3716	1.4062	178	.00034	3.023	376.4	4.802	1.474	348.6
100.00	6.00	458	1396.3	5.216	1.3770	1.3916	142	.00026	3.619	390.5	8.679	1.565	370.0
200.00	3.00	379	1286.1	5.216	1.3811	1.3808	117	.00022	4.111	399.1	13.870	1.619	382.7
400.00	1.50	312	1195.2	5.216	1.3858	1.3684	96	.00018	4.638	406.1	22.296	1.662	393.0
1000.00	.60	242	1098.9	5.216	1.3972	1.3404	74	.00013	5.394	413.4	41.979	1.706	403.5
2000.00	.30	198	1041.1	5.216	1.4157	1.2976	61	.00011	6.014	417.7	67.687	1.733	409.7
4000.00	.15	161	993.9	5.216	1.4362	1.2543	50	.00009	6.701	421.1	108.754	1.754	414.6
R = 0.250, PERCENT FUEL = 33.51, O/F = 1.984													
1.00	600.00	1817	1249.3	6.016	1.2827	1.4998	481	0.00092	0.000			0.000	0.0
1.05	571.43	1797	1220.2	6.016	1.2837	1.4955	477	.00091	.276	563.4	2.218	.207	50.3
1.20	500.00	1745	1142.1	6.016	1.2865	1.4840	467	.00089	.538	356.2	1.283	.398	96.6
1.40	428.57	1686	1054.7	6.016	1.2896	1.4712	456	.00086	.736	316.3	1.073	.536	130.1
1.60	375.00	1636	981.5	6.016	1.2924	1.4604	446	.00084	.876	306.6	1.015	.629	152.7
1.83	327.81	1587	909.9	6.016	1.2952	1.4494	436	.00081	1.000	304.5	1.000	.708	171.8
2.00	300.00	1555	863.9	6.016	1.2971	1.4423	429	.00080	1.076	305.1	1.005	.754	183.1
4.00	150.00	1322	535.1	6.016	1.3125	1.3874	378	.00068	1.578	325.5	1.256	1.027	249.3
10.00	60.00	1057	176.1	6.016	1.3329	1.3225	314	.00054	2.147	355.3	2.048	1.258	305.6
20.00	30.00	887	9954.0	6.016	1.3460	1.2849	269	.00046	2.563	373.7	3.127	1.382	335.7
40.00	15.00	741	9768.1	6.016	1.3568	1.2560	228	.00038	2.987	388.7	4.883	1.478	359.0
40.83	14.70	737	9763.1	6.016	1.3571	1.2552	227	.00038	3.000	389.1	4.949	1.481	359.6
100.00	6.00	581	9569.0	6.016	1.3663	1.2321	181	.00030	3.581	404.2	8.985	1.575	382.4
200.00	3.00	482	9447.8	6.016	1.3717	1.2189	151	.00025	4.064	413.4	14.396	1.630	395.9
400.00	1.50	399	9347.3	6.016	1.3755	1.2100	125	.00020	4.582	420.9	23.208	1.675	406.8
1000.00	.60	310	9240.5	6.016	1.3820	1.1949	95	.00015	5.327	428.7	43.893	1.722	418.1
2000.00	.30	256	9175.9	6.016	1.3883	1.1810	78	.00012	5.945	433.4	71.279	1.749	424.7
4000.00	.15	210	9122.7	6.016	1.4037	1.1485	64	.00010	6.606	437.2	115.650	1.771	430.2
R = 0.300, PERCENT FUEL = 29.57, O/F = 2.381													
1.00	600.00	2094	9932.7	6.815	1.2613	1.4145	551	0.00098	0.000			0.000	0.0
1.05	571.43	2073	9903.1	6.815	1.2623	1.4097	547	.00097	.279	568.6	2.206	.206	50.8
1.20	500.00	2016	9823.5	6.815	1.2650	1.3967	537	.00095	.542	359.8	1.277	.396	97.5
1.40	428.57	1952	9734.3	6.815	1.2681	1.3825	525	.00092	.742	319.8	1.071	.533	131.4
1.60	375.00	1898	9659.4	6.816	1.2708	1.3706	515	.00089	.882	310.3	1.013	.626	154.2
1.82	330.21	1847	9589.9	6.816	1.2734	1.3598	505	.00087	1.000	308.3	1.000	.701	172.7
2.00	300.00	1809	9538.8	6.816	1.2753	1.3519	498	.00085	1.082	309.1	1.006	.751	185.1
4.00	150.00	1553	9199.6	6.816	1.2894	1.2991	445	.00074	1.585	330.6	1.266	1.025	252.6
10.00	60.00	1257	8825.3	6.816	1.3095	1.2336	375	.00060	2.148	361.8	2.085	1.260	310.4
20.00	30.00	1064	8591.1	6.816	1.3248	1.1891	325	.00051	2.555	381.2	3.206	1.386	341.7
40.83	14.70	891	8388.2	6.816	1.3388	1.1522	277	.00042	2.981	397.4	5.106	1.488	366.6
40.00	15.00	895	8393.6	6.816	1.3384	1.1531	279	.00042	2.968	397.0	5.037	1.485	366.0
100.00	6.00	707	8180.3	6.816	1.3550	1.1174	223	.00033	3.544	413.5	9.324	1.585	390.5
200.00	3.00	590	8049.6	6.816	1.3603	1.1007	187	.00027	4.013	423.3	14.993	1.643	404.8
400.00	1.50	490	7940.8	6.816	1.3666	1.0867	156	.00023	4.517	431.3	24.234	1.689	416.3
1000.00	.60	383	7824.8	6.816	1.3743	1.0746	120	.00017	5.247	439.6	45.999	1.738	428.3
2000.00	.30	317	7754.3	6.816	1.3775	1.0638	98	.00014	5.852	444.6	74.912	1.767	435.4
4000.00	.15	262	7696.0	6.816	1.3827	1.0534	80	.00011	6.510	448.7	122.185	1.790	441.2

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.350, PERCENT FUEL = 26.47, O/F = 2.778													
1.00	600.00	2347	8892.8	7.610	1.2410	1.3691	611	0.00104	0.000			0.000	0.0
1.05	571.43	2325	8863.0	7.610	1.2421	1.3621	608	.00103	.281	570.0	2.195	.205	50.9
1.20	500.00	2266	8783.0	7.611	1.2451	1.3440	598	.00100	.546	361.0	1.273	.394	97.7
1.40	428.57	2198	8693.2	7.613	1.2485	1.3249	586	.00097	.747	321.2	1.068	.531	131.8
1.60	375.00	2140	8617.6	7.613	1.2513	1.3099	576	.00094	.887	311.8	1.012	.623	154.7
1.81	332.36	2089	8551.0	7.614	1.2538	1.2974	567	.00092	1.000	310.0	1.000	.695	172.5
2.00	300.00	2046	8495.7	7.614	1.2559	1.2874	559	.00090	1.088	310.9	1.007	.749	185.9
4.00	150.00	1771	8150.9	7.616	1.2699	1.2291	506	.00079	1.590	333.2	1.275	1.023	254.1
10.00	60.00	1451	7766.6	7.616	1.2885	1.1655	434	.00065	2.149	365.6	2.119	1.261	313.0
20.00	30.00	1238	7523.9	7.616	1.3036	1.1204	381	.00055	2.550	385.8	3.281	1.390	345.1
40.83	14.70	1045	7311.7	7.616	1.3192	1.0783	328	.00046	2.965	402.9	5.260	1.494	370.9
40.00	15.00	1050	7317.3	7.616	1.3188	1.0794	330	.00046	2.953	402.5	5.188	1.491	370.3
100.00	6.00	838	7092.4	7.616	1.3364	1.0365	267	.00036	3.511	419.8	9.676	1.594	395.8
200.00	3.00	702	6953.5	7.616	1.3475	1.0118	225	.00030	3.964	430.2	13.626	1.654	410.8
400.00	1.50	586	6837.3	7.616	1.3593	.9953	188	.00025	4.453	438.6	25.350	1.703	422.9
1000.00	.60	460	6712.8	7.616	1.3634	.9789	148	.00019	5.182	447.5	48.288	1.754	435.5
2000.00	.30	382	6636.9	7.616	1.3684	.9692	121	.00016	5.751	452.8	78.852	1.784	443.1
4000.00	.15	317	6573.8	7.616	1.3738	.9590	98	.00013	6.392	457.2	128.949	1.809	449.2
R = 0.400, PERCENT FUEL = 23.95, O/F = 3.175													
1.00	600.00	2574	8050.5	8.396	1.2209	1.3697	663	0.00110	0.000			0.000	0.0
1.05	571.43	2552	8020.9	8.397	1.2220	1.3599	660	.00109	.283	568.5	2.184	.204	50.7
1.20	500.00	2492	7941.2	8.401	1.2252	1.3344	650	.00106	.550	360.5	1.268	.392	97.5
1.40	428.57	2422	7851.7	8.404	1.2289	1.3072	639	.00102	.752	321.0	1.065	.528	131.3
1.60	375.00	2363	7776.1	8.406	1.2320	1.2856	630	.00100	.893	311.8	1.011	.621	154.5
1.79	334.53	2313	7713.0	8.408	1.2347	1.2685	621	.00097	1.000	310.2	1.000	.688	171.4
2.00	300.00	2266	7654.1	8.410	1.2372	1.2533	613	.00095	1.094	311.2	1.008	.746	185.7
4.00	150.00	1978	7306.9	8.414	1.2520	1.1787	561	.00083	1.594	334.3	1.284	1.022	254.4
10.00	60.00	1637	6916.6	8.416	1.2701	1.1109	489	.00069	2.149	367.6	2.150	1.262	314.1
20.00	30.00	1408	6667.8	8.416	1.2842	1.0669	434	.00059	2.545	388.6	3.351	1.393	346.9
40.00	15.00	1204	6454.3	8.416	1.2932	1.0253	380	.00050	2.940	405.9	5.334	1.497	372.7
40.83	14.70	1199	6448.5	8.416	1.2996	1.0242	379	.00050	2.951	406.3	5.409	1.500	373.4
100.00	6.00	970	6219.8	8.416	1.3188	.9767	313	.00040	3.482	424.1	10.029	1.603	399.1
200.00	3.00	818	6073.7	8.416	1.3318	.9478	266	.00033	3.920	435.0	16.282	1.666	414.7
400.00	1.50	687	5950.8	8.416	1.3428	.9249	224	.00027	4.391	443.9	26.525	1.717	427.4
1000.00	.60	542	5818.5	8.416	1.3537	.9037	176	.00021	5.076	453.3	50.761	1.770	440.7
2000.00	.30	452	5737.3	8.416	1.3595	.8928	146	.00017	5.648	459.0	83.105	1.802	448.6
4000.00	.15	376	5669.9	8.416	1.3647	.8835	119	.00014	6.271	463.6	136.261	1.828	455.1
R = 0.450, PERCENT FUEL = 21.87, O/F = 3.571													
1.00	600.00	2773	7354.5	9.167	1.2018	1.4156	707	0.00119	0.000			0.000	0.0
1.05	571.43	2752	7325.3	9.170	1.2029	1.4027	704	.00118	.285	565.0	2.172	.203	50.4
1.20	500.00	2692	7246.5	9.177	1.2060	1.3686	695	.00114	.554	358.6	1.263	.390	96.9
1.40	428.57	2624	7157.9	9.184	1.2097	1.3318	685	.00110	.757	319.6	1.063	.526	130.8
1.60	375.00	2565	7082.9	9.189	1.2128	1.3022	676	.00106	.899	310.7	1.010	.618	153.7
1.78	336.72	2517	7023.8	9.193	1.2154	1.2799	669	.00104	1.000	309.2	1.000	.682	169.6
2.00	300.00	2467	6961.6	9.197	1.2183	1.2573	661	.00101	1.100	310.3	1.009	.743	184.9
4.00	150.00	2174	6614.5	9.210	1.2347	1.1514	611	.00087	1.599	334.2	1.293	1.020	253.7
10.00	60.00	1817	6220.9	9.215	1.2537	1.0682	540	.00072	2.149	368.3	2.182	1.263	314.1
20.00	30.00	1575	5967.7	9.216	1.2670	1.0237	485	.00063	2.539	389.9	3.420	1.397	347.4
40.00	15.00	1357	5749.0	9.216	1.2811	.9828	429	.00054	2.927	407.8	5.476	1.503	373.8
40.83	14.70	1350	5743.0	9.216	1.2815	.9816	428	.00054	2.939	408.3	5.554	1.506	374.5
100.00	6.00	1104	5506.6	9.216	1.3008	.9325	358	.00043	3.455	426.8	10.381	1.612	401.0
200.00	3.00	937	5354.4	9.216	1.3152	.8996	307	.00036	3.879	438.3	16.950	1.678	417.2
400.00	1.50	792	5225.4	9.216	1.3282	.8727	261	.00030	4.334	447.7	27.755	1.731	430.4
1000.00	.60	629	5085.6	9.216	1.3418	.8465	207	.00023	4.994	457.6	53.398	1.787	444.3
2000.00	.30	526	4999.5	9.216	1.3502	.8313	172	.00019	5.544	463.6	87.714	1.820	452.7
4000.00	.15	439	4927.5	9.216	1.3562	.8210	142	.00016	6.148	468.5	144.197	1.848	459.5
R = 0.500, PERCENT FUEL = 20.12, O/F = 3.968													
1.00	600.00	2944	6769.6	9.919	1.1849	1.5012	745	0.00130	0.000			0.000	0.0
1.05	571.43	2923	6741.0	9.923	1.1859	1.4856	742	.00129	.287	559.8	2.162	.202	50.0
1.20	500.00	2866	6663.6	9.935	1.1835	1.4440	734	.00124	.558	355.7	1.258	.388	96.1
1.40	428.57	2800	6576.3	9.947	1.1917	1.3979	724	.00119	.762	317.3	1.061	.524	129.7
1.60	375.00	2742	6502.4	9.957	1.1946	1.3600	716	.00115	.904	308.6	1.009	.616	152.5
1.77	338.88	2699	6447.5	9.963	1.1970	1.3324	710	.00112	1.000	307.3	1.000	.676	167.4
2.00	300.00	2647	6382.5	9.971	1.1998	1.3008	702	.00109	1.106	308.6	1.010	.741	183.5
4.00	150.00	2356	6037.6	9.999	1.2169	1.1551	655	.00092	1.603	333.1	1.303	1.019	252.4
10.00	60.00	1990	5642.7	10.013	1.2378	1.0408	587	.00076	2.147	368.0	2.216	1.264	313.1
20.00	30.00	1737	5386.6	10.015	1.2515	.9888	532	.00066	2.532	390.1	3.491	1.401	346.9
40.00	15.00	1507	5163.1	10.016	1.2647	.9482	477	.00057	2.914	408.6	5.620	1.509	373.8
40.83	14.70	1501	5157.7	10.016	1.2651	.9471	475	.00057	2.926	409.1	5.701	1.512	374.5
100.00	6.00	1238	4914.9	10.016	1.2834	.8984	403	.00046	3.431	428.3	10.736	1.622	401.7
200.00	3.00	1059	4757.3	10.016	1.2984	.8634	350	.00039	3.842	440.3	17.634	1.690	418.5
400.00	1.50	900	4622.8	10.016	1.3125	.8333	300	.00032	4.280	450.2	29.032	1.745	432.2
1000.00	.60	720	4476.0	10.016	1.3291	.8013	240	.00025	4.914	460.7	56.203	1.804	446.7
2000.00	.30	606	4385.0	10.016	1.3387	.7841	201	.00021	5.445	467.0	92.675	1.839	455.5
4000.00	.15	507	4308.7	10.016	1.3473	.7696	166	.00017	6.024	472.2	152.844	1.868	462.7

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute, equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.600, PERCENT FUEL = 17.35, O/F = 4.762													
1.00	600.00	3208	5841.6	11.347	1.1593	1.7671	803	0.00160	0.000			0.000	0.0
1.05	571.43	3189	5814.3	11.356	1.1598	1.7482	801	.00158	.291	546.7	2.144	.200	48.8
1.20	500.00	3137	5740.5	11.379	1.1611	1.6966	794	.00152	.564	347.8	1.250	.385	93.8
1.40	428.57	3077	5656.9	11.404	1.1629	1.6375	786	.00146	.770	310.8	1.057	.520	126.8
1.60	375.00	3025	5586.0	11.425	1.1646	1.5869	779	.00140	.913	302.6	1.007	.612	149.1
1.75	342.61	2990	5538.8	11.438	1.1659	1.5531	774	.00137	1.000	301.5	1.000	.666	162.3
2.00	300.00	2938	5470.4	11.457	1.1680	1.5041	766	.00132	1.117	303.1	1.012	.737	179.7
4.00	150.00	2669	5134.6	11.535	1.1817	1.2723	727	.00108	1.613	328.7	1.323	1.017	248.0
10.00	60.00	2313	4742.5	11.593	1.2048	1.0538	667	.00085	2.145	365.0	2.288	1.268	309.3
20.00	30.00	2050	4483.6	11.609	1.2216	.9574	617	.00072	2.517	388.2	3.644	1.410	343.7
40.00	15.00	1803	4255.3	11.615	1.2359	.8996	564	.00063	2.885	407.6	5.926	1.524	371.5
40.83	14.70	1796	4249.0	11.615	1.2363	.8983	562	.00063	2.896	408.2	6.013	1.527	372.3
100.00	6.00	1506	3996.4	11.616	1.2528	.8482	490	.00052	3.381	428.7	11.474	1.643	400.7
200.00	3.00	1306	3829.9	11.616	1.2663	.8136	434	.00045	3.772	441.6	19.054	1.716	418.4
400.00	1.50	1125	3686.0	11.616	1.2806	.7807	379	.00038	4.182	452.4	31.724	1.776	433.1
1000.00	.60	916	3526.4	11.616	1.2996	.7420	311	.00030	4.769	464.0	62.274	1.841	448.8
2000.00	.30	778	3426.2	11.616	1.3130	.7177	264	.00025	5.257	471.1	103.640	1.880	458.4
4000.00	.15	658	3341.2	11.616	1.3245	.6983	222	.00020	5.791	476.9	172.288	1.913	466.4
R = 0.700, PERCENT FUEL = 15.25, O/F = 5.556													
1.00	600.00	3381	5138.3	12.664	1.1429	2.1301	846	0.00197	0.000			0.000	0.0
1.05	571.43	3364	5112.5	12.677	1.1430	2.1115	843	.00195	.293	531.5	2.133	.199	47.4
1.20	500.00	3317	5042.7	12.711	1.1433	2.0594	837	.00189	.568	338.5	1.245	.383	91.2
1.40	428.57	3263	4963.5	12.750	1.1438	1.9976	830	.00182	.775	302.7	1.054	.517	123.3
1.60	375.00	3217	4896.2	12.782	1.1443	1.9428	823	.00176	.920	295.1	1.006	.609	145.2
1.74	345.24	3188	4855.0	12.802	1.1447	1.9085	819	.00172	1.000	294.1	1.000	.659	157.0
2.00	300.00	3140	4786.1	12.834	1.1456	1.8496	813	.00166	1.125	295.9	1.014	.734	175.1
4.00	150.00	2903	4463.7	12.978	1.1526	1.5556	779	.00136	1.623	322.1	1.339	1.016	242.3
10.00	60.00	2584	4080.8	13.115	1.1702	1.2090	730	.00102	2.148	359.5	2.356	1.273	303.3
20.00	30.00	2337	3823.0	13.174	1.1884	1.0195	688	.00083	2.506	383.6	3.803	1.419	338.3
40.00	15.00	2088	3592.0	13.203	1.2067	.9006	640	.00070	2.855	404.1	6.256	1.539	366.8
40.83	14.70	2081	3585.6	13.203	1.2072	.8980	638	.00069	2.864	404.6	6.350	1.542	367.6
100.00	6.00	1775	3326.0	13.214	1.2263	.8183	571	.00057	3.327	426.4	12.271	1.666	397.1
200.00	3.00	1558	3152.5	13.216	1.2387	.7809	515	.00050	3.700	440.2	20.571	1.744	415.7
400.00	1.50	1359	3000.6	13.216	1.2515	.7484	459	.00043	4.089	451.9	34.597	1.809	431.3
1000.00	.60	1125	2829.9	13.216	1.2696	.7080	387	.00035	4.637	464.6	68.879	1.880	448.2
2000.00	.30	968	2721.0	13.216	1.2840	.6798	334	.00029	5.087	472.4	115.835	1.924	458.6
4000.00	.15	828	2627.5	13.216	1.2978	.6552	286	.00024	5.575	479.0	194.445	1.961	467.4
R = 0.800, PERCENT FUEL = 13.60, O/F = 6.349													
1.00	600.00	3481	4586.9	13.859	1.1337	2.4909	875	0.00234	0.000			0.000	0.0
1.05	571.43	3465	4562.6	13.875	1.1335	2.4777	873	.00232	.294	515.6	2.126	.198	46.0
1.20	500.00	3422	4496.8	13.919	1.1331	2.4401	867	.00227	.570	328.6	1.242	.381	88.5
1.40	428.57	3373	4422.2	13.969	1.1327	2.3938	861	.00221	.778	294.1	1.052	.516	119.7
1.60	375.00	3331	4358.6	14.012	1.1324	2.3513	855	.00216	.924	286.7	1.006	.607	140.9
1.73	346.81	3306	4321.9	14.037	1.1323	2.3254	851	.00213	1.000	286.0	1.000	.654	151.8
2.00	300.00	3261	4254.6	14.082	1.1321	2.2752	845	.00207	1.129	287.8	1.015	.733	170.0
4.00	150.00	3052	3948.2	14.288	1.1330	2.0021	816	.00177	1.630	314.1	1.350	1.016	235.7
10.00	60.00	2779	3579.7	14.522	1.1403	1.5823	775	.00136	2.155	351.9	2.409	1.276	296.0
20.00	30.00	2568	3327.2	14.656	1.1527	1.2725	741	.00107	2.505	376.8	3.944	1.427	331.1
40.00	15.00	2346	3097.0	14.745	1.1712	1.0267	703	.00084	2.837	398.3	6.587	1.552	360.1
40.83	14.70	2340	3090.5	14.747	1.1718	1.0207	702	.00083	2.846	398.8	6.689	1.555	360.8
100.00	6.00	2042	2826.6	14.800	1.1976	.8369	642	.00065	3.275	421.8	13.134	1.687	391.4
200.00	3.00	1815	2647.3	14.812	1.2135	.7683	591	.00055	3.623	436.6	22.231	1.771	410.8
400.00	1.50	1602	2488.5	14.815	1.2280	.7287	537	.00048	3.991	449.2	37.727	1.842	427.3
1000.00	.60	1347	2307.6	14.816	1.2422	.6880	484	.00040	4.507	463.0	76.063	1.919	445.3
2000.00	.30	1173	2190.6	14.816	1.2553	.6594	409	.00034	4.926	471.6	129.237	1.968	456.6
4000.00	.15	1016	2089.0	14.816	1.2694	.6320	356	.00028	5.375	478.9	219.200	2.009	466.2
R = 0.900, PERCENT FUEL = 12.28, O/F = 7.143													
1.00	600.00	3526	4142.9	14.930	1.1295	2.6696	896	0.00254	0.000			0.000	0.0
1.05	571.43	3511	4120.1	14.948	1.1293	2.6628	894	.00253	.294	500.1	2.123	.198	44.6
1.20	500.00	3469	4058.3	14.999	1.1285	2.6432	888	.00249	.571	318.8	1.241	.381	85.8
1.40	428.57	3422	3988.0	15.057	1.1277	2.6185	881	.00245	.780	285.4	1.052	.515	116.1
1.60	375.00	3382	3928.2	15.107	1.1270	2.5953	876	.00242	.926	278.3	1.005	.607	136.7
1.73	347.52	3360	3894.5	15.136	1.1267	2.5813	873	.00240	1.000	277.6	1.000	.653	147.0
2.00	300.00	3317	3830.1	15.190	1.1260	2.5526	866	.00235	1.132	279.4	1.016	.732	165.0
4.00	150.00	3122	3540.7	15.441	1.1236	2.3886	839	.00214	1.633	305.3	1.356	1.016	228.9
10.00	60.00	2881	3190.4	15.751	1.1229	2.0940	803	.00181	2.161	342.8	2.437	1.278	287.9
20.00	30.00	2705	2947.8	15.963	1.1254	1.8100	775	.00152	2.512	367.9	4.032	1.431	322.5
40.00	15.00	2528	2723.3	16.145	1.1327	1.4813	746	.00122	2.838	390.0	6.838	1.560	351.5
40.83	14.70	2523	2716.9	16.150	1.1330	1.4712	745	.00121	2.848	390.6	6.947	1.563	352.3
100.00	6.00	2279	2453.5	16.318	1.1553	1.0541	701	.00085	3.246	414.9	13.977	1.702	383.4
200.00	3.00	2072	2270.2	16.384	1.1797	.8410	659	.00065	3.555	430.8	24.037	1.791	403.7
400.00	1.50	1857	2105.2	16.408	1.1999	.7376	610	.00054	3.886	444.3	41.251	1.869	421.1
1000.00	.60	1585	1914.5	16.415	1.2177	.6764	540	.00045	4.367	459.3	84.153	1.954	440.3
2000.00	.30	1397	1789.5	16.416	1.2295	.6487	486	.00039	4.758	468.8	144.295	2.008	452.5
4000.00	.15	1224	1679.6	16.416	1.2418	.6217	431	.00033	5.175	476.9	247.166	2.055	463.0

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, lb(sec)/(lb)
R = 1.000, PERCENT FUEL = 11.19, O/F = 7.937													
1.00	600.00	3534	3777.9	15.886	1.1283	2.6053	910	0.00251	0.000			0.000	0.0
1.05	571.43	3519	3756.4	15.906	1.1280	2.6007	907	.00250	.295	485.3	2.122	.198	43.3
1.20	500.00	3478	3698.1	15.961	1.1272	2.5874	902	.00247	.572	309.4	1.240	.381	83.3
1.40	428.57	3431	3631.9	16.024	1.1263	2.5703	895	.00244	.780	277.0	1.051	.515	112.7
1.60	375.00	3392	3575.5	16.078	1.1255	2.5542	889	.00241	.926	270.2	1.005	.606	132.7
1.73	347.72	3370	3544.0	16.108	1.1251	2.5445	886	.00239	1.000	269.4	1.000	.652	142.7
2.00	300.00	3327	3483.1	16.168	1.1244	2.5243	880	.00236	1.132	271.3	1.016	.732	160.1
4.00	150.00	3137	3210.2	16.441	1.1212	2.4094	852	.00218	1.634	296.5	1.357	1.016	222.3
10.00	60.00	2903	2879.3	16.785	1.1186	2.2079	817	.00192	2.162	333.1	2.445	1.278	279.6
20.00	30.00	2738	2649.6	17.030	1.1181	2.0216	791	.00171	2.514	357.7	4.055	1.432	313.3
40.00	15.00	2578	2436.1	17.258	1.1191	1.8120	765	.00150	2.842	379.5	6.910	1.562	341.7
40.83	14.70	2573	2430.0	17.265	1.1191	1.8056	764	.00149	2.852	380.1	7.022	1.565	342.5
100.00	6.00	2371	2177.0	17.526	1.1239	1.5117	728	.00120	3.255	404.6	14.326	1.706	373.2
200.00	3.00	2214	1997.7	17.695	1.1315	1.2810	697	.00099	3.558	421.1	25.124	1.799	393.6
400.00	1.50	2052	1832.3	17.830	1.1437	1.0654	663	.00080	3.857	435.6	44.210	1.881	411.4
1000.00	.60	1826	1634.9	17.947	1.1679	.8338	611	.00059	4.260	452.2	93.124	1.974	431.8
2000.00	.30	1648	1501.7	17.991	1.1894	.7163	564	.00048	4.585	462.8	162.695	2.034	445.0
4000.00	.15	1470	1382.4	18.009	1.2091	.6444	514	.00040	4.942	472.0	282.648	2.087	456.5
R = 1.500, PERCENT FUEL = 7.749, O/F = 11.905													
1.00	600.00	3374	2626.1	19.463	1.1327	1.6233	930	0.00163	0.000			0.000	0.0
1.20	500.00	3315	2563.9	19.540	1.1321	1.5942	921	.00158	.571	273.0	1.242	.381	73.5
1.05	571.43	3358	2609.3	19.483	1.1325	1.6157	927	.00162	.294	428.4	2.125	.198	38.2
1.40	428.57	3267	2512.4	19.604	1.1317	1.5682	913	.00155	.779	244.3	1.052	.516	99.4
1.60	375.00	3226	2468.5	19.658	1.1314	1.5447	906	.00151	.924	238.3	1.006	.607	117.1
1.73	346.93	3202	2443.3	19.690	1.1313	1.5306	903	.00150	1.000	237.6	1.000	.654	126.1
2.00	300.00	3158	2396.7	19.748	1.1310	1.5034	896	.00146	1.130	239.1	1.015	.733	141.3
4.00	150.00	2953	2185.1	20.011	1.1313	1.3606	862	.00128	1.631	261.0	1.351	1.016	195.9
10.00	60.00	2692	1930.2	20.314	1.1356	1.1474	818	.00104	2.157	292.6	2.415	1.276	246.1
20.00	30.00	2496	1755.2	20.499	1.1432	.9816	782	.00086	2.509	313.5	3.967	1.428	275.3
40.00	15.00	2297	1594.7	20.640	1.1557	.8274	743	.00070	2.841	331.7	6.664	1.554	299.6
40.83	14.70	2291	1590.2	20.643	1.1562	.8232	742	.00070	2.850	332.2	6.768	1.557	300.2
100.00	6.00	2026	1404.5	20.752	1.1791	.6682	685	.00054	3.268	351.9	13.428	1.691	326.0
200.00	3.00	1818	1277.1	20.792	1.1984	.5904	635	.00045	3.599	364.7	22.891	1.777	342.6
400.00	1.50	1616	1163.4	20.807	1.2152	.5432	582	.00039	3.950	375.6	39.039	1.850	356.7
1000.00	.60	1366	1033.2	20.812	1.2336	.5048	509	.00032	4.450	387.5	79.054	1.931	372.3
2000.00	.30	1195	948.5	20.813	1.2462	.4834	454	.00027	4.858	395.0	134.733	1.982	382.1
4000.00	.15	1039	874.7	20.813	1.2594	.4636	401	.00023	5.296	401.4	229.310	2.025	390.4
R = 2.000, PERCENT FUEL = 5.927, O/F = 15.873													
1.00	600.00	3158	2016.0	21.832	1.1414	1.1081	919	0.00112	0.000			0.000	0.0
1.05	571.43	3141	2002.0	21.850	1.1414	1.1005	917	.00111	.293	391.2	2.132	.199	34.9
1.20	500.00	3097	1964.2	21.900	1.1417	1.0794	909	.00108	.568	249.2	1.245	.383	67.1
1.40	428.57	3046	1921.3	21.956	1.1421	1.0543	900	.00105	.776	222.9	1.054	.517	90.8
1.60	375.00	3002	1884.8	22.003	1.1426	1.0320	893	.00102	.920	217.2	1.006	.609	106.9
1.74	345.45	2975	1862.7	22.031	1.1430	1.0182	888	.00100	1.000	216.6	1.000	.658	115.5
2.00	300.00	2929	1825.1	22.078	1.1437	.9940	880	.00097	1.125	217.9	1.014	.734	128.9
4.00	150.00	2706	1650.2	22.286	1.1496	.8720	840	.00083	1.624	237.3	1.341	1.016	178.4
10.00	60.00	2413	1442.0	22.490	1.1641	.7166	784	.00065	2.151	265.0	2.365	1.273	223.5
20.00	30.00	2189	1301.4	22.588	1.1804	.6182	737	.00054	2.507	283.0	3.829	1.421	249.4
40.00	15.00	1965	1174.9	22.642	1.1988	.5459	686	.00045	2.852	298.3	6.321	1.541	270.5
40.83	14.70	1959	1171.4	22.643	1.1994	.5441	684	.00045	2.863	298.7	6.416	1.544	271.1
100.00	6.00	1678	1028.7	22.670	1.2212	.4875	614	.00037	3.316	314.9	12.437	1.670	293.1
200.00	3.00	1475	932.9	22.676	1.2351	.4613	557	.00032	3.683	325.3	20.879	1.749	307.0
400.00	1.50	1289	849.1	22.677	1.2476	.4417	501	.00028	4.069	334.1	35.155	1.815	318.7
1000.00	.60	1070	754.5	22.677	1.2641	.4194	430	.00023	4.614	343.6	70.143	1.887	331.3
2000.00	.30	923	694.1	22.677	1.2770	.4040	378	.00019	5.059	349.5	118.235	1.932	339.2
4000.00	.15	792	642.1	22.677	1.2904	.3894	329	.00016	5.539	354.5	199.011	1.970	345.8
R = 3.000, PERCENT FUEL = 4.031, O/F = 23.810													
1.00	600.00	2747	1381.4	24.718	1.1694	0.6509	869	0.00065	0.000			0.000	0.0
1.05	571.43	2729	1370.7	24.729	1.1701	.6451	866	.00065	.289	342.7	2.152	.201	30.6
1.20	500.00	2679	1341.7	24.759	1.1723	.6293	856	.00062	.561	217.9	1.254	.386	58.8
1.40	428.57	2622	1308.9	24.790	1.1749	.6114	845	.00060	.766	194.6	1.058	.522	79.4
1.60	375.00	2573	1281.1	24.815	1.1774	.5963	835	.00058	.909	189.4	1.008	.613	93.4
1.76	340.99	2538	1261.7	24.832	1.1793	.5858	828	.00057	1.000	188.6	1.000	.670	102.1
2.00	300.00	2491	1235.9	24.852	1.1819	.5720	819	.00055	1.112	189.5	1.011	.739	112.5
4.00	150.00	2237	1105.1	24.937	1.1983	.5059	765	.00046	1.608	205.1	1.314	1.018	155.0
10.00	60.00	1913	953.9	24.990	1.2209	.4460	690	.00038	2.146	227.2	2.253	1.266	192.9
20.00	30.00	1682	854.9	25.003	1.2358	.4185	631	.00033	2.524	241.2	3.569	1.405	214.0
40.00	15.00	1470	768.2	25.007	1.2483	.4000	572	.00029	2.900	253.0	5.778	1.517	231.0
40.83	14.70	1464	765.8	25.007	1.2487	.3995	571	.00028	2.911	253.3	5.862	1.520	231.4
100.00	6.00	1220	670.5	25.008	1.2635	.3811	498	.00024	3.408	265.7	11.130	1.633	248.7
200.00	3.00	1053	608.0	25.008	1.2755	.3679	444	.00021	3.807	273.4	18.422	1.703	259.4
400.00	1.50	904	554.2	25.008	1.2879	.3555	392	.00018	4.229	279.9	30.593	1.761	268.3
1000.00	.60	733	494.8	25.008	1.3053	.3398	329	.00014	4.829	286.9	59.908	1.824	277.8
2000.00	.30	622	457.5	25.008	1.3185	.3290	285	.00012	5.326	291.1	99.545	1.862	283.5
4000.00	.15	525	426.0	25.008	1.3312	.3194	245	.00010	5.868	294.6	165.173	1.893	288.3

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Concluded. Combustion-chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 4.000, PERCENT FUEL = 3.054, O/F = 31.746													
1.00	600.00	2381	1054.4	26.323	1.2036	0.4697	806	0.00045	0.000			0.000	0.0
1.05	571.43	2362	1045.7	26.328	1.2048	.4663	802	.00045	.285	308.9	2.174	.203	27.6
1.20	500.00	2309	1022.1	26.340	1.2079	.4572	790	.00044	.554	196.0	1.263	.390	53.0
1.40	428.57	2249	995.6	26.352	1.2116	.4473	777	.00042	.756	174.7	1.063	.526	71.5
1.60	375.00	2198	973.2	26.361	1.2149	.4393	765	.00041	.898	169.8	1.010	.618	84.0
1.78	336.49	2157	955.5	26.367	1.2175	.4332	756	.00040	1.000	169.0	1.000	.683	92.8
2.00	300.00	2113	937.0	26.374	1.2202	.4272	746	.00039	1.099	169.6	1.009	.744	101.1
4.00	150.00	1860	833.4	26.396	1.2355	.3982	685	.00034	1.599	182.6	1.293	1.020	138.7
10.00	60.00	1554	715.9	26.405	1.2521	.3743	605	.00028	2.150	201.3	2.182	1.263	171.6
20.00	30.00	1348	640.3	26.406	1.2632	.3612	546	.00025	2.542	213.1	3.423	1.397	189.8
40.00	15.00	1164	574.8	26.406	1.2741	.3499	491	.00022	2.931	222.9	5.493	1.503	204.3
40.83	14.70	1159	573.1	26.406	1.2744	.3495	489	.00022	2.943	223.2	5.572	1.506	204.7
100.00	6.00	952	502.1	26.406	1.2895	.3352	421	.00018	3.458	233.4	10.461	1.613	219.2
200.00	3.00	813	456.1	26.406	1.3022	.3243	371	.00016	3.876	239.8	17.162	1.679	228.2
400.00	1.50	690	417.0	26.406	1.3153	.3139	325	.00013	4.320	245.1	28.237	1.733	235.5
1000.00	.60	551	374.4	26.406	1.3331	.3012	269	.00011	4.959	250.7	54.608	1.790	243.3
2000.00	.30	463	348.0	26.406	1.3460	.2927	232	.00009	5.492	254.0	89.893	1.824	247.9
4000.00	.15	386	325.9	26.406	1.3564	.2864	197	.00007	6.079	256.8	147.835	1.853	251.8
R = 5.000, PERCENT FUEL = 2.458, O/F = 39.683													
1.00	600.00	2072	855.0	27.317	1.2317	0.3924	742	0.00036	0.000			0.000	0.0
1.05	571.43	2053	847.7	27.319	1.2327	.3906	738	.00036	.282	282.7	2.190	.204	25.2
1.20	500.00	2002	828.0	27.323	1.2355	.3859	725	.00035	.548	179.1	1.270	.393	48.5
1.40	428.57	1944	805.9	27.326	1.2387	.3808	711	.00034	.749	159.4	1.067	.530	65.4
1.60	375.00	1894	787.2	27.329	1.2413	.3767	699	.00033	.890	154.8	1.011	.622	76.8
1.80	333.54	1852	771.3	27.331	1.2436	.3734	689	.00032	1.000	154.0	1.000	.691	85.3
2.00	300.00	1813	757.2	27.332	1.2455	.3706	679	.00031	1.092	154.4	1.007	.747	92.3
4.00	150.00	1578	671.8	27.337	1.2571	.3559	617	.00028	1.594	165.8	1.281	1.023	126.2
10.00	60.00	1303	576.1	27.339	1.2710	.3410	559	.00023	2.152	182.2	2.143	1.262	155.8
20.00	30.00	1122	515.1	27.339	1.2815	.3309	484	.00020	2.551	192.6	3.341	1.393	172.0
40.00	15.00	961	462.7	27.339	1.2929	.3209	432	.00018	2.948	201.2	5.329	1.497	184.7
40.83	14.70	956	461.3	27.339	1.2932	.3206	430	.00018	2.959	201.4	5.405	1.499	185.1
100.00	6.00	777	405.0	27.339	1.3095	.3076	367	.00015	3.488	210.3	10.063	1.603	197.9
200.00	3.00	658	368.9	27.339	1.3228	.2979	321	.00012	3.919	215.8	16.396	1.666	205.7
400.00	1.50	554	338.4	27.339	1.3364	.2887	279	.00011	4.380	220.3	26.787	1.717	212.0
1000.00	.60	438	305.5	27.339	1.3536	.2782	229	.00008	5.049	225.0	51.327	1.771	218.7
2000.00	.30	365	285.3	27.339	1.3633	.2728	195	.00007	5.614	227.8	83.959	1.803	222.6
4000.00	.15	303	268.6	27.339	1.3697	.2693	164	.00006	6.236	230.1	137.411	1.830	225.9

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(e) Combustion-chamber pressure, 60 pounds per square inch absolute, frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.150, PERCENT FUEL = 45.65, O/F = 1.190													
1.00	60.00	1183	5313.5	4.416	1.3396	1.7753	314	0.00073	0.000			0.000	0.0
1.05	57.14	1168	5287.7	4.416	1.3406	1.7710	311	.00073	.271	530.0	2.250	.210	47.4
1.20	50.00	1129	5218.6	4.416	1.3436	1.7597	303	.00070	.527	334.2	1.297	.403	90.8
1.40	42.86	1085	5141.8	4.416	1.3469	1.7472	293	.00068	.722	296.1	1.081	.543	122.2
1.60	37.50	1049	5077.7	4.416	1.3497	1.7369	285	.00066	.860	286.6	1.018	.636	143.2
1.87	32.17	1008	5006.8	4.416	1.3528	1.7257	276	.00063	1.000	284.1	1.000	.725	163.4
2.00	30.00	989	4975.4	4.416	1.3540	1.7210	272	.00062	1.059	284.4	1.003	.761	171.5
4.00	15.00	824	4693.4	4.416	1.3651	1.6825	234	.00052	1.566	301.7	1.233	1.031	232.3
4.08	14.70	819	4685.8	4.416	1.3654	1.6815	232	.00052	1.579	302.3	1.244	1.038	233.7
10.00	6.00	643	4392.5	4.416	1.3748	1.6505	188	.00042	2.152	327.5	1.974	1.257	283.1
20.00	3.00	532	4209.8	4.416	1.3799	1.6344	159	.00035	2.586	343.5	2.982	1.376	309.9
40.00	1.50	439	4058.9	4.416	1.3824	1.6268	133	.00029	3.031	356.4	4.620	1.467	330.4
100.00	.60	340	3899.0	4.416	1.3882	1.6093	104	.00023	3.648	369.8	8.432	1.558	350.8
200.00	.30	280	3802.6	4.416	1.3926	1.5961	85	.00018	4.149	377.7	13.431	1.610	362.6
400.00	.15	230	3723.2	4.416	1.4068	1.5562	70	.00015	4.675	384.1	21.488	1.652	372.0
1000.00	.06	175	3640.1	4.416	1.4349	1.4847	55	.00011	5.438	390.6	39.928	1.694	381.6
2000.00	.03	142	3590.9	4.416	1.4550	1.4389	45	.00009	6.096	394.3	63.572	1.719	387.2
4000.00	.02	114	3551.2	4.416	1.4705	1.4065	38	.00007	6.845	397.3	100.938	1.739	391.6
R = 0.200, PERCENT FUEL = 38.65, O/F = 1.587													
1.00	60.00	1514	2969.7	5.216	1.3079	1.6183	402	0.00084	0.000			0.000	0.0
1.05	57.14	1497	2941.7	5.216	1.3090	1.6140	399	.00083	.274	552.1	2.233	.209	49.3
1.20	50.00	1450	2866.8	5.216	1.3120	1.6022	389	.00081	.533	348.6	1.289	.400	94.6
1.40	42.86	1398	2783.2	5.216	1.3155	1.5887	378	.00078	.730	309.3	1.077	.539	127.4
1.60	37.50	1354	2713.2	5.216	1.3185	1.5772	369	.00076	.869	299.6	1.016	.632	149.4
1.85	32.49	1307	2640.5	5.216	1.3217	1.5651	359	.00073	1.000	297.3	1.000	.716	169.2
2.00	30.00	1282	2601.2	5.216	1.3236	1.5584	353	.00072	1.068	297.8	1.004	.757	179.1
4.00	15.00	1079	2290.0	5.216	1.3391	1.5045	307	.00061	1.572	316.7	1.244	1.029	243.2
4.08	14.70	1073	2281.6	5.216	1.3395	1.5031	306	.00061	1.585	317.4	1.256	1.035	244.7
10.00	6.00	852	1954.3	5.216	1.3559	1.4516	251	.00048	2.148	344.7	2.009	1.257	297.2
20.00	3.00	709	1748.8	5.216	1.3656	1.4232	213	.00040	2.573	362.0	3.049	1.379	325.9
40.00	1.50	588	1578.0	5.216	1.3715	1.4066	179	.00034	3.010	376.0	4.739	1.472	348.0
100.00	.60	458	1396.4	5.216	1.3771	1.3913	142	.00026	3.619	390.5	8.679	1.565	370.0
200.00	.30	379	1286.2	5.216	1.3811	1.3807	117	.00022	4.111	399.1	13.870	1.619	382.7
400.00	.15	312	1195.2	5.216	1.3861	1.3677	96	.00018	4.638	406.1	22.295	1.662	392.9
1000.00	.06	242	1099.0	5.216	1.3973	1.3400	74	.00013	5.394	413.4	41.978	1.706	403.5
2000.00	.03	198	1041.2	5.216	1.4156	1.2977	61	.00011	6.014	417.6	67.687	1.733	409.6
4000.00	.02	161	994.0	5.216	1.4350	1.2568	50	.00009	6.704	421.1	108.753	1.754	414.6
R = 0.250, PERCENT FUEL = 33.51, O/F = 1.984													
1.00	60.00	1816	1249.3	6.015	1.2835	1.4954	481	0.00092	0.000			0.000	0.0
1.05	57.14	1797	1220.2	6.015	1.2845	1.4916	477	.00091	.276	563.4	2.219	.207	50.3
1.20	50.00	1744	1142.1	6.015	1.2871	1.4812	467	.00088	.538	356.1	1.283	.398	96.6
1.40	42.86	1685	1054.8	6.015	1.2901	1.4692	456	.00086	.736	316.2	1.073	.536	130.1
1.60	37.50	1635	981.6	6.015	1.2927	1.4590	446	.00083	.876	306.6	1.015	.629	152.6
1.83	32.78	1586	910.0	6.015	1.2955	1.4484	436	.00081	1.000	304.5	1.000	.708	171.8
2.00	30.00	1554	864.1	6.015	1.2973	1.4414	429	.00080	1.076	305.1	1.005	.754	183.1
4.00	15.00	1322	535.4	6.015	1.3126	1.3872	378	.00068	1.578	325.4	1.256	1.027	249.2
4.08	14.70	1315	526.5	6.015	1.3130	1.3857	376	.00068	1.592	326.1	1.267	1.033	250.8
10.00	6.00	1057	176.7	6.015	1.3330	1.3224	314	.00054	2.147	355.2	2.048	1.258	305.5
20.00	3.00	886	9954.7	6.015	1.3461	1.2847	269	.00046	2.563	373.6	3.127	1.382	335.6
40.00	1.50	740	9768.9	6.015	1.3569	1.2558	228	.00038	2.987	388.5	4.883	1.478	358.9
100.00	.60	580	9570.0	6.015	1.3664	1.2320	181	.00030	3.581	404.1	8.984	1.575	382.3
200.00	.30	481	9448.9	6.015	1.3717	1.2191	151	.00025	4.064	413.3	14.394	1.630	395.8
400.00	.15	399	9348.4	6.015	1.3755	1.2100	124	.00020	4.582	420.8	23.204	1.675	406.7
1000.00	.06	310	9241.7	6.015	1.3821	1.1948	95	.00015	5.328	428.6	43.886	1.722	418.0
2000.00	.03	256	9177.2	6.015	1.3886	1.1805	78	.00012	5.945	433.3	71.266	1.749	424.6
4000.00	.02	210	9124.0	6.015	1.4039	1.1482	64	.00010	6.607	437.0	115.624	1.771	430.0
R = 0.300, PERCENT FUEL = 29.57, O/F = 2.381													
1.00	60.00	2089	9932.7	6.812	1.2649	1.3928	550	0.00097	0.000			0.000	0.0
1.05	57.14	2068	9903.2	6.812	1.2657	1.3898	546	.00096	.278	568.1	2.208	.206	50.7
1.20	50.00	2011	9823.7	6.812	1.2678	1.3811	536	.00094	.541	359.4	1.278	.396	97.4
1.40	42.86	1946	9734.8	6.812	1.2704	1.3707	524	.00091	.741	319.4	1.071	.533	131.3
1.60	37.50	1891	9660.0	6.812	1.2727	1.3616	514	.00089	.881	309.9	1.013	.626	154.0
1.82	33.01	1840	9590.5	6.812	1.2750	1.3527	504	.00087	1.000	307.9	1.000	.701	172.6
2.00	30.00	1803	9539.8	6.812	1.2767	1.3460	497	.00085	1.082	308.6	1.006	.752	184.9
4.00	15.00	1547	9201.7	6.812	1.2901	1.2972	443	.00074	1.685	330.1	1.265	1.025	252.2
4.08	14.70	1540	9192.5	6.812	1.2906	1.2958	442	.00073	1.698	330.8	1.278	1.032	253.8
10.00	6.00	1252	8828.7	6.812	1.3101	1.2326	374	.00060	2.148	361.2	2.084	1.260	310.0
20.00	3.00	1059	8595.4	6.812	1.3254	1.1882	324	.00050	2.555	380.5	3.204	1.386	341.1
40.00	1.50	891	8398.6	6.812	1.3389	1.1525	277	.00042	2.969	396.3	5.032	1.485	365.4
100.00	.60	704	8186.3	6.812	1.3535	1.1170	224	.00033	3.545	412.7	9.315	1.584	389.8
200.00	.30	587	8056.1	6.812	1.3607	1.1005	186	.00027	4.015	422.5	14.975	1.642	404.1
400.00	.15	487	7947.8	6.812	1.3669	1.0868	155	.00023	4.519	430.5	24.203	1.689	415.6
1000.00	.06	381	7832.4	6.812	1.3727	1.0745	119	.00017	5.249	438.8	45.935	1.738	427.5
2000.00	.03	315	7762.2	6.812	1.3777	1.0660	97	.00014	5.855	443.8	74.800	1.766	434.6
4000.00	.02	260	7704.2	6.812	1.3833	1.0529	79	.00011	6.513	447.9	121.990	1.790	440.4

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(e) Continued. Combustion-chamber pressure, 60 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.350, PERCENT FUEL = 26.47, O/F = 2.778													
1.00	60.00	2329	8892.8	7.597	1.2510	1.3038	608	0.00099	0.000			0.000	0.0
1.05	57.14	2307	8863.2	7.597	1.2516	1.3011	604	.00098	.280	568.1	2.199	.205	50.7
1.20	50.00	2245	8783.7	7.597	1.2534	1.2936	594	.00096	.544	359.7	1.274	.394	97.4
1.40	42.86	2176	8694.6	7.597	1.2556	1.2849	582	.00094	.745	319.9	1.069	.532	131.3
1.60	37.50	2118	8619.6	7.597	1.2575	1.2774	572	.00092	.886	310.5	1.012	.624	154.2
1.81	33.18	2065	8552.7	7.597	1.2593	1.2705	563	.00090	1.000	308.6	1.000	.696	172.0
2.00	30.00	2023	8498.8	7.597	1.2608	1.2646	555	.00088	1.087	309.5	1.006	.750	185.2
4.00	15.00	1748	8157.4	7.597	1.2726	1.2211	501	.00078	1.590	331.6	1.273	1.024	253.0
4.08	14.70	1741	8148.1	7.597	1.2730	1.2198	499	.00077	1.603	332.4	1.286	1.030	254.6
10.00	6.00	1430	7777.6	7.597	1.2906	1.1616	429	.00064	2.150	363.7	2.114	1.261	311.5
20.00	3.00	1219	7537.8	7.597	1.3027	1.1171	376	.00054	2.551	383.8	3.272	1.390	343.4
40.00	1.50	1033	7334.0	7.597	1.3209	1.0765	325	.00046	2.955	400.2	5.170	1.491	368.3
100.00	.60	823	7112.3	7.597	1.3383	1.0347	263	.00036	3.515	417.4	9.636	1.593	393.6
200.00	.30	689	6975.5	7.597	1.3490	1.0110	221	.00030	3.970	427.7	15.552	1.653	408.4
400.00	.15	575	6861.1	7.597	1.3588	.9946	185	.00024	4.461	436.0	25.218	1.702	420.5
1000.00	.06	451	6738.6	7.597	1.3645	.9790	145	.00019	5.172	444.8	48.013	1.753	432.9
2000.00	.03	375	6664.0	7.597	1.3696	.9692	118	.00015	5.763	450.1	78.373	1.783	440.4
4000.00	.02	310	6602.0	7.597	1.3746	.9598	96	.00012	6.407	454.4	128.116	1.807	446.5
R = 0.400, PERCENT FUEL = 23.95, O/F = 3.175													
1.00	60.00	2531	8050.5	8.363	1.2404	1.2259	656	0.00100	0.000			0.000	0.0
1.05	57.14	2508	8021.3	8.363	1.2410	1.2237	653	.00099	.281	564.6	2.193	.205	50.4
1.20	50.00	2443	7942.8	8.363	1.2425	1.2174	642	.00097	.547	357.7	1.271	.393	96.8
1.40	42.86	2371	7854.5	8.363	1.2444	1.2099	631	.00095	.748	318.3	1.067	.530	130.6
1.60	37.50	2309	7780.4	8.363	1.2461	1.2033	620	.00093	.889	309.0	1.012	.623	153.3
1.80	33.31	2256	7716.2	8.363	1.2476	1.1972	611	.00091	1.000	307.3	1.000	.693	170.6
2.00	30.00	2209	7660.6	8.363	1.2490	1.1919	603	.00090	1.091	308.2	1.007	.748	184.2
4.00	15.00	1920	7321.0	8.363	1.2591	1.1547	549	.00080	1.594	330.7	1.280	1.023	251.9
4.08	14.70	1912	7311.7	8.363	1.2594	1.1536	548	.00079	1.607	331.5	1.292	1.030	253.5
10.00	6.00	1583	6940.6	8.363	1.2752	1.1009	476	.00067	2.151	363.4	2.138	1.262	310.8
20.00	3.00	1359	6698.7	8.363	1.2894	1.0585	421	.00057	2.548	383.9	3.327	1.393	343.0
40.00	1.50	1159	6491.7	8.363	1.3046	1.0178	368	.00048	2.945	400.8	5.287	1.496	368.3
100.00	.60	931	6264.8	8.363	1.3239	.9712	301	.00038	3.492	418.6	9.918	1.601	394.2
200.00	.30	784	6123.9	8.363	1.3366	.9436	255	.00032	3.934	429.2	16.077	1.663	409.4
400.00	.15	657	6005.5	8.363	1.3467	.9230	214	.00026	4.411	437.9	26.157	1.713	421.8
1000.00	.06	518	5878.1	8.363	1.3573	.9026	168	.00020	5.102	447.1	49.977	1.766	434.8
2000.00	.03	431	5800.3	8.363	1.3627	.8928	139	.00016	5.680	452.6	81.743	1.797	442.5
4000.00	.02	358	5735.5	8.363	1.3680	.8833	113	.00013	6.309	457.1	133.896	1.823	448.8
R = 0.450, PERCENT FUEL = 21.87, O/F = 3.571													
1.00	60.00	2696	7354.5	9.102	1.2326	1.1570	696	0.00099	0.000			0.000	0.0
1.05	57.14	2671	7325.9	9.102	1.2331	1.1550	692	.00099	.282	558.6	2.188	.204	49.9
1.20	50.00	2604	7249.0	9.102	1.2344	1.1496	682	.00097	.548	354.0	1.269	.392	95.8
1.40	42.86	2529	7162.6	9.102	1.2360	1.1434	670	.00095	.750	315.1	1.066	.529	129.2
1.60	37.50	2465	7089.8	9.102	1.2375	1.1377	660	.00093	.891	306.1	1.011	.622	151.8
1.80	33.41	2411	7028.4	9.102	1.2388	1.1326	651	.00092	1.000	304.4	1.000	.690	168.4
2.00	30.00	2362	6972.2	9.102	1.2401	1.1278	643	.00090	1.093	305.4	1.008	.747	182.4
4.00	15.00	2061	6638.0	9.102	1.2490	1.0950	589	.00081	1.597	328.1	1.284	1.023	249.7
4.08	14.70	2053	6628.8	9.102	1.2493	1.0940	587	.00080	1.610	328.9	1.297	1.029	251.3
10.00	6.00	1710	6261.7	9.102	1.2637	1.0464	516	.00068	2.153	361.0	2.157	1.263	308.4
20.00	3.00	1476	6021.0	9.102	1.2766	1.0076	460	.00059	2.547	381.8	3.370	1.395	340.6
40.00	1.50	1266	5813.8	9.102	1.2911	.9682	405	.00050	2.938	399.0	5.380	1.500	366.1
100.00	.60	1024	5585.4	9.102	1.3112	.9199	334	.00040	3.474	417.1	10.154	1.607	392.3
200.00	.30	866	5442.7	9.102	1.3250	.8901	285	.00033	3.906	428.0	16.525	1.670	407.9
400.00	.15	729	5322.2	9.102	1.3373	.8657	241	.00027	4.370	437.0	26.977	1.722	420.5
1000.00	.06	577	5192.1	9.102	1.3495	.8430	199	.00021	5.045	446.4	51.722	1.777	433.8
2000.00	.03	481	5112.3	9.102	1.3569	.8300	158	.00017	5.609	452.0	84.764	1.809	441.7
4000.00	.02	401	5045.7	9.102	1.3625	.8207	129	.00014	6.225	456.7	139.079	1.836	448.2
R = 0.500, PERCENT FUEL = 20.12, O/F = 3.968													
1.00	60.00	2828	6769.6	9.811	1.2265	1.0967	728	0.00098	0.000			0.000	0.0
1.05	57.14	2802	6741.8	9.811	1.2270	1.0949	724	.00098	.283	551.1	2.184	.204	49.2
1.20	50.00	2734	6666.9	9.811	1.2283	1.0899	714	.00096	.550	349.4	1.268	.392	94.5
1.40	42.86	2657	6582.8	9.811	1.2298	1.0841	702	.00094	.751	311.1	1.065	.528	127.5
1.60	37.50	2591	6511.8	9.811	1.2311	1.0791	692	.00092	.893	302.2	1.011	.621	149.8
1.79	33.49	2536	6453.1	9.811	1.2322	1.0749	684	.00091	1.000	300.6	1.000	.688	166.0
2.00	30.00	2484	6397.2	9.811	1.2333	1.0706	675	.00089	1.096	301.6	1.008	.746	180.0
4.00	15.00	2175	6070.5	9.811	1.2415	1.0411	622	.00080	1.599	324.4	1.288	1.022	246.6
4.08	14.70	2166	6061.5	9.811	1.2418	1.0402	620	.00080	1.612	325.1	1.301	1.029	248.2
10.00	6.00	1813	5701.2	9.811	1.2548	.9976	549	.00069	2.153	357.3	2.172	1.264	304.9
20.00	3.00	1571	5463.9	9.811	1.2667	.9619	492	.00060	2.545	378.1	3.404	1.397	337.1
40.00	1.50	1354	5258.9	9.811	1.2806	.9245	436	.00051	2.933	395.5	5.454	1.503	362.6
100.00	.60	1102	5031.6	9.811	1.3003	.8769	363	.00041	3.461	413.8	10.345	1.612	388.9
200.00	.30	936	4888.8	9.811	1.3150	.8455	312	.00034	3.885	424.9	16.895	1.677	404.5
400.00	.15	790	4767.9	9.811	1.3283	.8194	264	.00028	4.339	434.0	27.668	1.730	417.3
1000.00	.06	628	4636.8	9.811	1.3426	.7938	209	.00022	4.999	443.6	53.222	1.785	430.8
2000.00	.03	525	4556.1	9.811	1.3514	.7790	173	.00018	5.550	449.4	87.397	1.819	438.9
4000.00	.02	438	4488.6	9.811	1.3579	.7685	143	.00015	6.154	454.2	143.606	1.846	445.5

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(e) Continued. Combustion-chamber pressure, 60 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/(lb)
R = 0.600, PERCENT FUEL = 17.35, O/F = 4.762													
1.00	60.00	3015	5841.6	11.142	1.2182	0.9956	777	0.00095	0.000			0.000	0.0
1.05	57.14	2989	5815.5	11.142	1.2186	.9942	773	.00094	.284	534.1	2.179	.203	47.7
1.20	50.00	2918	5745.1	11.142	1.2197	.9901	763	.00093	.551	338.8	1.265	.391	91.6
1.40	42.86	2838	5666.0	11.142	1.2210	.9853	751	.00091	.754	301.8	1.064	.527	123.6
1.60	37.50	2770	5599.2	11.142	1.2222	.9810	741	.00089	.896	293.2	1.010	.620	145.2
1.79	33.59	2715	5545.4	11.142	1.2232	.9774	733	.00088	1.000	291.8	1.000	.685	160.5
2.00	30.00	2660	5491.2	11.142	1.2242	.9737	724	.00087	1.099	292.8	1.008	.745	174.6
4.00	15.00	2339	5182.6	11.142	1.2312	.9498	671	.00079	1.602	315.3	1.293	1.022	239.5
4.08	14.70	2330	5174.1	11.142	1.2314	.9491	669	.00078	1.615	316.0	1.307	1.028	241.0
10.00	6.00	1963	4831.8	11.142	1.2426	.9136	598	.00068	2.155	347.8	2.192	1.265	296.4
20.00	3.00	1710	4605.0	11.142	1.2533	.8826	541	.00060	2.543	368.5	3.452	1.399	328.0
40.00	1.50	1483	4407.9	11.142	1.2656	.8499	484	.00052	2.927	385.8	5.559	1.507	353.2
100.00	.60	1217	4187.7	11.142	1.2843	.8057	409	.00042	3.444	404.2	10.621	1.618	379.4
200.00	.30	1041	4048.4	11.142	1.2995	.7739	354	.00035	3.856	415.5	17.444	1.685	395.0
400.00	.15	884	3929.6	11.142	1.3139	.7464	303	.00029	4.295	424.7	28.712	1.740	407.9
1000.00	.06	707	3800.0	11.142	1.3311	.7170	242	.00023	4.931	434.5	55.548	1.798	421.5
2000.00	.03	594	3719.7	11.142	1.3414	.7007	202	.00019	5.465	440.4	91.527	1.833	429.7
4000.00	.02	497	3652.4	11.142	1.3504	.6874	168	.00015	6.048	445.3	150.804	1.862	436.4
R = 0.700, PERCENT FUEL = 15.25, O/F = 5.556													
1.00	60.00	3128	5138.3	12.360	1.2132	0.9147	811	0.00090	0.000			0.000	0.0
1.05	57.14	3101	5113.9	12.360	1.2136	.9135	807	.00090	.284	516.6	2.176	.203	46.1
1.20	50.00	3029	5048.1	12.360	1.2146	.9101	797	.00089	.552	327.7	1.264	.390	88.6
1.40	42.86	2947	4974.0	12.360	1.2157	.9060	785	.00087	.755	292.0	1.063	.527	119.6
1.60	37.50	2878	4911.5	12.360	1.2168	.9024	775	.00085	.898	283.8	1.010	.619	140.5
1.78	33.68	2823	4861.9	12.360	1.2177	.8993	766	.00084	1.000	282.4	1.000	.683	155.1
2.00	30.00	2765	4810.3	12.360	1.2187	.8960	758	.00083	1.100	283.4	1.009	.744	168.9
4.00	15.00	2439	4520.6	12.360	1.2249	.8755	704	.00076	1.604	305.4	1.296	1.021	231.8
4.08	14.70	2429	4512.6	12.360	1.2251	.8749	702	.00076	1.617	306.2	1.310	1.028	233.3
10.00	6.00	2055	4190.3	12.360	1.2353	.8440	631	.00066	2.156	337.2	2.204	1.265	287.2
20.00	3.00	1797	3975.9	12.360	1.2451	.8168	574	.00058	2.542	357.5	3.481	1.401	318.0
40.00	1.50	1564	3788.9	12.360	1.2564	.7879	517	.00051	2.923	374.6	5.624	1.509	342.7
100.00	.60	1291	3579.1	12.360	1.2741	.7473	440	.00042	3.434	392.8	10.796	1.623	368.3
200.00	.30	1108	3445.6	12.360	1.2890	.7171	384	.00035	3.839	404.0	17.797	1.691	383.8
400.00	.15	946	3331.4	12.360	1.3040	.6897	331	.00029	4.269	413.2	29.399	1.747	396.5
1000.00	.06	760	3206.1	12.360	1.3224	.6595	266	.00023	4.890	423.0	57.120	1.806	410.0
2000.00	.03	640	3128.2	12.360	1.3341	.6420	223	.00019	5.410	428.9	94.365	1.842	418.2
4000.00	.02	537	3062.8	12.360	1.3441	.6280	186	.00015	5.979	433.8	155.825	1.872	425.0
R = 0.800, PERCENT FUEL = 13.60, O/F = 6.349													
1.00	60.00	3188	4586.9	13.470	1.2103	0.8490	835	0.00086	0.000			0.000	0.0
1.05	57.14	3161	4564.0	13.470	1.2106	.8480	831	.00086	.285	499.6	2.174	.203	44.6
1.20	50.00	3088	4502.5	13.470	1.2115	.8451	821	.00084	.553	317.0	1.263	.390	85.7
1.40	42.86	3006	4433.2	13.470	1.2126	.8415	809	.00083	.756	282.5	1.063	.526	115.6
1.60	37.50	2936	4374.7	13.470	1.2136	.8382	798	.00082	.899	274.6	1.010	.618	135.9
1.78	33.69	2881	4328.7	13.470	1.2144	.8356	790	.00081	1.000	273.3	1.000	.682	149.9
2.00	30.00	2823	4279.9	13.470	1.2154	.8326	781	.00079	1.101	274.3	1.009	.744	163.4
4.00	15.00	2493	4006.4	13.470	1.2213	.8143	727	.00073	1.605	295.7	1.298	1.021	224.4
4.08	14.70	2484	4000.9	13.470	1.2215	.8137	725	.00072	1.618	296.4	1.312	1.028	225.8
10.00	6.00	2106	3698.1	13.470	1.2311	.7860	654	.00063	2.156	326.7	2.212	1.266	278.1
20.00	3.00	1845	3498.4	13.470	1.2402	.7617	597	.00056	2.542	346.5	3.499	1.402	308.0
40.00	1.50	1609	3319.9	13.470	1.2509	.7355	539	.00050	2.921	363.1	5.664	1.511	332.0
100.00	.60	1333	3121.5	13.470	1.2660	.6980	462	.00041	3.429	381.0	10.902	1.625	357.1
200.00	.30	1148	2994.8	13.470	1.2824	.6699	405	.00035	3.829	392.0	18.014	1.694	372.2
400.00	.15	982	2888.1	13.470	1.2975	.6434	350	.00029	4.254	401.1	29.828	1.751	384.7
1000.00	.06	792	2766.6	13.470	1.3164	.6138	284	.00023	4.865	410.8	58.120	1.811	398.0
2000.00	.03	669	2692.0	13.470	1.3290	.5960	239	.00019	5.377	416.6	96.197	1.848	406.1
4000.00	.02	562	2629.2	13.470	1.3397	.5819	200	.00015	5.937	421.5	159.100	1.878	412.7
R = 0.900, PERCENT FUEL = 12.28, O/F = 7.143													
1.00	60.00	3213	4142.9	14.479	1.2086	0.7951	852	0.00082	0.000			0.000	0.0
1.05	57.14	3186	4121.5	14.479	1.2089	.7942	848	.00082	.285	483.8	2.173	.203	43.2
1.20	50.00	3113	4063.8	14.479	1.2098	.7915	837	.00081	.553	307.0	1.263	.390	83.0
1.40	42.86	3031	3998.8	14.479	1.2108	.7883	825	.00079	.757	273.6	1.063	.526	112.0
1.60	37.50	2961	3943.9	14.479	1.2118	.7853	815	.00078	.899	266.0	1.010	.618	131.6
1.78	33.72	2907	3901.1	14.479	1.2126	.7829	806	.00077	1.000	264.7	1.000	.681	145.1
2.00	30.00	2848	3854.9	14.479	1.2135	.7802	797	.00076	1.102	265.7	1.009	.744	158.3
4.00	15.00	2518	3600.0	14.479	1.2192	.7634	742	.00069	1.606	286.5	1.299	1.021	217.4
4.08	14.70	2508	3592.9	14.479	1.2194	.7629	741	.00069	1.619	287.2	1.313	1.028	218.8
10.00	6.00	2129	3308.4	14.479	1.2287	.7374	669	.00061	2.156	316.7	2.216	1.266	269.5
20.00	3.00	1866	3118.4	14.479	1.2374	.7153	611	.00054	2.541	335.9	3.509	1.404	298.6
40.00	1.50	1632	2952.2	14.479	1.2478	.6910	553	.00048	2.919	352.2	5.686	1.512	321.9
100.00	.60	1354	2764.9	14.479	1.2644	.6562	476	.00039	3.425	369.6	10.964	1.626	346.3
200.00	.30	1166	2643.1	14.479	1.2786	.6299	418	.00034	3.824	380.3	18.140	1.696	361.0
400.00	.15	1001	2542.1	14.479	1.2918	.6048	363	.00028	4.245	389.2	30.080	1.753	373.2
1000.00	.06	809	2426.7	14.479	1.3106	.5762	295	.00022	4.851	398.7	58.719	1.814	386.2
2000.00	.03	684	2357.6	14.479	1.3230	.5588	250	.00018	5.357	404.5	97.311	1.851	394.1
4000.00	.02	575	2298.1	14.479	1.3337	.5446	210	.00015	5.912	409.2	161.114	1.882	400.7

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSI(NED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OX'GEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(e) Continued. Combustion-chamber pressure, 60 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ϵ	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/(lb)
R = 1.000, PERCENT FUEL = 11.19, O/F = 7.937													
1.00	60.00	3217	3777.9	15.399	1.2077	0.7503	864	0.000079	0.000			0.000	0.0
1.05	57.14	3190	3757.7	15.399	1.2080	.7494	860	.000078	.285	469.4	2.173	.203	41.9
1.20	50.00	3118	3703.4	15.399	1.2088	.7470	849	.000077	.554	297.9	1.262	.390	80.5
1.40	42.86	3036	3642.1	15.399	1.2099	.7439	837	.000076	.757	265.5	1.063	.526	108.7
1.60	37.50	2966	3590.4	15.399	1.2108	.7412	826	.000075	.899	256.1	1.010	.618	127.7
1.78	33.73	2912	3550.2	15.399	1.2116	.7389	818	.000074	1.000	256.9	1.000	.681	140.7
2.00	30.00	2853	3506.7	15.399	1.2125	.7364	808	.000073	1.102	257.9	1.009	.743	153.6
4.00	15.00	2523	3266.5	15.399	1.2181	.7207	753	.000066	1.606	278.1	1.300	1.021	210.9
4.08	14.70	2514	3259.8	15.399	1.2183	.7202	751	.000066	1.619	278.8	1.313	1.027	212.3
10.00	6.00	2135	2991.6	15.399	1.2274	.6965	678	.000058	2.156	307.4	2.218	1.266	261.6
20.00	3.00	1875	2812.4	15.399	1.2360	.6759	621	.000052	2.541	326.2	3.515	1.403	289.8
40.00	1.50	1638	2655.5	15.399	1.2462	.6532	562	.000046	2.919	341.9	5.698	1.512	312.5
100.00	.60	1361	2478.5	15.399	1.2625	.6207	485	.000038	3.424	359.0	10.997	1.627	336.2
200.00	.30	1175	2365.3	15.399	1.2764	.5960	427	.000032	3.821	369.4	18.208	1.697	350.6
400.00	.15	1008	2267.8	15.399	1.2912	.5722	372	.000027	4.241	378.1	30.218	1.754	362.5
1000.00	.06	815	2160.3	15.399	1.3103	.5449	304	.000021	4.844	387.4	59.055	1.816	375.2
2000.00	.03	690	2093.1	15.399	1.3235	.5280	258	.000018	5.347	393.0	97.944	1.853	382.9
4000.00	.02	581	2036.3	15.399	1.3348	.5145	217	.000015	5.898	397.7	162.475	1.884	389.3
R = 1.500, PERCENT FUEL = 7.749, O/F = 11.905													
1.00	60.00	3116	2626.1	18.987	1.2082	0.6073	889	0.000076	0.000			0.000	0.0
1.05	57.14	3090	2610.2	18.987	1.2085	.6065	884	.000075	.285	416.0	2.173	.203	37.1
1.20	50.00	3019	2567.5	18.987	1.2094	.6044	873	.000074	.553	264.0	1.263	.390	71.4
1.40	42.86	2939	2519.5	18.987	1.2105	.6019	859	.000073	.757	235.3	1.063	.526	96.3
1.60	37.50	2872	2478.9	18.987	1.2115	.5996	848	.000062	.899	228.7	1.010	.618	113.2
1.78	33.72	2819	2447.2	18.987	1.2123	.5977	839	.000081	1.000	227.6	1.000	.681	124.7
2.00	30.00	2762	2413.1	18.987	1.2132	.5956	829	.000060	1.102	228.5	1.009	.744	136.1
4.00	15.00	2442	2224.5	18.987	1.2189	.5828	770	.000055	1.606	246.4	1.300	1.021	186.9
4.08	14.70	2433	2219.3	18.987	1.2191	.5824	768	.000055	1.619	247.0	1.313	1.028	188.1
10.00	6.00	2066	2008.8	18.987	1.2282	.5633	692	.000048	2.156	272.3	2.217	1.266	231.8
20.00	3.00	1813	1868.3	18.987	1.2368	.5466	632	.000043	2.542	288.9	3.511	1.402	256.8
40.00	1.50	1584	1745.2	18.987	1.2467	.5289	573	.000038	2.920	302.9	5.691	1.512	276.9
100.00	.60	1315	1606.5	18.987	1.2624	.5035	495	.000031	3.425	318.0	10.982	1.627	297.9
200.00	.30	1136	1517.7	18.987	1.2757	.4843	439	.000027	3.824	327.2	18.188	1.696	310.6
400.00	.15	975	1441.2	18.987	1.2898	.4658	384	.000023	4.244	334.9	30.198	1.754	321.1
1000.00	.06	789	1356.9	18.987	1.3082	.4442	317	.000018	4.846	343.1	59.073	1.815	332.3
2000.00	.03	669	1304.1	18.987	1.3212	.4305	271	.000015	5.347	348.1	98.060	1.852	339.2
4000.00	.02	564	1259.5	18.987	1.3329	.4190	230	.000013	5.896	352.3	162.595	1.883	344.8
R = 2.000, PERCENT FUEL = 5.927, O/F = 15.873													
1.00	60.00	2966	2016.0	21.453	1.2116	0.5304	886	0.000067	0.000			0.000	0.0
1.05	57.14	2941	2002.7	21.453	1.2119	.5297	882	.000067	.284	381.8	2.175	.203	34.1
1.20	50.00	2873	1966.7	21.453	1.2129	.5277	870	.000066	.553	242.3	1.264	.390	65.5
1.40	42.86	2796	1926.3	21.453	1.2141	.5253	856	.000065	.756	215.9	1.063	.526	88.4
1.60	37.50	2731	1892.1	21.453	1.2151	.5232	844	.000064	.898	209.8	1.010	.619	103.9
1.78	33.68	2679	1865.1	21.453	1.2160	.5215	834	.000063	1.000	208.8	1.000	.683	114.6
2.00	30.00	2625	1836.7	21.453	1.2169	.5196	824	.000062	1.101	209.6	1.009	.744	124.9
4.00	15.00	2316	1678.3	21.453	1.2230	.5079	763	.000058	1.604	225.9	1.297	1.021	171.4
4.08	14.70	2308	1673.9	21.453	1.2232	.5076	761	.000057	1.618	226.4	1.311	1.028	172.5
10.00	6.00	1954	1497.4	21.453	1.2327	.4906	682	.000051	2.156	249.5	2.208	1.265	212.4
20.00	3.00	1711	1379.8	21.453	1.2416	.4760	622	.000047	2.543	264.6	3.492	1.401	235.3
40.00	1.50	1492	1277.1	21.453	1.2517	.4607	562	.000042	2.923	277.3	5.650	1.510	253.6
100.00	.60	1236	1161.6	21.453	1.2671	.4394	486	.000037	3.433	290.9	10.878	1.624	272.7
200.00	.30	1065	1087.9	21.453	1.2801	.4233	431	.000033	3.835	299.3	17.986	1.693	284.2
400.00	.15	912	1024.5	21.453	1.2935	.4082	378	.000030	4.259	306.2	29.822	1.750	293.7
1000.00	.06	737	954.7	21.453	1.3114	.3901	313	.000026	4.868	313.7	58.249	1.810	303.9
2000.00	.03	624	911.1	21.453	1.3241	.3784	269	.000023	5.374	318.2	96.601	1.847	310.1
4000.00	.02	525	874.3	21.453	1.3358	.3685	229	.000021	5.927	321.9	160.027	1.877	315.2
R = 3.000, PERCENT FUEL = 4.031, O/F = 23.810													
1.00	60.00	2655	1381.4	24.532	1.2209	0.4476	851	0.000067	0.000			0.000	0.0
1.05	57.14	2632	1371.0	24.532	1.2213	.4470	847	.000066	.283	337.8	2.181	.204	30.1
1.20	50.00	2569	1342.8	24.532	1.2224	.4452	834	.000065	.551	214.2	1.266	.391	57.9
1.40	42.86	2498	1311.2	24.532	1.2237	.4430	820	.000064	.753	190.8	1.064	.528	78.2
1.60	37.50	2437	1284.5	24.532	1.2249	.4411	807	.000063	.895	185.4	1.010	.620	91.8
1.79	33.56	2386	1262.8	24.532	1.2260	.4395	797	.000063	1.000	184.4	1.000	.686	101.6
2.00	30.00	2339	1241.4	24.532	1.2270	.4378	787	.000062	1.098	185.1	1.008	.745	110.4
4.00	15.00	2034	1118.2	24.532	1.2340	.4272	723	.000058	1.601	199.2	1.292	1.022	151.3
4.08	14.70	2046	1114.8	24.532	1.2342	.4269	721	.000058	1.615	199.7	1.305	1.028	152.3
10.00	6.00	1721	978.3	24.532	1.2448	.4119	641	.000053	2.155	219.7	2.187	1.264	187.3
20.00	3.00	1499	888.0	24.532	1.2540	.3999	581	.000049	2.546	232.7	3.443	1.399	207.2
40.00	1.50	1300	809.6	24.532	1.2646	.3872	523	.000046	2.931	243.6	5.545	1.506	223.1
100.00	.60	1068	721.9	24.532	1.2800	.3703	450	.000041	3.451	255.3	10.611	1.617	239.5
200.00	.30	916	666.3	24.532	1.2924	.3580	398	.000038	3.863	262.4	17.467	1.684	249.4
400.00	.15	781	618.8	24.532	1.3038	.3460	349	.000036	4.298	268.3	28.839	1.739	257.6
1000.00	.06	627	566.7	24.532	1.3180	.3318	289	.000033	4.924	274.5	56.029	1.798	266.3
2000.00	.03	528	534.3	24.532	1.3285	.3224	249	.000031	5.446	278.3	92.556	1.833	271.5
4000.00	.02	443	507.2	24.532	1.3373	.3142	214	.000029	6.016	281.5	156.735	1.862	275.8

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(e) Concluded. Combustion-chamber pressure, 60 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 4.000, PERCENT FUEL = 3.054, O/F =31.746													
1.00	60.00	2347	1054.4	26.257	1.2321	0.4017	798	0.00040	0.000			0.000	0.0
1.05	57.14	2326	1045.8	26.257	1.2326	.4010	794	.00039	.282	306.9	2.188	.204	27.4
1.20	50.00	2268	1022.6	26.257	1.2339	.3992	781	.00039	.548	194.5	1.269	.392	52.6
1.40	42.86	2202	996.5	26.257	1.2355	.3971	766	.00038	.750	173.1	1.066	.529	71.0
1.60	37.50	2147	974.5	26.257	1.2368	.3953	754	.00037	.892	168.2	1.011	.621	83.4
1.80	33.42	2100	956.0	26.257	1.2380	.3937	743	.00036	1.000	167.3	1.000	.690	92.5
2.00	30.00	2057	939.0	26.257	1.2391	.3922	733	.00036	1.094	167.8	1.008	.747	100.2
4.00	15.00	1796	838.1	26.257	1.2469	.3822	669	.00032	1.598	180.3	1.285	1.023	137.2
4.08	14.70	1789	835.3	26.257	1.2471	.3819	667	.00032	1.611	180.7	1.298	1.029	138.1
10.00	6.00	1493	724.3	26.257	1.2565	.3685	588	.00027	2.155	198.5	2.162	1.263	169.5
20.00	3.00	1292	651.4	26.257	1.2684	.3577	530	.00024	2.549	210.0	3.387	1.396	187.3
40.00	1.50	1113	588.3	26.257	1.2793	.3467	475	.00021	2.941	219.6	5.428	1.501	201.4
100.00	.60	908	518.5	26.257	1.2950	.3323	406	.00017	3.471	229.8	10.316	1.610	215.9
200.00	.30	773	474.5	26.257	1.3079	.3215	357	.00015	3.893	236.0	16.892	1.674	224.6
400.00	.15	655	437.1	26.257	1.3212	.3113	312	.00013	4.342	241.1	27.741	1.728	231.8
1000.00	.06	522	396.4	26.257	1.3386	.2992	258	.00010	4.990	246.5	53.515	1.784	239.3
2000.00	.03	437	371.3	26.257	1.3510	.2913	221	.00009	5.531	249.7	87.939	1.817	243.8
4000.00	.02	364	350.4	26.257	1.3601	.2859	187	.00007	6.129	252.3	144.427	1.845	247.5
R = 5.000, PERCENT FUEL = 2.458, O/F =39.683													
1.00	60.00	2062	855.0	27.299	1.2440	0.3711	740	0.00034	0.000			0.000	0.0
1.05	57.14	2042	847.7	27.299	1.2445	.3705	735	.00034	.281	282.0	2.195	.205	25.2
1.20	50.00	1989	828.1	27.299	1.2459	.3688	722	.00033	.546	178.6	1.272	.394	48.4
1.40	42.86	1929	806.1	27.299	1.2476	.3668	708	.00032	.747	158.9	1.068	.531	65.2
1.60	37.50	1879	787.6	27.299	1.2491	.3650	696	.00032	.888	154.3	1.012	.623	76.6
1.80	33.28	1835	771.5	27.299	1.2505	.3634	684	.00031	1.000	153.4	1.000	.694	85.2
2.00	30.00	1797	757.8	27.299	1.2517	.3620	675	.00031	1.090	153.8	1.007	.748	92.0
4.00	15.00	1560	673.2	27.299	1.2600	.3528	612	.00027	1.594	165.1	1.279	1.024	125.8
4.08	14.70	1554	670.9	27.299	1.2603	.3525	610	.00027	1.607	165.4	1.292	1.030	126.6
10.00	6.00	1287	578.5	27.299	1.2725	.3399	534	.00023	2.154	181.4	2.138	1.262	155.1
20.00	3.00	1107	518.2	27.299	1.2830	.3300	479	.00020	2.553	191.7	3.333	1.393	171.2
40.00	1.50	948	466.4	27.299	1.2943	.3201	427	.00018	2.950	200.2	5.313	1.496	183.9
100.00	.60	766	409.5	27.299	1.3111	.3068	363	.00014	3.491	209.2	10.027	1.602	196.9
200.00	.30	648	373.8	27.299	1.3244	.2972	317	.00012	3.924	214.6	16.328	1.665	204.6
400.00	.15	545	343.8	27.299	1.3380	.2881	276	.00010	4.387	219.1	26.662	1.716	210.9
1000.00	.06	431	311.4	27.299	1.3550	.2779	226	.00008	5.058	223.8	51.055	1.770	217.5
2000.00	.03	359	291.5	27.299	1.3642	.2726	192	.00007	5.625	226.6	83.484	1.802	221.4
4000.00	.02	298	275.0	27.299	1.3704	.2693	162	.00006	6.250	228.8	136.601	1.828	224.7

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(f) Combustion-chamber pressure, 150 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/lb
R = 0.150, PERCENT FUEL = 45.65, O/F = 1.190													
1.00	150.00	1183	5313.5	4.416	1.3396	1.7753	314	0.00073	0.000			0.000	0.0
1.05	142.86	1168	5287.7	4.416	1.3406	1.7710	311	.00073	.271	530.1	2.250	.210	47.4
1.20	125.00	1129	5218.6	4.416	1.3436	1.7597	303	.00070	.527	334.2	1.297	.403	90.8
1.40	107.14	1083	5141.8	4.416	1.3469	1.7472	293	.00068	.722	296.1	1.081	.543	122.2
1.60	93.75	1044	5077.7	4.416	1.3497	1.7369	285	.00066	.860	286.6	1.018	.636	143.2
1.87	80.42	1008	5006.8	4.416	1.3528	1.7257	276	.00063	1.000	284.1	1.000	.725	163.4
2.00	75.00	989	4975.4	4.416	1.3540	1.7210	272	.00062	1.059	284.4	1.003	.761	171.5
4.00	37.50	824	4693.4	4.416	1.3651	1.6823	234	.00052	1.566	301.7	1.233	1.031	232.3
10.00	15.00	643	4392.5	4.416	1.3748	1.6505	188	.00042	2.152	327.5	1.974	1.257	283.1
10.21	14.70	639	4386.6	4.416	1.3750	1.6501	187	.00041	2.165	328.1	1.997	1.261	284.0
20.00	7.50	532	4209.8	4.416	1.3799	1.6344	159	.00035	2.586	343.5	2.982	1.376	309.9
40.00	3.75	439	4058.9	4.416	1.3824	1.6268	133	.00029	3.031	356.4	4.620	1.467	330.4
100.00	1.50	340	3899.0	4.416	1.3882	1.6093	104	.00023	3.648	369.8	8.432	1.558	350.8
200.00	.75	280	3802.6	4.416	1.3926	1.5961	85	.00018	4.149	377.7	13.431	1.610	362.6
400.00	.38	230	3723.2	4.416	1.4008	1.5762	70	.00015	4.675	384.1	21.488	1.652	372.0
1000.00	.15	175	3640.1	4.416	1.4349	1.4847	55	.00011	5.438	390.6	39.928	1.694	381.6
2000.00	.08	142	3590.9	4.416	1.4550	1.4389	45	.00009	6.096	394.3	63.572	1.719	387.2
4000.00	.04	114	3551.2	4.416	1.4705	1.4065	36	.00007	6.845	397.3	100.938	1.739	391.6
R = 0.200, PERCENT FUEL = 38.65, O/F = 1.587													
1.00	150.00	1514	2969.7	5.216	1.3079	1.6183	402	0.00084	0.000			0.000	0.0
1.05	142.86	1497	2941.7	5.216	1.3090	1.6140	399	.00083	.274	552.2	2.233	.209	49.3
1.20	125.00	1450	2866.8	5.216	1.3120	1.6022	389	.00081	.533	348.6	1.289	.400	94.6
1.40	107.14	1398	2783.2	5.216	1.3155	1.5887	378	.00078	.730	309.3	1.077	.539	127.4
1.60	93.75	1354	2713.2	5.216	1.3185	1.5772	369	.00076	.869	299.6	1.016	.632	149.4
1.85	81.23	1307	2640.5	5.216	1.3217	1.5651	359	.00073	1.000	297.3	1.000	.716	169.2
2.00	75.00	1282	2601.1	5.216	1.3236	1.5584	353	.00072	1.068	297.8	1.004	.757	179.1
4.00	37.50	1079	2290.0	5.216	1.3391	1.5046	307	.00061	1.572	316.7	1.244	1.029	243.2
10.00	15.00	852	1954.3	5.216	1.3558	1.4516	251	.00048	2.146	344.7	2.009	1.257	297.2
10.21	14.70	847	1947.7	5.216	1.3562	1.4506	250	.00048	2.161	345.3	2.033	1.261	298.2
20.00	7.50	709	1748.8	5.216	1.3636	1.4282	213	.00040	2.573	362.0	3.049	1.379	325.9
40.00	3.75	588	1578.0	5.216	1.3715	1.4066	179	.00034	3.010	376.0	4.739	1.472	348.0
100.00	1.50	458	1396.3	5.216	1.3771	1.3913	142	.00026	3.619	390.5	8.679	1.565	370.0
200.00	.75	379	1286.2	5.216	1.3811	1.3807	117	.00022	4.111	399.1	13.870	1.619	382.7
400.00	.38	312	1195.2	5.216	1.3861	1.3677	96	.00018	4.638	406.1	22.295	1.662	392.9
1000.00	.15	242	1099.0	5.216	1.3973	1.3400	74	.00013	5.394	413.4	41.979	1.706	403.5
2000.00	.08	198	1041.1	5.216	1.4156	1.2977	61	.00011	6.014	417.6	67.687	1.733	409.6
4000.00	.04	161	993.9	5.216	1.4330	1.2568	50	.00009	6.704	421.1	108.754	1.754	414.6
R = 0.250, PERCENT FUEL = 33.51, O/F = 1.984													
1.00	150.00	1816	1249.3	6.016	1.2835	1.4955	481	0.00092	0.000			0.000	0.0
1.05	142.86	1797	1220.2	6.016	1.2844	1.4917	477	.00091	.276	563.4	2.219	.207	50.3
1.20	125.00	1744	1142.1	6.016	1.2870	1.4812	467	.00089	.538	356.1	1.283	.398	96.6
1.40	107.14	1683	1059.6	6.016	1.2900	1.4693	456	.00086	.736	316.3	1.073	.536	130.1
1.60	93.75	1635	981.5	6.016	1.2927	1.4590	446	.00083	.876	306.6	1.015	.629	152.6
1.83	81.95	1586	910.0	6.016	1.2954	1.4485	436	.00081	1.000	304.5	1.000	.708	171.8
2.00	75.00	1554	864.0	6.016	1.2973	1.4415	429	.00080	1.076	305.1	1.005	.754	183.1
4.00	37.50	1322	535.3	6.016	1.3125	1.3873	378	.00068	1.578	325.5	1.256	1.027	249.3
10.00	15.00	1057	176.5	6.016	1.3330	1.3225	314	.00054	2.147	355.3	2.048	1.258	305.5
10.21	14.70	1052	169.3	6.016	1.3334	1.3212	312	.00054	2.159	355.8	2.072	1.263	306.5
20.00	7.50	867	9954.4	6.016	1.3481	1.2848	269	.00046	2.763	373.6	3.147	1.382	335.7
40.00	3.75	740	9766.6	6.016	1.3589	1.2559	228	.00038	2.987	388.6	4.883	1.478	358.9
100.00	1.50	580	9569.7	6.016	1.3683	1.2320	181	.00030	3.381	404.1	8.985	1.575	382.3
200.00	.75	481	9448.5	6.016	1.3717	1.2191	151	.00025	4.084	413.3	14.393	1.630	395.9
400.00	.38	399	9348.0	6.016	1.3755	1.2100	124	.00020	4.782	420.8	23.206	1.675	406.7
1000.00	.15	310	9241.3	6.016	1.3821	1.1946	93	.00015	5.327	428.7	43.889	1.722	418.0
2000.00	.08	256	9178.7	6.016	1.3865	1.1805	78	.00012	5.945	433.3	71.271	1.749	424.7
4000.00	.04	210	9123.5	6.016	1.4039	1.1482	64	.00010	6.606	437.1	115.634	1.771	430.1
R = 0.300, PERCENT FUEL = 29.57, O/F = 2.381													
1.00	150.00	2092	9932.7	6.813	1.2648	1.3932	550	0.00097	0.000			0.000	0.0
1.05	142.86	2071	9903.1	6.813	1.2655	1.3901	546	.00096	.278	568.3	2.208	.206	50.8
1.20	125.00	2013	9823.6	6.813	1.2676	1.3814	536	.00094	.542	359.6	1.278	.396	97.5
1.40	107.14	1949	9734.5	6.813	1.2702	1.3711	524	.00091	.741	319.6	1.071	.533	131.3
1.60	93.75	1894	9659.7	6.813	1.2725	1.3619	514	.00089	.881	310.0	1.013	.626	154.1
1.82	82.52	1843	9590.2	6.813	1.2746	1.3530	504	.00087	1.000	308.1	1.000	.701	172.6
2.00	75.00	1805	9539.4	6.813	1.2765	1.3463	497	.00085	1.082	308.8	1.006	.752	185.0
4.00	37.50	1549	9200.9	6.813	1.2899	1.2976	444	.00074	1.589	330.2	1.266	1.025	252.4
10.00	15.00	1234	8827.4	6.813	1.3099	1.2529	374	.00060	2.146	361.4	2.084	1.260	310.1
10.21	14.70	1228	8819.9	6.813	1.3103	1.2515	373	.00060	2.160	362.1	2.110	1.264	311.2
20.00	7.50	1061	8593.8	6.813	1.3252	1.1885	324	.00050	2.755	380.8	3.204	1.386	341.3
40.00	3.75	893	8396.8	6.813	1.3387	1.1527	278	.00042	2.989	396.6	5.034	1.485	365.6
100.00	1.50	703	8184.1	6.813	1.3533	1.1172	223	.00033	3.345	413.0	9.318	1.584	390.1
200.00	.75	586	8053.8	6.813	1.3606	1.1005	186	.00027	4.014	422.8	14.981	1.642	404.3
400.00	.38	488	7943.3	6.813	1.3666	1.0866	155	.00023	4.718	430.8	24.215	1.689	415.9
1000.00	.15	381	7829.6	6.813	1.3726	1.0745	120	.00017	5.469	439.1	45.957	1.738	427.8
2000.00	.08	316	7759.4	6.813	1.3776	1.0660	97	.00014	5.854	444.1	74.839	1.766	434.9
4000.00	.04	261	7701.3	6.813	1.3831	1.0590	80	.00011	6.512	448.2	122.098	1.790	440.8

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNEDPPRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(f) Continued. Combustion-chamber pressure, 150 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, lb-sec/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, lb-sec/lb
R = 0.350, PERCENT FUEL = 26.47, O/F = 2.778													
1.00	150.00	2339	8892.8	7.604	1.2305	1.3047	610	0.00099	0.000			0.000	0.0
1.05	142.86	2310	8665.1	7.604	1.2511	1.3020	606	.00099	.280	369.0	2.199	.205	50.8
1.20	125.00	2254	8203.4	7.604	1.2949	1.2940	596	.00097	.544	360.3	1.274	.394	97.6
1.40	107.14	2183	8693.9	7.604	1.2551	1.2859	584	.00094	.745	320.4	1.069	.532	131.5
1.60	93.75	2126	8818.7	7.604	1.2570	1.2784	574	.00092	.886	311.0	1.012	.624	154.4
1.81	82.97	2074	8551.7	7.604	1.2587	1.2715	564	.00090	1.000	309.2	1.000	.696	172.3
2.00	75.00	2031	8497.3	7.604	1.2602	1.2656	556	.00089	1.087	310.0	1.007	.749	185.5
4.00	37.50	1756	8154.9	7.604	1.2720	1.2223	502	.00078	1.590	332.2	1.274	1.024	253.4
10.00	15.00	1436	7773.7	7.604	1.2899	1.1627	431	.00064	2.150	364.4	2.115	1.261	312.1
10.21	14.70	1430	7766.0	7.604	1.2904	1.1614	429	.00064	2.162	365.0	2.142	1.265	313.1
20.00	7.50	1225	7532.9	7.604	1.3050	1.1182	377	.00055	2.951	384.5	3.274	1.390	344.0
40.00	3.75	1039	7328.2	7.604	1.3202	1.0774	326	.00048	2.955	401.0	5.175	1.491	369.0
100.00	1.50	828	7103.5	7.604	1.3377	1.0353	264	.00038	3.514	418.2	9.648	1.594	394.4
200.00	.75	694	6968.0	7.604	1.3485	1.0112	223	.00030	3.969	428.5	15.575	1.654	409.2
400.00	.38	579	6853.0	7.604	1.3583	.9948	186	.00025	4.459	436.9	25.259	1.703	421.3
1000.00	.15	454	6729.9	7.604	1.3682	.9790	146	.00019	5.169	445.7	48.098	1.753	433.8
2000.00	.08	377	6654.8	7.604	1.3692	.9693	119	.00015	5.760	451.0	78.522	1.783	441.3
4000.00	.04	312	6592.3	7.604	1.3742	.9598	97	.00012	6.403	455.3	128.377	1.808	447.4
R = 0.400, PERCENT FUEL = 23.95, O/F = 3.175													
1.00	150.00	2553	8050.5	8.379	1.2395	1.2276	660	0.00101	0.000			0.000	0.0
1.05	142.86	2529	8021.1	8.379	1.2400	1.2254	656	.00100	.281	366.4	2.192	.205	50.6
1.20	125.00	2464	7942.1	8.379	1.2415	1.2192	646	.00098	.547	358.9	1.271	.393	97.1
1.40	107.14	2391	7853.3	8.379	1.2433	1.2118	634	.00096	.748	319.3	1.067	.530	131.0
1.60	93.75	2329	7778.6	8.379	1.2450	1.2052	624	.00094	.889	310.1	1.012	.623	153.8
1.80	83.31	2276	7714.2	8.379	1.2465	1.1992	615	.00092	1.000	308.3	1.000	.692	171.1
2.00	75.00	2229	7658.0	8.379	1.2479	1.1938	607	.00090	1.091	309.2	1.007	.748	184.8
4.00	37.50	1938	7316.0	8.379	1.2578	1.1570	553	.00080	1.594	331.9	1.280	1.023	252.8
10.00	15.00	1599	6932.6	8.379	1.2738	1.1033	480	.00067	2.152	364.8	2.141	1.262	311.9
10.21	14.70	1592	6924.9	8.379	1.2742	1.1021	479	.00067	2.163	365.4	2.168	1.267	313.0
20.00	7.50	1373	6688.7	8.379	1.2879	1.0609	425	.00058	2.948	385.4	3.332	1.393	344.2
40.00	3.75	1173	6479.7	8.379	1.3030	1.0200	371	.00049	2.944	402.4	5.298	1.496	369.7
100.00	1.50	943	6250.6	8.379	1.3224	.9728	304	.00039	3.490	420.3	9.946	1.602	395.7
200.00	.75	794	6108.2	8.379	1.3351	.9448	258	.00032	3.931	431.0	16.131	1.664	411.1
400.00	.38	666	5988.4	8.379	1.3455	.9235	217	.00026	4.406	439.8	26.255	1.714	423.6
1000.00	.15	525	5859.6	8.379	1.3562	.9029	170	.00020	5.095	449.0	50.189	1.767	436.6
2000.00	.08	437	5780.8	8.379	1.3617	.8928	141	.00017	5.672	454.5	82.113	1.799	444.4
4000.00	.04	363	5715.2	8.379	1.3670	.8833	115	.00014	6.299	459.1	134.543	1.824	450.8
R = 0.450, PERCENT FUEL = 21.87, O/F = 3.571													
1.00	150.00	2733	7354.5	9.133	1.2310	1.1595	701	0.00100	0.000			0.000	0.0
1.05	142.86	2708	7325.6	9.133	1.2315	1.1576	698	.00100	.282	361.5	2.187	.204	50.1
1.20	125.00	2640	7247.9	9.133	1.2328	1.1521	688	.00098	.549	355.9	1.269	.392	96.3
1.40	107.14	2564	7160.6	9.133	1.2344	1.1459	676	.00096	.750	316.8	1.066	.529	129.9
1.60	93.75	2500	7087.1	9.133	1.2358	1.1404	666	.00094	.892	307.7	1.011	.621	152.5
1.79	83.56	2446	7025.3	9.133	1.2371	1.1355	657	.00092	1.000	306.0	1.000	.689	169.2
2.00	75.00	2395	6968.2	9.133	1.2383	1.1307	649	.00091	1.094	307.0	1.008	.747	183.3
4.00	37.50	2092	6630.2	9.133	1.2471	1.0982	595	.00082	1.597	329.9	1.285	1.023	251.0
10.00	15.00	1738	6249.2	9.133	1.2614	1.0500	522	.00069	2.153	363.2	2.161	1.263	310.1
10.21	14.70	1730	6241.5	9.133	1.2617	1.0489	521	.00069	2.165	363.8	2.189	1.268	311.2
20.00	7.50	1501	6005.3	9.133	1.2741	1.0114	467	.00060	2.946	384.1	3.379	1.396	342.6
40.00	3.75	1289	5795.1	9.133	1.2864	.9720	411	.00051	2.937	401.5	5.399	1.500	368.4
100.00	1.50	1045	5563.1	9.133	1.3034	.9231	341	.00041	3.471	419.9	10.202	1.608	394.8
200.00	.75	885	5417.9	9.133	1.3224	.8924	291	.00034	3.901	430.9	16.618	1.672	410.5
400.00	.38	745	5295.2	9.133	1.3349	.8673	246	.00028	4.362	440.0	27.151	1.724	423.3
1000.00	.15	590	5162.6	9.133	1.3475	.8438	194	.00022	5.033	449.5	52.106	1.779	436.7
2000.00	.08	493	5081.2	9.133	1.3553	.8300	164	.00018	5.593	455.2	85.445	1.812	444.8
4000.00	.04	410	5013.2	9.133	1.3608	.8207	132	.00014	6.207	460.0	140.269	1.838	451.4
R = 0.500, PERCENT FUEL = 20.12, O/F = 3.968													
1.00	150.00	2881	6769.6	9.859	1.2244	1.0999	736	0.00099	0.000			0.000	0.0
1.05	142.86	2855	6741.4	9.859	1.2248	1.0981	734	.00099	.283	554.9	2.183	.204	49.5
1.20	125.00	2786	6665.5	9.859	1.2260	1.0932	726	.00097	.550	351.8	1.267	.392	95.2
1.40	107.14	2707	6580.2	9.859	1.2275	1.0875	710	.00095	.752	313.3	1.065	.528	128.4
1.60	93.75	2641	6508.2	9.859	1.2288	1.0824	700	.00093	.894	304.4	1.011	.620	150.8
1.79	83.79	2586	6447.1	9.859	1.2299	1.0783	692	.00092	1.000	302.8	1.000	.687	167.0
2.00	75.00	2533	6391.9	9.859	1.2310	1.0741	683	.00091	1.096	303.8	1.008	.746	181.3
4.00	37.50	2220	6060.2	9.859	1.2389	1.0452	630	.00082	1.600	326.8	1.289	1.022	248.5
10.00	15.00	1854	5684.8	9.859	1.2517	1.0024	556	.00070	2.154	360.2	2.177	1.264	307.2
10.21	14.70	1846	5677.1	9.859	1.2520	1.0014	556	.00070	2.166	360.8	2.205	1.268	308.3
20.00	7.50	1609	5443.2	9.859	1.2653	.9670	504	.00061	2.945	381.3	3.416	1.398	339.7
40.00	3.75	1386	5234.1	9.859	1.2788	.9297	445	.00053	2.932	398.8	5.481	1.504	365.5
100.00	1.50	1132	5001.9	9.859	1.2964	.8817	376	.00042	3.457	417.5	10.413	1.613	392.2
200.00	.75	963	4855.6	9.859	1.3112	.8493	320	.00035	3.878	428.8	17.030	1.679	408.1
400.00	.38	815	4731.6	9.859	1.3247	.8223	272	.00029	4.328	438.1	27.924	1.732	421.1
1000.00	.15	646	4597.2	9.859	1.3395	.7953	218	.00023	4.982	447.9	53.794	1.789	434.8
2000.00	.08	543	4514.2	9.859	1.3483	.7799	180	.00019	5.529	453.8	88.422	1.822	443.0
4000.00	.04	453	4444.8	9.859	1.3554	.7667	149	.00015	6.128	458.6	145.411	1.850	449.8

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(f) Continued. Combustion-chamber pressure, 150 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ϵ	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/(lb)
R = 0.600, PERCENT FUEL = 17.35, O/F = 4.762													
1.00	150.00	3097	5841.6	11.228	1.2152	0.9995	788	0.00096	0.000			0.000	0.0
1.05	142.86	3070	5815.0	11.228	1.2135	.9981	765	.00096	.284	539.3	2.177	.203	46.1
1.20	125.00	2998	5743.3	11.228	1.2166	.9942	774	.00094	.552	542.1	1.264	.391	92.5
1.40	107.14	2917	5662.6	11.228	1.2178	.9895	763	.00092	.755	504.8	1.064	.527	124.8
1.60	93.75	2848	5594.5	11.228	1.2189	.9853	753	.00091	.897	496.2	1.010	.619	146.6
1.78	84.08	2793	5540.1	11.228	1.2199	.9819	745	.00090	1.000	494.7	1.000	.684	162.0
2.00	75.00	2736	5484.2	11.228	1.2209	.9782	736	.00088	1.100	495.8	1.009	.744	176.3
4.00	37.50	2410	5169.0	11.228	1.2275	.9550	683	.00080	1.603	518.6	1.295	1.021	241.9
10.00	15.00	2027	4809.9	11.228	1.2363	.9197	611	.00070	2.155	551.7	2.199	1.265	299.6
10.21	14.70	2019	4802.6	11.228	1.2366	.9189	610	.00070	2.167	552.4	2.228	1.269	300.7
20.00	7.50	1770	4577.3	11.228	1.2465	.8893	555	.00062	2.543	572.8	3.469	1.400	331.7
40.00	3.75	1536	4374.7	11.228	1.2602	.8572	498	.00054	2.925	590.4	5.598	1.508	357.3
100.00	1.50	1266	4147.8	11.228	1.2783	.8128	423	.00044	3.439	609.3	10.724	1.621	383.9
200.00	.75	1086	4003.7	11.228	1.2933	.7804	368	.00037	3.846	620.8	17.650	1.688	399.9
400.00	.38	925	3880.6	11.228	1.3080	.7516	318	.00031	4.280	630.3	29.113	1.744	413.1
1000.00	.15	742	3745.9	11.228	1.3257	.7204	263	.00024	4.907	640.4	56.470	1.803	427.0
2000.00	.08	624	3662.3	11.228	1.3366	.7028	232	.00020	5.433	646.5	93.204	1.838	435.5
4000.00	.04	523	3592.1	11.228	1.3459	.6866	176	.00016	6.008	651.5	153.804	1.868	442.4
R = 0.700, PERCENT FUEL = 15.25, O/F = 5.556													
1.00	150.00	3231	5138.3	12.482	1.2096	0.9187	825	0.00092	0.000			0.000	0.0
1.05	142.86	3203	5113.3	12.482	1.2099	.9175	822	.00092	.285	522.5	2.174	.203	46.6
1.20	125.00	3130	5046.0	12.482	1.2108	.9143	811	.00090	.553	531.5	1.263	.390	89.6
1.40	107.14	3047	4970.2	12.482	1.2119	.9105	800	.00089	.756	495.4	1.063	.526	120.9
1.60	93.75	2976	4906.2	12.482	1.2129	.9070	789	.00087	.899	487.2	1.010	.618	142.1
1.78	84.26	2921	4856.1	12.482	1.2137	.9041	781	.00086	1.000	485.8	1.000	.682	156.7
2.00	75.00	2862	4802.5	12.482	1.2146	.9009	773	.00085	1.102	486.9	1.009	.744	170.9
4.00	37.50	2528	4505.4	12.482	1.2206	.8810	720	.00078	1.605	509.3	1.299	1.021	234.7
10.00	15.00	2136	4165.8	12.482	1.2303	.8504	648	.00068	2.156	541.8	2.213	1.266	290.9
10.21	14.70	2128	4158.8	12.482	1.2306	.8497	647	.00068	2.168	542.4	2.242	1.270	291.9
20.00	7.50	1873	3944.8	12.482	1.2393	.8244	592	.00061	2.542	562.5	3.502	1.402	322.3
40.00	3.75	1634	3751.6	12.482	1.2500	.7960	535	.00053	2.920	580.0	5.671	1.511	347.4
100.00	1.50	1354	3534.1	12.482	1.2670	.7556	459	.00044	3.427	598.7	10.922	1.625	373.6
200.00	.75	1167	3395.2	12.482	1.2813	.7251	402	.00037	3.828	610.2	18.053	1.694	389.5
400.00	.38	999	3273.9	12.482	1.2963	.6964	348	.00031	4.251	619.7	29.905	1.751	402.6
1000.00	.15	806	3144.6	12.482	1.3151	.6644	287	.00024	4.861	629.9	58.305	1.812	416.5
2000.00	.08	681	3066.6	12.482	1.3276	.6451	251	.00020	5.371	636.1	96.550	1.849	425.0
4000.00	.04	573	2993.8	12.482	1.3381	.6300	198	.00016	5.930	641.2	159.767	1.879	432.0
R = 0.800, PERCENT FUEL = 13.60, O/F = 6.349													
1.00	150.00	3304	4586.9	13.622	1.2063	0.8531	851	0.00088	0.000			0.000	0.0
1.05	142.86	3277	4563.5	13.622	1.2066	.8520	847	.00088	.285	505.8	2.172	.203	45.1
1.20	125.00	3202	4500.4	13.622	1.2075	.8491	837	.00086	.554	521.0	1.262	.390	86.8
1.40	107.14	3118	4429.3	13.622	1.2084	.8458	825	.00085	.757	486.1	1.062	.526	117.1
1.60	93.75	3047	4369.2	13.622	1.2093	.8428	815	.00084	.900	478.2	1.010	.618	137.6
1.78	84.36	2992	4322.8	13.622	1.2101	.8403	807	.00083	1.000	476.9	1.000	.681	151.6
2.00	75.00	2932	4271.9	13.622	1.2109	.8374	798	.00081	1.103	477.9	1.009	.743	165.5
4.00	37.50	2595	3992.8	13.622	1.2166	.8193	745	.00075	1.606	499.8	1.301	1.021	227.4
10.00	15.00	2198	3673.1	13.622	1.2236	.7965	683	.00066	2.156	531.5	2.222	1.266	282.0
10.21	14.70	2190	3666.5	13.622	1.2238	.7959	681	.00065	2.166	532.1	2.251	1.271	283.0
20.00	7.50	1931	3464.5	13.622	1.2340	.7694	617	.00059	2.541	551.7	3.522	1.403	312.5
40.00	3.75	1690	3281.6	13.622	1.2441	.7436	559	.00052	2.918	568.8	5.715	1.513	337.0
100.00	1.50	1405	3075.1	13.622	1.2601	.7088	483	.00043	3.421	587.3	11.042	1.628	362.7
200.00	.75	1214	2942.8	13.622	1.2739	.6785	425	.00037	3.817	598.6	18.300	1.698	378.2
400.00	.38	1043	2828.9	13.622	1.2880	.6510	370	.00031	4.234	608.0	30.397	1.756	391.1
1000.00	.15	845	2703.0	13.622	1.3060	.6195	309	.00024	4.834	618.1	59.468	1.818	404.9
2000.00	.08	716	2624.3	13.622	1.3214	.5956	265	.00020	5.334	624.6	98.706	1.855	413.2
4000.00	.04	603	2557.7	13.622	1.3367	.5744	214	.00016	5.882	629.3	163.055	1.887	420.2
R = 0.900, PERCENT FUEL = 12.28, O/F = 7.143													
1.00	150.00	3336	4142.9	14.653	1.2044	0.7990	870	0.00084	0.000			0.000	0.0
1.05	142.86	3308	4121.0	14.653	1.2047	.7981	866	.00084	.285	490.1	2.171	.203	45.7
1.20	125.00	3234	4061.7	14.653	1.2056	.7954	855	.00083	.554	511.0	1.262	.389	84.1
1.40	107.14	3150	3993.0	14.653	1.2065	.7923	843	.00081	.758	477.3	1.062	.525	113.5
1.60	93.75	3078	3938.6	14.653	1.2074	.7896	832	.00080	.900	469.6	1.009	.618	133.3
1.78	84.42	3024	3892.3	14.653	1.2081	.7874	824	.00079	1.000	468.3	1.000	.680	146.8
2.00	75.00	2962	3841.2	14.653	1.2089	.7848	815	.00078	1.104	469.4	1.009	.743	160.4
4.00	37.50	2625	3564.9	14.653	1.2143	.7684	761	.00071	1.607	490.6	1.302	1.021	220.4
10.00	15.00	2227	3264.0	14.653	1.2210	.7478	699	.00063	2.157	521.5	2.226	1.266	273.4
10.21	14.70	2219	3257.8	14.653	1.2212	.7472	697	.00063	2.168	522.1	2.256	1.271	274.4
20.00	7.50	1959	3067.4	14.653	1.2310	.7227	632	.00056	2.541	541.2	3.533	1.404	303.1
40.00	3.75	1716	2914.8	14.653	1.2408	.6988	575	.00050	2.916	557.9	5.740	1.514	326.9
100.00	1.50	1431	2719.7	14.653	1.2562	.6650	498	.00042	3.417	575.9	11.109	1.630	351.9
200.00	.75	1238	2594.4	14.653	1.2697	.6385	440	.00036	3.811	587.0	18.439	1.700	367.1
400.00	.38	1066	2486.3	14.653	1.2844	.6125	385	.00030	4.225	596.2	30.678	1.759	379.7
1000.00	.15	863	2366.6	14.653	1.3031	.5822	319	.00024	4.819	606.1	60.145	1.821	393.1
2000.00	.08	734	2291.6	14.653	1.3174	.5600	268	.00020	5.313	612.2	99.976	1.859	401.4
4000.00	.04	620	2228.1	14.653	1.3292	.5416	225	.00016	5.855	617.1	165.972	1.891	408.2

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(f) Continued. Combustion-chamber pressure, 150 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 1.000, PERCENT FUEL = 11.119, O/F = 7.937													
1.00	150.00	3341	3777.9	15.586	1.2053	0.7539	882	0.00081	0.000			0.000	0.0
1.05	142.86	3313	3757.2	15.586	1.2038	.7550	878	.00080	.265	479.5	2.170	.204	42.4
1.20	125.00	3239	3701.4	15.586	1.2040	.7505	866	.00079	.554	30 .6	1.261	.389	81.6
1.40	107.14	3155	3638.6	15.586	1.2036	.7477	853	.00078	.758	469.1	1.062	.526	110.1
1.60	93.75	3084	3585.5	15.586	1.2084	.7452	843	.00076	.901	461.6	1.009	.617	129.4
1.78	84.45	3029	3544.7	15.586	1.2071	.7432	836	.00075	1.000	460.4	1.000	.680	142.4
2.00	75.00	2968	3499.4	15.586	1.2079	.7407	827	.00074	1.104	461.4	1.009	.743	155.7
4.00	37.50	2631	3252.2	15.586	1.2132	.7254	772	.00068	1.607	482.1	1.303	1.021	213.9
10.00	15.00	2234	2968.5	15.586	1.2217	.7065	699	.00060	2.157	512.1	2.228	1.266	265.4
10.21	14.70	2226	2962.7	15.586	1.2219	.7019	697	.00060	2.168	512.7	2.238	1.271	266.3
20.00	7.50	1967	2783.1	15.586	1.2276	.6628	642	.00054	2.540	531.3	3.539	1.404	294.2
40.00	3.75	1724	2620.1	15.586	1.2372	.6606	584	.00048	2.915	547.5	5.752	1.515	317.4
100.00	1.50	1439	2435.8	15.586	1.2543	.6289	507	.00040	3.416	565.1	11.143	1.631	341.7
200.00	.75	1246	2317.3	15.586	1.2675	.6041	450	.00034	3.808	575.9	18.509	1.701	356.5
400.00	.38	1074	2214.9	15.586	1.2820	.5796	394	.00029	4.221	584.9	30.821	1.760	368.8
1000.00	.15	873	2101.5	15.586	1.3013	.5507	324	.00023	4.814	594.6	60.495	1.822	381.9
2000.00	.08	741	2030.3	15.586	1.3130	.5322	276	.00019	5.303	600.5	100.644	1.861	390.0
4000.00	.04	626	1970.0	15.586	1.3271	.5173	233	.00016	5.841	605.4	167.211	1.895	396.6
R = 1.500, PERCENT FUEL = 7.749, O/F =11.905													
1.00	150.00	3219	2626.1	19.176	1.2047	0.6098	965	0.00067	0.000			0.000	0.0
1.05	142.86	3193	2609.9	19.176	1.2050	.6091	901	.00067	.285	420.8	2.171	.203	37.6
1.20	125.00	3121	2566.2	19.176	1.2058	.6071	890	.00066	.554	267.1	1.262	.389	72.2
1.40	107.14	3040	2517.0	19.176	1.2068	.6047	876	.00064	.758	238.1	1.062	.526	97.4
1.60	93.75	2971	2475.4	19.176	1.2077	.6026	865	.00063	.900	231.5	1.010	.616	114.5
1.78	84.41	2916	2443.4	19.176	1.2084	.6008	856	.00063	1.000	230.4	1.000	.680	126.1
2.00	75.00	2859	2408.0	19.176	1.2093	.5988	846	.00062	1.103	231.3	1.009	.743	137.7
4.00	37.50	2534	2214.6	19.176	1.2147	.5863	787	.00056	1.607	249.6	1.302	1.021	189.2
10.00	15.00	2148	1992.8	19.176	1.2235	.5674	710	.00049	2.157	276.0	2.225	1.266	234.7
10.21	14.70	2140	1988.2	19.176	1.2237	.5669	708	.00049	2.168	276.5	2.235	1.271	235.6
20.00	7.50	1889	1847.9	19.176	1.2314	.5515	651	.00044	2.541	292.9	3.531	1.404	260.2
40.00	3.75	1655	1720.8	19.176	1.2408	.5340	592	.00039	2.917	307.2	5.736	1.514	280.7
100.00	1.50	1380	1577.0	19.176	1.2557	.5089	515	.00033	3.419	322.7	11.104	1.630	302.1
200.00	.75	1195	1484.7	19.176	1.2664	.4898	458	.00028	3.813	332.2	18.438	1.700	315.1
400.00	.38	1029	1404.9	19.176	1.2823	.4708	403	.00024	4.227	340.2	30.698	1.758	326.0
1000.00	.15	837	1316.6	19.176	1.3007	.4482	334	.00019	4.819	348.7	60.267	1.821	337.5
2000.00	.08	711	1261.1	19.176	1.3141	.4336	287	.00016	5.311	353.9	100.302	1.859	344.6
4000.00	.04	601	1214.1	19.176	1.3263	.4212	244	.00013	5.848	358.2	166.710	1.891	350.5
R = 2.000, PERCENT FUEL = 5.927, O/F =15.873													
1.00	150.00	3045	2016.0	21.610	1.2087	0.5325	900	0.00058	0.000			0.000	0.0
1.05	142.86	3020	2002.4	21.610	1.2091	.5318	896	.00058	.285	385.5	2.173	.203	34.4
1.20	125.00	2951	1965.8	21.610	1.2100	.5299	884	.00057	.553	244.6	1.263	.390	66.1
1.40	107.14	2873	1924.5	21.610	1.2111	.5275	870	.00056	.756	218.0	1.063	.526	89.2
1.60	93.75	2806	1889.6	21.610	1.2121	.5255	858	.00055	.899	211.9	1.010	.618	104.9
1.78	84.28	2755	1862.4	21.610	1.2129	.5238	848	.00054	1.000	210.9	1.000	.682	115.6
2.00	75.00	2699	1833.2	21.610	1.2139	.5220	838	.00053	1.102	211.7	1.009	.744	126.1
4.00	37.50	2383	1671.3	21.610	1.2196	.5108	777	.00049	1.605	228.3	1.299	1.021	173.2
10.00	15.00	2017	1486.2	21.610	1.2289	.4937	697	.00042	2.156	252.3	2.215	1.266	214.7
10.21	14.70	2009	1482.4	21.610	1.2291	.4933	695	.00042	2.168	252.8	2.244	1.270	215.5
20.00	7.50	1769	1365.7	21.610	1.2374	.4793	637	.00038	2.542	267.6	3.508	1.402	237.9
40.00	3.75	1546	1260.1	21.610	1.2470	.4643	577	.00033	2.921	280.6	5.685	1.512	256.5
100.00	1.50	1284	1141.2	21.610	1.2619	.4430	501	.00028	3.427	294.5	10.972	1.626	275.9
200.00	.75	1109	1065.1	21.610	1.2746	.4269	445	.00024	3.826	303.1	18.178	1.696	287.7
400.00	.38	952	999.5	21.610	1.2878	.4114	392	.00021	4.246	310.2	30.400	1.753	297.4
1000.00	.15	772	927.1	21.610	1.3057	.3927	326	.00017	4.847	317.9	59.148	1.815	307.8
2000.00	.08	655	881.7	21.610	1.3187	.3805	281	.00014	5.346	322.5	98.282	1.852	314.2
4000.00	.04	552	843.3	21.610	1.3307	.3700	240	.00012	5.891	326.4	163.108	1.883	319.4
R = 3.000, PERCENT FUEL = 4.031, O/F =23.810													
1.00	150.00	2695	1381.4	24.614	1.2194	0.4488	859	0.00047	0.000			0.000	0.0
1.05	142.86	2672	1370.8	24.614	1.2198	.4481	853	.00047	.283	337.8	2.180	.203	30.3
1.20	125.00	2608	1342.4	24.614	1.2209	.4463	842	.00046	.551	215.5	1.266	.391	58.3
1.40	107.14	2536	1310.4	24.614	1.2221	.4442	828	.00045	.754	191.9	1.064	.527	78.6
1.60	93.75	2475	1283.3	24.614	1.2233	.4423	815	.00044	.896	186.5	1.010	.620	92.4
1.78	83.99	2426	1261.5	24.614	1.2243	.4407	805	.00044	1.000	185.6	1.000	.685	102.1
2.00	75.00	2376	1239.7	24.614	1.2253	.4391	795	.00043	1.098	186.2	1.008	.745	111.1
4.00	37.50	2089	1114.9	24.614	1.2322	.4285	731	.00039	1.604	200.5	1.293	1.022	152.3
10.00	15.00	1752	973.1	24.614	1.2427	.4134	649	.00033	2.155	221.1	2.190	1.265	188.5
10.21	14.70	1745	970.2	24.614	1.2430	.4130	647	.00033	2.167	221.6	2.219	1.269	189.2
20.00	7.50	1527	881.5	24.614	1.2518	.4014	589	.00030	2.543	234.3	3.481	1.399	208.6
40.00	3.75	1326	801.7	24.614	1.2621	.3887	530	.00026	2.930	245.3	5.565	1.507	224.6
100.00	1.50	1091	716.6	24.614	1.2773	.3718	457	.00022	3.448	257.1	10.839	1.616	241.2
200.00	.75	936	659.9	24.614	1.2897	.3594	405	.00019	3.858	264.3	17.963	1.686	251.3
400.00	.38	799	607.4	24.614	1.3026	.3474	356	.00016	4.291	270.3	29.827	1.741	259.5
1000.00	.15	643	554.3	24.614	1.3201	.3329	299	.00013	4.914	276.7	58.470	1.800	268.3
2000.00	.08	542	521.2	24.614	1.3325	.3233	264	.00011	5.431	280.5	97.375	1.839	273.8
4000.00	.04	455	493.3	24.614	1.3449	.3148	233	.00009	5.997	283.7	154.220	1.865	278.0

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(f) Concluded. Combustion-chamber pressure, 150 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number, M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/lb
R = 4.000, PERCENT FUEL = 3.054, O/F = 31.746													
1.00	150.00	2363	1054.4	26.287	1.2315	0.4022	804	0.00040	0.000			0.000	0.0
1.05	142.86	2341	1045.7	26.287	1.2319	.4015	797	.00040	.282	307.7	2.187	.204	27.5
1.20	125.00	2283	1022.4	26.287	1.2332	.3997	784	.000 9	.548	195.0	1.269	.392	52.6
1.40	107.14	2217	996.2	26.287	1.2346	.3976	770	.000 8	.750	173.6	1.066	.529	71.2
1.60	93.75	2161	974.1	26.287	1.2361	.3957	757	.000 7	.892	166.6	1.011	.621	83.6
1.79	83.58	2114	955.5	26.287	1.2373	.3942	746	.00036	1.000	167.7	1.000	.689	92.8
2.00	75.00	2071	938.4	26.287	1.2384	.3927	736	.00036	1.094	168.3	1.008	.747	100.5
4.00	37.50	1809	836.9	26.287	1.2461	.3827	673	.00032	1.596	180.6	1.286	1.023	137.6
10.00	15.00	1505	722.4	26.287	1.2576	.3691	591	.00027	2.155	199.1	2.164	1.263	170.0
10.21	14.70	1498	720.0	26.287	1.2579	.3687	589	.00027	2.166	199.5	2.192	1.268	170.6
20.00	7.50	1303	648.9	26.287	1.2675	.3562	533	.00024	2.549	210.6	3.391	1.396	187.8
40.00	3.75	1123	585.5	26.287	1.2765	.3472	478	.00021	2.940	220.3	5.435	1.501	202.0
100.00	1.50	916	515.0	26.287	1.2939	.3326	409	.000 7	3.470	230.5	10.334	1.610	215.6
200.00	.75	780	470.7	26.287	1.3066	.3220	360	.000 5	3.891	236.8	16.929	1.675	225.4
400.00	.38	661	433.0	26.287	1.3200	.3118	315	.000 3	4.339	241.9	27.812	1.726	232.3
1000.00	.15	527	392.0	26.287	1.3375	.2996	260	.000 0	4.965	247.3	53.679	1.784	240.1
2000.00	.08	442	366.6	26.287	1.3501	.2915	223	.000 9	5.525	250.6	86.240	1.818	244.5
4000.00	.04	366	345.5	26.287	1.3594	.2859	189	.000 7	6.121	253.2	144.959	1.846	248.4
R = 5.000, PERCENT FUEL = 2.458, O/F = 39.683													
1.00	150.00	2066	855.0	27.307	1.2438	0.3712	741	0.000 4	0.000			0.000	0.0
1.05	142.86	2047	847.7	27.307	1.2443	.3706	736	.000 4	.281	282.3	2.194	.209	25.2
1.20	125.00	1994	828.1	27.307	1.2457	.3689	724	.000 3	.546	178.5	1.272	.394	48.4
1.40	107.14	1934	806.0	27.307	1.2474	.3669	709	.000 2	.747	159.1	1.066	.531	65.3
1.60	93.75	1883	787.5	27.307	1.2489	.3651	697	.00032	.888	154.4	1.012	.623	76.6
1.80	83.21	1839	771.3	27.307	1.2503	.3635	686	.000 1	1.000	153.6	1.000	.694	85.3
2.00	75.00	1801	757.6	27.307	1.2515	.3621	676	.000 1	1.090	154.0	1.007	.748	92.1
4.00	37.50	1564	672.8	27.307	1.2598	.3529	613	.000 7	1.594	165.2	1.279	1.023	125.9
10.00	15.00	1290	577.9	27.307	1.2722	.3401	535	.000 3	2.154	181.6	2.159	1.262	155.3
10.21	14.70	1284	576.0	27.307	1.2725	.3398	534	.000 3	2.166	181.9	2.166	1.267	155.8
20.00	7.50	1110	517.5	27.307	1.2827	.3302	480	.000 0	2.553	191.9	3.334	1.395	171.6
40.00	3.75	950	465.6	27.307	1.2940	.3203	429	.000 8	2.950	200.4	5.315	1.496	184.1
100.00	1.50	766	408.5	27.307	1.3108	.3069	363	.000 4	3.491	209.4	10.032	1.602	197.2
200.00	.75	650	372.8	27.307	1.3241	.2975	318	.000 2	3.924	214.9	16.359	1.665	204.8
400.00	.38	547	342.6	27.307	1.3377	.2883	276	.000 0	4.386	219.3	26.665	1.717	211.1
1000.00	.15	432	310.1	27.307	1.3547	.2779	227	.00008	5.057	224.0	51.132	1.770	217.7
2000.00	.08	360	290.2	27.307	1.3640	.2727	195	.00007	5.623	226.8	83.567	1.802	221.7
4000.00	.04	299	273.6	27.307	1.3703	.2695	162	.00006	6.246	229.1	136.744	1.826	224.5

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR

LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(g) Combustion-chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.150, PERCENT FUEL = 45.65, O/F = 1.190													
1.00	300.00	1183	5313.5	4.416	1.3396	1.7753	314	0.00073	0.000			0.000	0.0
1.05	285.71	1168	5287.7	4.416	1.3406	1.7710	311	.00073	.271	530.0	2.250	.210	47.4
1.20	250.00	1129	5210.6	4.416	1.3436	1.7597	303	.00070	.527	334.2	1.297	.403	90.8
1.40	214.29	1085	5141.8	4.416	1.3469	1.7472	293	.00068	.722	296.1	1.061	.543	122.2
1.60	187.50	1049	5077.7	4.416	1.3497	1.7369	285	.00066	.860	286.6	1.018	.636	143.2
1.87	160.64	1008	5006.6	4.416	1.3528	1.7257	276	.00063	1.000	284.1	1.000	.725	163.4
2.00	150.00	989	4975.4	4.416	1.3540	1.7210	272	.00062	1.059	284.4	1.003	.761	171.5
4.00	75.00	824	4693.4	4.416	1.3651	1.6625	234	.00052	1.566	301.7	1.233	1.031	232.3
10.00	30.00	643	4352.5	4.416	1.3748	1.6505	188	.00042	2.152	327.5	1.974	1.257	283.1
20.00	15.00	532	4209.8	4.416	1.3799	1.6344	159	.00035	2.586	343.5	2.982	1.376	309.9
20.41	14.70	529	4204.9	4.416	1.3801	1.6340	156	.00035	2.599	343.9	3.020	1.379	310.6
40.00	7.50	439	4058.9	4.416	1.3824	1.6268	133	.00029	3.031	356.4	4.620	1.467	330.4
100.00	3.00	340	3899.0	4.416	1.3862	1.6093	104	.00023	3.648	369.8	6.432	1.558	350.8
200.00	1.50	280	3802.6	4.416	1.3926	1.5961	85	.00018	4.149	377.7	13.431	1.610	362.6
400.00	.75	230	3723.2	4.416	1.4068	1.5562	70	.00015	4.675	384.1	21.488	1.652	372.0
1000.00	.30	175	3640.1	4.416	1.4349	1.4847	55	.00011	5.438	390.6	39.928	1.694	381.6
2000.00	.15	142	3590.9	4.416	1.4550	1.4389	45	.00009	6.096	394.3	63.572	1.719	387.2
4000.00	.08	114	3551.2	4.416	1.4705	1.4065	36	.00007	6.845	397.3	100.938	1.739	391.6
R = 0.200, PERCENT FUEL = 38.65, O/F = 1.587													
1.00	300.00	1514	2969.7	5.216	1.3079	1.6183	402	0.00084	0.000			0.000	0.0
1.05	285.71	1497	2941.7	5.216	1.3090	1.6140	399	.00083	.274	552.2	2.233	.209	49.3
1.20	250.00	1450	2866.8	5.216	1.3120	1.6022	389	.00081	.533	348.6	1.289	.400	94.6
1.40	214.29	1398	2783.2	5.216	1.3155	1.5887	378	.00078	.730	309.3	1.077	.539	127.4
1.60	187.50	1354	2713.2	5.216	1.3185	1.5772	369	.00076	.869	299.6	1.016	.632	149.4
1.85	162.47	1307	2640.5	5.216	1.3217	1.5651	359	.00073	1.000	297.3	1.000	.716	169.2
2.00	150.00	1282	2601.1	5.216	1.3235	1.5584	353	.00072	1.068	297.8	1.004	.757	179.1
4.00	75.00	1079	2290.0	5.216	1.3391	1.5046	307	.00061	1.572	316.7	1.244	1.029	243.2
10.00	30.00	852	1954.3	5.216	1.3558	1.4516	251	.00048	2.148	344.7	2.009	1.257	297.2
20.00	15.00	709	1748.8	5.216	1.3656	1.4232	213	.00040	2.573	362.0	3.049	1.379	325.9
20.41	14.70	705	1743.3	5.216	1.3658	1.4225	212	.00040	2.586	362.4	3.088	1.382	326.7
40.00	7.50	568	1578.0	5.216	1.3715	1.4066	179	.00034	3.010	376.0	4.739	1.472	348.0
100.00	3.00	458	1396.3	5.216	1.3771	1.3915	142	.00026	3.619	390.5	8.679	1.565	370.0
200.00	1.50	379	1286.2	5.216	1.3811	1.3807	117	.00022	4.111	399.1	13.670	1.619	382.7
400.00	.75	312	1195.2	5.216	1.3861	1.3677	96	.00018	4.638	406.1	22.296	1.662	392.9
1000.00	.30	242	1099.0	5.216	1.3973	1.3400	74	.00013	5.394	413.4	41.979	1.706	403.5
2000.00	.15	198	1041.1	5.216	1.4156	1.2977	61	.00011	6.014	417.7	67.667	1.733	409.5
4000.00	.08	161	993.9	5.216	1.4350	1.2568	50	.00009	6.704	421.1	108.754	1.754	414.6
R = 0.250, PERCENT FUEL = 33.51, O/F = 1.984													
1.00	300.00	1817	1249.3	6.016	1.2835	1.4955	481	0.00092	0.000			0.000	0.0
1.05	285.71	1797	1220.2	6.016	1.2844	1.4917	477	.00091	.276	563.4	2.219	.207	50.3
1.20	250.00	1745	1142.1	6.016	1.2870	1.4813	467	.00089	.538	356.2	1.283	.398	96.6
1.40	214.29	1665	1054.8	6.016	1.2900	1.4693	456	.00086	.736	316.5	1.073	.536	130.1
1.60	187.50	1635	981.5	6.016	1.2927	1.4591	446	.00083	.876	306.6	1.015	.629	152.6
1.83	163.90	1586	909.9	6.016	1.2954	1.4485	436	.00081	1.000	304.5	1.000	.708	171.8
2.00	150.00	1554	864.0	6.016	1.2973	1.4415	429	.00080	1.076	305.1	1.005	.754	183.1
4.00	75.00	1322	535.2	6.016	1.3125	1.3673	376	.00068	1.579	325.5	1.256	1.027	249.3
10.00	30.00	1057	176.3	6.016	1.3329	1.3225	314	.00054	2.147	355.3	2.048	1.258	305.6
20.00	15.00	887	9954.5	6.016	1.3401	1.2848	269	.00046	2.563	373.6	3.127	1.382	335.7
20.41	14.70	882	9948.3	6.016	1.3404	1.2838	267	.00045	2.575	374.1	3.167	1.386	336.5
40.00	7.50	740	9768.5	6.016	1.3509	1.2559	225	.00038	2.987	388.6	4.883	1.476	359.0
100.00	3.00	580	9569.5	6.016	1.3663	1.2320	181	.00030	3.581	404.1	6.985	1.575	382.3
200.00	1.50	481	9448.3	6.016	1.3717	1.2191	151	.00025	4.064	413.3	14.595	1.630	395.9
400.00	.75	399	9347.8	6.016	1.3755	1.2100	124	.00020	4.582	420.9	23.207	1.675	406.8
1000.00	.30	310	9241.1	6.016	1.3821	1.1940	95	.00015	5.327	428.7	43.690	1.722	418.0
2000.00	.15	256	9170.5	6.016	1.3865	1.1605	78	.00012	5.945	433.5	71.274	1.749	424.7
4000.00	.08	210	9123.3	6.016	1.4039	1.1462	64	.00010	6.606	437.1	115.639	1.771	430.1
R = 0.300, PERCENT FUEL = 29.57, O/F = 2.381													
1.00	300.00	2093	9932.7	6.814	1.2647	1.3935	550	0.00097	0.000			0.000	0.0
1.05	285.71	2072	9903.1	6.814	1.2655	1.3903	547	.00096	.278	568.5	2.208	.206	50.8
1.20	250.00	2015	9823.5	6.814	1.2676	1.3816	536	.00094	.542	359.7	1.278	.396	97.5
1.40	214.29	1950	9734.4	6.814	1.2701	1.3715	525	.00091	.741	319.7	1.071	.533	131.4
1.60	187.50	1895	9659.6	6.814	1.2724	1.3621	514	.00089	.881	310.1	1.013	.626	154.2
1.82	165.04	1844	9590.0	6.814	1.2747	1.3532	505	.00087	1.000	308.2	1.000	.701	172.7
2.00	150.00	1806	9539.2	6.814	1.2765	1.3465	497	.00085	1.082	308.9	1.006	.751	185.1
4.00	75.00	1550	9200.5	6.814	1.2878	1.2976	444	.00074	1.585	330.3	1.266	1.025	252.4
10.00	30.00	1255	8826.7	6.814	1.3076	1.2331	375	.00060	2.148	361.5	2.084	1.260	310.2
20.00	15.00	1062	8593.0	6.814	1.3291	1.1667	325	.00050	2.555	380.9	3.205	1.387	341.4
20.41	14.70	1057	8586.7	6.814	1.3295	1.1674	323	.00050	2.567	381.4	3.247	1.390	342.2
40.00	7.50	893	8395.8	6.814	[illegible]	1.1528	276	.00042	2.969	396.7	5.035	1.485	365.7
100.00	3.00	706	8163.0	6.814	[illegible]	1.1172	225	.00033	3.545	413.1	9.320	1.585	390.2
200.00	1.50	586	8052.6	6.814	[illegible]	1.1005	186	.00027	4.014	422.9	14.964	1.643	404.5
400.00	.75	469	7944.0	6.814	[illegible]	1.0866	156	.00023	4.518	430.9	24.219	1.689	416.0
1000.00	.30	382	7628.2	6.814	1.3725	1.0745	120	.00017	5.246	439.2	45.966	1.736	427.9
2000.00	.15	316	7757.9	6.814	1.3776	1.0640	98	.00014	5.853	444.2	74.658	1.767	435.0
4000.00	.08	261	7699.7	6.814	1.3910	1.0531	60	.00011	6.512	448.5	122.092	1.790	440.8

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(g) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/(lb)
R = 0.350, PERCENT FUEL = 26.47, O/F = 2.778													
1.00	300.00	2344	8892.8	7.607	1.2502	1.3052	610	0.00100	0.000			0.000	0.0
1.05	285.71	2321	8863.0	7.607	1.2509	1.3025	607	.00099	.280	369.5	2.199	.205	50.9
1.20	250.00	2259	8783.2	7.607	1.2527	1.2951	597	.00097	.345	360.6	1.274	.394	97.7
1.40	214.29	2190	8693.6	7.607	1.2548	1.2864	585	.00094	.745	320.7	1.069	.532	131.6
1.60	187.50	2131	8618.2	7.607	1.2567	1.2789	575	.00092	.886	311.3	1.012	.624	154.6
1.81	165.96	2079	8551.1	7.607	1.2584	1.2720	565	.00090	1.000	309.4	1.000	.696	172.4
2.00	150.00	2036	8496.8	7.607	1.2600	1.2661	557	.00089	1.087	310.3	1.007	.749	185.6
4.00	75.00	1760	8153.6	7.607	1.2717	1.2229	503	.00078	1.590	332.5	1.274	1.024	253.6
10.00	30.00	1440	7771.6	7.607	1.2896	1.1634	432	.00064	2.150	364.7	2.116	1.261	312.3
20.00	15.00	1229	7530.3	7.607	1.3046	1.1188	378	.00055	2.651	384.9	3.275	1.390	344.3
20.41	14.70	1223	7523.7	7.607	1.3051	1.1175	377	.00054	2.663	385.4	3.319	1.394	345.1
40.00	7.50	1042	7325.1	7.607	1.3199	1.0779	327	.00046	2.954	401.4	5.178	1.491	369.3
100.00	3.00	831	7101.8	7.607	1.3374	1.0356	269	.00036	3.314	418.7	9.654	1.594	394.8
200.00	1.50	696	6963.9	7.607	1.3482	1.0114	233	.00030	3.568	429.0	15.587	1.654	409.7
400.00	.75	581	6848.6	7.607	1.3580	.9949	187	.00025	4.457	437.4	25.280	1.703	421.7
1000.00	.30	456	6725.1	7.607	1.3689	.9790	146	.00019	5.168	446.2	48.144	1.754	434.3
2000.00	.15	378	6649.8	7.607	1.3690	.9693	119	.00015	5.758	451.5	78.603	1.784	441.8
4000.00	.08	314	6587.3	7.607	1.3740	.9598	97	.00012	6.400	455.8	128.518	1.808	447.9
R = 0.400, PERCENT FUEL = 23.95, O/F = 3.175													
1.00	300.00	2565	8050.5	8.389	1.2389	1.2285	662	0.00101	0.000			0.000	0.0
1.05	285.71	2541	8021.0	8.389	1.2394	1.2263	656	.00100	.281	367.5	2.192	.205	50.7
1.20	250.00	2476	7941.7	8.389	1.2409	1.2202	646	.00098	.347	359.5	1.271	.393	97.3
1.40	214.29	2403	7852.6	8.389	1.2427	1.2128	636	.00096	.748	319.9	1.067	.530	131.2
1.60	187.50	2341	7777.6	8.389	1.2444	1.2062	626	.00094	.889	310.6	1.012	.622	154.1
1.80	166.67	2287	7713.0	8.389	1.2459	1.2003	617	.00092	1.000	308.9	1.000	.692	171.4
2.00	150.00	2240	7656.5	8.389	1.2473	1.1949	609	.00091	1.091	309.8	1.007	.748	185.2
4.00	75.00	1948	7313.1	8.389	1.2571	1.1582	555	.00081	1.794	332.6	1.281	1.023	253.3
10.00	30.00	1608	6928.0	8.389	1.2730	1.1047	482	.00068	2.452	365.6	2.142	1.262	312.5
20.00	15.00	1382	6682.9	8.389	1.2870	1.0623	427	.00058	2.948	386.3	3.335	1.393	345.0
20.41	14.70	1376	6676.2	8.389	1.2874	1.0611	426	.00058	2.960	386.8	3.380	1.397	345.8
40.00	7.50	1180	6472.9	8.389	1.3020	1.0213	373	.00049	3.344	403.3	5.305	1.496	370.5
100.00	3.00	949	6242.4	8.389	1.3215	.9738	308	.00039	3.888	421.3	9.963	1.602	396.6
200.00	1.50	800	6099.1	8.389	1.3343	.9455	260	.00032	3.929	432.1	16.162	1.664	412.1
400.00	.75	671	5978.6	8.389	1.3448	.9239	219	.00027	4.403	440.9	26.311	1.715	424.6
1000.00	.30	529	5849.0	8.389	1.3556	.9031	171	.00021	5.091	450.1	50.311	1.768	437.7
2000.00	.15	441	5769.6	8.389	1.3612	.8928	142	.00017	5.667	455.7	82.327	1.799	445.5
4000.00	.08	366	5703.5	8.389	1.3665	.8833	118	.00014	6.293	460.3	134.918	1.825	451.9
R = 0.450, PERCENT FUEL = 21.87, O/F = 3.571													
1.00	300.00	2755	7354.5	9.152	1.2300	1.1611	705	0.00101	0.000			0.000	0.0
1.05	285.71	2730	7325.4	9.152	1.2305	1.1591	701	.00100	.282	363.2	2.186	.204	50.3
1.20	250.00	2662	7247.2	9.152	1.2318	1.1537	691	.00098	.549	357.0	1.268	.392	96.6
1.40	214.29	2586	7159.4	9.152	1.2334	1.1475	679	.00096	.751	317.8	1.066	.529	130.3
1.60	187.50	2521	7085.4	9.152	1.2348	1.1420	669	.00095	.892	308.7	1.011	.621	153.0
1.79	167.23	2467	7023.4	9.152	1.2360	1.1372	661	.00093	1.000	307.0	1.000	.689	169.7
2.00	150.00	2416	6965.8	9.152	1.2372	1.1324	652	.00092	1.094	308.0	1.008	.747	183.9
4.00	75.00	2112	6625.4	9.152	1.2459	1.1000	599	.00082	1.798	331.1	1.286	1.022	251.9
10.00	30.00	1755	6241.6	9.152	1.2600	1.0523	526	.00070	2.453	364.5	2.163	1.263	311.2
20.00	15.00	1517	5999.6	9.152	1.2726	1.0138	471	.00060	2.948	385.5	3.384	1.396	343.9
20.41	14.70	1511	5988.9	9.152	1.2730	1.0126	469	.00060	2.958	386.1	3.431	1.399	344.7
40.00	7.50	1304	5783.6	9.152	1.2868	.9743	415	.00052	3.936	403.0	5.411	1.501	369.7
100.00	3.00	1057	5549.4	9.152	1.3067	.9251	344	.00041	3.469	421.5	10.232	1.609	396.3
200.00	1.50	896	5402.6	9.152	1.3208	.8939	295	.00034	3.898	432.7	16.676	1.673	412.1
400.00	.75	755	5276.6	9.152	1.3334	.8684	249	.00028	4.357	441.8	27.260	1.725	425.0
1000.00	.30	599	5144.5	9.152	1.3482	.8443	197	.00022	5.026	451.4	52.343	1.780	438.5
2000.00	.15	500	5062.0	9.152	1.3583	.8300	164	.00018	5.584	457.2	85.868	1.813	446.6
4000.00	.08	417	4993.2	9.152	1.3678	.8207	134	.00015	6.196	462.0	141.008	1.840	453.3
R = 0.500, PERCENT FUEL = 20.12, O/F = 3.968													
1.00	300.00	2915	6769.6	9.891	1.2230	1.1020	741	0.00100	0.000			0.000	0.0
1.05	285.71	2889	6741.2	9.891	1.2234	1.1002	737	.00100	.283	357.3	2.182	.204	49.8
1.20	250.00	2819	6664.6	9.891	1.2246	1.0953	727	.00098	.550	353.4	1.267	.391	95.6
1.40	214.29	2741	6578.3	9.891	1.2261	1.0896	715	.00096	.752	314.7	1.065	.528	129.0
1.60	187.50	2674	6502.9	9.891	1.2273	1.0846	705	.00094	.894	305.8	1.011	.620	151.5
1.79	167.67	2619	6440.5	9.891	1.2284	1.0804	697	.00093	1.000	304.2	1.000	.687	167.7
2.00	150.00	2563	6380.5	9.891	1.2295	1.0763	689	.00091	1.097	305.2	1.008	.746	182.1
4.00	75.00	2230	6053.6	9.891	1.2372	1.0478	636	.00083	1.800	328.4	1.290	1.022	249.6
10.00	30.00	1881	5674.2	9.891	1.2497	1.0035	564	.00071	2.454	362.0	2.180	1.264	308.7
20.00	15.00	1633	5429.8	9.891	1.2611	.9702	508	.00062	2.945	383.3	3.424	1.398	341.4
20.41	14.70	1627	5423.1	9.891	1.2615	.9692	506	.00062	2.956	383.8	3.471	1.401	342.3
40.00	7.50	1411	5216.1	9.891	1.2744	.9331	451	.00053	3.931	401.0	5.457	1.504	367.4
100.00	3.00	1152	4982.7	9.891	1.2930	.8848	378	.00043	3.454	419.9	10.436	1.614	394.3
200.00	1.50	981	4834.4	9.891	1.3067	.8576	328	.00036	3.873	431.3	17.118	1.680	410.4
400.00	.75	831	4708.4	9.891	1.3203	.8342	277	.00030	4.321	440.7	28.092	1.734	423.5
1000.00	.30	662	4571.5	9.891	1.3373	.8086	221	.00023	4.971	450.6	54.169	1.791	437.3
2000.00	.15	553	4487.0	9.891	1.3488	.7936	184	.00019	5.515	456.6	89.096	1.825	445.7
4000.00	.08	463	4410.2	9.891	1.3598	.7808	152	.00016	6.111	461.5	146.602	1.853	452.5

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(g) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, lb(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, lb(sec)/lb
R = 0.600, PERCENT FUEL = 17.35, O/F = 4.762													
1.00	300.00	3155	5841.6	11.290	1.2131	1.0021	796	0.00097	0.000			0.000	0.0
1.05	285.71	3128	5814.6	11.290	1.2134	1.0008	793	.00097	.284	542.8	2.176	.203	48.4
1.20	250.00	3055	5742.0	11.290	1.2144	.9970	783	.00095	.552	544.4	1.264	.390	93.1
1.40	214.29	2973	5660.2	11.290	1.2156	.9924	771	.00093	.755	306.6	1.063	.527	125.6
1.60	187.50	2903	5591.2	11.290	1.2167	.9883	761	.00092	.898	298.2	1.010	.619	147.6
1.78	168.29	2848	5536.4	11.290	1.2176	.9849	753	.00091	1.000	296.6	1.000	.683	162.9
2.00	150.00	2790	5479.4	11.290	1.2186	.9813	744	.00089	1.100	297.9	1.009	.744	177.5
4.00	75.00	2460	5159.5	11.290	1.2249	.9585	692	.00082	1.604	320.9	1.296	1.021	243.6
10.00	30.00	2073	4794.7	11.290	1.2334	.9238	621	.00071	2.155	354.4	2.204	1.269	301.8
20.00	15.00	1812	4558.0	11.290	1.2392	.8940	565	.00063	2.542	375.7	3.481	1.401	334.2
20.41	14.70	1805	4551.5	11.290	1.2395	.8930	564	.00063	2.554	376.3	3.530	1.404	335.0
40.00	7.50	1577	4351.5	11.290	1.2465	.8622	509	.00055	2.923	393.6	5.624	1.509	360.1
100.00	3.00	1302	4119.9	11.290	1.2742	.8178	433	.00045	3.434	412.8	10.795	1.622	387.1
200.00	1.50	1118	3972.5	11.290	1.2890	.7851	378	.00038	3.839	424.5	17.794	1.691	403.3
400.00	.75	954	3846.3	11.290	1.3038	.7554	325	.00032	4.270	434.2	29.396	1.747	416.7
1000.00	.30	767	3708.0	11.290	1.3218	.7230	266	.00025	4.891	444.5	57.125	1.806	430.9
2000.00	.15	646	3622.0	11.290	1.3331	.7044	220	.00020	5.411	450.7	94.401	1.842	439.5
4000.00	.08	542	3549.6	11.290	1.3427	.6896	183	.00017	5.980	455.9	155.994	1.872	446.6
R = 0.700, PERCENT FUEL = 15.25, O/F = 5.556													
1.00	300.00	3307	5138.3	12.574	1.2069	0.9217	836	0.00094	0.000			0.000	0.0
1.05	285.71	3280	5112.9	12.574	1.2073	.9205	834	.00093	.285	526.7	2.172	.203	47.0
1.20	250.00	3205	5044.5	12.574	1.2082	.9172	829	.00092	.554	334.3	1.262	.390	90.3
1.40	214.29	3121	4967.4	12.574	1.2092	.9136	810	.00090	.757	297.9	1.062	.526	121.9
1.60	187.50	3049	4902.3	12.574	1.2101	.9103	800	.00089	.900	289.6	1.010	.618	143.3
1.78	168.68	2994	4851.8	12.574	1.2109	.9075	792	.00088	1.000	288.3	1.000	.681	157.9
2.00	150.00	2933	4796.8	12.574	1.2118	.9044	783	.00086	1.103	289.4	1.009	.743	172.4
4.00	75.00	2595	4494.4	12.574	1.2175	.8847	731	.00079	1.606	312.1	1.300	1.021	236.7
10.00	30.00	2197	4148.0	12.574	1.2267	.8551	660	.00070	2.156	345.0	2.220	1.266	293.5
20.00	15.00	1930	3922.2	12.574	1.2332	.8299	605	.00062	2.541	366.1	3.518	1.403	325.3
20.41	14.70	1922	3916.0	12.574	1.2335	.8290	603	.00062	2.552	366.6	3.567	1.406	326.1
40.00	7.50	1687	3724.3	12.574	1.2405	.8017	548	.00055	2.918	383.8	5.705	1.513	350.8
100.00	3.00	1402	3501.1	12.574	1.2618	.7618	473	.00045	3.422	403.0	11.013	1.628	377.4
200.00	1.50	1211	3358.2	12.574	1.2757	.7312	416	.00039	3.819	414.7	18.240	1.697	393.6
400.00	.75	1039	3235.2	12.574	1.2906	.7018	361	.00032	4.238	424.5	30.278	1.755	406.9
1000.00	.30	841	3099.5	12.574	1.3096	.6684	294	.00025	4.841	434.9	59.186	1.816	421.2
2000.00	.15	712	3014.7	12.574	1.3227	.6478	248	.00021	5.343	441.2	96.189	1.854	429.9
4000.00	.08	600	2943.0	12.574	1.3336	.6318	207	.00017	5.894	446.3	162.736	1.885	437.1
R = 0.800, PERCENT FUEL = 13.60, O/F = 6.349													
1.00	300.00	3393	4586.9	13.740	1.2033	0.8561	864	0.00090	0.000			0.000	0.0
1.05	285.71	3365	4563.0	13.740	1.2036	.8551	860	.00089	.285	510.4	2.170	.202	45.5
1.20	250.00	3290	4498.8	13.740	1.2044	.8522	849	.00088	.555	324.0	1.261	.389	87.6
1.40	214.29	3204	4426.4	13.740	1.2054	.8488	837	.00086	.758	288.8	1.062	.525	118.2
1.60	187.50	3132	4365.2	13.740	1.2062	.8460	827	.00085	.901	280.8	1.009	.617	138.9
1.78	168.91	3077	4318.3	13.740	1.2069	.8437	819	.00084	1.000	279.5	1.000	.680	152.9
2.00	150.00	3015	4266.0	13.740	1.2077	.8409	810	.00083	1.104	280.6	1.009	.743	167.1
4.00	75.00	2673	3981.2	13.740	1.2131	.8234	758	.00076	1.607	302.8	1.303	1.021	229.6
10.00	30.00	2270	3654.3	13.740	1.2216	.7974	687	.00067	2.157	335.0	2.229	1.266	284.9
20.00	15.00	1998	3440.7	13.740	1.2294	.7750	632	.00060	2.540	355.8	3.539	1.404	315.8
20.41	14.70	1990	3434.8	13.740	1.2297	.7743	630	.00060	2.551	356.2	3.590	1.408	316.6
40.00	7.50	1752	3252.9	13.740	1.2391	.7496	575	.00053	2.915	373.0	5.755	1.515	340.7
100.00	3.00	1462	3040.4	13.740	1.2542	.7136	499	.00045	3.416	391.9	11.146	1.631	366.8
200.00	1.50	1266	2903.8	13.740	1.2676	.6852	441	.00038	3.808	403.5	18.314	1.701	382.7
400.00	.75	1091	2785.9	13.740	1.2822	.6572	385	.00032	4.220	413.2	30.827	1.760	395.9
1000.00	.30	887	2655.2	13.740	1.3015	.6243	316	.00025	4.811	423.6	60.499	1.823	410.0
2000.00	.15	753	2573.1	13.740	1.3153	.6034	268	.00021	5.303	429.9	100.640	1.861	418.6
4000.00	.08	636	2503.6	13.740	1.3272	.5867	226	.00017	5.841	435.2	167.192	1.893	425.8
R = 0.900, PERCENT FUEL = 12.28, O/F = 7.143													
1.00	300.00	3430	4142.9	14.789	1.2013	0.8019	883	0.00086	0.000			0.000	0.0
1.05	285.71	3402	4120.6	14.789	1.2016	.8010	879	.00085	.286	494.7	2.169	.202	44.1
1.20	250.00	3327	4060.2	14.789	1.2024	.7983	868	.00084	.555	314.0	1.261	.389	84.9
1.40	214.29	3242	3992.2	14.789	1.2033	.7953	856	.00082	.759	280.0	1.062	.525	114.5
1.60	187.50	3169	3934.7	14.789	1.2041	.7926	846	.00081	.901	272.2	1.009	.617	134.6
1.77	169.04	3114	3890.9	14.789	1.2047	.7905	838	.00080	1.000	271.0	1.000	.679	148.1
2.00	150.00	3051	3841.4	14.789	1.2055	.7881	828	.00079	1.105	272.1	1.010	.743	162.0
4.00	75.00	2706	3573.5	14.789	1.2100	.7722	775	.00073	1.608	293.7	1.304	1.020	222.6
10.00	30.00	2303	3269.6	14.789	1.2158	.7486	709	.00065	2.157	325.0	2.234	1.267	276.3
20.00	15.00	2050	3064.0	14.789	1.2203	.7281	653	.00058	2.540	345.1	3.551	1.405	306.4
20.41	14.70	2023	3058.4	14.789	1.2206	.7275	647	.00058	2.551	345.7	3.602	1.408	307.2
40.00	7.50	1783	2886.6	14.789	1.2295	.7049	591	.00052	2.914	362.2	5.780	1.516	330.6
100.00	3.00	1491	2685.4	14.789	1.2401	.6787	515	.00043	3.412	380.6	11.219	1.633	356.1
200.00	1.50	1294	2559.0	14.789	1.2503	.6591	457	.00037	3.801	392.0	18.366	1.704	371.6
400.00	.75	1117	2446.8	14.789	1.2613	.6389	401	.00032	4.211	401.9	31.135	1.763	384.5
1000.00	.30	910	2319.3	14.789	1.2757	.6142	331	.00026	4.795	411.7	61.247	1.826	398.3
2000.00	.15	775	2241.0	14.789	1.2870	.5969	286	.00021	5.280	417.9	102.055	1.863	406.8
4000.00	.08	656	2174.5	14.789	1.2982	.5808	245	.00017	5.812	423.1	169.796	1.897	413.9

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(g) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio P_c/P	Static pressure, P, lb/sq in abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity k, cal/(sec)(cm)(°K)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/lb
R = 1.000, PERCENT FUEL = 11.19, O/F = 7.937													
1.00	300.00	3437	3777.9	15.734	1.2004	0.7565	896	0.00084	0.000			0.000	0.0
1.05	285.71	3409	3756.8	15.734	1.2006	.7558	892	.00083	.286	480.1	2.188	.204	42.8
1.20	250.00	3333	3699.9	15.734	1.2014	.7533	881	.00080	.555	474.8	1.260	.389	82.4
1.40	214.29	3243	3632.9	15.734	1.2023	.7505	869	.00077	.759	471.7	1.062	.525	111.2
1.60	187.50	3176	3581.7	15.734	1.2031	.7480	858	.00078	.902	469.2	1.009	.617	130.7
1.78	168.54	3121	3540.6	15.734	1.2038	.7461	850	.00077	1.000	467.0	1.000	.679	143.7
2.00	150.00	3058	3493.9	15.734	1.2045	.7439	841	.00076	1.105	464.1	1.010	.742	157.2
4.00	75.00	2715	3241.4	15.734	1.2095	.7291	787	.00070	1.608	285.1	1.305	1.020	216.1
10.00	30.00	2311	2951.0	15.734	1.2175	.7070	714	.00062	2.157	515.6	2.236	1.267	268.2
20.00	15.00	2039	2760.8	15.734	1.2249	.6879	658	.00056	2.940	335.1	3.557	1.405	297.5
20.41	14.70	2031	2755.6	15.734	1.2251	.6873	657	.00056	2.951	335.7	3.607	1.409	298.3
40.00	7.50	1792	2593.3	15.734	1.2339	.6663	601	.00050	2.913	351.7	5.792	1.516	321.0
100.00	3.00	1500	2403.2	15.734	1.2481	.6354	525	.00042	3.410	369.7	11.253	1.633	345.8
200.00	1.50	1303	2280.7	15.734	1.2609	.6104	467	.00036	3.799	380.8	18.738	1.705	360.9
400.00	.75	1126	2174.5	15.734	1.2749	.5857	410	.00031	4.206	390.1	31.282	1.764	373.5
1000.00	.30	919	2056.5	15.734	1.2942	.5556	340	.00024	4.788	400.1	61.611	1.828	387.0
2000.00	.15	783	1980.2	15.734	1.3083	.5360	291	.00020	5.270	406.2	102.755	1.867	395.3
4000.00	.08	663	1919.0	15.734	1.3209	.5193	246	.00017	5.798	411.2	171.104	1.899	402.2
R = 1.500, PERCENT FUEL = 7.749, O/F =11.905													
1.00	300.00	3297	2626.1	19.320	1.2021	0.6117	918	0.00068	0.000			0.000	0.0
1.05	285.71	3270	2609.6	19.320	1.2024	.6110	913	.00068	.285	424.3	2.169	.204	37.9
1.20	250.00	3197	2558.2	19.320	1.2032	.6090	902	.00066	.555	269.4	1.261	.389	72.8
1.40	214.29	3115	2515.1	19.320	1.2041	.6068	889	.00065	.758	240.1	1.062	.525	98.2
1.60	187.50	3049	2472.8	19.320	1.2050	.6047	877	.00064	.901	233.5	1.009	.617	115.5
1.78	168.99	2992	2440.6	19.320	1.2056	.6030	869	.00063	1.000	232.4	1.000	.679	127.0
2.00	150.00	2931	2404.3	19.320	1.2065	.6011	858	.00062	1.104	233.3	1.009	.743	138.9
4.00	75.00	2600	2207.3	19.320	1.2117	.5888	800	.00053	1.608	251.9	1.303	1.020	190.9
10.00	30.00	2210	1981.0	19.320	1.2200	.5705	724	.00045	2.157	278.7	2.232	1.266	236.9
20.00	15.00	1947	1832.9	19.320	1.2275	.5550	665	.00041	2.940	295.9	3.546	1.404	262.7
20.41	14.70	1940	1828.6	19.320	1.2277	.5545	664	.00041	2.951	296.3	3.597	1.408	263.4
40.00	7.50	1709	1702.7	19.320	1.2366	.5377	607	.00040	2.915	310.4	5.769	1.515	283.4
100.00	3.00	1429	1559.2	19.320	1.2507	.5151	529	.00035	3.414	326.2	11.194	1.632	305.3
200.00	1.50	1240	1468.2	19.320	1.2630	.4959	472	.00029	3.805	335.9	18.624	1.703	318.5
400.00	.75	1070	1377.9	19.320	1.2766	.4747	416	.00024	4.215	344.1	31.071	1.762	329.6
1000.00	.30	873	1266.6	19.320	1.2950	.4515	347	.00020	4.800	352.8	61.164	1.825	341.4
2000.00	.15	743	1229.1	19.320	1.3087	.4361	299	.00017	5.284	358.2	101.998	1.864	348.6
4000.00	.08	630	1180.2	19.320	1.3212	.4231	255	.00014	5.814	362.6	169.845	1.896	354.7
R = 2.000, PERCENT FUEL = 5.927, O/ =15.873													
1.00	300.00	3103	2015.0	21.723	1.2068	0.5339	710	0.00051	0.000			0.000	0.0
1.05	285.71	3077	2000.2	21.723	1.2071	.5333	708	.00050	.285	388.2	2.172	.203	34.6
1.20	250.00	3007	1965.1	21.723	1.2080	.5314	694	.00050	.554	246.3	1.262	.390	66.6
1.40	214.29	2928	1923.2	21.723	1.2090	.5291	680	.00050	.757	219.6	1.062	.526	89.9
1.60	187.50	2861	1887.2	21.723	1.2100	.5271	668	.00050	.900	213.4	1.010	.618	105.6
1.78	168.68	2809	1860.4	21.723	1.2108	.5255	658	.00050	1.000	212.4	1.000	.681	116.4
2.00	150.00	2752	1830.6	21.723	1.2117	.5236	648	.00050	1.103	213.3	1.009	.743	127.0
4.00	75.00	2435	1666.3	21.723	1.2173	.5125	787	.00040	1.606	230.0	1.300	1.021	174.4
10.00	30.00	2062	1478.1	21.723	1.2263	.4958	708	.00034	2.156	254.3	2.220	1.266	216.3
20.00	15.00	1811	1355.5	21.723	1.2344	.4817	648	.00030	2.941	269.8	3.519	1.403	239.7
20.41	14.70	1804	1352.1	21.723	1.2347	.4813	646	.00030	2.953	270.2	3.569	1.406	240.4
40.00	7.50	1585	1247.9	21.723	1.2437	.4666	586	.00030	2.919	282.9	5.710	1.513	258.5
100.00	3.00	1319	1120.5	21.723	1.2563	.4456	511	.00027	3.423	297.1	11.039	1.628	278.2
200.00	1.50	1141	1040.6	21.723	1.2706	.4292	455	.00024	3.820	305.8	18.315	1.698	290.1
400.00	.75	962	961.4	21.723	1.2838	.4136	404	.00022	4.237	313.1	30.473	1.756	300.0
1000.00	.30	748	867.1	21.723	1.3016	.3948	339	.00019	4.833	320.9	59.799	1.818	310.6
2000.00	.15	677	828.4	21.723	1.3147	.3822	289	.00017	5.326	325.6	99.507	1.856	317.1
4000.00	.08	572	820.8	21.723	1.3270	.3712	247	.00015	5.865	329.6	165.365	1.887	322.5
R = 3.000, PERCENT FUEL = 4.031, O/ =23.810													
1.00	300.00	2723	1281.4	24.669	1.2163	0.4495	665	0.00041	0.000			0.000	0.0
1.05	285.71	2699	1270.5	24.669	1.2167	.4488	660	.00041	.284	341.1	2.179	.203	30.4
1.20	250.00	2635	1242.1	24.669	1.2178	.4470	648	.00041	.551	216.3	1.265	.391	58.5
1.40	214.29	2563	1209.6	24.669	1.2211	.4449	633	.00041	.754	192.7	1.064	.527	78.9
1.60	187.50	2501	1282.6	24.669	1.2222	.4431	621	.00041	.896	187.3	1.010	.620	92.7
1.78	167.97	2452	1260.6	24.669	1.2231	.4415	610	.00041	1.000	186.3	1.000	.685	102.5
2.00	150.00	2401	1238.5	24.669	1.2242	.4399	600	.00041	1.099	187.0	1.008	.745	111.5
4.00	75.00	2112	1112.6	24.669	1.2310	.4293	737	.00037	1.602	201.3	1.293	1.022	152.9
10.00	30.00	1773	959.6	24.669	1.2413	.4144	652	.00031	2.155	222.1	2.193	1.265	189.3
20.00	15.00	1546	877.0	24.669	1.2502	.4025	594	.00028	2.943	235.4	3.457	1.400	209.5
20.41	14.70	1540	874.5	24.669	1.2505	.4021	592	.00028	2.956	235.7	3.505	1.403	210.0
40.00	7.50	1343	796.4	24.669	1.2595	.3898	536	.00026	2.929	246.5	5.575	1.507	225.6
100.00	3.00	1107	706.2	24.669	1.2725	.3729	466	.00022	3.446	258.4	10.691	1.619	242.4
200.00	1.50	950	648.9	24.669	1.2828	.3604	418	.00019	3.855	265.7	17.667	1.687	252.5
400.00	.75	812	599.5	24.669	1.3008	.3491	380	.00016	4.287	271.7	29.153	1.742	260.8
1000.00	.30	634	548.9	24.669	1.3182	.3357	330	.00013	4.906	278.1	56.766	1.801	269.6
2000.00	.15	522	512.3	24.669	1.3312	.3259	296	.00011	5.421	282.0	95.924	1.837	275.0
4000.00	.08	463	484.0	24.669	1.3432	.3153	221	.00009	5.985	285.2	155.224	1.867	279.4

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(g) Concluded. Combustion-chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 4.000, PERCENT FUEL = 3.054, O/F =31.746													
1.00	300.00	2372	1054.4	26.307	1.2311	0.4025	804	0.00040	0.000			0.000	0.0
1.05	285.71	2351	1045.7	26.307	1.2315	.4018	799	.00040	.282	308.3	2.187	.204	27.5
1.20	250.00	2292	1022.3	26.307	1.2328	.4000	786	.00039	.549	195.4	1.269	.392	52.9
1.40	214.29	2226	996.0	26.307	1.2343	.3979	772	.00038	.750	173.9	1.066	.529	71.3
1.60	187.50	2171	973.8	26.307	1.2357	.3960	759	.00037	.892	168.9	1.011	.621	83.7
1.79	167.18	2123	955.2	26.307	1.2369	.3945	748	.00037	1.000	168.0	1.000	.689	92.9
2.00	150.00	2080	938.0	26.307	1.2380	.3930	738	.00036	1.094	168.6	1.008	.747	100.6
4.00	75.00	1817	836.1	26.307	1.2456	.3831	675	.00032	1.598	181.2	1.286	1.023	137.8
10.00	30.00	1512	721.1	26.307	1.2570	.3694	593	.00028	2.155	199.5	2.165	1.263	170.3
20.00	15.00	1309	647.4	26.307	1.2669	.3585	535	.00024	2.549	211.1	3.393	1.396	188.2
20.41	14.70	1304	645.3	26.307	1.2672	.3582	533	.00024	2.560	211.4	3.439	1.400	188.7
40.00	7.50	1129	583.6	26.307	1.2777	.3476	480	.00021	2.940	220.7	5.440	1.502	202.4
100.00	3.00	921	512.9	26.307	1.2932	.3332	411	.00018	3.469	231.0	10.346	1.610	217.1
200.00	1.50	785	468.3	26.307	1.3061	.3223	362	.00015	3.890	237.3	16.952	1.675	225.8
400.00	.75	666	430.4	26.307	1.3193	.3121	316	.00013	4.338	242.4	27.857	1.729	233.0
1000.00	.30	531	389.1	26.307	1.3369	.2998	261	.00010	4.983	247.8	53.783	1.785	240.6
2000.00	.15	445	363.6	26.307	1.3495	.2917	224	.00009	5.521	251.1	88.429	1.819	245.2
4000.00	.08	371	342.4	26.307	1.3589	.2860	190	.00007	6.117	253.8	145.294	1.847	248.9
R = 5.000, PERCENT FUEL = 2.458, O/F =39.683													
1.00	300.00	2069	855.0	27.313	1.2437	0.3713	742	0.00034	0.000			0.000	0.0
1.05	285.71	2050	847.7	27.313	1.2442	.3707	737	.00034	.281	262.4	2.194	.205	25.2
1.20	250.00	1996	828.0	27.313	1.2456	.3690	724	.00033	.546	178.9	1.272	.394	48.4
1.40	214.29	1936	806.0	27.313	1.2473	.3670	710	.00033	.747	159.2	1.068	.531	65.3
1.60	187.50	1886	787.4	27.313	1.2488	.3652	697	.00032	.888	154.5	1.012	.623	76.7
1.80	166.43	1841	771.2	27.313	1.2501	.3636	686	.00031	1.000	153.6	1.000	.694	85.4
2.00	150.00	1803	757.5	27.313	1.2514	.3622	677	.00031	1.090	154.1	1.007	.748	92.1
4.00	75.00	1566	672.6	27.313	1.2596	.3530	614	.00027	1.694	165.3	1.279	1.023	126.0
10.00	30.00	1292	577.6	27.313	1.2721	.3402	536	.00023	2.154	181.7	2.139	1.262	155.4
20.00	15.00	1112	517.0	27.313	1.2825	.3303	481	.00020	2.553	192.0	3.334	1.393	171.5
20.41	14.70	1107	515.4	27.313	1.2829	.3300	479	.00020	2.564	192.3	3.380	1.397	171.9
40.00	7.50	952	465.1	27.313	1.2939	.3203	429	.00018	2.950	200.5	5.317	1.496	184.2
100.00	3.00	770	407.9	27.313	1.3106	.3070	364	.00014	3.491	209.6	10.036	1.603	197.2
200.00	1.50	651	372.1	27.313	1.3239	.2974	319	.00012	3.923	215.0	16.345	1.665	205.0
400.00	.75	548	341.9	27.313	1.3375	.2883	277	.00011	4.385	219.5	26.695	1.717	211.3
1000.00	.30	433	309.3	27.313	1.3545	.2780	227	.00008	5.056	224.2	51.130	1.770	217.9
2000.00	.15	361	289.4	27.313	1.3639	.2727	193	.00007	5.622	227.0	83.618	1.802	221.8
4000.00	.08	299	272.8	27.313	1.3702	.2693	163	.00006	6.246	229.3	136.832	1.829	225.1

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(h) Combustion-chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.150, PERCENT FUEL = 45.65, O/F = 1.190													
1.00	600.00	1183	5313.5	4.416	1.3396	1.7753	314	0.00073	0.000			0.000	0.0
1.05	571.43	1168	5287.7	4.416	1.3408	1.7710	311	.00073	.271	530.0	2.250	.210	47.4
1.20	500.00	1129	5218.6	4.416	1.3436	1.7597	303	.00070	.527	534.2	1.297	.403	90.8
1.40	428.57	1085	5141.8	4.416	1.3469	1.7472	293	.00068	.722	536.1	1.081	.543	122.2
1.60	375.00	1049	5077.7	4.416	1.3497	1.7369	285	.00066	.860	536.6	1.018	.636	143.2
1.87	321.68	1008	5006.8	4.416	1.3528	1.7257	276	.00063	1.000	536.1	1.000	.725	163.4
2.00	300.00	989	4975.4	4.416	1.3540	1.7210	272	.00062	1.059	536.4	1.003	.761	171.5
4.00	150.00	824	4693.4	4.416	1.3651	1.6825	234	.00052	1.566	501.7	1.233	1.031	232.3
10.00	60.00	643	4392.5	4.416	1.3748	1.6505	188	.00042	2.152	527.5	1.974	1.257	283.1
20.00	30.00	532	4209.8	4.416	1.3799	1.6344	159	.00035	2.586	543.5	2.982	1.376	309.9
40.00	15.00	439	4058.9	4.416	1.3824	1.6268	133	.00029	3.031	556.4	4.620	1.467	330.4
40.83	14.70	437	4054.8	4.416	1.3825	1.6266	132	.00029	3.044	556.8	4.682	1.469	330.9
100.00	6.00	340	3899.0	4.416	1.3882	1.6093	104	.00023	3.648	569.8	8.432	1.558	350.8
200.00	3.00	280	3802.6	4.416	1.3926	1.5961	85	.00018	4.149	577.7	13.431	1.610	362.6
400.00	1.50	230	3723.2	4.416	1.4068	1.5562	70	.00015	4.675	584.1	21.488	1.652	372.0
1000.00	.60	175	3640.1	4.416	1.4349	1.4847	55	.00011	5.438	590.6	39.928	1.694	381.6
2000.00	.30	142	3590.9	4.416	1.4550	1.4389	45	.00009	6.096	594.3	63.572	1.719	387.2
4000.00	.15	114	3551.2	4.416	1.4705	1.4065	36	.00007	6.845	597.3	100.938	1.739	391.6
R = 0.200, PERCENT FUEL = 38.65, O/F = 1.587													
1.00	600.00	1514	2969.7	5.216	1.3079	1.6183	402	0.00084	0.000			0.000	0.0
1.05	571.43	1497	2941.7	5.216	1.3090	1.6140	399	.00083	.274	552.2	2.233	.209	49.3
1.20	500.00	1450	2866.8	5.216	1.3120	1.6022	389	.00081	.533	548.6	1.289	.400	94.6
1.40	428.57	1398	2783.1	5.216	1.3155	1.5887	378	.00078	.730	509.3	1.077	.539	127.4
1.60	375.00	1354	2713.2	5.216	1.3185	1.5772	369	.00076	.869	499.6	1.016	.632	149.4
1.85	324.94	1307	2640.5	5.216	1.3217	1.5651	359	.00073	1.000	497.3	1.000	.716	169.2
2.00	300.00	1282	2601.1	5.216	1.3236	1.5584	353	.00072	1.068	497.8	1.004	.757	179.1
4.00	150.00	1079	2290.0	5.216	1.3391	1.5046	307	.00061	1.572	516.7	1.244	1.029	243.2
10.00	60.00	852	1954.3	5.216	1.3558	1.4516	251	.00048	2.148	544.7	2.009	1.257	297.2
20.00	30.00	709	1748.8	5.216	1.3656	1.4232	213	.00040	2.573	562.0	3.049	1.379	325.9
40.00	15.00	588	1578.0	5.216	1.3715	1.4066	179	.00034	3.010	576.0	4.739	1.472	348.0
40.83	14.70	585	1573.4	5.216	1.3716	1.4062	178	.00034	3.023	576.4	4.804	1.474	348.6
100.00	6.00	458	1396.3	5.216	1.3771	1.3913	142	.00026	3.619	590.5	8.679	1.565	370.0
200.00	3.00	379	1286.2	5.216	1.3811	1.3807	117	.00022	4.111	599.1	13.870	1.619	382.7
400.00	1.50	312	1195.2	5.216	1.3861	1.3677	96	.00018	4.638	606.1	22.296	1.662	392.9
1000.00	.60	242	1099.0	5.216	1.3973	1.3400	74	.00013	5.394	613.4	41.979	1.706	403.5
2000.00	.30	198	1041.1	5.216	1.4136	1.2977	61	.00011	6.014	617.7	67.687	1.733	409.7
4000.00	.15	161	993.9	5.216	1.4350	1.2568	50	.00009	6.704	621.1	108.754	1.754	414.6
R = 0.250, PERCENT FUEL = 33.51, O/F = 1.984													
1.00	600.00	1817	1249.3	6.016	1.2835	1.4955	481	0.00092	0.000			0.000	0.0
1.05	571.43	1797	1220.2	6.016	1.2844	1.4917	477	.00091	.276	563.4	2.219	.207	50.3
1.20	500.00	1745	1142.1	6.016	1.2870	1.4813	467	.00089	.538	556.2	1.283	.398	96.6
1.40	428.57	1686	1054.7	6.016	1.2900	1.4694	456	.00086	.736	516.3	1.073	.536	130.1
1.60	375.00	1636	981.5	6.016	1.2926	1.4591	446	.00083	.876	506.6	1.015	.629	152.7
1.83	327.79	1586	909.9	6.016	1.2954	1.4485	436	.00081	1.000	504.5	1.000	.708	171.8
2.00	300.00	1555	864.0	6.016	1.2973	1.4415	429	.00080	1.076	505.1	1.005	.754	183.1
4.00	150.00	1322	535.2	6.016	1.3125	1.3873	378	.00068	1.579	525.5	1.256	1.027	249.3
10.00	60.00	1057	176.3	6.016	1.3329	1.3225	314	.00054	2.147	555.3	2.048	1.258	305.6
20.00	30.00	887	9954.2	6.016	1.3461	1.2848	269	.00046	2.563	573.7	3.127	1.382	335.7
40.00	15.00	740	9768.3	6.016	1.3569	1.2559	228	.00038	2.987	588.6	4.883	1.478	359.0
40.83	14.70	736	9763.3	6.016	1.3572	1.2551	227	.00038	3.000	589.0	4.949	1.481	359.6
100.00	6.00	580	9569.3	6.016	1.3663	1.2320	181	.00030	3.581	604.2	8.985	1.575	382.3
200.00	3.00	481	9448.1	6.016	1.3717	1.2191	151	.00025	4.064	613.4	14.395	1.630	395.9
400.00	1.50	399	9347.6	6.016	1.3765	1.2100	124	.00020	4.582	620.9	23.207	1.675	406.8
1000.00	.60	310	9240.9	6.016	1.3821	1.1948	95	.00015	5.327	628.7	43.891	1.722	418.0
2000.00	.30	256	9176.3	6.016	1.3885	1.1805	78	.00012	5.945	633.4	71.275	1.749	424.7
4000.00	.15	210	9123.1	6.016	1.4039	1.1482	64	.00010	6.606	637.1	115.642	1.771	430.1
R = 0.300, PERCENT FUEL = 29.57, O/F = 2.381													
1.00	600.00	2094	9932.7	6.815	1.2647	1.3934	551	0.00097	0.000			0.000	0.0
1.05	571.43	2073	9903.1	6.815	1.2654	1.3904	547	.00096	.278	568.6	2.208	.206	50.8
1.20	500.00	2015	9823.5	6.815	1.2675	1.3817	537	.00094	.542	559.8	1.278	.396	97.5
1.40	428.57	1951	9734.4	6.815	1.2701	1.3714	525	.00091	.741	519.8	1.071	.533	131.4
1.60	375.00	1896	9659.5	6.815	1.2724	1.3622	515	.00089	.881	510.2	1.013	.626	154.2
1.82	330.09	1845	9589.9	6.815	1.2746	1.3534	505	.00087	1.000	508.2	1.000	.701	172.7
2.00	300.00	1807	9539.0	6.815	1.2764	1.3467	498	.00085	1.082	509.0	1.006	.751	185.1
4.00	150.00	1551	9200.2	6.815	1.2898	1.2980	444	.00074	1.585	530.4	1.266	1.025	252.5
10.00	60.00	1256	8826.3	6.815	1.3097	1.2332	375	.00060	2.148	561.6	2.084	1.260	310.3
20.00	30.00	1062	8592.4	6.815	1.3230	1.1988	325	.00050	2.555	581.0	3.205	1.387	341.5
40.00	15.00	894	8395.1	6.815	1.3366	1.1629	278	.00042	2.969	596.8	5.035	1.485	365.8
40.83	14.70	889	8389.8	6.815	1.3369	1.1620	277	.00042	2.981	597.2	5.104	1.488	366.4
100.00	6.00	706	8182.2	6.815	1.3532	1.1173	223	.00033	3.544	613.2	9.321	1.585	390.3
200.00	3.00	589	8051.7	6.815	1.3605	1.1006	187	.00027	4.014	623.0	14.986	1.643	404.6
400.00	1.50	489	7943.1	6.815	1.3667	1.0868	156	.00023	4.518	631.0	24.223	1.689	416.1
1000.00	.60	382	7827.2	6.815	1.3725	1.0745	120	.00017	5.248	639.4	45.976	1.738	428.0
2000.00	.30	316	7756.9	6.815	1.3775	1.0640	98	.00014	5.853	644.3	74.873	1.767	435.1
4000.00	.15	261	7698.7	6.815	1.3829	1.0531	80	.00011	6.511	648.4	122.117	1.790	440.9

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(h) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 0.350, PERCENT FUEL = 26.47, O/F = 2.778													
1.00	600.00	2347	8892.8	7.610	1.2500	1.3056	611	0.00100	0.000			0.000	0.0
1.05	571.43	2324	8863.0	7.610	1.2507	1.3029	607	.00099	.280	569.9	2.199	.205	50.9
1.20	500.00	2263	8783.0	7.610	1.2525	1.2955	597	.00097	.545	560.8	1.274	.394	97.7
1.40	428.57	2193	8693.3	7.610	1.2546	1.2868	585	.00094	.745	550.9	1.069	.532	131.7
1.60	375.00	2135	8617.9	7.610	1.2565	1.2793	575	.00092	.886	541.5	1.012	.624	154.7
1.81	331.93	2082	8550.7	7.610	1.2582	1.2724	566	.00090	1.000	509.6	1.000	.696	172.5
2.00	300.00	2039	8496.3	7.610	1.2597	1.2665	558	.00089	1.087	510.5	1.007	.749	185.7
4.00	150.00	1763	8152.6	7.610	1.2714	1.2233	504	.00078	1.590	332.7	1.274	1.024	253.8
10.00	60.00	1443	7770.0	7.610	1.2893	1.1638	432	.00064	2.150	365.0	2.116	1.261	312.6
20.00	30.00	1231	7528.4	7.610	1.3043	1.1192	379	.00055	2.551	385.2	3.276	1.390	344.6
40.00	15.00	1044	7322.8	7.610	1.3196	1.0783	328	.00046	2.954	401.7	5.180	1.491	369.6
40.83	14.70	1039	7317.2	7.610	1.3200	1.0772	326	.00046	2.966	402.1	5.252	1.494	370.3
100.00	6.00	832	7099.0	7.610	1.3371	1.0358	266	.00036	3.513	419.0	9.659	1.594	395.1
200.00	3.00	697	6960.9	7.610	1.3480	1.0115	224	.00030	3.967	429.3	15.596	1.654	410.0
400.00	1.50	582	6845.4	7.610	1.3558	.9950	187	.00025	4.457	437.8	25.296	1.703	422.1
1000.00	.60	457	6721.6	7.610	1.3638	.9790	147	.00019	5.166	446.6	48.178	1.754	434.6
2000.00	.30	379	6646.1	7.610	1.3686	.9693	120	.00016	5.756	451.9	78.663	1.784	442.1
4000.00	.15	314	6583.5	7.610	1.3738	.9597	97	.00013	6.399	456.2	128.622	1.809	448.3
R = 0.400, PERCENT FUEL = 23.95, O/F = 3.175													
1.00	600.00	2574	8050.5	8.396	1.2385	1.2292	663	0.00101	0.000			0.000	0.0
1.05	571.43	2550	8020.9	8.396	1.2390	1.2271	659	.00100	.281	568.3	2.191	.205	50.7
1.20	500.00	2485	7941.4	8.396	1.2405	1.2210	649	.00098	.547	560.0	1.271	.393	97.5
1.40	428.57	2412	7852.0	8.396	1.2423	1.2137	638	.00096	.748	550.4	1.067	.530	131.4
1.60	375.00	2350	7776.8	8.396	1.2439	1.2071	627	.00094	.890	541.1	1.012	.622	154.3
1.80	333.38	2296	7712.1	8.396	1.2454	1.2012	618	.00093	1.000	509.4	1.000	.692	171.6
2.00	300.00	2249	7655.4	8.396	1.2468	1.1958	610	.00091	1.091	510.3	1.007	.748	185.4
4.00	150.00	1956	7310.9	8.396	1.2566	1.1592	557	.00081	1.595	333.1	1.281	1.023	253.7
10.00	60.00	1615	6924.5	8.396	1.2724	1.1057	484	.00068	2.152	366.2	2.143	1.262	313.0
20.00	30.00	1388	6678.4	8.396	1.2803	1.0634	429	.00058	2.548	386.9	3.338	1.393	345.5
40.00	15.00	1186	6467.6	8.396	1.3013	1.0222	375	.00049	2.944	404.0	5.310	1.497	371.1
40.83	14.70	1181	6461.8	8.396	1.3018	1.0211	374	.00049	2.955	404.5	5.384	1.499	371.8
100.00	6.00	954	6236.1	8.396	1.3208	.9745	308	.00039	3.487	422.1	9.975	1.602	397.3
200.00	3.00	804	6092.2	8.396	1.3337	.9460	261	.00032	3.927	432.9	16.185	1.665	412.8
400.00	1.50	675	5971.1	8.396	1.3449	.9241	220	.00027	4.401	441.7	26.355	1.715	425.4
1000.00	.60	532	5840.7	8.396	1.3581	.9033	173	.00021	5.088	451.0	50.405	1.768	438.5
2000.00	.30	443	5760.9	8.396	1.3667	.8928	143	.00017	5.663	456.6	82.493	1.800	446.3
4000.00	.15	369	5694.5	8.396	1.3661	.8833	117	.00014	6.288	461.2	135.208	1.826	452.8
R = 0.450, PERCENT FUEL = 21.87, O/F = 3.571													
1.00	600.00	2773	7354.5	9.167	1.2292	1.1624	707	0.00101	0.000			0.000	0.0
1.05	571.43	2748	7325.3	9.167	1.2297	1.1604	704	.00101	.282	564.6	2.186	.204	50.4
1.20	500.00	2680	7246.7	9.167	1.2311	1.1550	694	.00099	.549	557.9	1.268	.392	96.8
1.40	428.57	2604	7158.4	9.167	1.2326	1.1487	682	.00097	.751	518.6	1.066	.529	130.6
1.60	375.00	2539	7084.0	9.167	1.2339	1.1433	672	.00095	.893	509.5	1.011	.621	153.4
1.79	334.56	2484	7021.9	9.167	1.2352	1.1386	663	.00094	1.000	507.8	1.000	.689	170.1
2.00	300.00	2433	6963.8	9.167	1.2364	1.1338	655	.00092	1.095	508.8	1.008	.746	184.4
4.00	150.00	2127	6621.6	9.167	1.2430	1.1016	602	.00083	1.598	332.0	1.286	1.022	252.5
10.00	60.00	1769	6235.4	9.167	1.2589	1.0541	529	.00070	2.153	365.5	2.165	1.263	312.0
20.00	30.00	1530	5987.8	9.167	1.2713	1.0157	474	.00061	2.546	386.7	3.389	1.396	344.8
40.00	15.00	1316	5774.3	9.167	1.2855	.9761	418	.00052	2.936	404.3	5.420	1.501	370.8
40.83	14.70	1310	5768.5	9.167	1.2859	.9750	417	.00052	2.947	404.7	5.497	1.504	371.5
100.00	6.00	1068	5538.2	9.167	1.3053	.9267	348	.00042	3.467	422.9	10.256	1.609	397.5
200.00	3.00	905	5390.3	9.167	1.3195	.8952	298	.00035	3.895	434.1	16.723	1.674	413.4
400.00	1.50	763	5265.1	9.167	1.3322	.8693	252	.00029	4.353	443.3	27.347	1.726	426.4
1000.00	.60	605	5129.7	9.167	1.3452	.8448	199	.00022	5.021	453.0	52.536	1.781	440.0
2000.00	.30	506	5046.4	9.167	1.3533	.8303	165	.00018	5.577	458.8	86.213	1.814	448.1
4000.00	.15	422	4976.9	9.167	1.3589	.8207	136	.00015	6.187	463.6	141.612	1.841	454.8
R = 0.500, PERCENT FUEL = 20.12, O/F = 3.968													
1.00	600.00	2944	6769.6	9.919	1.2218	1.1037	745	0.00101	0.000			0.000	0.0
1.05	571.43	2918	6741.0	9.919	1.2222	1.1020	741	.00100	.283	559.4	2.181	.204	49.9
1.20	500.00	2848	6663.8	9.919	1.2234	1.0971	731	.00099	.551	554.7	1.266	.391	95.9
1.40	428.57	2769	6577.1	9.919	1.2248	1.0914	720	.00097	.753	515.9	1.065	.528	129.4
1.60	375.00	2702	6503.9	9.919	1.2261	1.0865	710	.00095	.895	506.9	1.011	.620	152.0
1.79	335.48	2647	6444.3	9.919	1.2272	1.0823	701	.00093	1.000	505.4	1.000	.686	168.3
2.00	300.00	2592	6385.6	9.919	1.2282	1.0781	693	.00092	1.097	506.4	1.008	.745	182.8
4.00	150.00	2275	6048.0	9.919	1.2358	1.0500	640	.00083	1.601	329.7	1.291	1.022	250.6
10.00	60.00	1904	5665.2	9.919	1.2480	1.0081	568	.00072	2.154	363.5	2.183	1.264	310.0
20.00	30.00	1655	5418.4	9.919	1.2593	.9730	513	.00063	2.544	385.0	3.431	1.398	342.9
40.00	15.00	1431	5204.5	9.919	1.2724	.9359	457	.00054	2.930	402.8	5.512	1.505	369.0
40.83	14.70	1424	5198.6	9.919	1.2728	.9348	455	.00054	2.941	403.3	5.591	1.508	369.7
100.00	6.00	1170	4966.4	9.919	1.2916	.8875	383	.00044	3.452	421.9	10.495	1.615	396.1
200.00	3.00	997	4816.2	9.919	1.3065	.8539	331	.00037	3.869	433.4	17.193	1.681	412.3
400.00	1.50	845	4688.5	9.919	1.3202	.8260	282	.00030	4.315	442.9	28.235	1.735	425.5
1000.00	.60	674	4549.6	9.919	1.3357	.7971	225	.00024	4.962	452.9	54.491	1.792	439.5
2000.00	.30	565	4463.8	9.919	1.3449	.7812	187	.00019	5.504	458.9	89.675	1.827	447.9
4000.00	.15	472	4391.9	9.919	1.3524	.7688	155	.00016	6.096	463.9	147.626	1.855	454.9

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(h) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in abs	Temperature, T, K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ϵ	Thrust coefficient, C_f	Specific impulse, I, (lb)(sec)/lb
R = 0.600, PERCENT FUEL = 17.35, O/F = 4.762													
1.00	600.00	3208	5841.6	11.347	1.2112	1.0044	803	0.00098	0.000			0.000	0.0
1.05	571.43	3180	5814.3	11.347	1.2115	1.0031	800	.00096	.284	546.0	2.175	.203	48.7
1.20	500.00	3107	5740.3	11.347	1.2125	.9994	790	.00096	.553	346.4	1.263	.390	93.7
1.40	428.57	3024	5656.1	11.347	1.2136	.9950	778	.00094	.756	308.7	1.063	.526	126.4
1.60	375.00	2954	5588.2	11.347	1.2146	.9910	768	.00093	.898	300.0	1.010	.619	148.5
1.78	336.81	2898	5533.1	11.347	1.2155	.9877	760	.00092	1.000	298.6	1.000	.682	163.8
2.00	300.00	2839	5475.0	11.347	1.2165	.9841	752	.00090	1.101	299.7	1.009	.744	178.6
4.00	150.00	2506	5150.9	11.347	1.2227	.9616	700	.00083	1.604	323.0	1.298	1.021	245.1
10.00	60.00	2115	4780.9	11.347	1.2328	.9274	629	.00072	2.156	356.8	2.209	1.265	303.8
20.00	30.00	1851	4540.5	11.347	1.2422	.8982	574	.00064	2.542	378.4	3.492	1.401	336.5
40.00	15.00	1613	4330.4	11.347	1.2532	.8666	518	.00056	2.922	396.5	5.648	1.510	362.6
40.83	14.70	1607	4324.7	11.347	1.2536	.8658	516	.00056	2.933	397.0	5.730	1.513	363.3
100.00	6.00	1334	4094.4	11.347	1.2705	.8224	445	.00046	3.431	416.0	10.859	1.624	389.9
200.00	3.00	1148	3944.0	11.347	1.2851	.7895	387	.00039	3.833	427.9	17.925	1.692	406.3
400.00	1.50	981	3815.0	11.347	1.2999	.7590	334	.00033	4.260	437.7	29.654	1.749	419.9
1000.00	.60	790	3673.4	11.347	1.3161	.7256	270	.00025	4.876	448.2	57.726	1.809	434.4
2000.00	.30	667	3585.1	11.347	1.3299	.7060	227	.00021	5.391	454.6	95.510	1.846	443.1
4000.00	.15	560	3510.8	11.347	1.3397	.6906	189	.00017	5.955	459.8	157.952	1.876	450.3
R = 0.700, PERCENT FUEL = 15.25, O/F = 5.556													
1.00	600.00	3381	5138.3	12.664	1.2044	0.9246	846	0.00095	0.000			0.000	0.0
1.05	571.43	3353	5112.5	12.664	1.2047	.9234	842	.00094	.285	530.7	2.171	.203	47.4
1.20	500.00	3278	5043.0	12.664	1.2056	.9201	832	.00093	.554	336.8	1.262	.389	91.0
1.40	428.57	3192	4964.8	12.664	1.2066	.9164	820	.00091	.756	300.2	1.062	.525	122.4
1.60	375.00	3120	4898.7	12.664	1.2075	.9132	810	.00090	.900	291.9	1.009	.618	144.4
1.78	337.67	3064	4847.8	12.664	1.2082	.9106	802	.00089	1.000	290.6	1.000	.680	159.0
2.00	300.00	3002	4791.5	12.664	1.2090	.9076	793	.00088	1.103	291.7	1.009	.743	173.7
4.00	150.00	2660	4483.9	12.664	1.2146	.8862	742	.00080	1.607	314.7	1.302	1.021	238.6
10.00	60.00	2257	4131.1	12.664	1.2235	.8595	672	.00071	2.157	348.1	2.226	1.266	296.0
20.00	30.00	1985	3900.7	12.664	1.2314	.8349	617	.00064	2.541	369.4	3.532	1.404	328.2
40.00	15.00	1738	3696.4	12.664	1.2413	.8071	561	.00056	2.916	387.5	5.737	1.514	354.0
40.83	14.70	1732	3692.8	12.664	1.2416	.8063	559	.00056	2.927	388.0	5.821	1.517	354.6
100.00	6.00	1448	3469.8	12.664	1.2566	.7679	486	.00047	3.418	407.0	11.100	1.630	381.0
200.00	3.00	1253	3323.0	12.664	1.2704	.7372	429	.00040	3.812	419.0	18.418	1.700	397.4
400.00	1.50	1078	3196.4	12.664	1.2851	.7073	375	.00034	4.226	429.0	30.635	1.756	411.1
1000.00	.60	875	3056.3	12.664	1.3043	.6726	305	.00027	4.822	439.7	60.039	1.820	425.6
2000.00	.30	742	2968.5	12.664	1.3177	.6508	258	.00022	5.317	446.2	99.783	1.858	434.5
4000.00	.15	627	2894.2	12.664	1.3291	.6337	217	.00018	5.860	451.6	165.647	1.890	441.9
R = 0.800, PERCENT FUEL = 13.60, O/F = 6.349													
1.00	600.00	3481	4586.9	13.859	1.2004	0.8591	875	0.00091	0.000			0.000	0.0
1.05	571.43	3453	4562.6	13.859	1.2006	.8580	872	.00090	.286	514.8	2.166	.202	45.9
1.20	500.00	3376	4497.2	13.859	1.2014	.8552	861	.00089	.555	326.8	1.260	.389	88.3
1.40	428.57	3290	4423.6	13.859	1.2024	.8519	849	.00088	.759	291.4	1.062	.525	119.2
1.60	375.00	3217	4361.3	13.859	1.2032	.8490	839	.00086	.902	283.3	1.009	.617	140.1
1.77	338.19	3161	4314.0	13.859	1.2039	.8468	831	.00085	1.000	282.1	1.000	.679	154.1
2.00	300.00	3098	4260.3	13.859	1.2046	.8442	822	.00084	1.105	283.2	1.010	.742	168.6
4.00	150.00	2750	3969.9	13.859	1.2097	.8275	770	.00078	1.608	305.7	1.304	1.020	231.7
10.00	60.00	2341	3636.1	13.859	1.2177	.8022	700	.00069	2.157	338.4	2.236	1.267	287.6
20.00	30.00	2065	3417.4	13.859	1.2251	.7803	646	.00062	2.540	359.4	3.556	1.405	319.0
40.00	15.00	1814	3224.8	13.859	1.2342	.7557	590	.00055	2.913	377.1	5.791	1.516	344.3
40.83	14.70	1807	3219.5	13.859	1.2345	.7549	588	.00055	2.924	377.6	5.876	1.519	344.9
100.00	6.00	1518	3006.4	13.859	1.2485	.7205	514	.00046	3.410	396.4	11.247	1.633	370.8
200.00	3.00	1319	2865.5	13.859	1.2615	.6918	457	.00040	3.799	408.3	18.724	1.704	387.0
400.00	1.50	1139	2743.6	13.859	1.2756	.6636	401	.00034	4.207	418.2	31.251	1.764	400.5
1000.00	.60	929	2606.0	13.859	1.2951	.6294	330	.00027	4.789	428.9	61.524	1.827	415.0
2000.00	.30	791	2522.7	13.859	1.3091	.6073	281	.00022	5.272	435.5	102.579	1.866	423.8
4000.00	.15	670	2450.2	13.859	1.3216	.5893	237	.00018	5.801	440.9	170.764	1.899	431.2
R = 0.900, PERCENT FUEL = 12.28, O/F = 7.143													
1.00	600.00	3526	4142.9	14.930	1.1982	0.8047	896	0.00087	0.000			0.000	0.0
1.05	571.43	3498	4120.1	14.930	1.1985	.8038	892	.00087	.286	499.2	2.167	.202	44.5
1.20	500.00	3421	4056.7	14.930	1.1992	.8013	881	.00085	.556	317.0	1.260	.389	85.6
1.40	428.57	3334	3987.4	14.930	1.2001	.7983	869	.00084	.759	282.6	1.061	.525	115.6
1.60	375.00	3261	3930.8	14.930	1.2009	.7956	859	.00083	.904	274.8	1.009	.617	135.9
1.77	335.46	3205	3886.6	14.930	1.2015	.7936	851	.00082	1.000	273.6	1.000	.678	149.5
2.00	300.00	3141	3835.7	14.930	1.2022	.7913	842	.00081	1.106	274.8	1.010	.742	163.5
4.00	150.00	2792	3562.3	14.930	1.2070	.7760	789	.00074	1.609	296.7	1.306	1.020	224.8
10.00	60.00	2381	3247.3	14.930	1.2145	.7533	719	.00066	2.157	328.5	2.241	1.267	279.2
20.00	30.00	2103	3040.7	14.930	1.2218	.7332	664	.00060	2.539	349.0	3.569	1.406	309.7
40.00	15.00	1851	2858.5	14.930	1.2304	.7109	606	.00053	2.911	366.4	5.820	1.517	334.3
40.83	14.70	1844	2853.5	14.930	1.2306	.7102	[illegible]	[illegible]	2.922	366.8	5.906	1.520	[illegible]
100.00	6.00	1553	2651.4	14.930	1.2441	.6764	532	.00045	3.406	385.2	11.328	1.635	360.3
200.00	3.00	1352	2517.6	14.930	1.2566	.6519	475	.00039	3.792	396.9	18.892	1.707	376.1
400.00	1.50	1170	2401.4	14.930	1.2705	[illegible]	416	.00033	4.196	405.7	31.551	1.767	389.3
1000.00	.60	957	2272.0	14.930	[illegible]	[illegible]	347	.00026	4.772	417.2	62.339	[illegible]	[illegible]
2000.00	.30	817	2190.3	14.930	[illegible]	[illegible]	297	.00022	5.248	423.7	104.470	[illegible]	[illegible]
4000.00	.15	695	2120.8	14.930	[illegible]	.5551	251	[illegible]	5.769	429.0	[illegible]	1.904	[illegible]

TABLE II. - Concluded. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(h) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 1.000, PERCENT FUEL = 11.19, O/F = 7.937													
1.00	600.00	3534	3777.9	15.886	1.1972	0.7592	910	0.00083	0.000			0.000	0.0
1.05	571.43	3505	3756.4	15.886	1.1975	.7584	906	.00083	.286	484.5	2.166	.202	43.2
1.20	500.00	3429	3698.5	15.886	1.1982	.7560	895	.00082	.556	307.6	1.260	.389	83.1
1.40	428.57	3342	3633.2	15.886	1.1991	.7533	882	.00080	.760	274.3	1.061	.525	112.2
1.60	375.00	3269	3578.0	15.886	1.1999	.7508	872	.00079	.903	266.8	1.009	.617	131.9
1.77	338.98	3214	3536.6	15.886	1.2005	.7489	864	.00078	1.000	265.6	1.000	.677	144.9
2.00	300.00	3149	3488.4	15.886	1.2012	.7466	854	.00077	1.106	266.7	1.010	.742	158.7
4.00	150.00	2801	3230.7	15.886	1.2059	.7327	801	.00071	1.609	288.1	1.307	1.040	218.2
10.00	60.00	2390	2933.7	15.886	1.2133	.7115	730	.00063	2.157	319.0	2.244	1.267	271.0
20.00	30.00	2112	2738.7	15.886	1.2204	.6927	674	.00057	2.539	338.9	3.575	1.406	300.7
40.00	15.00	1864	2566.6	15.886	1.2287	.6720	618	.00051	2.911	355.8	5.833	1.518	324.6
40.83	14.70	1853	2561.9	15.886	1.2290	.6714	616	.00051	2.922	356.3	5.919	1.521	325.3
100.00	6.00	1565	2370.8	15.886	1.2421	.6418	542	.00043	3.404	374.2	11.363	1.636	349.9
200.00	3.00	1362	2244.2	15.886	1.2543	.6169	484	.00037	3.789	385.6	18.966	1.708	365.3
400.00	1.50	1180	2134.2	15.886	1.2676	.5921	428	.00032	4.192	395.2	31.744	1.768	378.2
1000.00	.60	967	2011.5	15.886	1.2870	.5609	356	.00026	4.764	405.5	62.740	1.833	392.0
2000.00	.30	826	1933.9	15.886	1.3015	.5403	306	.00021	5.238	411.8	104.909	1.873	400.6
4000.00	.15	701	1867.6	15.886	1.3145	.5226	260	.00018	5.755	417.0	175.109	1.908	407.7
R = 1.500, PERCENT FUEL = 7.749, O/F =11.905													
1.00	600.00	3374	2626.1	19.463	1.1996	0.6136	930	0.00069	0.000			0.000	0.0
1.05	571.43	3346	2609.3	19.463	1.1999	.6129	925	.00069	.286	427.7	2.168	.202	38.2
1.20	500.00	3273	2564.2	19.463	1.2007	.6109	914	.00067	.555	271.5	1.260	.389	73.4
1.40	428.57	3189	2513.4	19.463	1.2016	.6086	901	.00066	.759	242.1	1.061	.525	99.0
1.60	375.00	3118	2470.4	19.463	1.2023	.6067	889	.00065	.902	235.4	1.009	.617	116.4
1.77	338.29	3065	2437.8	19.463	1.2030	.6051	881	.00065	1.000	234.4	1.000	.678	128.0
2.00	300.00	3003	2400.6	19.463	1.2037	.6032	871	.00064	1.105	235.3	1.010	.742	140.1
4.00	150.00	2668	2200.2	19.463	1.2068	.5912	813	.00058	1.609	254.1	1.305	1.020	192.5
10.00	60.00	2272	1969.5	19.463	1.2166	.5735	737	.00052	2.157	281.2	2.238	1.267	239.0
20.00	30.00	2009	1818.3	19.463	1.2238	.5583	679	.00047	2.539	298.7	3.561	1.405	265.1
40.00	15.00	1763	1685.2	19.463	1.2325	.5413	620	.00042	2.913	313.5	5.802	1.517	286.1
40.83	14.70	1756	1681.5	19.463	1.2327	.5406	619	.00041	2.924	313.9	5.887	1.519	286.7
100.00	6.00	1477	1533.9	19.463	1.2460	.5172	543	.00035	3.409	329.6	11.282	1.634	308.3
200.00	3.00	1285	1438.3	19.463	1.2579	.4979	486	.00030	3.797	339.5	18.804	1.703	321.8
400.00	1.50	1112	1351.6	19.463	1.2711	.4787	430	.00026	4.203	347.8	31.433	1.765	333.0
1000.00	.60	909	1257.3	19.463	1.2895	.4548	360	.00021	4.781	356.8	62.045	1.829	345.1
2000.00	.30	776	1197.7	19.463	1.3036	.4383	311	.00018	5.259	362.3	103.674	1.868	352.5
4000.00	.15	659	1147.0	19.463	1.3160	.4252	268	.00015	5.780	366.9	172.958	1.901	358.7
R = 2.000, PERCENT FUEL = 5.927, O/F =15.873													
1.00	600.00	3158	2016.0	21.832	1.2049	0.5352	919	0.00060	0.000			0.000	0.0
1.05	571.43	3132	2002.1	21.832	1.2052	.5346	915	.00059	.285	390.6	2.171	.203	34.9
1.20	500.00	3061	1964.4	21.832	1.2060	.5328	903	.00058	.554	247.9	1.262	.389	67.0
1.40	428.57	2981	1922.0	21.832	1.2071	.5308	889	.00057	.756	221.0	1.062	.526	90.4
1.60	375.00	2914	1886.2	21.832	1.2080	.5292	877	.00056	.900	214.8	1.010	.618	106.3
1.78	337.61	2861	1856.6	21.832	1.2088	.5279	868	.00056	1.000	213.9	1.000	.680	117.0
2.00	300.00	2804	1826.2	21.832	1.2098	.5262	856	.00055	1.103	214.7	1.009	.743	127.9
4.00	150.00	2483	1661.5	21.832	1.2151	.5143	797	.00050	1.607	231.6	1.302	1.021	175.6
10.00	60.00	2105	1470.5	21.832	1.2238	.4977	718	.00044	2.157	256.1	2.225	1.266	217.9
20.00	30.00	1852	1345.8	21.832	1.2316	.4840	658	.00039	2.541	271.9	3.530	1.403	241.5
40.00	15.00	1622	1236.4	21.832	1.2407	.4692	599	.00035	2.918	285.1	5.734	1.514	260.5
40.83	14.70	1618	1233.5	21.832	1.2409	.4688	597	.00035	2.929	285.5	5.818	1.517	261.0
100.00	6.00	1355	1112.6	21.832	1.2549	.4461	521	.00029	3.420	299.5	11.102	1.629	280.4
200.00	3.00	1172	1033.0	21.832	1.2659	.4321	465	.00025	3.814	308.5	18.444	1.700	292.5
400.00	1.50	1010	964.3	21.832	1.2800	.4181	411	.00022	4.228	315.7	30.731	1.758	302.5
1000.00	.60	822	886.1	21.832	1.2977	.3985	344	.00018	4.819	323.7	60.419	1.821	313.3
2000.00	.30	700	840.2	21.832	1.3108	.3838	296	.00015	5.308	328.5	100.676	1.859	319.9
4000.00	.15	592	799.5	21.832	1.3234	.3709	255	.00012	5.841	332.8	167.527	1.894	325.4
R = 3.000, PERCENT FUEL = 4.031, O/F =23.810													
1.00	600.00	2747	1381.4	24.718	1.2174	0.4502	869	0.00048	0.000			0.000	0.0
1.05	571.43	2723	1370.7	24.718	1.2178	.4495	865	.00046	.284	342.3	2.179	.203	30.6
1.20	500.00	2659	1341.8	24.718	1.2189	.4477	852	.00047	.551	217.1	1.265	.391	58.7
1.40	428.57	2586	1309.3	24.718	1.2201	.4456	838	.00046	.754	193.4	1.064	.527	79.2
1.60	375.00	2524	1281.9	24.718	1.2212	.4438	825	.00045	.896	187.9	1.010	.619	93.1
1.79	336.06	2475	1259.6	24.718	1.2222	.4423	815	.00044	1.000	187.0	1.000	.685	102.8
2.00	300.00	2424	1237.5	24.718	1.2232	.4408	805	.00044	1.099	187.7	1.008	.745	111.9
4.00	150.00	2133	1110.7	24.718	1.2299	.4301	741	.00039	1.604	202.1	1.294	1.022	153.5
10.00	60.00	1792	966.4	24.718	1.2401	.4152	659	.00034	2.156	223.0	2.195	1.265	190.0
20.00	30.00	1564	873.0	24.718	1.2480	.4034	599	.00030	2.545	236.3	3.481	1.400	210.5
40.00	15.00	1357	791.7	24.718	1.2567	.3907	540	.00027	2.928	247.5	5.566	1.508	226.5
40.83	14.70	1353	787.5	24.718	1.2570	.3903	539	.00026	2.940	247.8	5.667	1.510	226.9
100.00	6.00	1141	700.6	24.718	1.2677	.3749	467	.00022	3.444	259.5	10.719	1.620	243.4
200.00	3.00	985	642.6	24.718	1.2773	.3613	414	.00019	3.852	266.8	17.885	1.687	253.5
400.00	1.50	843	592.5	24.718	1.2872	.3492	364	.00016	4.283	272.9	29.266	1.743	261.9
1000.00	.60	664	538.4	24.718	1.3010	.3344	303	.00013	4.900	279.4	57.031	1.803	270.8
2000.00	.30	560	504.3	24.718	1.3109	.3244	261	.00011	5.413	283.3	94.417	1.839	276.3
4000.00	.15	471	475.7	24.718	1.3200	.3157	224	.00009	5.973	286.6	156.162	1.868	280.7

TABLE II. - Concluded. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 4000 FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(h) Concluded. Combustion-chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathfrak{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Viscosity, μ, micro poises	Thermal conductivity, k, cal/(sec)(°K)(cm)	Mach number M	Specific impulse in vacuum, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/(lb)
R = 4.000, PERCENT FUEL = 3.054, O/F = 31.746													
1.00	600.00	2381	1054.4	26.323	1.2307	0.4027	806	0.00040	0.000			0.000	0.0
1.05	571.43	2359	1045.7	26.323	1.2312	.4021	801	.00040	.282	308.7	2.187	.209	27.6
1.20	500.00	2300	1022.2	26.323	1.2325	.4003	788	.00039	.549	195.7	1.269	.392	52.9
1.40	428.57	2234	995.8	26.323	1.2340	.3981	774	.00038	.750	174.2	1.066	.529	71.4
1.60	375.00	2178	973.6	26.323	1.2353	.3963	761	.00037	.892	169.2	1.011	.621	83.9
1.79	334.41	2131	954.9	26.323	1.2365	.3947	750	.00037	1.000	168.3	1.000	.689	93.0
2.00	300.00	2087	937.6	26.323	1.2376	.3932	740	.00036	1.094	168.8	1.008	.747	100.8
4.00	150.00	1824	835.4	26.323	1.2452	.3833	676	.00032	1.598	181.4	1.286	1.023	138.0
10.00	60.00	1518	720.1	26.323	1.2566	.3697	595	.00028	2.155	199.8	2.166	1.263	170.6
20.00	30.00	1315	646.1	26.323	1.2665	.3588	537	.00024	2.549	211.4	3.394	1.396	188.5
40.00	15.00	1134	582.1	26.323	1.2771	.3479	481	.00021	2.939	221.1	5.444	1.502	202.7
40.83	14.70	1129	580.3	26.323	1.2775	.3476	480	.00021	2.951	221.4	5.521	1.505	203.1
100.00	6.00	926	511.0	26.323	1.2927	.3334	412	.00018	3.469	231.4	10.356	1.611	217.4
200.00	3.00	789	466.2	26.323	1.3055	.3226	363	.00015	3.889	237.7	16.972	1.676	226.2
400.00	1.50	669	428.2	26.323	1.3187	.3124	317	.00013	4.336	242.8	27.895	1.729	233.4
1000.00	.60	534	386.7	26.323	1.3363	.3000	262	.00010	4.980	248.3	53.871	1.785	241.0
2000.00	.30	447	361.1	26.323	1.3489	.2918	225	.00009	5.518	251.6	88.590	1.819	245.6
4000.00	.15	373	339.7	26.323	1.3586	.2860	191	.00007	6.112	254.3	145.580	1.847	249.4
R = 5.000, PERCENT FUEL = 2.458, O/F = 39.683													
1.00	600.00	2072	855.0	27.317	1.2436	0.3714	742	0.00034	0.000			0.000	0.0
1.05	571.43	2052	847.7	27.317	1.2441	.3708	737	.00034	.281	282.6	2.194	.205	25.2
1.20	500.00	1999	828.0	27.317	1.2455	.3691	725	.00033	.546	179.0	1.272	.394	48.5
1.40	428.57	1939	805.9	27.317	1.2472	.3671	710	.00033	.747	159.2	1.068	.531	65.3
1.60	375.00	1888	787.3	27.317	1.2487	.3653	698	.00032	.888	154.6	1.012	.623	76.7
1.80	332.87	1844	771.2	27.317	1.2500	.3637	687	.00031	1.000	153.7	1.000	.694	85.4
2.00	300.00	1806	757.4	27.317	1.2512	.3623	677	.00031	1.090	154.2	1.007	.748	92.2
4.00	150.00	1568	672.4	27.317	1.2595	.3531	614	.00027	1.594	165.4	1.279	1.023	126.0
10.00	60.00	1294	577.3	27.317	1.2720	.3402	536	.00023	2.154	181.8	2.139	1.262	155.4
20.00	30.00	1113	516.7	27.317	1.2824	.3303	481	.00020	2.553	192.1	3.335	1.393	171.6
40.00	15.00	953	464.7	27.317	1.2937	.3204	429	.00018	2.950	200.7	5.318	1.497	184.3
40.83	14.70	949	463.3	27.317	1.2940	.3201	428	.00018	2.962	200.9	5.393	1.499	184.6
100.00	6.00	771	407.4	27.317	1.3104	.3071	364	.00014	3.490	209.7	10.039	1.603	197.4
200.00	3.00	652	371.6	27.317	1.3237	.2975	319	.00012	3.923	215.2	16.351	1.665	205.1
400.00	1.50	549	341.3	27.317	1.3373	.2884	277	.00011	4.385	219.6	26.706	1.717	211.4
1000.00	.60	434	308.7	27.317	1.3544	.2780	228	.00008	5.055	224.3	51.154	1.770	218.0
2000.00	.30	361	288.7	27.317	1.3638	.2727	193	.00007	5.621	227.1	83.660	1.803	222.0
4000.00	.15	300	272.1	27.317	1.3701	.2693	163	.00006	6.245	229.4	136.905	1.829	225.2

TABLE III. - THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Combustion-chamber pressure, 60 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_t	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_p$
R = 0.15, PERCENT FUEL = 45.65, O/F = 1.190									
1.00	1183	0.0000					1.7753	0.00000	0.0000
1.05	1168	.0000	2.250	0.0000	47.4	0.0000	1.7711	.00000	.0000
1.20	1129	.0000	1.297	.0000	90.8	.0000	1.7597	.00000	.0000
1.40	1085	.0000	1.081	.0000	122.2	.0000	1.7472	.00000	.0000
1.60	1049	.0000	1.018	.0000	143.2	.0000	1.7369	.00000	.0000
1.87	1008	.0000	1.000	.0000	163.4	.0000	1.7257	.00000	.0000
2.00	989	.0000	1.003	.0000	171.5	.0000	1.7210	.00000	.0000
4.00	824	.0000	1.233	.0000	232.3	.0000	1.6826	.00000	.0000
4.08	819	.0000	1.244	.0000	233.7	.0000	1.6816	.00000	.0000
10.00	643	.0000	1.974	.0000	283.1	.0000	1.6507	.00000	.0000
20.00	532	.0000	2.983	.0000	309.9	.0000	1.6343	.00000	.0000
40.00	439	.0000	4.620	.0000	330.4	.0000	1.6268	.00000	.0000
100.00	340	.0000	8.432	.0000	350.8	.0000	1.6099	.00000	.0000
200.00	280	.0000	13.431	.0000	362.6	.0000	1.5951	.00000	.0000
400.00	230	.0000	21.488	.0000	372.0	.0000	1.5573	.00000	.0000
1000.00	175	.0000	39.928	.0000	381.6	.0000	1.4871	.00000	.0000
2000.00	142	.0000	63.572	.0000	387.2	.0000	1.4402	.00000	.0000
4000.00	114	.0000	100.939	.0000	391.6	.0000	1.4116	.00000	.0000
R = 3.20, PERCENT FUEL = 38.65, O/F = 1.587									
1.00	1514	0.0000					1.6194	0.00000	-0.0001
1.05	1497	.0000	2.233	0.0000	49.3	0.0000	1.6149	.00000	- .0001
1.20	1450	.0000	1.289	.0000	94.6	.0000	1.6028	.00000	.0000
1.40	1398	.0000	1.077	.0000	127.4	.0000	1.5891	.00000	.0000
1.60	1354	.0000	1.016	.0000	149.4	.0000	1.5774	.00000	.0000
1.85	1307	.0000	1.000	.0000	165.2	.0000	1.5653	.00000	.0000
2.00	1282	.0000	1.004	.0000	179.1	.0000	1.5585	.00000	.0000
4.00	1079	.0000	1.244	.0000	243.2	.0000	1.5046	.00000	.0000
4.08	1073	.0000	1.256	.0000	244.7	.0000	1.5031	.00000	.0000
10.00	852	.0000	2.009	.0000	297.2	.0000	1.4516	.00000	.0000
20.00	709	.0000	3.049	.0000	325.9	.0000	1.4232	.00000	.0000
40.00	588	.0000	4.739	.0000	348.0	.0000	1.4067	.00000	.0000
100.00	458	.0000	8.679	.0000	370.0	.0000	1.3916	.00000	.0000
200.00	379	.0000	13.870	.0000	382.7	.0000	1.3807	.00000	.0000
400.00	312	.0000	22.296	.0000	393.0	.0000	1.3681	.00000	.0000
1000.00	242	.0000	41.979	.0000	403.5	.0000	1.3398	.00000	.0000
2000.00	198	.0000	67.687	.0000	409.7	.0000	1.2994	.00000	.0000
4000.00	161	.0000	108.755	.0000	414.6	.0000	1.2564	.00000	.0000
R = 0.25, PERCENT FUEL = 33.51, O/F = 1.984									
1.00	1816	0.0003					1.5088	0.00004	-0.0013
1.05	1797	.0003	2.218	0.0001	50.3	0.0001	1.5036	.00004	- .0012
1.20	1744	.0002	1.283	.0001	96.6	.0001	1.4898	.00003	- .0008
1.40	1686	.0001	1.073	.0000	130.1	.0001	1.4751	.00002	- .0005
1.60	1636	.0001	1.015	.0000	152.6	.0001	1.4630	.00001	- .0004
1.83	1587	.0000	1.000	.0000	171.8	.0001	1.4513	.00001	- .0002
2.00	1555	.0000	1.005	.0000	183.1	.0001	1.4436	.00001	- .0002
4.00	1322	.0000	1.256	.0000	249.3	.0000	1.3875	.00000	.0000
4.08	1316	.0000	1.268	.0000	250.8	.0000	1.3860	.00000	.0000
10.00	1057	.0000	2.048	.0000	305.6	.0000	1.3426	.00000	.0000
20.00	887	.0000	3.127	.0000	335.7	.0000	1.2848	.00000	.0000
40.00	741	.0000	4.883	.0000	359.0	.0000	1.2559	.00000	.0000
100.00	581	.0000	8.985	.0000	382.4	.0000	1.2321	.00000	.0000
200.00	482	.0000	14.396	.0000	395.9	.0000	1.2190	.00000	.0000
400.00	399	.0000	23.208	.0000	406.8	.0000	1.2100	.00000	.0000
1000.00	310	.0000	43.894	.0000	418.1	.0000	1.1943	.00000	.0000
2000.00	256	.0000	71.279	.0000	424.7	.0000	1.1803	.00000	.0000
4000.00	210	.0000	115.650	.0000	430.2	.0000	1.1487	.00000	.0000
R = 0.30, PERCENT FUEL = 29.57, O/F = 2.381									
1.00	2089	0.0017					1.4578	0.00032	-0.0084
1.05	2069	.0015	2.204	0.0007	50.7	0.0007	1.4493	.00028	- .0076
1.20	2013	.0011	1.277	.0004	97.4	.0006	1.4276	.00021	- .0057
1.40	1950	.0008	1.070	.0002	131.3	.0005	1.4052	.00015	- .0041
1.60	1896	.0005	1.013	.0001	154.1	.0004	1.3879	.00010	- .0030
1.82	1846	.0004	1.000	.0000	172.5	.0004	1.3729	.00007	- .0022
2.00	1808	.0003	1.006	-.0001	185.1	.0003	1.3623	.00006	- .0017
4.00	1553	-.0001	1.266	-.0002	252.5	.0002	1.3008	.00001	- .0002
4.08	1546	-.0001	1.278	-.0002	254.1	.0002	1.2992	.00001	- .0002
10.00	1258	-.0001	2.085	-.0002	310.4	.0001	1.2337	.00000	.0000
20.00	1064	-.0002	3.207	-.0001	341.6	.0001	1.1891	.00000	.0000
40.00	896	-.0002	5.038	-.0001	365.9	.0001	1.1531	.00000	.0000
100.00	708	-.0002	9.326	-.0001	390.5	.0000	1.1174	.00000	.0000
200.00	590	-.0002	14.995	-.0001	404.8	.0000	1.1006	.00000	.0000
400.00	490	-.0002	24.237	-.0001	416.3	.0000	1.0867	.00000	.0000
1000.00	383	-.0002	46.005	-.0001	428.3	.0000	1.0745	.00000	.0000
2000.00	317	-.0002	74.922	-.0001	435.4	.0000	1.0643	.00000	.0000
4000.00	262	-.0002	122.202	-.0001	441.2	.0000	1.0526	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Continued. Combustion-chamber pressure, 60 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ϵ	Area-ratio exponent, n_ϵ	Specific impulse, I, (lb)(sec)/lb	Specific impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_p$
R = 0.35, PERCENT FUEL = 26.47, O/F = 2.778									
1.00	2329	0.0052					1.4897	0.00122	-0.0294
1.05	2309	.0048	2.189	0.0018	50.7	0.0020	1.4752	.00112	- .0273
1.20	2253	.0039	1.270	.0012	97.5	.0018	1.4382	.00089	- .0220
1.40	2189	.0030	1.067	.0007	131.5	.0016	1.3999	.00067	- .0170
1.60	2133	.0023	1.012	.0003	154.4	.0014	1.3707	.00051	- .0134
1.80	2085	.0018	1.000	.0000	171.8	.0013	1.3475	.00040	- .0107
2.00	2042	.0014	1.007	-.0002	185.6	.0012	1.3289	.00032	- .0087
4.00	1772	-.0001	1.277	-.0010	253.8	.0007	1.2391	.00006	- .0018
4.08	1764	-.0001	1.289	-.0010	255.4	.0007	1.2371	.00005	- .0017
10.00	1452	-.0005	2.121	-.0010	312.8	.0004	1.1665	.00000	- .0001
20.00	1239	-.0006	3.285	-.0009	345.0	.0002	1.1208	.00000	.0000
40.00	1051	-.0006	5.194	-.0009	370.1	.0002	1.0795	.00000	.0000
100.00	838	-.0006	9.687	-.0008	395.7	.0002	1.0366	.00000	.0000
200.00	703	-.0006	15.643	-.0008	410.7	.0002	1.0120	.00000	.0000
400.00	587	-.0006	25.377	-.0008	422.9	.0002	.9954	.00000	.0000
1000.00	460	-.0007	48.339	-.0008	435.5	.0001	.9790	.00000	.0000
2000.00	382	-.0007	78.934	-.0008	443.0	.0001	.9694	.00000	.0000
4000.00	317	-.0007	129.082	-.0008	449.2	.0000	.9600	.00000	.0000
R = 0.40, PERCENT FUEL = 23.95, O/F = 3.175									
1.00	2531	0.0105					1.6075	0.00316	-0.0710
1.05	2512	.0100	2.173	0.0029	50.4	0.0035	1.5870	.00296	- .0671
1.20	2458	.0086	1.263	.0021	96.9	.0033	1.5334	.00248	- .0571
1.40	2396	.0071	1.063	.0012	130.8	.0034	1.4758	.00198	- .0469
1.60	2342	.0059	1.010	.0005	153.8	.0033	1.4300	.00162	- .0390
1.78	2298	.0050	1.000	.0000	169.9	.0031	1.3954	.00136	- .0332
2.00	2252	.0041	1.008	-.0005	184.9	.0028	1.3620	.00112	- .0279
4.00	1978	.0004	1.289	-.0026	253.7	.0011	1.2147	.00028	- .0079
4.08	1970	.0004	1.302	-.0026	255.3	.0011	1.2116	.00027	- .0076
10.00	1640	-.0011	2.160	-.0031	313.6	.0010	1.1161	.00003	- .0009
20.00	1411	-.0014	3.365	-.0030	346.5	.0008	1.0681	.00000	- .0001
40.00	1207	-.0015	5.356	-.0029	372.4	.0008	1.0259	.00000	.0000
100.00	972	-.0015	10.068	-.0028	398.9	.0006	.9772	.00000	.0000
200.00	820	-.0016	16.345	-.0028	414.5	.0005	.9481	.00000	.0000
400.00	689	-.0016	26.628	-.0027	427.3	.0004	.9252	.00000	.0000
1000.00	543	-.0017	50.955	-.0027	440.6	.0003	.9041	.00000	.0000
2000.00	453	-.0017	83.421	-.0027	448.5	.0003	.8930	.00000	.0000
4000.00	377	-.0017	136.777	-.0027	455.1	.0003	.8834	.00000	.0000
R = 0.45, PERCENT FUEL = 21.87, O/F = 3.571									
1.00	2696	0.0164					1.7899	0.00627	-0.1342
1.05	2678	.0158	2.159	0.0033	49.9	0.0066	1.7649	.00597	- .1286
1.20	2628	.0143	1.257	.0025	96.0	.0059	1.6982	.00519	- .1137
1.40	2570	.0126	1.060	.0015	129.6	.0054	1.6247	.00438	- .0977
1.60	2519	.0111	1.009	.0006	152.4	.0052	1.5642	.00374	- .0849
1.77	2481	.0100	1.000	.0000	167.2	.0050	1.5208	.00330	- .0759
2.00	2434	.0087	1.010	-.0008	183.5	.0047	1.4702	.00281	- .0657
4.00	2167	.0024	1.303	-.0044	252.4	.0031	1.2440	.00095	- .0246
4.08	2159	.0023	1.316	-.0045	254.0	.0031	1.2389	.00091	- .0237
10.00	1822	-.0016	2.204	-.0064	313.0	.0020	1.0871	.00013	- .0040
20.00	1581	-.0025	3.454	-.0066	346.5	.0011	1.0282	.00002	- .0006
40.00	1362	-.0027	5.529	-.0064	373.1	.0011	.9843	.00000	- .0001
100.00	1109	-.0029	10.479	-.0062	400.5	.0009	.9335	.00000	.0000
200.00	942	-.0030	17.107	-.0061	416.8	.0008	.9005	.00000	.0000
400.00	796	-.0031	28.011	-.0061	430.1	.0008	.8733	.00000	.0000
1000.00	632	-.0032	53.887	-.0061	444.1	.0008	.8469	.00000	.0000
2000.00	529	-.0033	88.516	-.0061	452.5	.0008	.8317	.00000	.0000
4000.00	441	-.0033	145.512	-.0060	459.4	.0008	.8212	.00000	.0000
R = 0.50, PERCENT FUEL = 20.12, O/F = 3.968									
1.00	2828	0.0218					2.0170	0.01049	-0.2173
1.05	2811	.0213	2.147	0.0033	49.2	0.0077	1.9891	.01009	- .2101
1.20	2765	.0198	1.251	.0024	94.7	.0071	1.9138	.00904	- .1908
1.40	2711	.0181	1.057	.0015	128.0	.0070	1.8287	.00789	- .1696
1.60	2664	.0166	1.008	.0006	150.6	.0070	1.7571	.00697	- .1520
1.76	2632	.0156	1.000	.0000	164.2	.0069	1.7087	.00637	- .1403
2.00	2585	.0140	1.012	-.0009	181.4	.0066	1.6426	.00557	- .1247
4.00	2335	.0062	1.317	-.0055	250.2	.0050	1.3401	.00237	- .0580
4.08	2327	.0060	1.331	-.0056	251.8	.0050	1.3326	.00230	- .0565
10.00	1996	-.0012	2.252	-.0097	311.3	.0030	1.0939	.00048	- .0135
20.00	1748	-.0035	3.552	-.0107	345.4	.0020	1.0036	.00009	- .0030
40.00	1518	-.0043	5.719	-.0107	372.6	.0020	.9523	.00001	- .0004
100.00	1247	-.0046	10.920	-.0105	400.8	.0010	.9003	.00000	.0000
200.00	1067	-.0048	17.932	-.0104	417.7	.0010	.8650	.00000	.0000
400.00	907	-.0050	29.520	-.0103	431.6	.0000	.8347	.00000	.0000
1000.00	727	-.0052	57.146	-.0103	446.3	.0000	.8023	.00000	.0000
2000.00	611	-.0053	94.228	-.0103	455.1	.0000	.7848	.00000	.0000
4000.00	512	-.0054	155.405	-.0103	462.4	.0000	.7703	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Continued. Combustion-chamber pressure, 60 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 0.60, PERCENT FUEL = 17.35, O/F = 4.762									
1.00	3015	0.0304					2.5641	0.02196	-0.4374
1.05	3001	.0300	2.131	0.0026	47.7	0.0108	2.5343	.02139	- .4278
1.20	2961	.0288	1.244	.0020	91.9	.0106	2.4522	.01985	- .4019
1.40	2914	.0274	1.054	.0012	124.2	.0103	2.3566	.01813	- .3722
1.60	2874	.0262	1.006	.0005	146.2	.0101	2.2736	.01668	- .3469
1.74	2849	.0254	1.000	.0000	158.0	.0100	2.2225	.01582	- .3315
2.00	2807	.0240	1.014	-.0008	176.3	.0097	2.1350	.01439	- .3055
4.00	2595	.0165	1.339	-.0032	244.1	.0085	1.7214	.00832	- .1889
4.08	2588	.0162	1.354	-.0034	245.7	.0084	1.7099	.00816	- .1858
10.00	2299	.0053	2.346	-.0120	305.5	.0067	1.2736	.00301	- .0756
20.00	2063	-.0021	3.762	-.0165	340.5	.0054	1.0527	.00101	- .0278
40.00	1825	-.0064	6.136	-.0169	368.8	.0042	.9310	.00024	- .0074
100.00	1529	-.0084	11.885	-.0195	398.6	.0030	.8551	.00002	- .0007
200.00	1326	-.0089	19.729	-.0193	416.6	.0024	.8178	.00000	- .0001
400.00	1144	-.0093	32.844	-.0192	431.6	.0019	.7842	.00000	.0000
1000.00	932	-.0098	64.475	-.0193	447.7	.0015	.7449	.00000	.0000
2000.00	792	-.0101	107.316	-.0193	457.5	.0012	.7201	.00000	.0000
4000.00	670	-.0104	178.419	-.0194	465.6	.0010	.7001	.00000	.0000
R = 0.70, PERCENT FUEL = 15.25, O/F = 5.556									
1.00	3128	0.0362					3.1609	0.03650	-0.7110
1.05	3114	.0358	2.122	0.0020	46.1	0.0126	3.1356	.03584	- .7011
1.20	3078	.0349	1.240	.0015	88.9	.0125	3.0646	.03406	- .6738
1.40	3037	.0339	1.051	.0009	120.2	.0123	2.9793	.03201	- .6417
1.60	3001	.0329	1.005	.0003	141.5	.0121	2.9028	.03026	- .6135
1.73	2981	.0324	1.000	.0000	152.2	.0120	2.8581	.02927	- .5973
2.00	2943	.0313	1.015	-.0006	170.8	.0118	2.7698	.02738	- .5657
4.00	2761	.0255	1.353	-.0040	237.0	.0106	2.3262	.01894	- .4152
4.08	2756	.0254	1.369	-.0041	238.6	.0108	2.3126	.01870	- .4108
10.00	2517	.0180	2.414	-.0099	297.8	.0094	1.7290	.00970	- .2309
20.00	2320	.0071	3.943	-.0155	333.0	.0082	1.3390	.00478	- .1218
40.00	2108	-.0021	6.551	-.0215	362.1	.0069	1.0559	.00183	- .0505
100.00	1813	-.0103	12.932	-.0265	391.3	.0053	.8583	.00031	- .0098
200.00	1596	-.0127	21.699	-.0276	412.5	.0042	.7942	.00005	- .0019
400.00	1395	-.0137	36.494	-.0277	428.6	.0034	.7553	.00001	- .0002
1000.00	1156	-.0146	72.660	-.0277	446.0	.0026	.7136	.00000	.0000
2000.00	996	-.0152	122.229	-.0279	456.8	.0022	.6848	.00000	.0000
4000.00	853	-.0158	205.254	-.0281	465.9	.0018	.6596	.00000	.0000
R = 0.80, PERCENT FUEL = 13.60, O/F = 6.349									
1.00	3188	0.0395					3.6135	0.05035	-0.9676
1.05	3175	.0392	2.117	0.0016	44.6	0.0136	3.5978	.04974	- .9597
1.20	3141	.0385	1.238	.0012	86.0	.0135	3.5527	.04808	- .9377
1.40	3103	.0377	1.050	.0007	116.3	.0133	3.4973	.04616	- .9115
1.60	3070	.0370	1.005	.0002	137.0	.0132	3.4461	.04449	- .8880
1.72	3052	.0366	1.000	.0000	147.0	.0131	3.4169	.04357	- .8748
2.00	3016	.0358	1.016	-.0005	165.3	.0130	3.3544	.04169	- .8472
4.00	2853	.0317	1.361	-.0030	229.7	.0122	3.0181	.03300	- .7089
4.08	2848	.0316	1.376	-.0030	231.2	.0122	3.0070	.03275	- .7046
10.00	2645	.0252	2.453	-.0069	289.2	.0112	2.4611	.02178	- .5040
20.00	2487	.0188	4.060	-.0110	324.1	.0103	1.9810	.01399	- .3434
40.00	2321	.0102	6.873	-.0166	353.4	.0093	1.5084	.00757	- .1977
100.00	2074	-.0038	13.944	-.0261	385.5	.0078	1.0340	.00229	- .0656
200.00	1868	-.0125	23.785	-.0319	405.7	.0065	.8417	.00065	- .0201
400.00	1658	-.0170	40.475	-.0345	422.9	.0054	.7527	.00013	- .0044
1000.00	1398	-.0191	81.660	-.0353	441.8	.0042	.6975	.00001	- .0004
2000.00	1220	-.0201	138.794	-.0355	453.6	.0035	.6676	.00000	.0000
4000.00	1058	-.0210	235.555	-.0358	463.7	.0029	.6395	.00000	.0000
R = 0.90, PERCENT FUEL = 12.28, O/F = 7.143									
1.00	3213	0.0410					3.7588	0.05880	-1.1225
1.05	3201	.0408	2.115	0.0014	43.2	0.0141	3.7501	.05827	-1.1167
1.20	3168	.0401	1.238	.0010	85.2	.0139	3.7253	.05683	-1.1004
1.40	3131	.0394	1.050	.0005	115.6	.0138	3.6942	.05515	-1.0809
1.60	3099	.0388	1.005	.0002	137.7	.0137	3.6652	.05371	-1.0639
1.72	3082	.0385	1.000	.0000	148.2	.0136	3.6487	.05293	-1.0538
2.00	3047	.0378	1.017	-.0004	166.2	.0134	3.6123	.05129	-1.0336
4.00	2892	.0346	1.364	-.0024	222.6	.0128	3.4127	.04380	- .9301
4.08	2888	.0345	1.379	-.0025	224.1	.0128	3.4059	.04358	- .9269
10.00	2701	.0300	2.470	-.0053	280.5	.0120	3.0640	.03399	- .7736
20.00	2564	.0261	4.112	-.0077	314.7	.0113	2.7328	.02668	- .6403
40.00	2429	.0214	7.032	-.0107	343.6	.0107	2.3391	.01951	- .4947
100.00	2246	.0125	14.621	-.0166	375.8	.0097	1.7259	.01052	- .2887
200.00	2095	.0019	25.591	-.0241	396.6	.0088	1.2476	.00487	- .1433
400.00	1919	-.0112	44.582	-.0335	414.7	.0077	.8980	.00150	- .0477
1000.00	1660	-.0218	91.675	-.0406	435.1	.0062	.7114	.00018	- .0064
2000.00	1468	-.0242	157.405	-.0420	448.0	.0052	.6631	.00003	- .0010
4000.00	1289	-.0256	269.819	-.0424	459.1	.0043	.6325	.00000	- .0001

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Continued. Combustion-chamber pressure, 60 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_t	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_{p_r}, cal/(g)(°K)	$\left(\frac{\partial \ln \overline{M}R}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \overline{M}R}{\partial \ln T}\right)_P$
R = 1.00, PERCENT FUEL = 11.19, O/F = 7.937									
1.00	3217	0.0412					3.6327	0.06081	-1.1607
1.05	3205	.0410	2.115	0.0014	41.9	0.0141	3.6262	.06031	-1.1555
1.20	3173	.0404	1.237	.0010	80.8	.0140	3.6075	.05894	-1.1409
1.40	3136	.0397	1.050	.0006	109.3	.0138	3.5839	.05736	-1.1235
1.60	3104	.0391	1.005	.0002	128.7	.0137	3.5618	.05599	-1.1080
1.72	3088	.0388	1.000	.0000	137.9	.0136	3.5493	.05526	-1.0995
2.00	3053	.0382	1.017	-.0004	155.4	.0135	3.5214	.05371	-1.0811
4.00	2900	.0351	1.364	-.0023	216.0	.0129	3.3683	.04671	- .9903
4.08	2896	.0350	1.380	-.0024	217.5	.0129	3.3631	.04650	- .9874
10.00	2713	.0310	2.474	-.0049	272.3	.0121	3.1047	.03772	- .8556
20.00	2579	.0277	4.124	-.0070	305.6	.0115	2.8627	.03120	- .7448
40.00	2452	.0242	7.068	-.0092	333.7	.0109	2.5882	.02502	- .6289
100.00	2287	.0187	14.785	-.0127	365.2	.0101	2.1850	.01751	- .4723
200.00	2164	.0137	26.152	-.0160	385.7	.0095	1.8612	.01248	- .3562
400.00	2037	.0075	46.510	-.0202	403.9	.0089	1.5363	.00816	- .2476
1000.00	1859	-.0030	99.697	-.0277	424.9	.0079	1.1390	.00380	- .1267
2000.00	1710	-.0127	176.636	-.0348	438.8	.0070	.8974	.00170	- .0615
4000.00	1549	-.0219	310.311	-.0417	451.0	.0061	.7318	.00058	- .0230
R = 1.50, PERCENT FUEL = 7.74, O/F = 1.905									
1.00	3116	0.0362					2.2973	0.03957	-0.7944
1.05	3103	.0359	2.117	0.0016	37.2	0.0126	2.2869	.03905	- .7873
1.20	3070	.0352	1.238	.0012	71.6	.0125	2.2574	.03763	- .7675
1.40	3031	.0344	1.050	.0007	96.8	.0123	2.2216	.03601	- .7443
1.60	2999	.0336	1.005	.0002	114.1	.0122	2.1892	.03461	- .7238
1.72	2981	.0332	1.000	.0000	122.4	.0121	2.1710	.03385	- .7124
2.00	2945	.0324	1.016	-.0005	137.7	.0120	2.1323	.03230	- .6887
4.00	2782	.0284	1.361	-.0029	191.3	.0112	1.9340	.02538	- .5752
4.08	2777	.0282	1.377	-.0030	192.6	.0112	1.9277	.02518	- .5717
10.00	2576	.0223	2.454	-.0065	240.8	.0102	1.6300	.01698	- .4190
20.00	2421	.0168	4.065	-.0099	270.0	.0094	1.3799	.01144	- .3029
40.00	2263	.0102	6.896	-.0141	294.4	.0086	1.1285	.00685	- .1965
100.00	2040	-.0003	14.098	-.0212	321.3	.0073	.8344	.00264	- .0862
200.00	1856	-.0082	24.259	-.0267	338.4	.0063	.6739	.00096	- .0355
400.00	1664	-.0139	41.606	-.0306	353.1	.0053	.5774	.00026	- .0112
1000.00	1415	-.0175	84.484	-.0326	369.3	.0041	.5156	.00003	- .0017
2000.00	1240	-.0187	144.082	-.0331	379.5	.0034	.4898	.00000	- .0003
4000.00	1080	-.0196	245.360	-.0334	388.2	.0029	.4690	.00000	.0000
R = 2.00, PERCENT FUEL = 5.92, O/F = 5.873									
1.00	2966	0.0297					1.5209	0.02254	-0.4874
1.05	2953	.0294	2.122	0.0019	34.1	0.0107	1.5098	.02210	- .4802
1.20	2917	.0285	1.240	.0014	65.7	.0106	1.4788	.02091	- .4605
1.40	2877	.0275	1.052	.0008	88.8	.0104	1.4419	.01957	- .4376
1.60	2841	.0266	1.005	.0003	104.6	.0102	1.4091	.01842	- .4178
1.73	2821	.0260	1.000	.0000	112.6	.0101	1.3901	.01778	- .4064
2.00	2783	.0250	1.015	-.0006	126.3	.0099	1.3529	.01657	- .3846
4.00	2604	.0197	1.353	-.0037	175.2	.0090	1.1688	.01130	- .2831
4.08	2599	.0196	1.368	-.0038	176.4	.0090	1.1632	.01116	- .2802
10.00	2365	.0117	2.412	-.0087	220.1	.0078	.9205	.00575	- .1616
20.00	2177	.0048	3.941	-.0131	246.1	.0067	.7501	.00286	- .0890
40.00	1978	-.0019	6.557	-.0175	267.6	.0056	.6166	.00114	- .0400
100.00	1706	-.0080	12.980	-.0214	290.7	.0043	.5100	.00022	- .0096
200.00	1505	-.0102	21.822	-.0224	305.0	.0035	.4699	.00005	- .0024
400.00	1318	-.0111	36.754	-.0227	316.9	.0029	.4457	.00001	- .0005
1000.00	1095	-.0118	73.335	-.0227	329.9	.0022	.4221	.00000	.0000
2000.00	945	-.0123	123.637	-.0228	338.0	.0018	.4064	.00000	.0000
4000.00	812	-.0128	208.163	-.0230	344.8	.0015	.3916	.00000	.0000
R = 3.00, PERCENT FUEL = 4.03, O/F = 3.810									
1.00	2655	0.0175					0.8140	0.00697	-0.1761
1.05	2640	.0171	2.140	0.0026	30.2	0.0067	.8048	.00672	- .1708
1.20	2599	.0160	1.248	.0019	58.1	.0065	.7795	.00604	- .1566
1.40	2550	.0147	1.056	.0011	78.5	.0063	.7506	.00531	- .1408
1.60	2509	.0135	1.007	.0005	92.3	.0061	.7260	.00472	- .1276
1.75	2481	.0127	1.000	.0000	100.3	.0059	.7099	.00435	- .1193
2.00	2438	.0116	1.013	-.0007	111.3	.0057	.6858	.00382	- .1070
4.00	2216	.0057	1.325	-.0043	153.7	.0046	.5739	.00175	- .0550
4.08	2209	.0055	1.339	-.0044	154.8	.0045	.5710	.00170	- .0538
10.00	1915	-.0002	2.286	-.0079	191.7	.0032	.4712	.00044	- .0165
20.00	1691	-.0026	3.629	-.0092	213.1	.0024	.4277	.00011	- .0050
40.00	1480	-.0036	5.877	-.0095	230.2	.0019	.4030	.00002	- .0012
100.00	1229	-.0040	11.319	-.0093	248.1	.0013	.3820	.00000	- .0001
200.00	1061	-.0042	18.732	-.0092	258.9	.0011	.3686	.00000	.0000
400.00	911	-.0043	31.103	-.0092	267.9	.0009	.3561	.00000	.0000
1000.00	739	-.0045	60.907	-.0092	277.4	.0006	.3403	.00000	.0000
2000.00	627	-.0047	101.211	-.0092	283.3	.0005	.3295	.00000	.0000
4000.00	529	-.0048	167.951	-.0092	288.1	.0004	.3198	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Concluded. Combustion-chamber pressure, 60 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ϵ	Area-ratio exponent, n_ϵ	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 4.00, PERCENT FUEL = 3.05, O/F = 1.746									
1.00	2347	0.0079					0.5285	0.00185	-0.0553
1.05	2330	.0075	2.165	0.0021	27.4	0.0032	.5227	.00175	- .0525
1.20	2282	.0066	1.260	.0015	52.7	.0030	.5073	.00147	- .0454
1.40	2228	.0056	1.061	.0009	71.2	.0028	.4906	.00120	- .0380
1.60	2180	.0047	1.009	.0004	83.6	.0026	.4772	.00099	- .0323
1.78	2143	.0041	1.000	.0000	92.1	.0024	.4674	.00085	- .0283
2.00	2101	.0034	1.009	-.0004	100.7	.0023	.4569	.00071	- .0242
4.00	1858	.0006	1.297	-.0021	138.3	.0016	.4102	.00021	- .0084
4.08	1851	.0006	1.311	-.0021	139.2	.0016	.4092	.00020	- .0082
10.00	1556	-.0008	2.192	-.0027	171.3	.0010	.3769	.00003	- .0015
20.00	1351	-.0011	3.439	-.0027	189.6	.0007	.3619	.00000	- .0003
40.00	1167	-.0012	5.518	-.0027	204.1	.0005	.3501	.00000	.0000
100.00	954	-.0013	10.507	-.0026	219.1	.0004	.3354	.00000	.0000
200.00	815	-.0013	17.236	-.0025	228.0	.0003	.3244	.00000	.0000
400.00	692	-.0014	28.358	-.0025	235.4	.0002	.3141	.00000	.0000
1000.00	553	-.0014	54.842	-.0025	243.2	.0002	.3013	.00000	.0000
2000.00	464	-.0015	90.278	-.0025	247.9	.0001	.2929	.00000	.0000
4000.00	387	-.0015	148.471	-.0025	251.7	.0001	.2865	.00000	.0000
R = 5.00, PERCENT FUEL = 2.45, O/F = 9.683									
1.00	2062	0.0027					0.4109	0.00043	-0.0153
1.05	2044	.0025	2.186	0.0010	25.2	0.0011	.4079	.00040	- .0142
1.20	1995	.0020	1.269	.0007	48.4	.0010	.4004	.00032	- .0116
1.40	1938	.0016	1.066	.0004	65.3	.0009	.3925	.00024	- .0091
1.60	1890	.0012	1.011	.0002	76.7	.0008	.3864	.00019	- .0073
1.80	1849	.0010	1.000	.0000	85.1	.0008	.3816	.00015	- .0060
2.00	1811	.0008	1.007	-.0001	92.2	.0007	.3775	.00012	- .0050
4.00	1578	.0000	1.282	-.0005	126.2	.0004	.3579	.00003	- .0013
4.08	1571	.0000	1.295	-.0005	127.0	.0004	.3575	.00002	- .0012
10.00	1304	-.0003	2.145	-.0006	155.7	.0002	.3413	.00000	- .0001
20.00	1122	-.0003	3.345	-.0006	171.9	.0002	.3309	.00000	.0000
40.00	961	-.0003	5.334	-.0005	184.7	.0001	.3209	.00000	.0000
100.00	778	-.0003	10.072	-.0005	197.8	.0001	.3076	.00000	.0000
200.00	659	-.0004	16.410	-.0005	205.6	.0001	.2979	.00000	.0000
400.00	555	-.0004	26.810	-.0005	212.0	.0001	.2888	.00000	.0000
1000.00	438	-.0004	51.370	-.0005	218.6	.0000	.2783	.00000	.0000
2000.00	365	-.0004	84.029	-.0005	222.6	.0000	.2728	.00000	.0000
4000.00	303	-.0004	137.526	-.0005	225.9	.0000	.2693	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Combustion-chamber pressure, 150 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, I	Specific heat, c_{pr}, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 0.15, PERCENT FUEL = 45.65, O/F = 1.190									
1.00	1183	0.0000					1.7752	0.00000	0.0000
1.05	1168	.0000	2.250	0.0000	47.4	0.0000	1.7711	.00000	.0000
1.20	1129	.0000	1.297	.0000	90.8	.0000	1.7597	.00000	.0000
1.40	1085	.0000	1.081	.0000	122.2	.0000	1.7473	.00000	.0000
1.60	1049	.0000	1.018	.0000	143.2	.0000	1.7368	.00000	.0000
1.87	1008	.0000	1.000	.0000	163.4	.0000	1.7257	.00000	.0000
2.00	989	.0000	1.003	.0000	171.5	.0000	1.7210	.00000	.0000
4.00	824	.0000	1.233	.0000	232.3	.0000	1.6825	.00000	.0000
10.00	643	.0000	1.974	.0000	283.1	.0000	1.6505	.00000	.0000
10.21	639	.0000	1.997	.0000	284.0	.0000	1.6501	.00000	.0000
20.00	532	.0000	2.982	.0000	309.9	.0000	1.6343	.00000	.0000
40.00	439	.0000	4.620	.0000	330.4	.0000	1.6269	.00000	.0000
100.00	340	.0000	8.432	.0000	350.8	.0000	1.6091	.00000	.0000
200.00	280	.0000	13.431	.0000	362.6	.0000	1.5971	.00000	.0000
400.00	230	.0000	21.488	.0000	372.0	.0000	1.5556	.00000	.0000
1000.00	175	.0000	39.928	.0000	381.6	.0000	1.4845	.00000	.0000
2000.00	142	.0000	63.572	.0000	387.2	.0000	1.4387	.00000	.0000
4000.00	114	.0000	100.938	.0000	391.6	.0000	1.4054	.00000	.0000
R = 0.20, PERCENT FUEL = 38.65, O/F = 1.587									
1.00	1514	0.0000					1.6191	0.00000	-0.0001
1.05	1497	.0000	2.233	0.0000	49.3	0.0000	1.6146	.00000	.0000
1.20	1450	.0000	1.289	.0000	94.6	.0000	1.6026	.00000	.0000
1.40	1398	.0000	1.077	.0000	127.4	.0000	1.5889	.00000	.0000
1.60	1354	.0000	1.016	.0000	149.4	.0000	1.5773	.00000	.0000
1.85	1307	.0000	1.000	.0000	169.2	.0000	1.5652	.00000	.0000
2.00	1282	.0000	1.004	.0000	179.1	.0000	1.5585	.00000	.0000
4.00	1079	.0000	1.244	.0000	243.2	.0000	1.5045	.00000	.0000
10.00	852	.0000	2.009	.0000	297.2	.0000	1.4516	.00000	.0000
10.21	847	.0000	2.033	.0000	298.2	.0000	1.4506	.00000	.0000
20.00	709	.0000	3.049	.0000	325.9	.0000	1.4232	.00000	.0000
40.00	588	.0000	4.739	.0000	348.0	.0000	1.4067	.00000	.0000
100.00	458	.0000	8.679	.0000	370.0	.0000	1.3914	.00000	.0000
200.00	379	.0000	13.870	.0000	382.7	.0000	1.3807	.00000	.0000
400.00	312	.0000	22.295	.0000	393.0	.0000	1.3677	.00000	.0000
1000.00	242	.0000	41.979	.0000	403.5	.0000	1.3402	.00000	.0000
2000.00	198	.0000	67.687	.0000	409.7	.0000	1.2958	.00000	.0000
4000.00	161	.0000	108.754	.0000	414.6	.0000	1.2580	.00000	.0000
R = 0.25, PERCENT FUEL = 33.51, O/F = 1.984									
1.00	1816	0.0002					1.5040	0.00003	-0.0009
1.05	1797	.0002	2.218	0.0001	50.3	0.0001	1.4992	.00002	- .0008
1.20	1745	.0001	1.283	.0001	96.6	.0001	1.4867	.00002	- .0005
1.40	1686	.0001	1.073	.0000	130.1	.0001	1.4730	.00001	- .0003
1.60	1636	.0000	1.015	.0000	152.7	.0000	1.4616	.00001	- .0002
1.83	1587	.0000	1.000	.0000	171.8	.0000	1.4503	.00000	- .0001
2.00	1555	.0000	1.005	.0000	183.1	.0000	1.4429	.00000	- .0001
4.00	1322	.0000	1.256	.0000	249.3	.0000	1.3875	.00000	.0000
10.00	1057	.0000	2.048	.0000	305.6	.0000	1.3225	.00000	.0000
10.21	1052	.0000	2.073	.0000	306.6	.0000	1.3213	.00000	.0000
20.00	887	.0000	3.127	.0000	335.7	.0000	1.2847	.00000	.0000
40.00	741	.0000	4.883	.0000	359.0	.0000	1.2559	.00000	.0000
100.00	581	.0000	8.985	.0000	382.4	.0000	1.2320	.00000	.0000
200.00	482	.0000	14.396	.0000	395.9	.0000	1.2190	.00000	.0000
400.00	399	.0000	23.208	.0000	406.8	.0000	1.2100	.00000	.0000
1000.00	310	.0000	43.894	.0000	418.1	.0000	1.1953	.00000	.0000
2000.00	256	.0000	71.280	.0000	424.7	.0000	1.1803	.00000	.0000
4000.00	210	.0000	115.651	.0000	430.2	.0000	1.1481	.00000	.0000
R = 0.30, PERCENT FUEL = 29.57, O/F = 2.381									
1.00	2092	0.0011					1.4348	0.00020	-0.0054
1.05	2071	.0010	2.205	0.0004	50.8	0.0004	1.4282	.00018	- .0049
1.20	2015	.0007	1.277	.0003	97.5	.0004	1.4111	.00013	- .0037
1.40	1951	.0005	1.070	.0002	131.4	.0003	1.3931	.00009	- .0026
1.60	1897	.0003	1.013	.0001	154.2	.0003	1.3786	.00007	- .0019
1.82	1846	.0002	1.000	.0000	172.6	.0002	1.3659	.00005	- .0014
2.00	1809	.0002	1.006	.0000	185.1	.0002	1.3567	.00004	- .0011
4.00	1553	-.0001	1.266	-.0001	252.5	.0001	1.2999	.00000	- .0002
10.00	1258	-.0001	2.085	-.0001	310.4	.0001	1.2337	.00000	.0000
10.21	1251	-.0001	2.111	-.0001	311.5	.0001	1.2322	.00000	.0000
20.00	1064	-.0001	3.206	-.0001	341.7	.0000	1.1891	.00000	.0000
40.00	895	-.0001	5.037	-.0001	366.0	.0000	1.1531	.00000	.0000
100.00	708	-.0001	9.325	-.0001	390.5	.0000	1.1175	.00000	.0000
200.00	590	-.0001	14.994	-.0001	404.8	.0000	1.1008	.00000	.0000
400.00	490	-.0001	24.235	-.0001	416.5	.0000	1.0868	.00000	.0000
1000.00	383	-.0001	46.002	-.0001	428.3	.0000	1.0745	.00000	.0000
2000.00	317	-.0001	74.917	-.0001	435.4	.0000	1.0637	.00000	.0000
4000.00	262	-.0001	122.193	-.0001	441.2	.0000	1.0533	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Continued. Combustion-chamber pressure, 150 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_t	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 0.35, PERCENT FUEL = 26.47, O/F = 2.778									
1.00	2339	0.0036					1.4271	0.00081	-0.0194
1.05	2317	.0033	2.192	0.0012	50.6	0.0014	1.4164	.00074	- .0180
1.20	2259	.0026	1.271	.0009	97.6	.0012	1.3889	.00058	- .0144
1.40	2195	.0020	1.067	.0005	131.6	.0011	1.3604	.00043	- .0110
1.60	2137	.0015	1.012	.0004	154.6	.0010	1.3385	.00033	- .0086
1.80	2087	.0011	1.000	.0000	172.1	.0009	1.3209	.00026	- .0069
2.00	2044	.0009	1.007	-.0001	185.7	.0008	1.3068	.00021	- .0056
4.00	1772	-.0001	1.276	-.0006	264.0	.0005	1.2337	.00004	- .0011
10.00	1451	-.0003	2.120	-.0006	312.9	.0003	1.1659	.00000	- .0001
10.21	1444	-.0003	2.147	-.0006	314.0	.0003	1.1645	.00000	- .0001
20.00	1239	-.0004	3.282	-.0006	345.1	.0002	1.1206	.00000	.0000
40.00	1051	-.0004	5.191	-.0005	370.2	.0001	1.0794	.00000	.0000
100.00	838	-.0004	9.681	-.0005	395.8	.0001	1.0366	.00000	.0000
200.00	702	-.0004	15.634	-.0005	410.8	.0001	1.0119	.00000	.0000
400.00	586	-.0004	25.362	-.0005	422.9	.0001	.9953	.00000	.0000
1000.00	460	-.0004	48.312	-.0005	435.5	.0000	.9789	.00000	.0000
2000.00	382	-.0004	78.890	-.0005	443.0	.0000	.9694	.00000	.0000
4000.00	317	-.0004	129.010	-.0005	449.2	.0000	.9587	.00000	.0000
R = 0.40, PERCENT FUEL = 23.95, O/F = 3.175									
1.00	2553	0.0078					1.4879	0.00219	-0.0489
1.05	2532	.0074	2.178	0.0022	50.6	0.0029	1.4725	.00205	- .0460
1.20	2475	.0063	1.265	.0016	97.2	.0027	1.4323	.00169	- .0388
1.40	2410	.0051	1.064	.0009	131.2	.0025	1.3894	.00134	- .0315
1.60	2353	.0041	1.011	.0004	154.1	.0023	1.3555	.00108	- .0259
1.79	2306	.0034	1.000	.0000	170.6	.0021	1.3293	.00090	- .0219
2.00	2260	.0028	1.008	-.0004	185.3	.0020	1.3052	.00074	- .0183
4.00	1978	.0002	1.286	-.0017	264.0	.0013	1.1954	.00018	- .0050
10.00	1638	-.0006	2.155	-.0021	313.9	.0007	1.1133	.00002	- .0005
10.21	1631	-.0008	2.182	-.0021	315.0	.0007	1.1119	.00001	- .0005
20.00	1410	-.0010	3.338	-.0020	346.7	.0005	1.0674	.00000	- .0001
40.00	1206	-.0010	5.344	-.0019	372.5	.0004	1.0256	.00000	.0000
100.00	971	-.0011	10.047	-.0018	399.0	.0003	.9769	.00000	.0000
200.00	819	-.0011	16.311	-.0018	414.6	.0002	.9479	.00000	.0000
400.00	688	-.0011	26.573	-.0018	427.4	.0002	.9251	.00000	.0000
1000.00	543	-.0011	50.851	-.0018	440.6	.0001	.9040	.00000	.0000
2000.00	452	-.0012	83.253	-.0018	448.6	.0001	.8930	.00000	.0000
4000.00	376	-.0012	136.502	-.0018	455.1	.0001	.8832	.00000	.0000
R = 0.45, PERCENT FUEL = 21.87, O/F = 3.571									
1.00	2733	0.0131					1.6077	0.00457	-0.0965
1.05	2713	.0126	2.185	0.0030	50.1	0.0048	1.5881	.00433	- .0921
1.20	2659	.0112	1.259	.0022	96.4	.0045	1.5361	.00372	- .0806
1.40	2598	.0096	1.061	.0013	130.2	.0042	1.4792	.00309	- .0684
1.60	2542	.0083	1.009	.0006	153.0	.0040	1.4330	.00261	- .0586
1.77	2499	.0073	1.000	.0000	168.4	.0038	1.3991	.00227	- .0519
2.00	2451	.0063	1.009	-.0006	184.2	.0036	1.3621	.00192	- .0447
4.00	2171	.0014	1.298	-.0033	253.0	.0025	1.1951	.00061	- .0159
10.00	1819	-.0013	2.193	-.0046	313.5	.0015	1.0768	.00008	- .0025
10.21	1812	-.0013	2.221	-.0046	314.7	.0015	1.0750	.00008	- .0024
20.00	1578	-.0018	3.448	-.0046	346.9	.0011	1.0258	.00001	- .0004
40.00	1359	-.0020	5.502	-.0045	373.4	.0008	.9835	.00000	.0000
100.00	1108	-.0021	10.428	-.0043	400.7	.0006	.9330	.00000	.0000
200.00	939	-.0022	17.026	-.0043	417.0	.0005	.9001	.00000	.0000
400.00	794	-.0023	27.879	-.0043	430.2	.0004	.8730	.00000	.0000
1000.00	631	-.0023	53.635	-.0042	444.2	.0003	.8467	.00000	.0000
2000.00	528	-.0024	88.103	-.0042	452.6	.0002	.8316	.00000	.0000
4000.00	440	-.0024	144.834	-.0042	459.5	.0002	.8211	.00000	.0000
R = 0.50, PERCENT FUEL = 20.12, O/F = 3.968									
1.00	2881	0.0185					1.7727	0.00757	-0.1623
1.05	2862	.0179	2.153	0.0032	49.6	0.0066	1.7501	.00764	- .1564
1.20	2811	.0165	1.254	.0024	95.3	.0064	1.6893	.00676	- .1407
1.40	2752	.0148	1.059	.0014	128.8	.0061	1.6211	.00583	- .1234
1.60	2701	.0133	1.006	.0008	151.5	.0058	1.5642	.00509	- .1096
1.76	2664	.0123	1.000	.0000	165.6	.0056	1.5246	.00459	- .1001
2.00	2615	.0109	1.011	-.0008	182.4	.0054	1.4743	.00399	- .0883
4.00	2348	.0042	1.311	-.0046	251.2	.0041	1.2448	.00159	- .0388
10.00	1994	-.0013	2.215	-.0076	312.2	.0027	1.0652	.00030	- .0084
10.21	1986	-.0014	2.264	-.0076	313.3	.0027	1.0625	.00029	- .0080
20.00	1743	-.0028	3.522	-.0061	346.1	.0020	.9956	.00006	- .0018
40.00	1512	-.0035	5.670	-.0050	373.2	.0015	.9502	.00001	- .0003
100.00	1242	-.0035	10.629	-.0038	401.3	.0011	.8994	.00000	.0000
200.00	1063	-.0036	17.784	-.0038	418.1	.0008	.8642	.00000	.0000
400.00	904	-.0038	29.278	-.0037	431.9	.0007	.8340	.00000	.0000
1000.00	724	-.0039	56.678	-.0037	446.5	.0005	.8019	.00000	.0000
2000.00	606	-.0040	93.457	-.0037	455.3	.0004	.7843	.00000	.0000
4000.00	510	-.0041	154.133	-.0037	462.6	.0003	.7700	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Continued. Combustion-chamber pressure, 150 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ϵ	Area-ratio exponent, n_ϵ	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 0.60, PERCENT FUEL = 17.35, O/F = 4.762									
1.00	3097	0.0278					2.2005	0.01775	-0.3453
1.05	3081	.0273	2.136	0.0028	48.2	0.0097	2.1752	.01724	- .3370
1.20	3036	.0260	1.247	.0021	92.7	.0095	2.1055	.01587	- .3143
1.40	2985	.0245	1.055	.0012	125.3	.0092	2.0248	.01435	- .2887
1.60	2940	.0232	1.007	.0005	147.5	.0090	1.9551	.01310	- .2669
1.74	2911	.0223	1.000	.0000	159.9	.0088	1.9107	.01232	- .2533
2.00	2865	.0208	1.013	-.0008	177.8	.0086	1.8396	.01112	- .2318
4.00	2630	.0131	1.333	-.0053	245.9	.0073	1.5032	.00605	- .1359
10.00	2308	.0028	2.321	-.0113	307.2	.0056	1.1596	.00198	- .0496
10.71	2300	.0026	2.352	-.0115	308.4	.0055	1.1536	.00192	- .0483
20.00	2058	-.0028	3.708	-.0146	342.0	.0044	1.0010	.00062	- .0171
40.00	1815	-.0056	6.038	-.0159	370.1	.0034	.9136	.00014	- .0043
100.00	1518	-.0068	11.693	-.0161	399.6	.0024	.8515	.00001	- .0004
200.00	1317	-.0072	19.413	-.0160	417.4	.0019	.8157	.00000	.0000
400.00	1135	-.0075	32.319	-.0159	432.3	.0016	.7825	.00000	.0000
1000.00	924	-.0079	63.444	-.0159	448.2	.0012	.7435	.00000	.0000
2000.00	786	-.0082	105.595	-.0160	457.9	.0010	.7189	.00000	.0000
4000.00	665	-.0084	175.548	-.0160	466.0	.0008	.6994	.00000	.0000
R = 0.70, PERCENT FUEL = 15.25, O/F = 5.556									
1.00	3231	0.0345					2.7036	0.03093	-0.5863
1.05	3216	.0342	2.126	0.0022	46.7	0.0118	2.6809	.03031	- .5771
1.20	3176	.0332	1.242	.0016	89.8	.0117	2.6171	.02863	- .5518
1.40	3130	.0320	1.052	.0010	121.5	.0115	2.5409	.02672	- .5222
1.60	3091	.0309	1.006	.0004	143.1	.0113	2.4728	.02509	- .4963
1.73	3068	.0303	1.000	.0000	154.2	.0112	2.4318	.02414	- .4809
2.00	3025	.0291	1.015	-.0007	172.6	.0109	2.3550	.02242	- .4527
4.00	2823	.0227	1.348	-.0044	239.3	.0099	1.9694	.01481	- .3188
10.00	2550	.0123	2.391	-.0105	300.2	.0084	1.4750	.00697	- .1640
10.21	2544	.0121	2.425	-.0107	301.4	.0083	1.4650	.00683	- .1610
20.00	2331	.0036	3.886	-.0160	335.4	.0071	1.1743	.00316	- .0801
40.00	2102	-.0040	6.425	-.0207	364.2	.0059	.9713	.00111	- .0305
100.00	1797	-.0095	12.637	-.0237	395.0	.0044	.8358	.00017	- .0054
200.00	1579	-.0110	21.191	-.0241	413.9	.0035	.7871	.00003	- .0010
400.00	1379	-.0117	35.638	-.0241	429.8	.0029	.7520	.00000	- .0001
1000.00	1142	-.0124	70.952	-.0242	447.0	.0022	.7111	.00000	.0000
2000.00	983	-.0129	119.341	-.0243	457.6	.0018	.6825	.00000	.0000
4000.00	841	-.0134	200.371	-.0245	466.6	.0015	.6576	.00000	.0000
R = 0.80, PERCENT FUEL = 13.60, O/F = 6.349									
1.00	3304	0.0387					3.1245	0.04443	-0.8285
1.05	3290	.0384	2.121	0.0017	45.2	0.0131	3.1098	.04384	- .8209
1.20	3253	.0376	1.240	.0012	87.0	.0129	3.0677	.04222	- .7997
1.40	3211	.0367	1.051	.0007	117.7	.0128	3.0158	.04035	- .7744
1.60	3174	.0359	1.005	.0003	138.6	.0126	2.9681	.03872	- .7517
1.72	3154	.0355	1.000	.0000	148.9	.0125	2.9401	.03781	- .7387
2.00	3115	.0345	1.016	-.0005	167.3	.0124	2.8824	.03601	- .7125
4.00	2935	.0299	1.357	-.0032	232.2	.0116	2.5693	.02763	- .5803
10.00	2704	.0224	2.437	-.0077	292.0	.0105	2.0604	.01710	- .3892
10.21	2699	.0222	2.472	-.0078	293.2	.0104	2.0482	.01688	- .3849
20.00	2526	.0150	4.017	-.0123	327.1	.0095	1.6425	.01020	- .2476
40.00	2338	.0056	6.763	-.0183	356.3	.0084	1.2625	.00500	- .1301
100.00	2064	-.0069	13.610	-.0265	388.1	.0068	.9242	.00131	- .0377
200.00	1846	-.0128	23.116	-.0302	408.0	.0056	.7993	.00034	- .0106
400.00	1634	-.0155	39.267	-.0315	424.9	.0046	.7393	.00006	- .0022
1000.00	1375	-.0169	79.186	-.0318	443.4	.0036	.6930	.00000	- .0002
2000.00	1199	-.0177	134.569	-.0320	455.0	.0030	.6639	.00000	.0000
4000.00	1039	-.0185	226.324	-.0322	464.6	.0025	.6361	.00000	.0000
R = 0.90, PERCENT FUEL = 12.28, O/F = 7.143									
1.00	3336	0.0406					3.2851	0.05319	-0.9836
1.05	3322	.0404	2.118	0.0015	43.8	0.0136	3.2773	.05266	- .9781
1.20	3286	.0397	1.239	.0011	84.3	.0135	3.2547	.05127	- .9625
1.40	3246	.0389	1.051	.0006	114.0	.0134	3.2263	.04965	- .9439
1.60	3211	.0383	1.005	.0002	134.3	.0132	3.1997	.04824	- .9273
1.72	3192	.0379	1.000	.0000	144.2	.0132	3.1843	.04747	- .9179
2.00	3154	.0372	1.016	-.0004	162.1	.0130	3.1513	.04589	- .8963
4.00	2984	.0335	1.360	-.0025	225.2	.0124	2.9668	.03662	- .7996
10.00	2775	.0266	2.457	-.0056	283.5	.0115	2.6406	.02912	- .6491
10.21	2770	.0264	2.493	-.0057	284.6	.0115	2.6322	.02891	- .6455
20.00	2623	.0241	4.082	-.0083	317.9	.0108	2.3275	.02207	- .5209
40.00	2474	.0185	6.960	-.0118	346.9	.0101	1.9560	.01523	- .3817
100.00	2267	.0076	14.365	-.0190	375.0	.0090	1.3985	.00709	- .1940
200.00	2092	-.0040	24.996	-.0271	399.6	.0080	1.0225	.00275	- .0812
400.00	1896	-.0144	43.709	-.0344	417.5	.0068	.8018	.00073	- .0234
1000.00	1628	-.0205	80.419	-.0361	437.4	.0054	.6923	.00008	- .0029
2000.00	1437	-.0221	151.666	-.0357	450.0	.0045	.6560	.00001	- .0004
4000.00	1261	-.0232	259.926	-.0370	460.6	.0036	.6277	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Continued. Combustion-chamber pressure, 150 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 1.00, PERCENT FUEL = 11.19, O/F = 7.937									
1.00	3341	0.0410					3.1852	0.05537	-1.0233
1.05	3328	.0407	2.118	0.0014	42.5	0.0137	3.1796	.05488	-1.0184
1.20	3292	.0401	1.238	.0010	81.8	.0136	3.1630	.05356	-1.0046
1.40	3252	.0394	1.050	.0006	110.7	.0134	3.1421	.05203	- .9883
1.60	3217	.0387	1.005	.0002	130.3	.0133	3.1225	.05071	- .9736
1.72	3199	.0384	1.000	.0000	139.8	.0132	3.1111	.04999	- .9654
2.00	3161	.0377	1.016	-.0004	157.3	.0131	3.0866	.04851	- .9483
4.00	2994	.0344	1.361	-.0024	218.6	.0125	2.9493	.04178	- .8627
10.00	2789	.0299	2.462	-.0051	275.3	.0117	2.7109	.03318	- .7361
10.21	2785	.0298	2.498	-.0051	276.4	.0117	2.7049	.03300	- .7331
20.00	2644	.0264	4.097	-.0073	308.7	.0111	2.4914	.02701	- .6325
40.00	2505	.0224	7.007	-.0097	337.0	.0105	2.2430	.02121	- .5248
100.00	2325	.0164	14.608	-.0135	368.5	.0096	1.8808	.01429	- .3815
200.00	2188	.0108	25.757	-.0172	389.0	.0090	1.5942	.00978	- .2777
400.00	2048	.0040	45.624	-.0218	407.1	.0082	1.3134	.00606	- .1838
1000.00	1850	-.0070	97.111	-.0295	427.8	.0072	.9862	.00255	- .0857
2000.00	1688	-.0158	170.978	-.0360	441.5	.0064	.8018	.00103	- .0380
4000.00	1517	-.0229	298.702	-.0412	453.4	.0055	.6840	.00032	- .0129
R = 1.50, PERCENT FUEL = 7.74, O/F = 1.905									
1.00	3219	0.0350					1.9992	0.03449	-0.6756
1.05	3206	.0347	2.120	0.0017	37.6	0.0120	1.9899	.03400	- .6690
1.20	3169	.0340	1.240	.0012	72.4	.0119	1.9637	.03266	- .6507
1.40	3127	.0331	1.051	.0007	97.9	.0117	1.9320	.03114	- .6292
1.60	3091	.0323	1.005	.0003	115.3	.0116	1.9032	.02983	- .6103
1.72	3071	.0318	1.000	.0000	123.9	.0115	1.8866	.02910	- .5995
2.00	3031	.0309	1.016	-.0005	139.2	.0113	1.8526	.02767	- .5780
4.00	2853	.0265	1.357	-.0030	193.2	.0106	1.6765	.02125	- .4742
10.00	2626	.0199	2.439	-.0069	243.0	.0095	1.4088	.01364	- .3340
10.21	2621	.0197	2.474	-.0070	244.0	.0095	1.4026	.01348	- .3309
20.00	2455	.0140	4.027	-.0105	272.2	.0087	1.1931	.00880	- .2329
40.00	2281	.0071	6.805	-.0149	296.6	.0078	.9827	.00498	- .1440
100.00	2037	-.0027	13.824	-.0214	323.4	.0065	.7495	.00176	- .0586
200.00	1842	-.0092	23.681	-.0258	340.3	.0055	.6298	.00060	- .0229
400.00	1644	-.0133	40.495	-.0284	354.7	.0046	.5593	.00016	- .0071
1000.00	1393	-.0158	82.105	-.0297	370.6	.0036	.5103	.00002	- .0010
2000.00	1220	-.0167	139.978	-.0300	380.6	.0030	.4869	.00000	- .0002
4000.00	1062	-.0175	236.311	-.0302	389.2	.0025	.4666	.00000	.0000
R = 2.00, PERCENT FUEL = 5.92, O/F = 5.873									
1.00	3045	0.0278					1.3351	0.01897	-0.4038
1.05	3031	.0275	2.126	0.0020	34.4	0.0100	1.3254	.01858	- .3974
1.20	2992	.0266	1.242	.0015	66.3	.0098	1.2984	.01750	- .3799
1.40	2947	.0255	1.052	.0009	89.7	.0096	1.2665	.01629	- .3596
1.60	2909	.0245	1.006	.0003	105.6	.0094	1.2381	.01526	- .3420
1.73	2886	.0239	1.000	.0000	113.8	.0093	1.2211	.01467	- .3316
2.00	2845	.0229	1.015	-.0006	127.4	.0091	1.1894	.01361	- .3127
4.00	2649	.0174	1.348	-.0038	176.6	.0082	1.0314	.00899	- .2244
10.00	2388	.0092	2.393	-.0087	221.6	.0069	.8231	.00434	- .1226
10.21	2382	.0091	2.427	-.0088	222.4	.0069	.8187	.00425	- .1206
20.00	2184	.0028	3.895	-.0128	247.5	.0059	.6852	.00206	- .0650
40.00	1974	-.0028	6.456	-.0164	268.9	.0049	.5809	.00079	- .0282
100.00	1694	-.0074	12.741	-.0192	291.8	.0037	.4985	.00015	- .0066
200.00	1492	-.0090	21.403	-.0199	305.9	.0030	.4656	.00003	- .0017
400.00	1305	-.0097	36.042	-.0200	317.7	.0024	.4438	.00001	- .0003
1000.00	1084	-.0103	71.914	-.0200	330.6	.0019	.4209	.00000	.0000
2000.00	935	-.0107	121.231	-.0201	338.5	.0015	.4053	.00000	.0000
4000.00	803	-.0111	204.087	-.0202	345.2	.0013	.3906	.00000	.0000
R = 3.00, PERCENT FUEL = 4.03, O/F = 3.810									
1.00	2695	0.0153					0.7383	0.00555	-0.1399
1.05	2679	.0149	2.145	0.0025	30.3	0.0059	.7306	.00533	- .1355
1.20	2634	.0138	1.251	.0018	58.4	.0057	.7094	.00477	- .1236
1.40	2582	.0125	1.057	.0011	78.9	.0054	.6854	.00416	- .1105
1.60	2537	.0114	1.007	.0004	92.8	.0052	.6650	.00368	- .0997
1.75	2507	.0107	1.000	.0000	101.1	.0051	.6513	.00337	- .0927
2.00	2462	.0096	1.012	-.0006	111.9	.0049	.6319	.00295	- .0830
4.00	2226	.0044	1.320	-.0038	154.3	.0038	.5411	.00131	- .0417
10.00	1914	-.0004	2.271	-.0067	192.3	.0027	.4589	.00032	- .0123
10.21	1907	-.0005	2.301	-.0067	193.0	.0026	.4575	.00031	- .0119
20.00	1687	-.0022	3.601	-.0076	213.5	.0020	.4232	.00008	- .0038
40.00	1475	-.0030	5.831	-.0076	230.6	.0015	.4015	.00002	- .0009
100.00	1224	-.0033	11.252	-.0077	248.4	.0011	.3816	.00000	- .0001
200.00	1057	-.0034	18.588	-.0076	259.1	.0009	.3682	.00000	.0000
400.00	908	-.0036	30.867	-.0075	268.1	.0007	.3559	.00000	.0000
1000.00	736	-.0037	60.444	-.0075	277.6	.0005	.3401	.00000	.0000
2000.00	629	-.0039	100.439	-.0075	283.4	.0004	.3292	.00000	.0000
4000.00	527	-.0040	166.864	-.0076	288.2	.0004	.3196	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Concluded. Combustion-chamber pressure, 150 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 4.00, PERCENT FUEL = 3.05, O/F = 1.746									
1.00	2363	0.0064					0.5005	0.00142	-0.0427
1.05	2344	.0061	2.169	0.0018	27.5	0.0026	.4958	.00134	- .0405
1.20	2295	.0053	1.261	.0013	52.8	.0024	.4833	.00112	- .0349
1.40	2238	.0044	1.062	.0007	71.3	.0022	.4699	.00091	- .0292
1.60	2188	.0037	1.010	.0003	83.8	.0021	.4590	.00075	- .0247
1.78	2149	.0032	1.000	.0000	92.4	.0020	.4509	.00064	- .0216
2.00	2107	.0027	1.009	-.0003	100.9	.0018	.4426	.00053	- .0185
4.00	1859	.0005	1.295	-.0016	138.5	.0013	.4044	.00016	- .0065
10.00	1555	-.0007	2.187	-.0021	171.5	.0008	.3757	.00002	- .0011
10.21	1549	-.0007	2.215	-.0021	172.1	.0008	.3752	.00002	- .0011
20.00	1350	-.0009	3.431	-.0021	189.7	.0006	.3616	.00000	- .0002
40.00	1166	-.0010	5.506	-.0021	204.2	.0004	.3500	.00000	.0000
100.00	953	-.0010	10.485	-.0020	219.2	.0003	.3353	.00000	.0000
200.00	814	-.0011	17.201	-.0020	228.1	.0002	.3244	.00000	.0000
400.00	691	-.0011	28.301	-.0019	235.5	.0002	.3140	.00000	.0000
1000.00	552	-.0011	54.731	-.0019	243.2	.0001	.3012	.00000	.0000
2000.00	463	-.0012	90.095	-.0020	247.9	.0001	.2928	.00000	.0000
4000.00	387	-.0012	148.169	-.0020	251.7	.0001	.2864	.00000	.0000
R = 5.00, PERCENT FUEL = 2.45, O/F = 9.683									
1.00	2066	0.0021					0.4020	0.00033	-0.0118
1.05	2048	.0020	2.188	0.0008	25.2	0.0009	.3996	.00030	- .0109
1.20	1998	.0016	1.269	.0005	48.4	.0008	.3934	.00024	- .0089
1.40	1941	.0012	1.066	.0003	65.3	.0007	.3869	.00018	- .0070
1.60	1892	.0010	1.011	.0001	76.7	.0006	.3818	.00014	- .0056
1.80	1850	.0007	1.000	.0000	85.2	.0006	.3777	.00011	- .0046
2.00	1812	.0006	1.007	-.0001	92.2	.0005	.3742	.00009	- .0038
4.00	1578	.0000	1.281	-.0004	126.2	.0003	.3570	.00002	- .0010
10.00	1303	-.0002	2.144	-.0005	155.7	.0002	.3411	.00000	- .0001
10.21	1298	-.0002	2.171	-.0005	156.3	.0002	.3408	.00000	- .0001
20.00	1122	-.0002	3.343	-.0004	171.9	.0001	.3309	.00000	.0000
40.00	961	-.0003	5.332	-.0004	184.7	.0001	.3209	.00000	.0000
100.00	778	-.0003	10.068	-.0004	197.9	.0001	.3076	.00000	.0000
200.00	658	-.0003	16.403	-.0004	205.6	.0001	.2979	.00000	.0000
400.00	554	-.0003	26.799	-.0004	212.0	.0000	.2887	.00000	.0000
1000.00	438	-.0003	51.350	-.0004	218.7	.0000	2782	.00000	.0000
2000.00	365	-.0003	83.996	-.0004	222.6	.0000	2728	.00000	.0000
4000.00	303	-.0003	137.472	-.0004	225.9	.0000	2693	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Combustion-chamber pressure, 300 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ϵ	Area-ratio exponent, n_ϵ	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 0.15, PERCENT FUEL = 45.65, O/F = 1.190									
1.00	1183	0.0000					1.7752	0.00000	0.0000
1.05	1166	.0000	2.250	0.0000	47.4	0.0000	1.7710	.00000	.0000
1.20	1129	.0000	1.297	.0000	90.8	.0000	1.7597	.00000	.0000
1.40	1085	.0000	1.081	.0000	122.2	.0000	1.7472	.00000	.0000
1.60	1049	.0000	1.018	.0000	143.2	.0000	1.7369	.00000	.0000
1.87	1008	.0000	1.000	.0000	163.4	.0000	1.7257	.00000	.0000
2.00	989	.0000	1.003	.0000	171.5	.0000	1.7210	.00000	.0000
4.00	824	.0000	1.233	.0000	232.3	.0000	1.6825	.00000	.0000
10.00	643	.0000	1.974	.0000	283.1	.0000	1.6505	.00000	.0000
20.00	532	.0000	2.982	.0000	309.9	.0000	1.6344	.00000	.0000
20.41	529	.0000	3.020	.0000	310.6	.0000	1.6339	.00000	.0000
40.00	439	.0000	4.620	.0000	330.4	.0000	1.6267	.00000	.0000
100.00	340	.0000	8.432	.0000	350.8	.0000	1.6099	.00000	.0000
200.00	280	.0000	13.431	.0000	362.6	.0000	1.5970	.00000	.0000
400.00	230	.0000	21.488	.0000	372.0	.0000	1.5571	.00000	.0000
1000.00	175	.0000	39.928	.0000	381.6	.0000	1.4840	.00000	.0000
2000.00	142	.0000	63.572	.0000	387.2	.0000	1.4387	.00000	.0000
4000.00	114	.0000	100.938	.0000	391.6	.0000	1.4046	.00000	.0000
R = 0.20, PERCENT FUEL = 38.65, O/F = 1.587									
1.00	1514	0.0000					1.6188	0.00000	0.0000
1.05	1497	.0000	2.233	0.0000	49.3	0.0000	1.6144	.00000	.0000
1.20	1450	.0000	1.289	.0000	94.6	.0000	1.6025	.00000	.0000
1.40	1398	.0000	1.077	.0000	127.4	.0000	1.5889	.00000	.0000
1.60	1354	.0000	1.016	.0000	149.4	.0000	1.5773	.00000	.0000
1.85	1307	.0000	1.000	.0000	169.2	.0000	1.5652	.00000	.0000
2.00	1282	.0000	1.004	.0000	179.1	.0000	1.5585	.00000	.0000
4.00	1079	.0000	1.244	.0000	243.2	.0000	1.5046	.00000	.0000
10.00	852	.0000	2.009	.0000	297.2	.0000	1.4516	.00000	.0000
20.00	709	.0000	3.049	.0000	325.9	.0000	1.4232	.00000	.0000
20.41	705	.0000	3.088	.0000	326.7	.0000	1.4225	.00000	.0000
40.00	588	.0000	4.739	.0000	348.0	.0000	1.4065	.00000	.0000
100.00	458	.0000	8.679	.0000	370.0	.0000	1.3913	.00000	.0000
200.00	379	.0000	13.870	.0000	382.7	.0000	1.3807	.00000	.0000
400.00	312	.0000	22.296	.0000	393.0	.0000	1.3677	.00000	.0000
1000.00	242	.0000	41.979	.0000	403.5	.0000	1.3402	.00000	.0000
2000.00	198	.0000	67.687	.0000	409.7	.0000	1.2977	.00000	.0000
4000.00	161	.0000	108.755	.0000	414.6	.0000	1.2571	.00000	.0000
R = 0.25, PERCENT FUEL = 33.51, O/F = 1.984									
1.00	1817	0.0001					1.5015	0.00002	-0.0006
1.05	1797	.0001	2.218	0.0001	50.3	0.0001	1.4971	.00002	- .0005
1.20	1745	.0001	1.283	.0000	96.6	.0000	1.4852	.00001	- .0004
1.40	1686	.0000	1.073	.0000	130.1	.0000	1.4719	.00001	- .0002
1.60	1636	.0000	1.015	.0000	152.7	.0000	1.4609	.00000	- .0002
1.83	1587	.0000	1.000	.0000	171.8	.0000	1.4498	.00000	- .0001
2.00	1555	.0000	1.005	.0000	183.1	.0000	1.4425	.00000	- .0001
4.00	1322	.0000	1.256	.0000	249.3	.0000	1.3875	.00000	.0000
10.00	1057	.0000	2.048	.0000	305.6	.0000	1.3226	.00000	.0000
20.00	887	.0000	3.127	.0000	335.7	.0000	1.2849	.00000	.0000
20.41	882	.0000	3.168	.0000	336.5	.0000	1.2838	.00000	.0000
40.00	741	.0000	4.883	.0000	359.0	.0000	1.2560	.00000	.0000
100.00	581	.0000	8.985	.0000	382.4	.0000	1.2321	.00000	.0000
200.00	482	.0000	14.396	.0000	395.9	.0000	1.2192	.00000	.0000
400.00	399	.0000	23.208	.0000	406.8	.0000	1.2099	.00000	.0000
1000.00	310	.0000	43.894	.0000	418.1	.0000	1.1949	.00000	.0000
2000.00	256	.0000	71.280	.0000	424.7	.0000	1.1801	.00000	.0000
4000.00	210	.0000	115.650	.0000	430.2	.0000	1.1475	.00000	.0000
R = 0.30, PERCENT FUEL = 29.67, O/F = 2.381									
1.00	2093	0.0008					1.4230	0.00014	-0.0038
1.05	2072	.0007	2.206	0.0003	50.8	0.0003	1.4174	.00013	- .0035
1.20	2016	.0005	1.277	.0002	97.5	.0003	1.4027	.00010	- .0026
1.40	1952	.0004	1.070	.0001	131.4	.0002	1.3869	.00007	- .0019
1.60	1897	.0002	1.013	.0000	154.2	.0002	1.3740	.00005	- .0014
1.82	1846	.0002	1.000	.0000	172.7	.0002	1.3623	.00003	- .0010
2.00	1809	.0001	1.006	.0000	185.1	.0002	1.3539	.00003	- .0008
4.00	1553	.0000	1.266	-.0001	252.6	.0001	1.2994	.00000	- .0001
10.00	1257	-.0001	2.085	-.0001	310.4	.0000	1.2336	.00000	.0000
20.00	1064	-.0001	3.206	-.0001	341.7	.0000	1.1891	.00000	.0000
20.41	1059	-.0001	3.248	-.0001	342.5	.0000	1.1878	.00000	.0000
40.00	895	-.0001	5.037	-.0001	366.0	.0000	1.1531	.00000	.0000
100.00	707	-.0001	9.325	-.0001	390.5	.0000	1.1173	.00000	.0000
200.00	590	-.0001	14.993	.0000	404.8	.0000	1.1006	.00000	.0000
400.00	493	-.0001	24.234	.0000	416.3	.0000	1.0865	.00000	.0000
1000.00	383	-.0001	46.000	.0000	428.3	.0000	1.0745	.00000	.0000
2000.00	317	-.0001	74.914	.0000	435.4	.0000	1.0637	.00000	.0000
4000.00	262	-.0001	122.189	-.0000	441.2	.0000	1.0523	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_t	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 0.35, PERCENT FUEL = 26.47, O/F = 2.778									
1.00	2344	0.0026					1.3936	0.00059	-0.0141
1.05	2322	.0024	1.194	0.0009	50.9	0.0010	1.3850	.00054	- .0130
1.20	2263	.0019	1.272	.0006	97.7	.0009	1.3629	.00042	- .0104
1.40	2196	.0014	1.068	.0004	131.7	.0008	1.3398	.00031	- .0079
1.60	2139	.0011	1.012	.0001	154.7	.0007	1.3219	.00024	- .0062
1.80	2088	.0008	1.000	.0000	172.3	.0006	1.3072	.00018	- .0049
2.00	2045	.0006	1.007	-.0001	185.8	.0006	1.2955	.00015	- .0040
4.00	1771	-.0001	1.275	-.0004	254.0	.0004	1.2310	.00003	- .0008
10.00	1451	-.0003	2.119	-.0004	313.0	.0002	1.1657	.00000	.0000
20.00	1238	-.0003	3.281	-.0004	345.1	.0001	1.1295	.00000	.0000
20.41	1232	-.0003	3.325	-.0004	345.9	.0001	1.1192	.00000	.0000
40.00	1051	-.0003	5.189	-.0004	370.2	.0001	1.0794	.00000	.0000
100.00	838	-.0003	9.678	-.0004	395.8	.0001	1.0365	.00000	.0000
200.00	702	-.0003	15.630	-.0003	410.8	.0001	1.0119	.00000	.0000
400.00	586	-.0003	25.355	-.0003	422.9	.0000	.9954	.00000	.0000
1000.00	460	-.0003	48.298	-.0003	435.5	.0000	.9791	.00000	.0000
2000.00	382	-.0003	78.868	-.0003	443.0	.0000	.9692	.00000	.0000
4000.00	317	-.0003	128.975	-.0003	449.2	.0000	.9598	.00000	.0000
R = 0.40, PERCENT FUEL = 23.95, O/F = 3.175									
1.00	2565	0.0061					1.4407	0.00163	-0.0363
1.05	2543	.0057	1.181	0.0018	50.7	0.0013	1.4084	.00152	- .0341
1.20	2484	.0048	1.267	.0013	97.4	.0011	1.3764	.00125	- .0286
1.40	2417	.0038	1.065	.0007	131.4	.0009	1.3423	.00098	- .0230
1.60	2359	.0031	1.011	.0003	154.4	.0007	1.3153	.00079	- .0186
1.79	2310	.0025	1.000	.0000	171.1	.0006	1.2941	.00065	- .0158
2.00	2263	.0020	1.008	-.0003	185.6	.0005	1.2752	.00053	- .0132
4.00	1978	.0001	1.285	-.0013	254.2	.0009	1.1857	.00013	- .0036
10.00	1637	-.0006	2.152	-.0015	314.0	.0006	1.1119	.00001	- .0004
20.00	1409	-.0007	3.354	-.0014	346.8	.0004	1.0671	.00000	.0000
20.41	1403	-.0007	3.399	-.0014	347.6	.0004	1.0658	.00000	.0000
40.00	1205	-.0008	5.338	-.0014	372.6	.0003	1.0255	.00000	.0000
100.00	970	-.0008	10.036	-.0013	399.1	.0002	.9768	.00000	.0000
200.00	819	-.0008	16.294	-.0013	414.7	.0002	.9478	.00000	.0000
400.00	687	-.0008	26.545	-.0013	427.4	.0001	.9250	.00000	.0000
1000.00	542	-.0009	50.799	-.0013	440.7	.0001	.9038	.00000	.0000
2000.00	452	-.0009	83.167	-.0013	448.6	.0001	.8929	.00000	.0000
4000.00	376	-.0009	136.362	-.0013	455.1	.0001	.8831	.00000	.0000
R = 0.45, PERCENT FUEL = 21.87, O/F = 3.571									
1.00	2755	0.0107					1.5003	0.00351	-0.0738
1.05	2734	.0102	1.169	0.0026	50.3	0.0019	1.4843	.00332	- .0702
1.20	2677	.0090	1.261	.0019	96.7	.0017	1.4419	.00283	- .0610
1.40	2611	.0076	1.062	.0011	130.5	.0014	1.3959	.00233	- .0513
1.60	2555	.0065	1.010	.0005	153.4	.0012	1.3588	.00195	- .0438
1.78	2510	.0056	1.000	.0000	169.1	.0010	1.3312	.00168	- .0384
2.00	2460	.0048	1.009	-.0005	184.6	.0008	1.3023	.00142	- .0329
4.00	2173	.0010	1.295	-.0026	252.4	.0000	1.1697	.00044	- .0113
10.00	1818	-.0010	2.187	-.0035	313.8	.0002	1.0717	.00006	- .0017
20.00	1576	-.0014	3.427	-.0034	347.2	.0009	1.0246	.00001	- .0003
20.41	1569	-.0014	3.474	-.0034	348.1	.0009	1.0233	.00001	- .0003
40.00	1358	-.0015	5.487	-.0033	373.6	.0008	.9831	.00000	.0000
100.00	1105	-.0016	10.401	-.0032	400.9	.0005	.9327	.00000	.0000
200.00	938	-.0017	16.983	-.0032	417.1	.0004	.8999	.00000	.0000
400.00	793	-.0017	27.808	-.0032	430.3	.0003	.8728	.00000	.0000
1000.00	630	-.0018	53.499	-.0032	444.3	.0002	.8465	.00000	.0000
2000.00	527	-.0018	87.879	-.0032	452.6	.0002	.8315	.00000	.0000
4000.00	440	-.0018	144.468	-.0031	459.5	.0001	.8211	.00000	.0000
R = 0.50, PERCENT FUEL = 20.12, O/F = 3.968									
1.00	2915	0.0158					1.6231	0.00633	-0.1275
1.05	2895	.0153	1.158	0.0029	49.8	0.0026	1.6042	.00604	- .1225
1.20	2841	.0139	1.256	.0022	95.7	.0024	1.5535	.00531	- .1095
1.40	2778	.0123	1.060	.0013	129.3	.0021	1.4970	.00454	- .0953
1.60	2724	.0109	1.009	.0006	152.0	.0019	1.4502	.00393	- .0839
1.77	2684	.0099	1.000	.0000	166.6	.0017	1.4168	.00351	- .0760
2.00	2633	.0087	1.010	-.0007	183.0	.0014	1.3768	.00303	- .0667
4.00	2352	.0030	1.307	-.0039	251.9	.0003	1.1932	.00116	- .0281
10.00	1992	-.0012	2.224	-.0061	312.7	.0021	1.0508	.00021	- .0059
20.00	1740	-.0023	3.504	-.0064	346.6	.0016	.9916	.00004	- .0014
20.41	1732	-.0023	3.553	-.0064	347.5	.0016	.9902	.00004	- .0014
40.00	1509	-.0026	5.642	-.0063	373.5	.0012	.9491	.00001	- .0004
100.00	1240	-.0028	10.777	-.0061	401.5	.0008	.8988	.00000	.0000
200.00	1060	-.0029	17.699	-.0061	418.3	.0007	.8638	.00000	.0000
400.00	902	-.0030	29.139	-.0060	432.1	.0005	.8336	.00000	.0000
1000.00	722	-.0031	56.410	-.0060	446.6	.0004	.8015	.00000	.0000
2000.00	607	-.0032	93.015	-.0060	455.4	.0003	.7842	.00000	.0000
4000.00	508	-.0033	153.404	-.0060	462.7	.0003	.7698	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 0.60, PERCENT FUEL = 17.35, O/F = 4.762									
1.00	3155	0.0254					1.9667	0.01480	-0.2833
1.05	3137	.0249	2.140	0.0028	48.5	0.0088	1.9446	.01434	- .2759
1.20	3089	.0235	1.248	.0021	95.3	.0085	1.8842	.01312	- .2559
1.40	3033	.0220	1.056	.0013	126.1	.0083	1.8145	.01177	- .2335
1.50	2985	.0206	1.007	.0005	148.4	.0080	1.7545	.01067	- .2145
1.75	2953	.0197	1.000	.0000	161.2	.0079	1.7154	.00997	- .2024
2.00	2904	.0182	1.013	-.0008	178.8	.0076	1.6559	.00894	- .1843
4.00	2652	.0106	1.328	-.0051	247.0	.0064	1.3741	.00466	- .1037
10.00	2311	.0015	2.303	-.0104	308.3	.0047	1.0984	.00142	- .0356
20.00	2054	-.0029	3.673	-.0127	343.0	.0036	.9752	.00043	- .0118
20.41	2047	-.0029	3.726	-.0128	343.9	.0036	.9726	.00041	- .0113
40.00	1808	-.0049	5.977	-.0136	370.9	.0028	.9053	.00009	- .0029
100.00	1512	-.0058	11.573	-.0136	400.2	.0020	.8496	.00001	- .0003
200.00	1311	-.0061	19.216	-.0135	418.0	.0016	.8145	.00000	.0007
400.00	1130	-.0063	31.993	-.0134	432.7	.0013	.7815	.00000	.0000
1000.00	919	-.0066	62.803	-.0134	448.6	.0010	.7427	.00000	.0000
2000.00	782	-.0069	104.524	-.0135	458.2	.0008	.7183	.00000	.0000
4000.00	661	-.0071	173.763	-.0135	466.3	.0007	.6988	.00000	.0000
R = 0.70, PERCENT FUEL = 15.25, O/F = 5.556									
1.00	3307	0.0328					2.3992	0.02681	-0.4983
1.05	3291	.0324	2.129	0.0023	47.0	0.0111	2.3785	.02623	- .4898
1.20	3248	.0314	1.244	.0017	90.6	.0109	2.3204	.02465	- .4663
1.40	3198	.0301	1.053	.0010	122.4	.0107	2.2512	.02286	- .4389
1.60	3156	.0289	1.006	.0004	144.1	.0105	2.1898	.02134	- .4151
1.73	3130	.0282	1.000	.0000	155.6	.0104	2.1520	.02044	- .4007
2.00	3085	.0269	1.014	-.0007	173.9	.0102	2.0841	.01889	- .3752
4.00	2865	.0201	1.344	-.0046	240.8	.0091	1.7441	.01201	- .2554
10.00	2569	.0096	2.374	-.0108	301.9	.0075	1.3258	.00529	- .1237
20.00	2335	.0015	3.843	-.0156	336.9	.0063	1.0849	.00226	- .0572
20.41	2328	.0013	3.900	-.0158	337.9	.0062	1.0791	.00219	- .0557
40.00	2095	-.0047	6.337	-.0193	361.6	.0051	.9294	.00075	- .0206
100.00	1785	-.0086	12.441	-.0212	396.1	.0038	.8253	.00011	- .0035
200.00	1568	-.0097	20.858	-.0214	414.9	.0030	.7835	.00002	- .0006
400.00	1368	-.0102	35.080	-.0214	430.6	.0025	.7500	.00000	- .0001
1000.00	1133	-.0108	69.841	-.0214	447.6	.0019	.7094	.00000	.0000
2000.00	975	-.0113	117.461	-.0215	458.2	.0016	.6811	.00000	.0000
4000.00	834	-.0117	197.192	-.0217	467.0	.0013	.6564	.00000	.0000
R = 0.80, PERCENT FUEL = 13.60, O/F = 6.349									
1.00	3393	0.0377					2.7921	0.03990	-0.7279
1.05	3378	.0374	2.123	0.0018	45.6	0.0126	2.7781	.03933	- .7206
1.20	3338	.0366	1.241	.0013	87.8	.0124	2.7382	.03775	- .7001
1.40	3292	.0356	1.052	.0008	118.7	.0122	2.6891	.03593	- .6756
1.60	3253	.0347	1.005	.0003	139.8	.0121	2.6439	.03435	- .6538
1.73	3231	.0342	1.000	.0000	150.4	.0120	2.6168	.03345	- .6410
2.00	3189	.0332	1.015	-.0005	168.7	.0118	2.5628	.03173	- .6169
4.00	2995	.0282	1.354	-.0034	234.0	.0110	2.2689	.02369	- .4897
10.00	2744	.0199	2.423	-.0083	294.1	.0098	1.8019	.01386	- .3122
20.00	2550	.0118	3.982	-.0132	329.1	.0088	1.4368	.00779	- .1878
20.41	2544	.0116	4.042	-.0134	330.1	.0087	1.4265	.00763	- .1844
40.00	2344	.0025	6.676	-.0191	358.3	.0076	1.1265	.00355	- .0922
100.00	2053	-.0080	13.365	-.0258	389.8	.0060	.8717	.00085	- .0245
200.00	1830	-.0123	22.652	-.0282	409.5	.0050	.7805	.00021	- .0066
400.00	1617	-.0141	38.453	-.0289	426.2	.0041	.7331	.00004	- .0013
1000.00	1360	-.0152	77.533	-.0291	444.4	.0031	.6903	.00000	- .0001
2000.00	1185	-.0159	131.747	-.0292	455.9	.0026	.6615	.00000	.0000
4000.00	1027	-.0166	223.495	-.0294	465.6	.0022	.6339	.00000	.0000
R = 0.90, PERCENT FUEL = 12.28, O/F = 7.143									
1.00	3430	0.0401					2.9626	0.04890	-0.8833
1.05	3416	.0398	2.121	0.0015	44.2	0.0132	2.9553	.04840	- .8780
1.20	3377	.0391	1.240	.0011	85.1	.0131	2.9343	.04704	- .8631
1.40	3334	.0383	1.051	.0006	115.1	.0129	2.9078	.04546	- .8452
1.60	3296	.0376	1.005	.0002	135.5	.0128	2.8830	.04409	- .8291
1.72	3276	.0372	1.000	.0000	145.6	.0127	2.8682	.04332	- .8199
2.00	3235	.0364	1.016	-.0004	163.6	.0126	2.8374	.04180	- .8012
4.00	3054	.0326	1.358	-.0026	227.1	.0119	2.6636	.03473	- .7059
10.00	2829	.0271	2.448	-.0058	285.8	.0110	2.3536	.02551	- .5605
20.00	2666	.0222	4.058	-.0088	320.2	.0103	2.0547	.01871	- .4366
20.41	2661	.0220	4.121	-.0089	321.2	.0103	2.0450	.01851	- .4328
40.00	2503	.0158	6.901	-.0128	349.2	.0095	1.7023	.01221	- .3040
100.00	2276	.0037	14.187	-.0208	381.3	.0083	1.2030	.00498	- .1364
200.00	2084	-.0074	24.518	-.0284	401.7	.0073	.9125	.00171	- .0508
400.00	1877	-.0152	42.200	-.0336	419.4	.0061	.7617	.00042	- .0136
1000.00	1606	-.0192	86.184	-.0357	439.0	.0048	.6840	.00004	- .0016
2000.00	1416	-.0204	147.806	-.0361	451.3	.0040	.6520	.00001	- .0002
4000.00	1241	-.0213	253.224	-.0363	462.0	.0034	.6246	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 1.00, PERCENT FUEL = 11.19, O/F = 7.937									
1.00	3437	0.0405					2.8811	0.05123	-0.9244
1.05	3423	.0403	2.120	0.0014	42.9	0.0153	2.8760	.05076	- .9197
1.20	3384	.0396	1.239	.0010	82.6	.0132	2.8611	.04948	- .9067
1.40	3341	.0389	1.051	.0006	111.7	.0121	2.8421	.04800	- .8912
1.60	3304	.0382	1.005	.0002	131.5	.0129	2.8243	.04672	- .8773
1.72	3284	.0378	1.000	.0000	141.3	.0129	2.8138	.04601	- .8693
2.00	3244	.0371	1.016	-.0004	158.8	.0127	2.7914	.04460	- .8532
4.00	3065	.0336	1.359	-.0024	220.4	.0111	2.6657	.03811	- .7719
10.00	2847	.0289	2.453	-.0052	277.5	.0103	2.4459	.02986	- .6519
20.00	2692	.0251	4.076	-.0075	311.1	.0107	2.2431	.02398	- .5541
20.41	2687	.0250	4.140	-.0075	312.0	.0106	2.2367	.02381	- .5512
40.00	2542	.0209	6.959	-.0100	339.4	.0100	2.0143	.01851	- .4532
100.00	2349	.0144	14.469	-.0141	370.9	.0092	1.6831	.01209	- .3207
200.00	2203	.0084	25.445	-.0180	391.3	.0085	1.4246	.00801	- .2268
400.00	2052	.0014	44.925	-.0228	409.3	.0077	1.1770	.00475	- .1443
1000.00	1839	-.0094	95.113	-.0303	429.9	.0067	.8997	.00185	- .0626
2000.00	1668	-.0171	166.760	-.0360	443.3	.0058	.7520	.00070	- .0260
4000.00	1493	-.0227	290.406	-.0400	455.0	.0050	.6606	.00020	- .0083
R = 1.50, PERCENT FUEL = 7.74, O/F = 1.905									
1.00	3297	0.0338					1.8003	0.03075	-0.5921
1.05	3282	.0335	2.123	0.0017	37.9	0.0135	1.7919	.03029	- .5859
1.20	3243	.0327	1.241	.0012	75.0	.0114	1.7680	.02902	- .5689
1.40	3198	.0318	1.052	.0007	98.7	.0122	1.7391	.02758	- .5486
1.60	3159	.0309	1.005	.0003	116.2	.0110	1.7131	.02635	- .5312
1.73	3137	.0304	1.000	.0000	125.0	.0110	1.6977	.02565	- .5210
2.00	3096	.0295	1.015	-.0005	140.2	.0108	1.6672	.02432	- .5012
4.00	2904	.0249	1.354	-.0031	194.6	.0100	1.5078	.01834	- .4053
10.00	2661	.0179	2.427	-.0071	244.6	.0089	1.2677	.01140	- .2780
20.00	2478	.0118	3.997	-.0108	273.8	.0081	1.0774	.00711	- .1886
20.41	2472	.0116	4.058	-.0110	274.6	.0080	1.0719	.00700	- .1862
40.00	2291	.0050	6.734	-.0151	298.2	.0071	.8963	.00387	- .1126
100.00	2032	-.0040	13.621	-.0211	324.8	.0059	.7030	.00129	- .0437
200.00	1830	-.0093	23.271	-.0245	341.5	.0049	.6070	.00043	- .0167
400.00	1629	-.0125	39.732	-.0264	355.8	.0041	.5500	.00011	- .0051
1000.00	1379	-.0144	80.499	-.0273	371.5	.0032	.5072	.00001	- .0007
2000.00	1207	-.0152	137.214	-.0276	381.4	.0027	.4850	.00000	- .0001
4000.00	1050	-.0159	233.567	-.0278	389.8	.0024	.4650	.00000	.0000
R = 2.00, PERCENT FUEL = 5.92, O/F = 5.873									
1.00	3103	0.0262					1.2138	0.01648	-0.3472
1.05	3088	.0258	2.129	0.0020	34.7	0.0093	1.2052	.01611	- .3414
1.20	3046	.0249	1.243	.0015	66.7	.0092	1.1812	.01513	- .3255
1.40	2998	.0237	1.053	.0009	90.2	.0090	1.1528	.01402	- .3074
1.60	2957	.0228	1.006	.0003	106.2	.0088	1.1276	.01309	- .2914
1.73	2932	.0222	1.000	.0000	114.7	.0087	1.1122	.01255	- .2819
2.00	2889	.0211	1.014	-.0006	128.2	.0085	1.0844	.01160	- .2651
4.00	2679	.0155	1.344	-.0038	177.5	.0075	.9449	.00749	- .1868
10.00	2402	.0076	2.379	-.0086	222.6	.0063	.7644	.00348	- .0990
20.00	2188	.0017	3.861	-.0123	248.5	.0053	.6477	.00160	- .0512
20.41	2181	.0015	3.918	-.0124	249.2	.0052	.6447	.00156	- .0501
40.00	1970	-.0031	6.385	-.0153	265.8	.0043	.5611	.00060	- .0218
100.00	1686	-.0068	12.580	-.0174	282.5	.0033	.4923	.00012	- .0051
200.00	1483	-.0080	21.125	-.0179	306.5	.0026	.4632	.00003	- .0013
400.00	1297	-.0086	35.572	-.0180	318.2	.0021	.4427	.00000	- .0004
1000.00	1076	-.0092	70.973	-.0180	331.0	.0016	.4201	.00000	.0000
2000.00	929	-.0095	119.641	-.0180	338.9	.0014	.4046	.00000	.0000
4000.00	797	-.0099	201.392	-.0182	345.5	.0011	.3900	.00000	.0000
R = 3.00, PERCENT FUEL = 4.03, O/F = 3.810									
1.00	2723	0.0136					0.6909	0.00463	-0.1169
1.05	2705	.0132	2.148	0.0023	30.5	0.0052	.6842	.00445	- .1131
1.20	2658	.0122	1.252	.0017	58.6	.0050	.6659	.00396	- .1029
1.40	2604	.0110	1.058	.0010	79.2	.0048	.6451	.00344	- .0917
1.60	2556	.0100	1.008	.0004	93.1	.0046	.6275	.00303	- .0825
1.76	2523	.0093	1.000	.0000	101.6	.0045	.6155	.00276	- .0763
2.00	2477	.0083	1.012	-.0006	112.2	.0043	.5991	.00241	- .0682
4.00	2232	.0036	1.317	-.0034	154.7	.0033	.5216	.00106	- .0336
10.00	1914	-.0005	2.261	-.0058	192.6	.0023	.4517	.00026	- .0099
20.00	1684	-.0020	3.584	-.0065	213.8	.0017	.4206	.00007	- .0030
20.41	1678	-.0020	3.634	-.0065	214.4	.0017	.4199	.00006	- .0029
40.00	1472	-.0026	5.802	-.0066	230.8	.0013	.4007	.00001	- .0007
100.00	1222	-.0028	11.177	-.0065	248.6	.0009	.3813	.00000	- .0001
200.00	1055	-.0030	18.498	-.0065	259.3	.0007	.3680	.00000	.0000
400.00	906	-.0031	30.718	-.0064	268.2	.0006	.3557	.00000	.0000
1000.00	735	-.0032	60.154	-.0064	277.7	.0005	.3399	.00000	.0000
2000.00	623	-.0033	99.956	-.0064	283.5	.0004	.3291	.00000	.0000
4000.00	526	-.0034	165.857	-.0065	288.3	.0003	.3195	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Concluded. Combustion-chamber pressure, 300 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 4.00, PERCENT FUEL = 3.05, O/F = 1.746									
1.00	2372	0.0055					0.4836	0.00116	-0.0351
1.05	2354	.0052	2.172	0.0015	27.5	0.0022	.4796	.00109	- .0333
1.20	2303	.0045	1.262	.0011	52.9	.0021	.4689	.00091	- .0287
1.40	2244	.0037	1.063	.0006	71.4	.0019	.4574	.00074	- .0239
1.60	2194	.0031	1.010	.0003	83.9	.0018	.4481	.00061	- .0203
1.78	2153	.0027	1.000	.0000	92.6	.0017	.4412	.00052	- .0177
2.00	2110	.0022	1.009	-.0003	101.0	.0016	.4341	.00043	- .0151
4.00	1859	.0004	1.294	-.0013	138.6	.0011	.4010	.00013	- .0053
10.00	1555	-.0006	2.184	-.0018	171.6	.0006	.3749	.00002	- .0009
20.00	1349	-.0007	3.426	-.0018	189.8	.0005	.3614	.00000	- .0002
20.41	1343	-.0008	3.474	-.0018	190.2	.0005	.3611	.00000	- .0002
40.00	1165	-.0008	5.499	-.0017	204.2	.0003	.3499	.00000	.0000
100.00	952	-.0009	10.472	-.0016	219.2	.0002	.3352	.00000	.0000
200.00	813	-.0009	17.179	-.0016	228.1	.0002	.3243	.00000	.0000
400.00	690	-.0009	28.266	-.0016	235.5	.0002	.3139	.00000	.0000
1000.00	552	-.0009	54.663	-.0016	243.2	.0001	.3012	.00000	.0000
2000.00	463	-.0010	89.984	-.0016	247.9	.0001	.2928	.00000	.0000
4000.00	386	-.0010	147.985	-.0016	251.8	.0001	.2864	.00000	.0000
R = 5.00, PERCENT FUEL = 2.45, O/F = 9.683									
1.00	2069	0.0018					0.3968	0.00027	-0.0097
1.05	2051	.0016	2.189	0.0006	25.2	0.0007	.3947	.00025	- .0090
1.20	2000	.0013	1.270	.0004	48.5	.0007	.3893	.00020	- .0074
1.40	1942	.0010	1.066	.0002	65.4	.0006	.3835	.00015	- .0058
1.60	1893	.0008	1.011	.0001	76.8	.0005	.3790	.00012	- .0046
1.80	1851	.0006	1.000	.0000	85.3	.0005	.3753	.00009	- .0038
2.00	1813	.0005	1.007	-.0001	92.2	.0005	.3722	.00008	- .0032
4.00	1578	.0000	1.281	-.0003	126.2	.0003	.3564	.00002	- .0008
10.00	1303	-.0002	2.143	-.0004	155.8	.0002	.3411	.00000	- .0001
20.00	1122	-.0002	3.342	-.0004	172.0	.0001	.3309	.00000	.0000
20.41	1117	-.0002	3.388	-.0004	172.4	.0001	.3306	.00000	.0000
40.00	961	-.0002	5.330	-.0003	184.7	.0001	.3209	.00000	.0000
100.00	777	-.0002	10.066	-.0003	197.9	.0001	.3076	.00000	.0000
200.00	658	-.0002	16.399	-.0003	205.7	.0000	.2979	.00000	.0000
400.00	554	-.0002	26.792	-.0003	212.0	.0000	.2887	.00000	.0000
1000.00	438	-.0002	51.338	-.0003	218.7	.0000	.2782	.00000	.0000
2000.00	365	-.0003	83.976	-.0003	222.6	.0000	.2728	.00000	.0000
4000.00	303	-.0003	137.439	-.0003	225.9	.0000	.2693	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Combustion-chamber pressure, 600 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific impulse exponent, n_I	Specific heat, c_{p_r}, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 0.15, PERCENT FUEL = 45.65, O/F = 1.190									
1.00	1183	0.0000					1.7753	0.00000	0.0000
1.05	1168	.0000	2.250	0.0000	47.4	0.0000	1.7710	.00000	.0000
1.20	1129	.0000	1.297	.0000	90.8	.0000	1.7597	.00000	.0000
1.40	1085	.0000	1.081	.0000	122.2	.0000	1.7472	.00000	.0000
1.60	1049	.0000	1.018	.0000	143.2	.0000	1.7370	.00000	.0000
1.87	1008	.0000	1.000	.0000	163.4	.0000	1.7256	.00000	.0000
2.00	989	.0000	1.003	.0000	171.5	.0000	1.7210	.00000	.0000
4.00	824	.0000	1.233	.0000	232.3	.0000	1.6824	.00000	.0000
10.00	643	.0000	1.974	.0000	283.1	.0000	1.6506	.00000	.0000
20.00	532	.0000	2.983	.0000	309.9	.0000	1.6345	.00000	.0000
40.00	439	.0000	4.620	.0000	330.4	.0000	1.6269	.00000	.0000
40.83	437	.0000	4.682	.0000	330.9	.0000	1.6267	.00000	.0000
100.00	340	.0000	8.432	.0000	350.8	.0000	1.6089	.00000	.0000
200.00	280	.0000	13.431	.0000	362.6	.0000	1.5951	.00000	.0000
400.00	230	.0000	21.488	.0000	372.0	.0000	1.5558	.00000	.0000
1000.00	175	.0000	39.928	.0000	381.6	.0000	1.4852	.00000	.0000
2000.00	142	.0000	63.572	.0000	387.2	.0000	1.4387	.00000	.0000
4000.00	114	.0000	100.938	.0000	391.6	.0000	1.4039	.00000	.0000
R = 0.20, PERCENT FUEL = 38.65, O/F = 1.587									
1.00	1514	0.0000					1.6187	0.00000	0.0000
1.05	1497	.0000	2.233	0.0000	49.3	0.0000	1.6143	.00000	.0000
1.20	1450	.0000	1.289	.0000	94.6	.0000	1.6024	.00000	.0000
1.40	1398	.0000	1.077	.0000	127.4	.0000	1.5888	.00000	.0000
1.60	1354	.0000	1.016	.0000	149.4	.0000	1.5773	.00000	.0000
1.85	1307	.0000	1.000	.0000	169.2	.0000	1.5651	.00000	.0000
2.00	1282	.0000	1.004	.0000	175.1	.0000	1.5584	.00000	.0000
4.00	1079	.0000	1.244	.0000	243.2	.0000	1.5046	.00000	.0000
10.00	852	.0000	2.009	.0000	297.2	.0000	1.4516	.00000	.0000
20.00	709	.0000	3.049	.0000	325.9	.0000	1.4232	.00000	.0000
40.00	588	.0000	4.739	.0000	346.0	.0000	1.4066	.00000	.0000
40.83	585	.0000	4.802	.0000	348.6	.0000	1.4062	.00000	.0000
100.00	458	.0000	8.679	.0000	370.0	.0000	1.3916	.00000	.0000
200.00	379	.0000	13.870	.0000	382.7	.0000	1.3808	.00000	.0000
400.00	312	.0000	22.296	.0000	393.0	.0000	1.3684	.00000	.0000
1000.00	242	.0000	41.979	.0000	403.5	.0000	1.3402	.00000	.0000
2000.00	198	.0000	67.687	.0000	409.7	.0000	1.2976	.00000	.0000
4000.00	161	.0000	108.754	.0000	414.6	.0000	1.2543	.00000	.0000
R = 0.25, PERCENT FUEL = 33.51, O/F = 1.984									
1.00	1817	0.0001					1.4998	0.00001	-0.0004
1.05	1797	.0001	2.218	0.0000	50.3	0.0000	1.4955	.00001	- .0004
1.20	1745	.0001	1.283	.0000	96.6	.0000	1.4840	.00001	- .0003
1.40	1686	.0000	1.073	.0000	130.1	.0000	1.4712	.00001	- .0002
1.60	1636	.0000	1.015	.0000	152.7	.0000	1.4604	.00000	- .0001
1.83	1587	.0000	1.000	.0000	171.8	.0000	1.4494	.00000	- .0001
2.00	1555	.0000	1.005	.0000	183.1	.0000	1.4423	.00000	- .0001
4.00	1322	.0000	1.256	.0000	249.3	.0000	1.3874	.00000	.0000
10.00	1057	.0000	2.048	.0000	305.6	.0000	1.3225	.00000	.0000
20.00	887	.0000	3.127	.0000	335.7	.0000	1.2849	.00000	.0000
40.00	741	.0000	4.883	.0000	359.0	.0000	1.2560	.00000	.0000
40.83	737	.0000	4.949	.0000	359.6	.0000	1.2552	.00000	.0000
100.00	581	.0000	8.985	.0000	382.4	.0000	1.2321	.00000	.0000
200.00	482	.0000	14.396	.0000	395.9	.0000	1.2189	.00000	.0000
400.00	399	.0000	23.208	.0000	406.8	.0000	1.2100	.00000	.0000
1000.00	310	.0000	43.893	.0000	418.1	.0000	1.1949	.00000	.0000
2000.00	256	.0000	71.279	.0000	424.7	.0000	1.1810	.00000	.0000
4000.00	210	.0000	115.650	.0000	430.2	.0000	1.1485	.00000	.0000
R = 0.30, PERCENT FUEL = 29.57, O/F = 2.381									
1.00	2094	0.0006					1.4145	0.00010	-0.0027
1.05	2073	.0005	2.206	0.0002	50.8	0.0002	1.4097	.00009	- .0025
1.20	2016	.0004	1.277	.0001	97.5	.0002	1.3967	.00007	- .0019
1.40	1952	.0003	1.071	.0001	131.4	.0002	1.3825	.00005	- .0013
1.60	1898	.0002	1.013	.0000	154.2	.0001	1.3706	.00003	- .0010
1.82	1847	.0001	1.000	.0000	172.7	.0001	1.3598	.00002	- .0007
2.00	1809	.0001	1.006	.0000	185.1	.0001	1.3519	.00002	- .0006
4.00	1553	.0000	1.266	-.0001	252.6	.0001	1.2991	.00000	- .0001
10.00	1257	.0000	2.085	-.0001	310.4	.0000	1.2336	.00000	.0000
20.00	1064	-.0001	3.206	.0000	341.7	.0000	1.1891	.00000	.0000
40.83	891	-.0001	5.106	.0000	366.6	.0000	1.1522	.00000	.0000
40.00	895	-.0001	5.037	.0000	366.0	.0000	1.1531	.00000	.0000
100.00	707	-.0001	9.324	.0000	390.5	.0000	1.1174	.00000	.0000
200.00	590	-.0001	14.993	.0000	404.8	.0000	1.1007	.00000	.0000
400.00	490	-.0001	24.234	.0000	416.3	.0000	1.0867	.00000	.0000
1000.00	383	-.0001	45.999	.0000	428.3	.0000	1.0746	.00000	.0000
2000.00	317	-.0001	74.912	.0000	435.4	.0000	1.0638	.00000	.0000
4000.00	262	-.0001	122.185	.0000	441.2	.0000	1.0534	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_t	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 0.35, PERCENT FUEL = 26.47, O/F = 2.778									
1.00	2347	0.0019					1.3691	0.00042	-0.0101
1.05	2325	.0018	2.195	0.0007	50.9	0.0007	1.3621	.00039	- .0093
1.20	2266	.0014	1.273	.0005	97.7	.0007	1.3440	.00030	- .0074
1.40	2198	.0010	1.068	.0003	131.8	.0006	1.3249	.00022	- .0057
1.60	2140	.0008	1.012	.0001	154.7	.0005	1.3099	.00017	- .0044
1.81	2089	.0006	1.000	.0000	172.5	.0005	1.2974	.00013	- .0035
2.00	2046	.0004	1.007	-.0001	185.9	.0004	1.2874	.00010	- .0028
4.00	1771	-.0001	1.275	-.0003	254.1	.0003	1.2291	.00002	- .0006
10.00	1451	-.0002	2.119	-.0003	313.0	.0001	1.1655	.00000	.0000
20.00	1238	-.0002	3.281	-.0003	345.1	.0001	1.1204	.00000	.0000
40.83	1045	-.0002	5.260	-.0003	370.9	.0001	1.0783	.00000	.0000
40.00	1050	-.0002	5.188	-.0003	370.3	.0001	1.0794	.00000	.0000
100.00	838	-.0002	9.676	-.0003	395.8	.0001	1.0365	.00000	.0000
200.00	702	-.0002	15.626	-.0002	410.8	.0000	1.0118	.00000	.0000
400.00	586	-.0002	25.350	-.0002	422.9	.0000	.9953	.00000	.0000
1000.00	460	-.0002	48.288	-.0002	435.5	.0000	.9789	.00000	.0000
2000.00	382	-.0002	78.852	-.0002	443.1	.0000	.9692	.00000	.0000
4000.00	317	-.0002	128.949	-.0002	445.2	.0000	.9590	.00000	.0000
R = 0.40, PERCENT FUEL = 23.95, O/F = 3.175									
1.00	2574	0.0046					1.3697	0.00120	-0.0266
1.05	2552	.0043	2.184	0.0014	50.7	0.0017	1.3599	.00112	- .0250
1.20	2492	.0036	1.268	.0010	97.5	.0016	1.3344	.00091	- .0208
1.40	2422	.0028	1.065	.0006	131.5	.0014	1.3072	.00071	- .0167
1.60	2363	.0023	1.011	.0002	154.5	.0013	1.2856	.00057	- .0136
1.79	2313	.0018	1.000	.0000	171.4	.0012	1.2685	.00047	- .0113
2.00	2266	.0015	1.008	-.0002	185.7	.0011	1.2533	.00038	- .0095
4.00	1978	.0001	1.284	-.0009	254.4	.0007	1.1787	.00009	- .0025
10.00	1637	-.0005	2.150	-.0011	314.1	.0004	1.1109	.00001	- .0003
20.00	1408	-.0005	3.351	-.0010	346.9	.0003	1.0669	.00000	.0000
40.00	1204	-.0006	5.334	-.0010	372.7	.0002	1.0253	.00000	.0000
40.83	1199	-.0006	5.409	-.0010	373.4	.0002	1.0242	.00000	.0000
100.00	970	-.0006	10.029	-.0009	399.1	.0002	.9767	.00000	.0000
200.00	818	-.0006	16.282	-.0009	414.7	.0001	.9478	.00000	.0000
400.00	687	-.0006	26.525	-.0009	427.4	.0001	.9249	.00000	.0000
1000.00	542	-.0006	50.761	-.0009	440.7	.0001	.9037	.00000	.0000
2000.00	452	-.0006	83.105	-.0009	448.6	.0001	.8928	.00000	.0000
4000.00	376	-.0006	136.261	-.0009	455.1	.0000	.8835	.00000	.0000
R = 0.45, PERCENT FUEL = 21.87, O/F = 3.571									
1.00	2773	0.0085					1.4156	0.00266	-0.0555
1.05	2752	.0081	2.172	0.0021	50.4	0.0031	1.4027	.00251	- .0527
1.20	2692	.0070	1.263	.0015	96.9	.0029	1.3686	.00212	- .0455
1.40	2624	.0059	1.063	.0009	130.8	.0027	1.3318	.00174	- .0380
1.60	2565	.0049	1.010	.0004	153.7	.0025	1.3022	.00144	- .0322
1.78	2517	.0043	1.000	.0000	169.6	.0023	1.2799	.00123	- .0280
2.00	2467	.0036	1.009	-.0004	184.9	.0022	1.2573	.00104	- .0240
4.00	2174	.0006	1.293	-.0020	253.7	.0015	1.1514	.00031	- .0081
10.00	1817	-.0008	2.182	-.0026	314.1	.0009	1.0682	.00004	- .0012
20.00	1575	-.0011	3.420	-.0025	347.4	.0007	1.0237	.00001	- .0002
40.00	1357	-.0012	5.476	-.0024	375.8	.0005	.9828	.00000	.0000
40.83	1350	-.0012	5.554	-.0024	374.5	.0005	.9816	.00000	.0000
100.00	1104	-.0012	10.381	-.0024	401.0	.0003	.9325	.00000	.0000
200.00	937	-.0013	16.950	-.0023	417.2	.0003	.8996	.00000	.0000
400.00	792	-.0013	27.755	-.0023	430.4	.0002	.8727	.00000	.0000
1000.00	629	-.0014	53.398	-.0023	444.3	.0002	.8465	.00000	.0000
2000.00	526	-.0014	87.714	-.0023	452.7	.0001	.8313	.00000	.0000
4000.00	439	-.0014	144.197	-.0023	459.5	.0001	.8210	.00000	.0000
R = 0.50, PERCENT FUEL = 20.12, O/F = 3.968									
1.00	2944	0.0131					1.5012	0.00493	-0.0983
1.05	2923	.0127	2.162	0.0026	50.0	0.0047	1.4856	.00469	- .0943
1.20	2866	.0114	1.258	.0019	96.1	.0044	1.4440	.00409	- .0837
1.40	2800	.0099	1.061	.0012	129.7	.0042	1.3979	.00347	- .0723
1.60	2742	.0087	1.009	.0005	152.5	.0039	1.3600	.00298	- .0633
1.77	2699	.0078	1.000	.0000	167.4	.0038	1.3324	.00264	- .0568
2.00	2647	.0068	1.010	-.0006	183.5	.0036	1.3008	.00227	- .0497
4.00	2356	.0021	1.303	-.0032	252.4	.0026	1.1551	.00083	- .0202
10.00	1990	-.0010	2.216	-.0047	313.1	.0017	1.0408	.00015	- .0041
20.00	1737	-.0018	3.491	-.0049	346.9	.0012	.9888	.00003	- .0009
40.00	1507	-.0020	5.620	-.0048	373.8	.0009	.9482	.00000	- .0001
40.83	1501	-.0020	5.701	-.0048	374.5	.0009	.9471	.00000	- .0001
100.00	1238	-.0022	10.736	-.0047	401.7	.0007	.8984	.00000	.0000
200.00	1059	-.0023	17.634	-.0046	418.5	.0005	.8634	.00000	.0000
400.00	900	-.0023	29.032	-.0046	432.2	.0004	.8333	.00000	.0000
1000.00	720	-.0024	56.203	-.0046	446.7	.0003	.8013	.00000	.0000
2000.00	606	-.0025	92.675	-.0046	455.5	.0002	.7841	.00000	.0000
4000.00	507	-.0025	152.844	-.0046	462.7	.0002	.7696	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ϵ	Area-ratio exponent, n_ϵ	Specific impulse, I, (lb)/(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 0.60, PERCENT FUEL = 17.35, O/F = 4.762									
1.00	3208	0.0226					1.7671	0.01210	-0.2283
1.05	3189	.0221	2.144	0.0028	48.8	0.0078	1.7482	.01170	- .2219
1.20	3137	.0208	1.250	.0021	93.8	.0075	1.6966	.01063	- .2047
1.40	3077	.0192	1.057	.0013	126.8	.0073	1.6375	.00947	- .1854
1.60	3025	.0178	1.007	.0005	149.1	.0070	1.5869	.00852	- .1693
1.75	2990	.0169	1.000	.0000	162.3	.0069	1.5531	.00791	- .1588
2.00	2938	.0155	1.012	-.0008	179.7	.0066	1.5041	.00705	- .1438
4.00	2669	.0083	1.323	-.0048	248.0	.0054	1.2723	.00352	- .0779
10.00	2313	.0006	2.288	-.0091	309.3	.0039	1.0538	.00101	- .0253
20.00	2050	-.0027	3.644	-.0108	343.7	.0030	.9574	.00029	- .0081
40.00	1803	-.0041	5.926	-.0113	371.5	.0023	.8996	.00006	- .0019
40.83	1796	-.0041	6.013	-.0113	372.3	.0023	.8983	.00006	- .0019
100.00	1506	-.0047	11.474	-.0112	400.7	.0017	.8482	.00000	- .0002
200.00	1306	-.0050	19.054	-.0111	418.4	.0013	.8136	.00000	.0000
400.00	1125	-.0052	31.724	-.0110	433.1	.0011	.7807	.00000	.0000
1000.00	916	-.0055	62.274	-.0110	448.8	.0008	.7420	.00000	.0000
2000.00	778	-.0056	103.640	-.0111	458.4	.0007	.7177	.00000	.0000
4000.00	658	-.0058	172.288	-.0111	466.4	.0005	.6983	.00000	.0000
R = 0.70, PERCENT FUEL = 15.25, O/F = 5.556									
1.00	3381	0.0307					2.1301	0.02284	-0.4169
1.05	3364	.0303	2.133	0.0024	47.4	0.0103	2.1115	.02230	- .4091
1.20	3317	.0291	1.245	.0018	91.2	.0101	2.0594	.02085	- .3876
1.40	3263	.0278	1.054	.0011	123.3	.0098	1.9976	.01921	- .3628
1.60	3217	.0266	1.006	.0004	145.2	.0096	1.9428	.01783	- .3412
1.74	3188	.0258	1.000	.0000	157.0	.0095	1.9085	.01699	- .3280
2.00	3140	.0245	1.014	-.0007	175.1	.0093	1.8496	.01560	- .3055
4.00	2903	.0173	1.339	-.0047	242.3	.0082	1.5556	.00954	- .2008
10.00	2584	.0070	2.356	-.0106	303.3	.0066	1.2090	.00394	- .0917
20.00	2337	.0000	3.803	-.0147	338.3	.0054	1.0195	.00159	- .0403
40.00	2088	-.0048	6.256	-.0174	366.8	.0043	.9006	.00050	- .0139
40.83	2081	-.0049	6.350	-.0175	367.6	.0043	.8980	.00048	- .0135
100.00	1775	-.0076	12.271	-.0186	397.1	.0032	.8183	.00007	- .0023
200.00	1558	-.0083	20.571	-.0186	415.7	.0026	.7809	.00001	- .0004
400.00	1359	-.0087	34.597	-.0186	431.3	.0021	.7484	.00000	- .0001
1000.00	1125	-.0093	68.879	-.0186	448.2	.0016	.7080	.00000	.0000
2000.00	968	-.0096	115.835	-.0187	458.6	.0013	.6798	.00000	.0000
4000.00	828	-.0100	194.445	-.0188	467.4	.0011	.6552	.00000	.0000
R = 0.80, PERCENT FUEL = 13.60, O/F = 6.349									
1.00	3481	0.0364					2.4909	0.03537	-0.6319
1.05	3465	.0361	2.126	0.0018	46.0	0.0119	2.4777	.03482	- .6249
1.20	3422	.0352	1.242	.0014	88.5	.0118	2.4401	.03330	- .6052
1.40	3373	.0341	1.052	.0008	119.7	.0116	2.3938	.03155	- .5818
1.60	3331	.0332	1.006	.0003	140.9	.0114	2.3513	.03003	- .5609
1.73	3306	.0326	1.000	.0000	151.8	.0113	2.3254	.02915	- .5485
2.00	3261	.0316	1.015	-.0006	170.0	.0112	2.2752	.02752	- .5249
4.00	3052	.0260	1.350	-.0036	235.7	.0103	2.0021	.01991	- .4058
10.00	2779	.0170	2.409	-.0088	296.0	.0090	1.5823	.01097	- .2447
20.00	2568	.0087	3.944	-.0139	331.1	.0080	1.2725	.00579	- .1390
40.00	2346	.0000	6.587	-.0192	360.1	.0068	1.0267	.00247	- .0641
40.83	2340	-.0002	6.689	-.0194	360.8	.0068	1.0207	.00240	- .0625
100.00	2042	-.0083	13.134	-.0243	391.4	.0055	.8369	.00055	- .0159
200.00	1815	-.0113	22.231	-.0256	410.8	.0043	.7683	.00013	- .0041
400.00	1602	-.0126	37.727	-.0261	427.3	.0035	.7287	.00002	- .0008
1000.00	1347	-.0135	76.063	-.0262	445.3	.0027	.6880	.00000	- .0001
2000.00	1173	-.0141	129.237	-.0263	456.6	.0023	.6594	.00000	.0000
4000.00	1016	-.0147	219.200	-.0265	466.2	.0019	.6320	.00000	.0000
R = 0.90, PERCENT FUEL = 12.28, O/F = 7.143									
1.00	3526	0.0393					2.6696	0.04460	-0.7874
1.05	3511	.0390	2.123	0.0015	44.6	0.0127	2.6628	.04411	- .7823
1.20	3469	.0383	1.241	.0011	85.8	.0126	2.6432	.04279	- .7680
1.40	3422	.0374	1.052	.0006	116.1	.0125	2.6185	.04126	- .7508
1.60	3382	.0367	1.005	.0002	136.7	.0123	2.5953	.03994	- .7355
1.73	3360	.0362	1.000	.0000	147.0	.0123	2.5813	.03918	- .7265
2.00	3317	.0354	1.016	-.0005	165.0	.0121	2.5526	.03773	- .7087
4.00	3122	.0314	1.356	-.0027	228.9	.0114	2.3886	.03089	- .6170
10.00	2881	.0254	2.437	-.0061	287.9	.0105	2.0940	.02200	- .4769
20.00	2705	.0199	4.032	-.0094	322.5	.0098	1.8100	.01550	- .3584
40.00	2528	.0127	6.838	-.0138	351.5	.0089	1.4813	.00946	- .2345
40.83	2523	.0125	6.947	-.0140	352.3	.0089	1.4712	.00930	- .2309
100.00	2279	-.0001	13.977	-.0222	383.4	.0076	1.0541	.00335	- .0922
200.00	2072	-.0095	24.037	-.0286	403.7	.0065	.8410	.00105	- .0313
400.00	1857	-.0149	41.251	-.0319	421.1	.0055	.7376	.00025	- .0080
1000.00	1585	-.0176	84.153	-.0331	440.3	.0043	.6784	.00002	- .0009
2000.00	1397	-.0186	144.295	-.0333	452.3	.0036	.6487	.00000	- .0001
4000.00	1224	-.0194	247.166	-.0335	463.0	.0030	.6217	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 1.00, PERCENT FUEL = 11.19, O/F = 7.937									
1.00	3534	0.0399					2.6053	0.04709	-0.8301
1.05	3519	.0396	2.122	0.0014	43.3	0.0129	2.6007	.04664	- .8258
1.20	3478	.0389	1.240	.0010	83.3	.0128	2.5874	.04541	- .8135
1.40	3431	.0381	1.051	.0006	112.7	.0126	2.5703	.04399	- .7989
1.60	3392	.0374	1.005	.0002	132.7	.0125	2.5542	.04277	- .7857
1.73	3370	.0370	1.000	.0000	142.7	.0124	2.5445	.04208	- .7781
2.00	3327	.0363	1.016	-.0004	160.1	.0123	2.5243	.04073	- .7630
4.00	3137	.0327	1.357	-.0024	222.3	.0117	2.4094	.03451	- .6863
10.00	2903	.0277	2.445	-.0053	279.6	.0108	2.2079	.02666	- .5732
20.00	2738	.0236	4.055	-.0077	313.3	.0102	2.0416	.02111	- .4817
40.00	2578	.0192	6.910	-.0103	341.7	.0096	1.8120	.01600	- .3879
40.83	2573	.0190	7.022	-.0104	342.5	.0095	1.8056	.01585	- .3851
100.00	2371	.0123	14.326	-.0146	373.2	.0087	1.5117	.01011	- .2667
200.00	2214	.0061	25.124	-.0186	393.6	.0080	1.2810	.00647	- .1829
400.00	2052	-.0011	44.210	-.0235	411.4	.0072	1.0654	.00366	- .1117
1000.00	1826	-.0112	93.124	-.0305	431.8	.0061	.8338	.00132	- .0452
2000.00	1648	-.0177	162.695	-.0352	445.0	.0053	.7163	.00047	- .0177
4000.00	1470	-.0220	282.648	-.0381	456.5	.0045	.6444	.00013	- .0053
R = 1.50, PERCENT FUEL = 7.74, O/F = 1.905									
1.00	3374	0.0324					1.6233	0.02714	-0.5145
1.20	3315	.0312	1.242	0.0013	73.5	0.0107	1.5942	.02553	- .4930
1.05	3358	.0321	2.125	.0017	38.2	.0109	1.6157	.02671	- .5088
1.40	3267	.0302	1.052	.0007	99.4	.0106	1.5682	.02418	- .4745
1.60	3226	.0293	1.006	.0003	117.1	.0104	1.5447	.02304	- .4583
1.73	3202	.0288	1.000	.0000	126.1	.0103	1.5306	.02237	- .4488
2.00	3158	.0278	1.015	-.0005	141.3	.0102	1.5034	.02115	- .4308
4.00	2953	.0230	1.351	-.0032	195.9	.0094	1.3606	.01566	- .3433
10.00	2692	.0158	2.415	-.0073	246.1	.0083	1.1474	.00942	- .2294
20.00	2496	.0097	3.967	-.0110	275.3	.0074	.9816	.00569	- .1516
40.00	2297	.0032	6.664	-.0151	299.5	.0065	.8274	.00298	- .0879
40.83	2291	.0030	6.768	-.0152	300.2	.0065	.8232	.00292	- .0863
100.00	2026	-.0048	13.428	-.0204	326.0	.0053	.6882	.00095	- .0328
200.00	1818	-.0091	22.891	-.0229	342.6	.0044	.5904	.00031	- .0123
400.00	1616	-.0115	39.039	-.0243	356.7	.0036	.5432	.00008	- .0037
1000.00	1366	-.0130	79.054	-.0249	372.3	.0028	.5048	.00001	- .0005
2000.00	1195	-.0137	134.733	-.0251	382.1	.0024	.4834	.00000	- .0001
4000.00	1039	-.0143	229.310	-.0253	390.4	.0020	.4636	.00000	.0000
R = 2.00, PERCENT FUEL = 5.92, O/F = 5.873									
1.00	3158	0.0243					1.1081	0.01418	-0.2964
1.05	3141	.0240	2.132	0.0020	34.9	0.0086	1.1005	.01385	- .2912
1.20	3097	.0230	1.245	.0015	67.1	.0085	1.0794	.01296	- .2770
1.40	3046	.0219	1.054	.0009	90.8	.0083	1.0543	.01197	- .2606
1.60	3002	.0209	1.006	.0003	106.9	.0081	1.0320	.01114	- .2465
1.74	2975	.0203	1.000	.0000	115.5	.0080	1.0182	.01064	- .2379
2.00	2929	.0192	1.014	-.0006	128.9	.0078	.9940	.00980	- .2232
4.00	2706	.0137	1.341	-.0037	178.4	.0069	.8720	.00619	- .1546
10.00	2413	.0061	2.365	-.0083	223.5	.0056	.7166	.00278	- .0797
20.00	2189	.0008	3.829	-.0115	248.4	.0047	.6182	.00125	- .0405
40.00	1965	-.0032	6.321	-.0140	270.5	.0038	.5459	.00046	- .0170
40.83	1959	-.0033	6.416	-.0141	271.1	.0038	.5441	.00045	- .0166
100.00	1678	-.0082	12.437	-.0156	293.1	.0029	.4875	.00009	- .0039
200.00	1475	-.0072	20.879	-.0160	307.0	.0023	.4613	.00002	- .0010
400.00	1289	-.0076	35.155	-.0160	318.7	.0019	.4417	.00000	- .0004
1000.00	1070	-.0081	70.143	-.0160	331.3	.0014	.4194	.00000	.0000
2000.00	923	-.0084	118.235	-.0161	339.2	.0012	.4040	.00000	.0000
4000.00	792	-.0087	199.011	-.0162	345.8	.0010	.3894	.00000	.0000
R = 3.00, PERCENT FUEL = 4.03, O/F = 3.810									
1.00	2747	0.0120					0.6509	0.00385	-0.0973
1.05	2729	.0117	2.152	0.0022	30.6	0.0046	.6451	.00369	- .0940
1.20	2679	.0107	1.254	.0016	58.8	.0044	.6293	.00328	- .0853
1.40	2622	.0096	1.058	.0009	79.4	.0042	.6114	.00284	- .0758
1.60	2573	.0086	1.008	.0004	93.4	.0040	.5963	.00249	- .0680
1.76	2538	.0079	1.000	.0000	102.1	.0039	.5858	.00226	- .0628
2.00	2491	.0071	1.011	-.0005	112.5	.0037	.5720	.00197	- .0561
4.00	2237	.0029	1.314	-.0030	155.0	.0029	.5059	.00085	- .0275
10.00	1913	-.0005	2.253	-.0050	192.9	.0020	.4460	.00021	- .0087
20.00	1682	-.0017	3.569	-.0055	214.0	.0015	.4185	.00005	- .0025
40.00	1470	-.0022	5.778	-.0056	231.0	.0011	.4000	.00001	- .0006
40.83	1464	-.0022	5.862	-.0056	231.4	.0011	.3995	.00001	- .0006
100.00	1220	-.0024	11.130	-.0055	248.7	.0008	.3811	.00000	- .0001
200.00	1054	-.0025	18.422	-.0055	259.4	.0006	.3679	.00000	.0000
400.00	904	-.0026	30.593	-.0054	268.3	.0005	.3555	.00000	.0000
1000.00	733	-.0027	59.908	-.0054	277.8	.0004	.3398	.00000	.0000
2000.00	622	-.0028	99.545	-.0054	283.5	.0003	.3290	.00000	.0000
4000.00	525	-.0029	165.173	-.0055	288.3	.0003	.3194	.00000	.0000

TABLE III. - Concluded. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

[Equilibrium composition during isentropic expansion. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Concluded. Combustion-chamber pressure, 600 pounds per square inch absolute

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, (lb)(sec)/lb	Specific-impulse exponent, n_I	Specific heat, c_p, cal/(g)(°K)	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathfrak{M}}{\partial \ln T}\right)_P$
R = 4.00, PERCENT FUEL = 3.05, O/F = 1.746									
1.00	2381	0.0046					0.4697	0.00095	-0.0288
1.05	2362	.0044	2.174	0.0013	27.6	0.0019	.4663	.00089	- .0274
1.20	2309	.0038	1.263	.0009	53.0	.0017	.4572	.00075	- .0235
1.40	2249	.0031	1.063	.0005	71.5	.0016	.4473	.00060	- .0196
1.60	2198	.0026	1.010	.0002	84.0	.0015	.4393	.00050	- .0166
1.78	2157	.0022	1.000	.0000	92.8	.0014	.4332	.00042	- .0145
2.00	2113	.0018	1.009	-.0002	101.1	.0013	.4272	.00035	- .0124
4.00	1860	.0003	1.293	-.0011	138.7	.0009	.3982	.00011	- .0044
10.00	1554	-.0005	2.182	-.0015	171.6	.0005	.3743	.00002	- .0008
20.00	1348	-.0006	3.423	-.0015	189.8	.0004	.3612	.00000	- .0004
40.00	1164	-.0007	5.493	-.0014	204.3	.0003	.3499	.00000	.0000
40.83	1159	-.0007	5.572	-.0014	204.7	.0003	.3495	.00000	.0000
100.00	952	-.0007	10.461	-.0014	219.2	.0002	.3352	.00000	.0000
200.00	813	-.0007	17.162	-.0013	228.2	.0002	.3243	.00000	.0000
400.00	690	-.0008	28.237	-.0013	235.5	.0001	.3139	.00000	.0000
1000.00	551	-.0008	54.608	-.0013	243.3	.0001	.3012	.00000	.0000
2000.00	463	-.0008	89.893	-.0013	247.9	.0001	.2927	.00000	.0000
4000.00	386	-.0008	147.835	-.0013	251.8	.0001	.2864	.00000	.0000
R = 5.00, PERCENT FUEL = 2.45, O/F = 9.683									
1.00	2072	0.0015					0.3924	0.00022	-0.0080
1.05	2053	.0014	2.190	0.0005	25.2	0.0006	.3906	.00020	- .0074
1.20	2002	.0011	1.270	.0004	48.5	.0006	.3859	.00016	- .0061
1.40	1944	.0008	1.067	.0002	65.4	.0005	.3808	.00012	- .0049
1.60	1894	.0007	1.011	.0001	76.8	.0004	.3767	.00010	- .0038
1.80	1852	.0005	1.000	.0000	85.3	.0004	.3734	.00008	- .0032
2.00	1813	.0004	1.007	-.0001	92.3	.0004	.3706	.00006	- .0026
4.00	1578	.0000	1.281	-.0003	126.2	.0002	.3559	.00001	- .0007
10.00	1303	-.0002	2.143	-.0003	155.8	.0001	.3410	.00000	- .0001
20.00	1122	-.0002	3.341	-.0003	172.0	.0001	.3309	.00000	.0000
40.00	961	-.0002	5.329	-.0003	184.7	.0001	.3209	.00000	.0000
40.83	956	-.0002	5.405	-.0003	185.1	.0001	.3206	.00000	.0000
100.00	777	-.0002	10.063	-.0003	197.9	.0000	.3076	.00000	.0000
200.00	658	-.0002	16.396	-.0003	205.7	.0000	.2979	.00000	.0000
400.00	554	-.0002	26.787	-.0003	212.0	.0000	.2887	.00000	.0000
1000.00	438	-.0002	51.327	-.0003	218.7	.0000	.2782	.00000	.0000
2000.00	365	-.0002	83.959	-.0003	222.6	.0000	.2728	.00000	.0000
4000.00	303	-.0002	137.411	-.0003	225.9	.0000	.2693	.00000	.0000

TABLE IV. - EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID HYDROGEN AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions; compositions are given in mole fractions. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Combustion-chamber pressure, 60 pounds per square inch absolute

R = 0.15, PERCENT FUEL = 45.65, O/F = 1.190														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	32.17	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, ^{o}K	1183	1129	1085	1049	1008	824	819	643	532	439	340	280	175	142
H_2	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000
H_2O	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000
R = 0.20, PERCENT FUEL = 38.65, O/F = 1.587														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	32.49	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, ^{o}K	1514	1450	1398	1354	1307	1079	1073	852	709	588	458	379	242	198
H	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0. 0000	0.00000	0.00000	0.00000	0.00000
H_2	.79999	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000
H_2O	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000
R = 0.25, PERCENT FUEL = 33.51, O/F = 1.984														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	32.78	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, ^{o}K	1816	1744	1686	1636	1587	1322	1316	1057	887	741	581	482	310	256
H	0.00017	0.00010	0.00006	0.00004	0.00003	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.74985	.74991	.74994	.74996	.74998	.75000	.75000	.75000	.75000	.75000	.75000	.75000	.75000	.75000
H_2O	.24997	.24998	.24999	.24999	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000
R = 0.30, PERCENT FUEL = 29.57, O/F = 2.381														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	33.04	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, ^{o}K	2089	2013	1950	1896	1846	1553	1546	1258	1064	896	708	590	383	317
H	0.00120	0.00080	0.00056	0.00040	0.00029	0.00003	0.00003	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.69899	.69932	.69953	.69966	.69976	.69998	.69998	.70000	.70000	.70000	.70000	.70000	.70000	.70000
H_2O	.29975	.29984	.29989	.29992	.29995	.30000	.30000	.30000	.30000	.30000	.30000	.30000	.30000	.30000
OH	.00006	.00004	.00002	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.35, PERCENT FUEL = 26.47, O/F = 2.778														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	33.32	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, ^{o}K	2329	2253	2189	2133	2085	1772	1764	1452	1239	1051	838	703	460	382
H	0.00446	0.00328	0.00248	0.00192	0.00151	0.00022	0.00021	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.64640	.64735	.64799	.64844	.64877	.64982	.64983	.64999	.65000	.65000	.65000	.65000	.65000	.65000
H_2O	.34873	.34910	.34934	.34951	.34962	.34995	.34995	.35000	.35000	.35000	.35000	.35000	.35000	.35000
OH	.00041	.00027	.00019	.00013	.00010	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.40, PERCENT FUEL = 23.95, O/F = 3.175														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	33.62	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, ^{o}K	2531	2458	2396	2342	2298	1978	1970	1640	1411	1207	972	820	543	453
H	0.01092	0.00867	0.00702	0.00577	0.00488	0.00106	0.00102	0.00010	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00002	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.59160	.59331	.59456	.59552	.59621	.59916	.59920	.59992	.59999	.60000	.60000	.60000	.60000	.60000
H_2O	.39584	.39683	.39752	.39802	.39837	.39970	.39972	.39998	.40000	.40000	.40000	.40000	.40000	.40000
O_2	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00161	.00118	.00088	.00068	.00054	.00007	.00007	.00000	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.45, PERCENT FUEL = 21.87, O/F = 3.571														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	33.93	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, ^{o}K	2695	2628	2570	2519	2481	2167	2159	1822	1581	1362	1109	942	632	529
H	0.02018	0.01699	0.01451	0.01253	0.01115	0.00340	0.00328	0.00050	0.00007	0.00001	0.00000	0.00000	0.00000	0.00000
O	.00010	.00007	.00005	.00003	.00003	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.53544	.53767	.53942	.54083	.54161	.54745	.54754	.54962	.54994	.54999	.55000	.55000	.55000	.55000
H_2O	.43989	.44163	.44326	.44436	.44509	.44877	.44882	.44985	.44998	.45000	.45000	.45000	.45000	.45000
O_2	.00003	.00002	.00002	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00435	.00342	.00275	.00224	.00191	.00038	.00036	.00003	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.50, PERCENT FUEL = 20.12, O/F = 3.968														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	34.19	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, ^{o}K	2828	2765	2711	2664	2632	2335	2327	1996	1748	1518	1247	1067	727	611
H	0.03077	0.02704	0.02402	0.02151	0.01985	0.00801	0.00779	0.00174	0.00035	0.00005	0.00000	0.00000	0.00000	0.00000
O	.00036	.00026	.00020	.00015	.00013	.00002	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.47961	.48192	.48382	.48541	.48648	.49436	.49451	.49874	.49974	.49996	.50000	.50000	.50000	.50000
H_2O	.47995	.48307	.48546	.48736	.48856	.49621	.49633	.49934	.49988	.49999	.50000	.50000	.50000	.50000
O_2	.00015	.00011	.00008	.00006	.00005	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00915	.00760	.00642	.00550	.00491	.00140	.00134	.00018	.00002	.00000	.00000	.00000	.00000	.00000
R = 0.60, PERCENT FUEL = 17.35, O/F = 4.762														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	34.55	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, ^{o}K	3015	2961	2914	2874	2849	2595	2588	2299	2063	1825	1529	1326	932	792
H	0.04998	0.04628	0.04316	0.04048	0.03884	0.02303	0.02267	0.00943	0.00343	0.00087	0.00008	0.00001	0.00000	0.00000
O	.00202	.00167	.00141	.00121	.00109	.00031	.00030	.00004	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.37569	.37696	.37809	.37911	.37975	.38683	.38701	.39416	.39776	.39942	.39995	.40000	.40000	.40000
H_2O	.54591	.55160	.55518	.55999	.56225	.58144	.58182	.59399	.59819	.59962	.59997	.60000	.60000	.60000
O_2	.00119	.00100	.00085	.00073	.00066	.00019	.00019	.00002	.00000	.00000	.00000	.00000	.00000	.00000
OH	.02520	.02250	.02031	.01849	.01741	.00819	.00801	.00235	.00059	.00009	.00000	.00000	.00000	.00000
R = 0.70, PERCENT FUEL = 15.25, O/F = 5.556														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	34.75	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, ^{o}K	3128	3076	3037	3001	2981	2761	2756	2517	2320	2108	1813	1596	1156	996
H	0.06035	0.05790	0.05532	0.05308	0.05130	0.03770	0.03735	0.02275	0.01262	0.00555	0.00108	0.00020	0.00000	0.00000
O	.00590	.00525	.00473	.00429	.00406	.00192	.00186	.00058	.00015	.00002	.00000	.00000	.00000	.00000
H_2	.28927	.28865	.28855	.28833	.28822	.28814	.28818	.29058	.29361	.29700	.29936	.29986	.30000	.30000
H_2O	.59195	.59964	.60636	.61193	.61505	.64682	.64752	.67406	.68797	.69579	.69938	.69991	.70000	.70000
O_2	.00488	.00441	.00402	.00370	.00352	.00177	.00174	.00056	.00015	.00002	.00000	.00000	.00000	.00000
OH	.04705	.04376	.04101	.03867	.03735	.02366	.02335	.01147	.00511	.00161	.00018	.00002	.00000	.00000

TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID HYDROGEN AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions; compositions are given in mole fractions. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(a) Concluded. Combustion-chamber pressure, 60 pounds per square inch absolute

R = 0.80, PERCENT FUEL = 13.60, O/F = 6.349														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	34.85	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, °K	3188	3141	3103	3070	3052	2853	2848	2645	2467	2321	2074	1866	1398	1220
H	0.06315	0.06063	0.05851	0.05668	0.05538	0.04433	0.04406	0.03227	0.02337	0.01491	0.00581	0.00193	0.00003	0.00000
O	.01163	.01075	.01003	.00943	.00910	.00574	.00567	.00292	.00142	.00050	.00006	.00000	.00000	.00000
H_2	.22260	.22082	.21935	.21804	.21734	.20957	.20939	.20240	.19864	.19598	.19782	.19910	.19998	.20000
H_2O	.62032	.62957	.63734	.64402	.64767	.66843	.66935	.72400	.75565	.77675	.79340	.79834	.79998	.80000
O_2	.01305	.01237	.01178	.01127	.01099	.00771	.00763	.00435	.00226	.00084	.00010	.00001	.00000	.00000
OH	.06925	.06585	.06301	.06056	.05922	.04422	.04367	.02401	.01667	.01002	.00273	.00061	.00000	.00000
R = 0.90, PERCENT FUEL = 12.26, O/F = 7.143														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	34.89	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, °K	3213	3168	3131	3099	3082	2892	2888	2701	2564	2429	2246	2095	1660	1468
H	0.05966	0.05741	0.05554	0.05392	0.05306	0.04322	0.04299	0.03322	0.02616	0.01960	0.01179	0.00671	0.00049	0.00008
O	.01787	.01686	.01602	.01531	.01493	.01084	.01074	.00708	.00474	.00264	.00107	.00032	.00000	.00000
H_2	.17295	.17043	.16826	.16640	.16536	.15316	.15266	.13957	.12926	.11931	.10766	.10205	.09983	.09996
H_2O	.63534	.64519	.65350	.66066	.66454	.70941	.71046	.75677	.79114	.82334	.86120	.88268	.89946	.89993
O_2	.02642	.02572	.02511	.02457	.02427	.02046	.02038	.01383	.01205	.00822	.00362	.00120	.00000	.00000
OH	.08775	.08436	.08156	.07912	.07782	.06287	.06252	.04755	.03665	.02648	.01445	.00704	.00021	.00002
R = 1.00, PERCENT FUEL = 11.19, O/F = 7.937														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	34.91	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, °K	3217	3173	3136	3104	3086	2900	2896	2[illegible]13	2579	2452	2267	2164	1859	1710
H	0.05353	0.05143	0.04967	0.04817	0.04736	0.03825	0.03804	0.02[illegible]12	0.02281	0.01710	0.01061	0.00665	0.00115	0.00032
O	.02347	.02234	.02141	.02061	.02019	.01555	.01544	.01[illegible]17	.00834	.00592	.00339	.00198	.00027	.00007
H_2	.13620	.13340	.13100	.12891	.12777	.11406	.11372	.09[illegible]41	.08610	.07346	.05642	.04354	.01649	.00812
H_2O	.64117	.65113	.65953	.66681	.67071	.71636	.71746	.76[illegible]07	.80109	.83610	.88022	.91125	.96976	.98579
O_2	.04445	.04394	.04349	.04306	.04286	.03983	.03975	.03579	.03223	.02625	.02245	.01773	.00708	.00358
OH	.10118	.09776	.09490	.09245	.09111	.07595	.07560	.06042	.04942	.03917	.02695	.01686	.00525	.00213
R = 1.50, PERCENT FUEL = 7.749, O/F = 1.905														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	34.86	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, °K	3116	3070	3031	2999	2981	2782	2777	2[illegible]76	2421	2263	2040	1656	1415	1240
H	0.02428	0.02275	0.02149	0.02042	0.01985	0.01367	0.01353	0.00[illegible]08	0.00476	0.00237	0.00061	0.00013	0.00000	0.00000
O	.03338	.03164	.03019	.02895	.02826	.02092	.02075	.01[illegible]82	.00921	.00541	.00196	.00063	.00001	.00000
H_2	.04909	.04690	.04504	.04344	.04257	.03260	.03236	.02[illegible]31	.01523	.00915	.00341	.00112	.00002	.00000
H_2O	.61197	.62046	.62758	.63371	.63735	.67453	.67542	.71[illegible]44	.73829	.76068	.78293	.79298	.79969	.79995
O_2	.16807	.16939	.17049	.17144	.17195	.17767	.17781	.18[illegible]46	.18756	.19134	.19560	.19792	.19988	.19998
OH	.11322	.10887	.10520	.10204	.10031	.08060	.08013	.05[illegible]87	.04493	.03104	.01549	.00721	.00041	.00007
R = 2.00, PERCENT FUEL = 5.927, O/F = 5.873														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	34.75	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, °K	2966	2917	2877	2841	2821	2604	2599	2[illegible]65	2177	1976	1706	1505	1095	945
H	0.01009	0.00913	0.00833	0.00770	0.00734	0.00395	0.00388	0.00[illegible]52	0.00054	0.00013	0.00001	0.00000	0.00000	0.00000
O	.02669	.02468	.02302	.02162	.02083	.01295	.01276	.00[illegible]30	.00291	.00101	.00013	.00002	.00000	.00000
H_2	.02078	.01933	.01812	.01709	.01651	.01053	.01040	.00[illegible]27	.00249	.00088	.00012	.00002	.00000	.00000
H_2O	.55950	.56635	.57205	.57691	.57966	.60605	.60869	.63[illegible]97	.64880	.65667	.66479	.66621	.66666	.66667
O_2	.29223	.29473	.29661	.29859	.29959	.31006	.31030	.31[illegible]86	.32570	.32978	.33245	.33311	.33333	.33333
OH	.09071	.08579	.08166	.07810	.07606	.05447	.05396	.03[illegible]09	.01955	.00954	.00250	.00064	.00001	.00000
R = 3.00, PERCENT FUEL = 4.031, O/F = 3.810														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	34.33	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, °K	2655	2599	2550	2509	2481	2216	2209	1715	1691	1460	1229	1061	739	627
H	0.00150	0.00122	0.00100	0.00084	0.00074	0.00018	0.00017	0.00[illegible]02	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.01009	.00860	.00745	.00652	.00595	.00206	.00200	.00[illegible]37	.00006	.00001	.00000	.00000	.00000	.00000
H_2	.00406	.00348	.00303	.00267	.00244	.00087	.00085	.00[illegible]16	.00003	.00000	.00000	.00000	.00000	.00000
H_2O	.46403	.46616	.47144	.47420	.47595	.48901	.48926	.49[illegible]76	.49904	.49979	.49998	.50000	.50000	.50000
O_2	.47702	.47971	.48185	.48361	.48473	.49311	.49327	.49[illegible]00	.49942	.49987	.49999	.50000	.50000	.50000
OH	.04329	.03883	.03519	.03215	.03020	.01476	.01445	.00[illegible]	.00144	.00033	.00003	.00000	.00000	.00000
R = 4.00, PERCENT FUEL = 3.054, O/F = 1.746														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	33.79	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, °K	2347	2262	2226	2180	2143	1858	1851	1556	1351	1167	954	815	553	464
H	0.00016	0.00011	0.00008	0.00006	0.00004	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00245	.00185	.00144	.00114	.00094	.00016	.00015	.00001	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.00068	.00052	.00041	.00032	.00027	.00005	.00004	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2O	.38930	.39099	.39247	.39361	.39441	.39858	.39864	.39974	.39996	.39999	.40000	.40000	.40000	.40000
O_2	.59176	.59331	.59449	.59552	.59595	.59865	.59890	.59962	.59997	.60000	.60000	.60000	.60000	.60000
OH	.01595	.01322	.01116	.00955	.00840	.00255	.00247	.00042	.00007	.00001	.00000	.00000	.00000	.00000
R = 5.00, PERCENT FUEL = 2.458, O/F = 9.683														
Pressure, lb/sq in. abs	60.00	50.00	42.86	37.50	33.40	15.00	14.70	6.00	3.00	1.50	0.60	0.30	0.06	0.03
Temperature, °K	2062	1995	1938	1890	1849	1578	1571	1504	1122	961	776	659	436	365
H	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00042	.00028	.00019	.00014	.00010	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.00008	.00006	.00004	.00003	.00002	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2O	.33026	.33109	.33159	.33174	.33220	.33311	.33312	.33331	.33333	.33333	.33333	.33333	.33333	.33333
O_2	.66433	.66492	.66532	.66580	.66581	.66650	.66651	.66665	.66667	.66667	.66667	.66667	.66667	.66667
OH	.00479	.00364	.00285	.00229	.00187	.00037	.00035	.00003	.00000	.00000	.00000	.00000	.00000	.00000

TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID HYDROGEN AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions; compositions are given in mole fractions. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Combustion-chamber pressure, 150 pounds per square inch absolute

R = 0.15, PERCENT FUEL = 45.65, O/F = 1.190														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	80.42	37.50	15.00	14.70	7.50	3.75	1.50	0.75	0.15	0.08
Temperature, °K	1183	1129	1085	1049	1008	824	643	639	532	439	340	280	175	142
H_2	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000
H_2O	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000
R = 0.20, PERCENT FUEL = 38.65, O/F = 1.587														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	81.24	37.50	15.00	14.70	7.50	3.75	1.50	0.75	0.15	0.08
Temperature, °K	1514	1450	1398	1354	1307	1079	852	847	709	588	458	379	242	198
H	0.00001	0.00000	0.00 00	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.79999	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000	.80000
H_2O	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000
R = 0.25, PERCENT FUEL = 33.51, O/F = 1.984														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	81.96	37.50	15.00	14.70	7.50	3.75	1.50	0.75	0.15	0.08
Temperature, °K	1816	1745	1686	1636	1587	1322	1057	1052	887	741	581	482	310	256
H	0.00011	0.00007	0.00004	0.00003	0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.74990	.74994	.74996	.74998	.74998	.75000	.75000	.75000	.75000	.75000	.75000	.75000	.75000	.75000
H_2O	.24998	.24999	.24999	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000
R = 0.30, PERCENT FUEL = 29.57, O/F = 2.381														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	82.58	37.50	15.00	14.70	7.50	3.75	1.50	0.75	0.15	0.08
Temperature, °K	2092	2015	1951	1897	1846	1553	1258	1251	1064	895	708	590	383	317
H	0.00077	0.00051	0.00036	0.00026	0.00018	0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.69935	.69957	.69970	.69978	.69984	.69999	.70000	.70000	.70000	.70000	.70000	.70000	.70000	.70000
H_2O	.29984	.29990	.29993	.29995	.29997	.30000	.30000	.30000	.30000	.30000	.30000	.30000	.30000	.30000
OH	.00004	.00002	.00001	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.35, PERCENT FUEL = 26.47, O/F = 2.778														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	83.19	37.50	15.00	14.70	7.50	3.75	1.50	0.75	0.15	0.08
Temperature, °K	2339	2259	2193	2137	2037	1772	1451	1444	1239	1051	838	702	460	382
H	0.00296	0.00215	0.00161	0.00124	0.00097	0.00014	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.64761	.64826	.64869	.64899	.64921	.64988	.64999	.64999	.65000	.65000	.65000	.65000	.65000	.65000
H_2O	.34915	.34941	.34957	.34968	.34976	.34997	.35000	.35000	.35000	.35000	.35000	.35000	.35000	.35000
OH	.00028	.00018	.00012	.00009	.00006	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.40, PERCENT FUEL = 23.95, O/F = 3.175														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	83.64	37.50	15.00	14.70	7.50	3.75	1.50	0.75	0.15	0.08
Temperature, °K	2553	2475	2410	2353	2306	1978	1638	1631	1410	1206	971	819	543	452
H	0.00758	0.00593	0.00474	0.00386	0.00322	0.00067	0.00006	0.00006	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.59418	.59543	.59633	.59701	.59750	.59947	.59995	.59995	.60000	.60000	.60000	.60000	.60000	.60000
H_2O	.39709	.39782	.39832	.39867	.39892	.39981	.39999	.39999	.40000	.40000	.40000	.40000	.40000	.40000
OH	.00115	.00082	.00061	.00046	.00036	.00004	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.45, PERCENT FUEL = 21.87, O/F = 3.571														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	84.32	37.50	15.00	14.70	7.50	3.75	1.50	0.75	0.15	0.08
Temperature, °K	2733	2659	2596	2542	2499	2171	1819	1812	1578	1359	1106	939	631	528
H	0.01469	0.01217	0.01025	0.00875	0.00768	0.00220	0.00031	0.00029	0.00004	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00006	.00004	.00002	.00002	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.53941	.54117	.54253	.54360	.54436	.54835	.54977	.54978	.54997	.55000	.55000	.55000	.55000	.55000
H_2O	.44255	.44408	.44520	.44603	.44660	.44920	.44991	.44991	.44999	.45000	.45000	.45000	.45000	.45000
O_2	.00002	.00001	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00328	.00253	.00199	.00160	.00134	.00025	.00002	.00002	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.50, PERCENT FUEL = 20.12, O/F = 3.968														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	85.15	37.50	15.00	14.70	7.50	3.75	1.50	0.75	0.15	0.08
Temperature, °K	2881	2811	2752	2701	2664	2346	1994	1986	1743	1512	1242	1063	724	608
H	0.02339	0.02026	0.01776	0.01573	0.01434	0.00537	0.00108	0.00104	0.00021	0.00003	0.00000	0.00000	0.00000	0.00000
O	.00021	.00015	.00011	.00008	.00007	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.48452	.48646	.48804	.48934	.49024	.49622	.49921	.49925	.49984	.49998	.50000	.50000	.50000	.50000
H_2O	.48452	.48713	.48911	.49065	.49167	.49746	.49959	.49961	.49993	.49999	.50000	.50000	.50000	.50000
O_2	.00009	.00006	.00005	.00003	.00003	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00727	.00594	.00493	.00416	.00366	.00095	.00011	.00010	.00001	.00000	.00000	.00000	.00000	.00000
R = 0.60, PERCENT FUEL = 17.35, O/F = 4.762														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	86.09	37.50	15.00	14.70	7.50	3.75	1.50	0.75	0.15	0.08
Temperature, °K	3097	3036	2985	2940	2911	2630	2308	2300	2058	1815	1518	1317	924	786
H	0.04050	0.03714	0.03433	0.03193	0.03042	0.01688	0.00625	0.00608	0.00211	0.00051	0.00004	0.00000	0.00000	0.00000
O	.00139	.00113	.00093	.00078	.00070	.00017	.00002	.00002	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.38033	.38152	.38257	.38351	.38412	.39033	.39613	.39623	.39864	.39966	.39997	.40000	.40000	.40000
H_2O	.55514	.56032	.56446	.56766	.56994	.58629	.59503	.59616	.59890	.59978	.59998	.60000	.60000	.60000
O_2	.00082	.00067	.00056	.00047	.00042	.00011	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000
OH	.02181	.01923	.01716	.01545	.01440	.00623	.00157	.00152	.00036	.00005	.00000	.00000	.00000	.00000
R = 0.70, PERCENT FUEL = 15.25, O/F = 5.556														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	86.66	37.50	15.00	14.70	7.50	3.75	1.50	0.75	0.15	0.08
Temperature, °K	3232	3176	3130	3097	3068	2623	2550	2544	2331	2102	1797	1579	1142	983
H	0.05131	0.04846	0.04605	0.04396	0.04273	0.02980	0.01664	0.01637	0.00661	0.00337	0.00029	0.00010	0.00000	0.00000
O	.00449	.00394	.00355	.00314	.00294	.00126	.00032	.00030	.00007	.00001	.00000	.00000	.00000	.00000
H_2	.29131	.29091	.29063	.29045	.29034	.29046	.29298	.29306	.29578	.29816	.29965	.29994	.30000	.30000
H_2O	.60591	.61347	.61971	.62458	.62805	.63735	.66104	.66145	.69199	.69747	.69967	.69995	.70000	.70000
O_2	.00375	.00334	.00301	.00273	.00256	.00117	.00031	.00030	.00007	.00001	.00000	.00000	.00000	.00000
OH	.04323	.03989	.03711	.03475	.03335	.01995	.00672	.00852	.00346	.00097	.00009	.00001	.00000	.00000

TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID HYDROGEN AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions; compositions are given in mole fractions. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(b) Concluded. Combustion-chamber pressure, 150 pounds per square inch absolute

R = 0.80, PERCENT FUEL = 13.66, O/F = 6.345														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	86.97	37.50	15.00	4.70	1.50	0.75	0.15	0.08		
Temperature, °K	3304	3253	3211	3174	3154	2935	2704	2699	2526	2364	1846	1575	1199	
H	0.05409	0.05174	0.04977	0.04807	0.04712	0.03661	0.02552	0.02526	0.01751	0.01028	0.00345	0.00103	0.00032	0.00000
O	.00948	.00870	.00806	.00752	.00723	.00431	.00197	.00193	.00084	.00025	.00002	.00000	.00000	.00000
H_2	.22134	.21952	.21800	.21669	.21597	.20828	.20161	.20149	.19855	.19761	.19664	.19951	.19999	.20000
H_2O	.63789	.64703	.65470	.66128	.66495	.70457	.74301	.74379	.76869	.78433	.79627	.79915	.79999	.80000
O_2	.01095	.01030	.00973	.00925	.00897	.00593	.00300	.00294	.00135	.00041	.00003	.00000	.00000	.00000
OH	.06624	.06271	.05974	.05719	.05577	.04031	.02489	.02457	.01486	.00712	.00159	.00031	.00000	.00000
R = 0.90, PERCENT FUEL = 12.24, O/F = 7.143														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	87.09	37.50	15.00	4.70	1.50	0.75	0.15	0.08		
Temperature, °K	3336	3286	3246	3211	3192	2984	2775	2770	2623	2474	2267	2092	1826	1437
H	0.05120	0.04913	0.04740	0.04592	0.04510	0.03611	0.02704	0.02685	0.02072	0.01493	0.00863	0.00416	0.00023	0.00004
O	.01521	.01428	.01351	.01287	.01252	.00882	.00549	.00543	.00347	.00190	.00057	.00013	.00000	.00000
H_2	.16903	.16643	.16418	.16222	.16113	.14651	.13461	.13430	.12432	.11474	.10473	.10075	.09992	.09998
H_2O	.65494	.66481	.67313	.68031	.68427	.72893	.77575	.77677	.80923	.84001	.87358	.89004	.89977	.89997
O_2	.02360	.02289	.02226	.02171	.02140	.01759	.01300	.01289	.00936	.00583	.00203	.00049	.00000	.00000
OH	.08600	.08247	.07952	.07697	.07558	.06002	.04411	.04377	.03291	.02259	.01086	.00444	.00009	.00001
R = 1.00, PERCENT FUEL = 11.11, O/F = 7.937														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	87.13	37.50	15.00	4.70	1.50	0.75	0.15	0.08		
Temperature, °K	3341	3292	3252	3217	3199	2994	2789	2785	2644	2505	2325	2188	1850	1666
H	0.04560	0.04368	0.04207	0.04069	0.03994	0.03168	0.02349	0.02332	0.01792	0.01297	0.00755	0.00442	0.00057	0.00013
O	.02044	.01940	.01854	.01781	.01741	.01317	.00921	.00913	.00669	.00458	.00245	.00133	.00015	.00003
H_2	.13070	.12776	.12526	.12306	.12186	.10759	.09139	.09102	.07874	.06586	.04878	.03619	.01164	.00514
H_2O	.66145	.67146	.67991	.68721	.69121	.73690	.78551	.78658	.82121	.85561	.89629	.92757	.97901	.99114
O_2	.04143	.04090	.04043	.04000	.03975	.03662	.03248	.03238	.02886	.02488	.01910	.01455	.00498	.00226
OH	.10038	.09681	.09364	.09123	.08982	.07405	.05793	.05758	.04659	.03611	.02382	.01593	.00366	.00130
R = 1.50, PERCENT FUEL = 7.74, O/F = 1.905														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	86.98	37.50	15.00	4.70	1.50	0.75	0.15	0.08		
Temperature, °K	3219	3169	3127	3091	3071	2853	2626	2621	2455	2281	2037	1842	1393	1220
H	0.01925	0.01792	0.01683	0.01591	0.01540	0.01017	0.00563	0.00554	0.00309	0.00139	0.00030	0.00006	0.00000	0.00000
O	.02906	.02743	.02607	.02491	.02427	.01747	.01103	.01090	.00698	.00382	.00122	.00035	.00000	.00000
H_2	.04359	.04143	.03961	.03805	.03718	.02759	.01796	.01776	.01162	.00649	.00212	.00062	.00001	.00000
H_2O	.62812	.63646	.64346	.64946	.65261	.68917	.72532	.72608	.74928	.76922	.78768	.79523	.79981	.79997
O_2	.16847	.16983	.17097	.17195	.17249	.17642	.18445	.18458	.18868	.19246	.19649	.19846	.19992	.19999
OH	.11152	.10693	.10306	.09972	.09785	.07718	.05562	.05515	.04036	.02661	.01220	.00528	.00026	.00004
R = 2.00, PERCENT FUEL = 5.92, O/F = 5.873														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	86.67	37.50	15.00	4.70	1.50	0.75	0.15	0.08		
Temperature, °K	3045	2992	2947	2909	2886	2649	2388	2382	2184	1974	1694	1492	1084	935
H	0.00745	0.00667	0.00604	0.00552	0.00523	0.00263	0.00091	0.00088	0.00029	0.00006	0.00000	0.00000	0.00000	0.00000
O	.02225	.02043	.01893	.01767	.01694	.01005	.00453	.00443	.00194	.00061	.00007	.00001	.00000	.00000
H_2	.01742	.01608	.01497	.01403	.01348	.00819	.00379	.00371	.00166	.00054	.00007	.00001	.00000	.00000
H_2O	.57080	.57738	.58265	.58746	.59015	.61669	.64010	.64055	.65278	.66072	.66233	.66652	.66666	.66667
O_2	.29542	.29784	.29994	.30169	.30270	.31283	.32403	.32424	.32722	.33062	.33270	.33318	.33333	.33333
OH	.08666	.08157	.07730	.07363	.07149	.04961	.02864	.02822	.01610	.00744	.00183	.00046	.00000	.00000
R = 3.00, PERCENT FUEL = 4.03, O/F = 3.810														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	85.98	37.50	15.00	4.70	1.50	0.75	0.15	0.08		
Temperature, °K	2695	2634	2582	2537	2517	2226	1914	1907	1687	1475	1224	1057	736	625
H	0.00096	0.00077	0.00062	0.00051	0.00045	0.00010	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00762	.00641	.00549	.00475	.00429	.00139	.00023	.00022	.00004	.00000	.00000	.00000	.00000	.00000
H_2	.00307	.00260	.00224	.00195	.00176	.00059	.00010	.00010	.00002	.00000	.00000	.00000	.00000	.00000
H_2O	.46923	.47297	.47594	.47837	.47995	.49117	.49748	.49796	.49927	.49984	.49999	.50000	.50000	.50000
O_2	.48042	.48284	.48478	.48632	.48734	.49449	.49846	.49851	.49956	.49990	.49999	.50000	.50000	.50000
OH	.03870	.03441	.03096	.02809	.02621	.01226	.00372	.00360	.00112	.00025	.00002	.00000	.00000	.00000
R = 4.00, PERCENT FUEL = 3.05, O/F = 1.746														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	84.31	37.50	15.00	4.70	1.50	0.75	0.15	0.08		
Temperature, °K	2363	2295	2238	2188	2149	1859	1555	1549	1390	1188	933	814	552	463
H	0.00009	0.00006	0.00004	0.00003	0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00169	.00126	.00097	.00076	.00062	.00010	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.00047	.00035	.00027	.00022	.00018	.00003	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2O	.39096	.39265	.39369	.39464	.39551	.39872	.39980	.39984	.39996	.40000	.40000	.40000	.40000	.40000
O_2	.59335	.59463	.59557	.59626	.59676	.59911	.59986	.59987	.59998	.60000	.60000	.60000	.60000	.60000
OH	.01343	.01105	.00926	.00787	.00688	.00204	.00033	.00032	.00006	.00001	.00000	.00000	.00000	.00000
R = 5.00, PERCENT FUEL = 2.45, O/F = 9.683														
Pressure, lb/sq in. abs	150.00	125.00	107.14	93.75	83.45	37.50	15.00	4.70	1.50	0.75	0.15	0.08		
Temperature, °K	2066	1998	1941	1892	1850	1578	1303	1298	1172	981	778	656	438	365
H	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00028	.00018	.00013	.00009	.00007	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.00006	.00004	.00003	.00002	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2O	.33094	.33154	.33194	.33222	.33243	.33316	.33332	.33332	.33333	.33333	.33333	.33333	.33333	.33333
O_2	.66482	.66529	.66561	.66583	.66599	.66654	.66666	.66666	.66667	.66667	.66667	.66667	.66667	.66667
OH	.00389	.00295	.00230	.00183	.00149	.00030	.00003	.00003	.00000	.00000	.00000	.00000	.00000	.00000

TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID HYDROGEN AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions; compositions are given in mole fractions. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Combustion-chamber pressure, 300 pounds per square inch absolute

R = 0.15, PERCENT FUEL = 45.65, O/F = 1.190														
Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	160.84	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	1183	1129	1085	1049	1008	824	643	532	529	439	340	280	175	142
H_2	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000
H_2O	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000
R = 0.20, PERCENT FUEL = 38.65, O/F = 1.587														
Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	162.47	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	1514	1450	1398	1354	1307	1079	852	709	705	588	458	379	242	198
H_2	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000
H_2O	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000
R = 0.25, PERCENT FUEL = 33.51, O/F = 1.984														
Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	163.91	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	1817	1745	1685	1636	1587	1322	1057	887	882	741	581	482	310	256
H	0.00008	0.00005	0.00003	0.00002	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.74993	.74996	.74997	.74998	.74999	.75000	.75000	.75000	.75000	.75000	.75000	.75000	.75000	.75000
H_2O	.24999	.24999	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000
R = 0.30, PERCENT FUEL = 29.57, O/F = 2.381														
Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	165.12	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	2093	2016	1952	1897	1846	1553	1257	1064	1059	895	707	590	383	317
H	0.00055	0.00037	0.00025	0.00018	0.00013	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.69954	.69969	.69979	.69985	.69989	.69999	.70000	.70000	.70000	.70000	.70000	.70000	.70000	.70000
H_2O	.29988	.29993	.29995	.29997	.29998	.30000	.30000	.30000	.30000	.30000	.30000	.30000	.30000	.30000
OH	.00003	.00002	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.35, PERCENT FUEL = 26.47, O/F = 2.778														
Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	166.26	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	2344	2263	2196	2139	2088	1771	1451	1238	1232	1051	838	702	460	382
H	0.00214	0.00155	0.00116	0.00089	0.00069	0.00010	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.64827	.64875	.64906	.64928	.64944	.64992	.65000	.65000	.65000	.65000	.65000	.65000	.65000	.65000
H_2O	.34939	.34957	.34969	.34977	.34983	.34998	.35000	.35000	.35000	.35000	.35000	.35000	.35000	.35000
OH	.00020	.00013	.00009	.00006	.00004	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.40, PERCENT FUEL = 23.95, O/F = 3.175														
Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	167.44	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	2565	2484	2417	2359	2310	1978	1637	1409	1403	1205	970	819	542	452
H	0.00565	0.00437	0.00347	0.00281	0.00233	0.00048	0.00004	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.59566	.59662	.59731	.59782	.59819	.59962	.59997	.60000	.60000	.60000	.60000	.60000	.60000	.60000
H_2O	.39782	.39839	.39877	.39903	.39922	.39987	.39999	.40000	.40000	.40000	.40000	.40000	.40000	.40000
OH	.00086	.00061	.00045	.00034	.00026	.00003	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.45, PERCENT FUEL = 21.87, O/F = 3.571														
Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	168.67	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	2755	2677	2611	2555	2510	2173	1818	1576	1569	1358	1105	938	630	527
H	0.01130	0.00927	0.00773	0.00654	0.00570	0.00157	0.00021	0.00003	0.00003	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00003	.00002	.00001	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.54185	.54328	.54436	.54521	.54582	.54882	.54984	.54998	.54998	.55000	.55000	.55000	.55000	.55000
H_2O	.44423	.44547	.44636	.44702	.44747	.44943	.44994	.44999	.44999	.45000	.45000	.45000	.45000	.45000
O_2	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00258	.00196	.00153	.00122	.00101	.00018	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000
R = 0.50, PERCENT FUEL = 20.12, O/F = 3.968														
Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	169.85	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	2915	2841	2778	2724	2684	2352	1992	1740	1732	1509	1240	1060	722	607
H	0.01858	0.01592	0.01383	0.01214	0.01097	0.00391	0.00076	0.00015	0.00014	0.00002	0.00000	0.00000	0.00000	0.00000
O	.00014	.00010	.00007	.00005	.00004	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.48771	.48936	.49069	.49177	.49253	.49725	.49945	.49989	.49990	.49999	.50000	.50000	.50000	.50000
H_2O	.48758	.48980	.49145	.49273	.49359	.49815	.49971	.49995	.49995	.49999	.50000	.50000	.50000	.50000
O_2	.00006	.00004	.00003	.00002	.00002	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00595	.00479	.00393	.00328	.00285	.00070	.00008	.00001	.00001	.00000	.00000	.00000	.00000	.00000
R = 0.60, PERCENT FUEL = 17.35, O/F = 4.762														
Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	171.73	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	3155	3089	3033	2985	2953	2652	2311	2054	2047	1808	1512	1311	919	782
H	0.03386	0.03080	0.02826	0.02611	0.02472	0.01303	0.00450	0.00145	0.00140	0.00034	0.00003	0.00000	0.00000	0.00000
O	.00100	.00080	.00065	.00054	.00047	.00010	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.38357	.38467	.38564	.38650	.38737	.39252	.39720	.39906	.39909	.39977	.39998	.40000	.40000	.40000
H_2O	.56191	.56662	.57036	.57341	.57531	.58937	.59714	.59924	.59927	.59985	.59999	.60000	.60000	.60000
O_2	.00059	.00047	.00039	.00032	.00028	.00006	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.01907	.01664	.01470	.01313	.01214	.00492	.00114	.00025	.00023	.00004	.00000	.00000	.00000	.00000
R = 0.70, PERCENT FUEL = 15.25, O/F = 5.556														
Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	172.98	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	3307	3248	3196	3151	3130	2865	2569	2335	2328	2095	1785	1568	1133	975
H	0.04433	0.04165	0.03940	0.03742	0.03528	0.02440	0.01280	0.00623	0.00607	0.00230	0.00038	0.00007	0.00000	0.00000
O	.00353	.00306	.00259	.00235	.00222	.00087	.00019	.00004	.00003	.00000	.00000	.00000	.00000	.00000
H_2	.29263	.29226	.29203	.29186	.29176	.29210	.29453	.29692	.29699	.29874	.29977	.29996	.30000	.30000
H_2O	.61574	.62295	.62557	.63485	.63779	.66477	.68544	.69425	.69443	.69830	.69979	.69997	.70000	.70000
O_2	.00298	.00262	.00233	.00210	.00196	.00081	.00018	.00003	.00003	.00000	.00000	.00000	.00000	.00000
OH	.03978	.03644	.03368	.03152	.02997	.01705	.00686	.00255	.00244	.00065	.00006	.00001	.00000	.00000

TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID HYDROGEN AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions; compositions are given in mole fractions. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(c) Concluded. Combustion-chamber pressure, 300 pounds per square inch absolute

R = 0.80, PERCENT FUEL = 13.60, O/F = 6.349

Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	173.68	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	3393	3338	3292	3253	3231	2995	2744	2590	2544	2344	2053	1830	1360	1165
H	0.04749	0.04529	0.04344	0.04185	0.04094	0.03116	0.02091	0.01370	0.01349	0.00752	0.00228	0.00064	0.00001	0.00000
O	.00793	.00722	.00665	.00617	.00590	.00334	.00139	.00053	.00051	.00013	.00001	.00000	.00000	.00000
H_2	.22002	.21819	.21667	.21536	.21463	.20716	.20102	.19656	.19634	.19810	.19908	.19967	.20000	.20000
H_2O	.65200	.66098	.66849	.67492	.67856	.71884	.75696	.77427	.77482	.78675	.79759	.79946	.80000	.80000
O_2	.00939	.00876	.00827	.00776	.00750	.00470	.00215	.00086	.00083	.00022	.00001	.00000	.00000	.00000
OH	.06318	.05956	.05653	.05393	.05243	.03681	.02134	.01404	.01180	.00527	.00103	.00019	.00000	.00000

R = 0.90, PERCENT FUEL = 12.28, O/F = 7.143

Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	173.98	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	3430	3377	3334	3298	3276	3054	2829	2666	2661	2503	2276	2084	1609	1416
H	0.04506	0.04313	0.04153	0.04015	0.03939	0.03109	0.02278	0.01705	0.01689	0.01187	0.00605	0.00278	0.00013	0.00002
O	.01323	.01237	.01167	.01107	.01075	.00738	.00440	.00264	.00259	.00133	.00033	.00006	.00000	.00000
H_2	.16552	.16281	.16051	.15850	.15737	.14454	.13059	.12090	.12021	.11147	.10296	.10027	.09992	.09999
H_2O	.67094	.68077	.68904	.69619	.70016	.74437	.79034	.82271	.82306	.85169	.88119	.89372	.89987	.89999
O_2	.02140	.02068	.02006	.01950	.01919	.01540	.01090	.00745	.00735	.00425	.00119	.00042	.00000	.00000
OH	.08385	.08023	.07720	.07458	.07313	.05721	.04098	.02966	.02934	.01940	.00629	.00295	.00005	.00000

R = 1.00, PERCENT FUEL = 11.19, O/F = 7.937

Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	174.06	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	3437	3384	3341	3304	3284	3065	2847	2692	2687	2542	2349	2203	1839	1668
H	0.03987	0.03809	0.03661	0.03534	0.03464	0.02707	0.01963	0.01465	0.01451	0.01030	0.00569	0.00313	0.00032	0.00006
O	.01816	.01719	.01639	.01571	.01534	.01143	.00782	.00555	.00549	.00369	.00186	.00095	.00007	.00001
H_2	.12585	.12283	.12025	.11800	.11674	.10213	.08562	.07483	.07444	.05991	.04504	.03688	.00872	.00356
H_2O	.67806	.68605	.69248	.70377	.70783	.75328	.80148	.83467	.83769	.87031	.91144	.93400	.98446	.99392
O_2	.03906	.03851	.03802	.03758	.03733	.03412	.02993	.02730	.02618	.02232	.01667	.01432	.00373	.00157
OH	.09900	.09532	.09224	.08959	.08813	.07197	.05551	.04501	.04369	.03548	.02132	.01372	.00270	.00087

R = 1.50, PERCENT FUEL = 7.749, O/F = 1.905

Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	173.72	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	3297	3243	3198	3159	3137	2904	2661	2478	2472	2291	2052	1830	1379	1207
H	0.01582	0.01466	0.01370	0.01289	0.01243	0.00794	0.00416	0.00216	0.00211	0.00090	0.00017	0.00003	0.00000	0.00000
O	.02582	.02428	.02300	.02192	.02131	.01498	.00911	.00554	.00544	.00287	.00083	.00022	.00000	.00000
H_2	.03926	.03716	.03540	.03388	.03302	.02388	.01492	.00924	.00909	.00488	.00145	.00040	.00000	.00000
H_2O	.64080	.64897	.65560	.66186	.66499	.70013	.73457	.75381	.75741	.77472	.79041	.79642	.79986	.79998
O_2	.16901	.17040	.17157	.17257	.17313	.17919	.18535	.18759	.18971	.19333	.19708	.19878	.19994	.19999
OH	.10929	.10454	.10054	.09708	.09512	.07387	.05190	.03966	.03623	.02331	.01006	.00415	.00019	.00003

R = 2.00, PERCENT FUEL = 5.927, O/F = 5.873

Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	173.03	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	3103	3046	2998	2957	2932	2679	2402	2188	2181	1970	1686	1483	1076	929
H	0.00578	0.00513	0.00461	0.00419	0.00395	0.00188	0.00060	0.00018	0.00017	0.00004	0.00000	0.00000	0.00000	0.00000
O	.01907	.01741	.01605	.01491	.01424	.00813	.00346	.00140	.00136	.00042	.00005	.00001	.00000	.00000
H_2	.11498	.11375	.11273	.11187	.11136	.00864	.00289	.00120	.00116	.00037	.00004	.00001	.00000	.00000
H_2O	.57933	.58564	.59085	.59527	.59788	.62279	.64414	.65524	.65550	.66191	.66562	.66642	.66666	.66667
O_2	.29800	.30043	.30244	.30414	.30515	.31491	.32334	.32721	.32832	.33113	.33283	.33321	.33333	.33333
OH	.08282	.07765	.07333	.06963	.06742	.04564	.02936	.01877	.01348	.00614	.00145	.00036	.00000	.00000

R = 3.00, PERCENT FUEL = 4.031, O/F = 3.810

Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	170.82	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	2723	2658	2604	2556	2523	2232	1914	1684	1678	1472	1222	1053	735	623
H	0.00067	0.00053	0.00042	0.00035	0.00030	0.00006	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00605	.00505	.00428	.00368	.00330	.00102	.00016	.00003	.00002	.00000	.00000	.00000	.00000	.00000
H_2	.00244	.00205	.00175	.00151	.00136	.00043	.00007	.00001	.00001	.00000	.00000	.00000	.00000	.00000
H_2O	.47287	.47830	.47900	.48120	.48265	.49253	.49792	.49940	.49942	.49987	.49999	.50000	.50000	.50000
O_2	.48280	.48501	.48675	.48816	.48909	.49537	.49873	.49964	.49965	.49992	.49999	.50000	.50000	.50000
OH	.03516	.03107	.02779	.02510	.02330	.01058	.00312	.00093	.00089	.00021	.00002	.00000	.00000	.00000

R = 4.00, PERCENT FUEL = 3.054, O/F = 1.746

Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	168.42	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	2372	2303	2244	2194	2153	1859	1595	1349	1343	1163	926	813	552	463
H	0.00006	0.00004	0.00003	0.00002	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00126	.00094	.00071	.00056	.00045	.00007	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.00035	.00026	.00020	.00016	.00013	.00002	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2O	.39225	.39372	.39480	.39562	.39621	.39893	.39983	.39997	.39997	.40000	.40000	.40000	.40000	.40000
O_2	.59436	.59547	.59627	.59687	.59730	.59926	.59989	.59998	.59998	.60000	.60000	.60000	.60000	.60000
OH	.01171	.00958	.00799	.00677	.00589	.00172	.00028	.00005	.00005	.00001	.00000	.00000	.00000	.00000

R = 5.00, PERCENT FUEL = 2.458, O/F = 9.683

Pressure, lb/sq in. abs	300.00	250.00	214.29	187.50	165.83	75.00	30.00	15.00	14.70	7.50	3.00	1.50	0.30	0.15
Temperature, °K	2069	2000	1943	1893	1851	1576	1303	1122	1117	961	777	676	456	385
O	0.00020	0.00013	0.00009	0.00006	0.00005	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.00004	.00002	.00002	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2O	.33131	.33184	.33216	.33240	.33256	.33319	.33333	.33333	.33333	.33333	.33333	.33333	.33333	.33333
O_2	.66513	.66632	.66678	.66697	.66710	.66656	.66666	.66667	.66667	.66667	.66667	.66667	.66667	.66667
OH	.00331	.00250	.00195	.00155	.00126	.00025	.00002	.00000	.00000	.00000	.00000	.00000	.00000	.00000

TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID HYDROGEN AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions; compositions are given in mole fractions. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Combustion-chamber pressure, 600 pounds per square inch absolute

R = 0.15, PERCENT FUEL = 45.65, O/F = 1.190

Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	321.68	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, ^{o}K	1183	1129	1085	1049	1008	824	643	532	439	437	340	280	175	142
H_2	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000	0.85000
H_2O	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000	.15000

R = 0.20, PERCENT FUEL = 38.65, O/F = 1.587

Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	324.94	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, ^{o}K	1514	1450	1398	1354	1307	1079	852	709	588	585	458	379	242	198
H_2	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000	0.80000
H_2O	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000

R = 0.25, PERCENT FUEL = 33.51, O/F = 1.984

Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	327.81	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, ^{o}K	1817	1745	1686	1636	1587	1322	1057	887	741	737	581	482	310	256
H	0.00006	0.00003	0.00002	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.74995	.74997	.74998	.74999	.74999	.75000	.75000	.75000	.75000	.75000	.75000	.75000	.75000	.75000
H_2O	.24999	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000	.25000

R = 0.30, PERCENT FUEL = 29.57, O/F = 2.381

Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	330.21	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, ^{o}K	2094	2016	1952	1898	1847	1553	1257	1064	895	891	707	590	383	317
H	0.00039	0.00026	0.00018	0.00013	0.00009	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.69967	.69978	.69985	.69989	.69992	.69999	.70000	.70000	.70000	.70000	.70000	.70000	.70000	.70000
H_2O	.29992	.29995	.29996	.29998	.29998	.30000	.30000	.30000	.30000	.30000	.30000	.30000	.30000	.30000
OH	.00002	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000

R = 0.35, PERCENT FUEL = 26.47, O/F = 2.778

Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	332.36	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, ^{o}K	2347	2266	2199	2140	2089	1771	1451	1238	1050	1045	838	702	460	382
H	0.00154	0.00111	0.00083	0.00063	0.00049	0.00007	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.64875	.64910	.64933	.64949	.64960	.64994	.65000	.65000	.65000	.65000	.65000	.65000	.65000	.65000
H_2O	.34956	.34969	.34978	.34984	.34988	.34998	.35000	.35000	.35000	.35000	.35000	.35000	.35000	.35000
OH	.00015	.00009	.00006	.00004	.00003	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000

R = 0.40, PERCENT FUEL = 23.95, O/F = 3.175

Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	334.53	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, ^{o}K	2574	2492	2422	2363	2313	1978	1637	1408	1204	1199	970	818	542	452
H	0.00416	0.00320	0.00252	0.00203	0.00167	0.00034	0.00003	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.59681	.59753	.59805	.59842	.59870	.59973	.59998	.60000	.60000	.60000	.60000	.60000	.60000	.60000
H_2O	.39839	.39882	.39910	.39930	.39944	.39991	.39999	.40000	.40000	.40000	.40000	.40000	.40000	.40000
OH	.00064	.00045	.00033	.00024	.00019	.00002	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000

R = 0.45, PERCENT FUEL = 21.87, O/F = 3.571

Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	336.72	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, ^{o}K	2773	2692	2624	2565	2517	2174	1817	1575	1357	1350	1104	937	629	526
H	0.00856	0.00695	0.00575	0.00483	0.00417	0.00112	0.00015	0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00002	.00001	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.54383	.54496	.54581	.54646	.54694	.54916	.54989	.54998	.55000	.55000	.55000	.55000	.55000	.55000
H_2O	.44560	.44659	.44728	.44779	.44814	.44959	.44996	.44999	.45000	.45000	.45000	.45000	.45000	.45000
O_2	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00198	.00149	.00115	.00091	.00074	.00013	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000

R = 0.50, PERCENT FUEL = 20.12, O/F = 3.968

Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	338.88	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, ^{o}K	2944	2866	2800	2742	2699	2356	1990	1737	1507	1501	1238	1059	720	606
H	0.01447	0.01228	0.01057	0.00921	0.00825	0.00282	0.00053	0.00010	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000
O	.00009	.00006	.00004	.00003	.00002	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.49042	.49180	.49268	.49376	.49438	.49801	.49962	.49992	.49999	.49999	.50000	.50000	.50000	.50000
H_2O	.49024	.49207	.49342	.49446	.49516	.49866	.49980	.49997	.50000	.50000	.50000	.50000	.50000	.50000
O_2	.00003	.00002	.00002	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00475	.00377	.00307	.00253	.00218	.00050	.00005	.00001	.00000	.00000	.00000	.00000	.00000	.00000

R = 0.60, PERCENT FUEL = 17.35, O/F = 4.762

Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	342.61	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, ^{o}K	3208	3137	3077	3025	2990	2669	2313	2050	1803	1796	1506	1306	916	778
H	0.02778	0.02506	0.02282	0.02094	0.01970	0.00988	0.00321	0.00100	0.00023	0.00022	0.00002	0.00000	0.00000	0.00000
O	.00069	.00054	.00043	.00035	.00030	.00006	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.38651	.38751	.38839	.38916	.38968	.39432	.39800	.39935	.39985	.39985	.39999	.40000	.40000	.40000
H_2O	.56851	.57250	.57560	.57846	.58016	.59191	.59796	.59948	.59990	.59991	.59999	.60000	.60000	.60000
O_2	.00041	.00032	.00026	.00021	.00018	.00004	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.01629	.01406	.01230	.01088	.00998	.00379	.00081	.00017	.00002	.00002	.00000	.00000	.00000	.00000

R = 0.70, PERCENT FUEL = 15.25, O/F = 5.556

Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	345.24	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, ^{o}K	3381	3317	3263	3217	3188	2903	2584	2337	2088	2081	1775	1556	1125	966
H	0.03771	0.03524	0.03316	0.03138	0.03028	0.01959	0.00964	0.00443	0.00156	0.00151	0.00025	0.00004	0.00000	0.00000
O	.00269	.00229	.00199	.00175	.00161	.00058	.00011	.00002	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.29362	.29350	.29328	.29315	.29309	.29356	.29563	.29779	.29914	.29917	.29965	.29997	.30000	.30000
H_2O	.62760	.63436	.63957	.64449	.64727	.67154	.68906	.69594	.69866	.69890	.69966	.69996	.70000	.70000
O_2	.00229	.00199	.00174	.00155	.00143	.00054	.00011	.00002	.00000	.00000	.00000	.00000	.00000	.00000
OH	.03590	.03263	.02995	.02759	.02632	.01420	.00526	.00180	.00044	.00042	.00004	.00000	.00000	.00000

TABLE IV. - Concluded. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID HYDROGEN AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions; composit ons are given in mole fractions. Equivalence ratio, R; oxidant-fuel ratio, O/F.]

(d) Concluded. Combustion-chamber pressure, 600 pou ds per square inch absolute

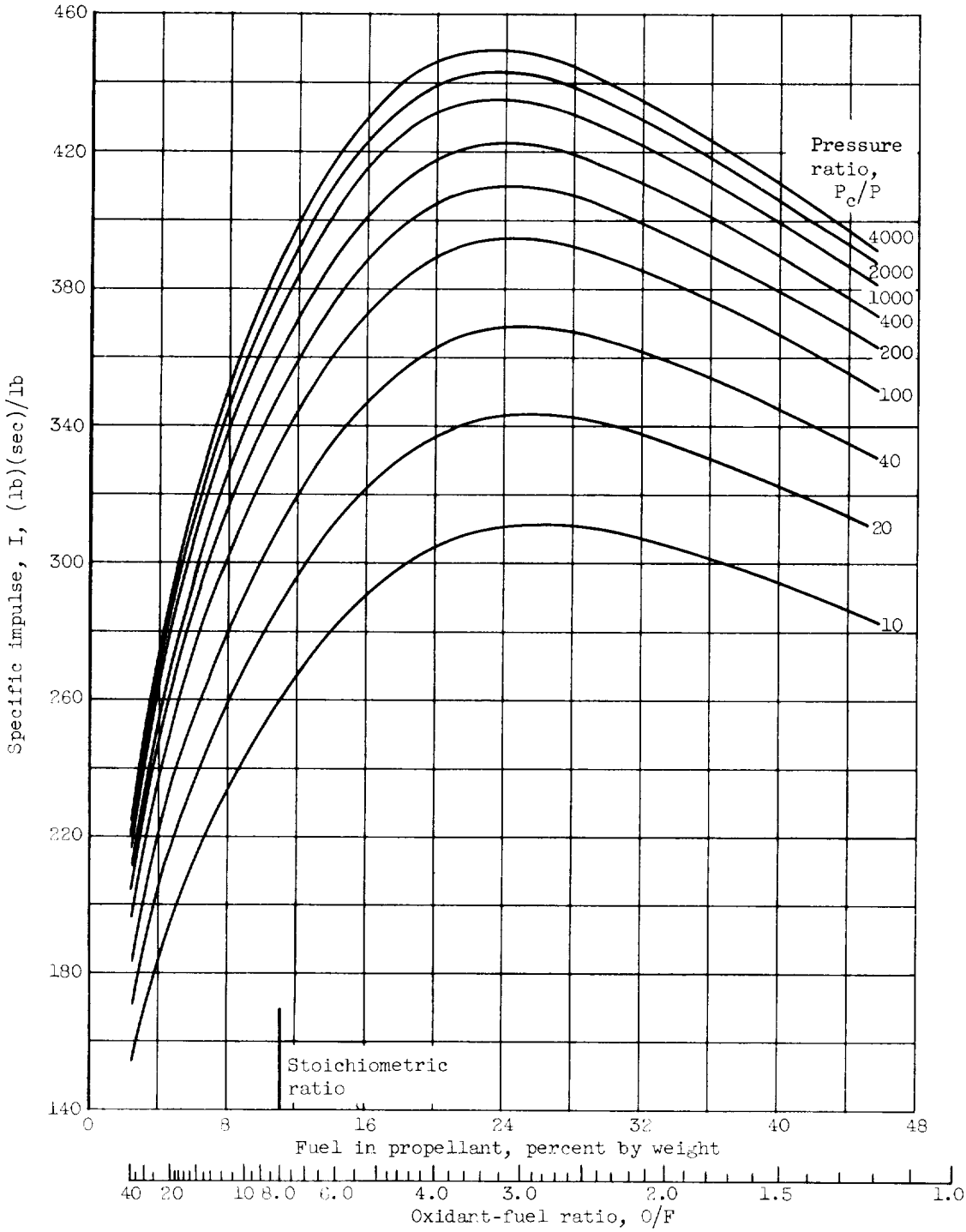
R = 0.80, PERCENT FUEL = 13.60, O/F = 6.349													
Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	346.81	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, °K	3481	3422	3373	3331	3306	3052	2779	2566	2346	2340	2042	1815	1347	1173
H	0.04117	0.03913	0.03742	0.03595	0.03510	0.02609	0.01678	0.01045	0.00538	0.00526	0.00149	0.00040	0.00001	0.00000
O	.00646	.00584	.00534	.00492	.00468	.00250	.00094	.00032	.00007	.00006	.00000	.00000	.00000	.00000
H_2	.21839	.21659	.21509	.21381	.21308	.20598	.20057	.19869	.19855	.19856	.19938	.19981	.20000	.20000
H_2O	.66670	.67542	.68269	.68890	.69250	.72890	.76212	.78057	.79211	.79235	.79845	.79968	.80000	.80000
O_2	.00786	.00727	.00678	.00635	.00610	.00359	.00147	.00052	.00011	.00011	.00001	.00000	.00000	.00000
OH	.05941	.05575	.05269	.05006	.04854	.03294	.01813	.00945	.00378	.00366	.00096	.00011	.00000	.00000
R = 0.90, PERCENT FUEL = 12.28, O/F = 7.143														
Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	347.52	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, °K	3526	3469	3422	3382	3360	3122	2881	2705	2528	2523	2279	2072	1585	1397
H	0.03919	0.03743	0.03596	0.03469	0.03398	0.02643	0.01890	0.01378	0.00923	0.00910	0.00431	0.00182	0.00007	0.00001
O	.01130	.01053	.00989	.00935	.00905	.00604	.00342	.00193	.00088	.00086	.00017	.00002	.00000	.00000
H_2	.16146	.15871	.15636	.15433	.15316	.14025	.12644	.11674	.10852	.10831	.10171	.10005	.09997	.10000
H_2O	.68792	.69763	.70580	.71285	.71686	.76023	.80490	.83571	.86232	.86302	.88712	.89611	.89999	.89999
O_2	.01917	.01845	.01782	.01727	.01695	.01322	.00890	.00570	.00292	.00285	.00064	.00009	.00000	.00000
OH	.08096	.07727	.07417	.07150	.06999	.05383	.03743	.02614	.01614	.01587	.00605	.00190	.00003	.00000
R = 1.00, PERCENT FUEL = 11.19, O/F = 7.937														
Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	347.72	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, °K	3534	3478	3431	3392	3370	3137	2903	2738	2578	2573	2371	2214	1826	1648
H	0.03443	0.03281	0.03146	0.03030	0.02966	0.02281	0.01615	0.01177	0.00802	0.00792	0.00417	0.00216	0.00018	0.00003
O	.01593	.01504	.01430	.01368	.01334	.00978	.00653	.00452	.00291	.00286	.00138	.00066	.00004	.00001
H_2	.12040	.11731	.11467	.11237	.11107	.09622	.07953	.06669	.05387	.05349	.03741	.02591	.00641	.00244
H_2O	.69574	.70566	.71402	.72125	.72534	.77027	.81775	.85216	.88474	.88567	.92390	.94942	.98868	.99587
O_2	.03662	.03605	.03555	.03510	.03484	.03159	.02737	.02375	.01983	.01971	.01437	.01027	.00274	.00108
OH	.09689	.09314	.08999	.08729	.08577	.06934	.05267	.04111	.03063	.03034	.01877	.01159	.00195	.00058
R = 1.50, PERCENT FUEL = 7.749, O/F = 1.905														
Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	346.93	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, °K	3374	3315	3267	3226	3202	2953	2692	2496	2297	2291	2026	1818	1366	1195
H	0.01276	0.01175	0.01093	0.01023	0.00984	0.00606	0.00299	0.00146	0.00056	0.00055	0.00009	0.00001	0.00000	0.00000
O	.02263	.02121	.02002	.01902	.01844	.01265	.00739	.00430	.00211	.00206	.00056	.00014	.00000	.00000
H_2	.03486	.03285	.03117	.02972	.02889	.02032	.01216	.00720	.00359	.00351	.00098	.00025	.00000	.00000
H_2O	.65376	.66167	.66829	.67395	.67722	.71084	.74322	.77358	.77939	.77974	.79254	.79729	.79990	.79998
O_2	.16978	.17119	.17238	.17340	.17399	.18014	.18637	.19058	.19418	.19427	.19760	.19904	.19996	.19999
OH	.10621	.10133	.09722	.09368	.09163	.06998	.04787	.03287	.02016	.01983	.00823	.00326	.00014	.00002
R = 2.00, PERCENT FUEL = 5.927, O/F = 5.873														
Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	345.45	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, °K	3158	3097	3046	3002	2975	2706	2413	2189	1965	1959	1678	1475	1070	963
H	0.00439	0.00387	0.00345	0.00311	0.00291	0.00132	0.00039	0.00011	0.00002	0.00002	0.00000	0.00000	0.00000	0.00000
O	.01610	.01461	.01339	.01238	.01178	.00648	.00260	.00101	.00029	.00028	.00003	.00000	.00000	.00000
H_2	.01269	.01157	.01065	.00988	.00942	.00529	.00218	.00086	.00025	.00024	.00003	.00000	.00000	.00000
H_2O	.58773	.59371	.59864	.60281	.60532	.62843	.64767	.66728	.66285	.66296	.66584	.66647	.66666	.66667
O_2	.30070	.30305	.30500	.30665	.30765	.31693	.32491	.33905	.33154	.33159	.33293	.33324	.33333	.33333
OH	.07838	.07319	.06887	.06517	.06293	.04155	.02225	.01169	.00505	.00491	.00116	.00028	.00000	.00000
R = 3.00, PERCENT FUEL = 4.031, O/F = 3.810														
Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	340.99	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, °K	2747	2679	2622	2573	2538	2237	1913	1682	1470	1464	1220	1053	733	622
H	0.00046	0.00036	0.00028	0.00023	0.00020	0.00004	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00474	.00392	.00330	.00282	.00251	.00075	.00012	.00002	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.00191	.00159	.00135	.00116	.00103	.00032	.00005	.00001	.00000	.00000	.00000	.00000	.00000	.00000
H_2O	.47624	.47934	.48178	.48375	.48507	.49370	.49827	.49951	.49989	.49990	.49999	.50000	.50000	.50000
O_2	.48500	.48699	.48855	.48981	.49065	.49611	.49895	.49970	.49993	.49994	.49999	.50000	.50000	.50000
OH	.03164	.02780	.02474	.02224	.02055	.00909	.00261	.00077	.00017	.00016	.00001	.00000	.00000	.00000
R = 4.00, PERCENT FUEL = 3.054, O/F = 1.746														
Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	336.49	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, °K	2381	2309	2249	2198	2157	1860	1554	1348	1164	1159	952	813	551	463
H	0.00004	0.00002	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O	.00094	.00069	.00052	.00040	.00033	.00005	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2	.00026	.00019	.00015	.00011	.00009	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2O	.39338	.39465	.39559	.39629	.39680	.39910	.39986	.39998	.40000	.40000	.40000	.40000	.40000	.40000
O_2	.59523	.59618	.59686	.59738	.59774	.59938	.59991	.59998	.60000	.60000	.60000	.60000	.60000	.60000
OH	.01015	.00826	.00687	.00580	.00503	.00145	.00023	.00004	.00000	.00000	.00000	.00000	.00000	.00000
R = 5.00, PERCENT FUEL = 2.458, O/F = 9.683														
Pressure, lb/sq in. abs	600.00	500.00	428.57	375.00	333.54	150.00	60.00	30.00	15.00	14.70	6.00	3.00	0.60	0.30
Temperature, °K	2072	2002	1944	1894	1852	1578	1303	1122	961	956	777	658	438	365
O	0.00014	0.00009	0.00006	0.00005	0.00003	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	.00003	.00002	.00001	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
H_2O	.33163	.33269	.33234	.33295	.33270	.33321	.33332	.33333	.33333	.33333	.33333	.33333	.33333	.33333
O_2	.66538	.66571	.66593	.66606	.66620	.66658	.66666	.66667	.66667	.66667	.66667	.66667	.66667	.66667
OH	.00282	.00212	.00165	.00131	.00107	.00021	.00002	.00000	.00000	.00000	.00000	.00000	.00000	.00000

TABLE V. - SUMMARY OF COMBUSTION PARAMETERS, CHARACTERISTIC VELOCITY, AND PERFORMANCE FOR EXPANSION TO SEA LEVEL FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

Equivalence ratio, R, 2(O)/H	Fuel, percent by weight	Oxidant-fuel weight ratio, O/F	Combustion temperature, T_e, °K	Exit temperature, T_c, °K	Characteristic velocity, c*, ft/sec	Characteristic-velocity exponent, n_{c*}	Entropy, s, $\frac{cal}{(g)(^oK)}$	Area ratio, ϵ	Coefficient of thrust, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
CHAMBER PRESSURE, 60 POUNDS PER SQUARE INCH ABSOLUTE, EQUILIBRIUM COMPOSITION										
0.150	45.65	1.190	1183	819	7247	0.0000	9.3807	1.244	1.038	233.7
.200	38.65	1.587	1514	1073	7607	.0000	8.5172	1.256	1.035	244.7
.250	33.51	1.984	1816	1316	7814	.0000	7.8147	1.268	1.033	250.8
.300	29.57	2.381	2089	1546	7930	.0000	7.2390	1.278	1.031	254.1
.350	26.47	2.778	2329	1764	7988	.0001	6.7611	1.289	1.029	255.4
.400	23.95	3.175	2531	1970	8001	.0009	6.3590	1.302	1.027	255.3
.450	21.87	3.571	2696	2159	7973	.0025	6.0167	1.316	1.025	254.0
.500	20.12	3.968	2826	2327	7912	.0045	5.7222	1.331	1.024	251.8
.600	17.35	4.762	3015	2588	7729	.0080	5.2415	1.364	1.023	245.7
.700	15.25	5.556	3128	2756	7508	.0105	4.8659	1.369	1.022	238.6
.800	13.60	6.349	3188	2848	7277	.0119	4.5644	1.376	1.022	231.2
.900	12.28	7.143	3213	2888	7054	.0125	4.3169	1.379	1.022	224.1
1.000	11.19	7.937	3217	2896	6846	.0126	4.1101	1.380	1.022	217.5
1.500	7.749	11.905	3116	2777	6061	.0109	3.4371	1.377	1.022	192.6
2.000	5.927	15.873	2986	2599	5550	.0087	3.0853	1.368	1.022	176.4
3.000	4.031	23.810	2625	2209	4866	.0040	2.6810	1.339	1.023	154.8
4.000	3.054	31.746	2347	1851	4366	.0009	2.4399	1.311	1.026	139.2
5.000	2.458	39.683	2062	1571	3972	.0001	2.2965	1.295	1.029	127.0
CHAMBER PRESSURE, 150 POUNDS PER SQUARE INCH ABSOLUTE, EQUILIBRIUM COMPOSITION										
0.150	45.65	1.190	1183	839	7247	0.0000	8.9684	1.997	1.261	284.0
.200	38.65	1.587	1514	847	7607	.0000	8.1681	2.033	1.261	298.2
.250	33.51	1.984	1816	1052	7814	.0000	7.5120	2.073	1.262	308.6
.300	29.57	2.381	2092	1251	7929	.0000	6.9718	2.111	1.264	314.5
.350	26.47	2.778	2339	1444	7988	.0000	6.5215	2.147	1.265	314.0
.400	23.95	3.175	2553	1631	8006	.0005	6.1415	2.182	1.266	315.0
.450	21.87	3.571	2733	1812	7988	.0016	5.8170	2.221	1.267	314.7
.500	20.12	3.968	2881	1988	7940	.0033	5.5371	2.264	1.270	313.3
.600	17.35	4.762	3097	2300	7782	.0068	5.0787	2.352	1.275	308.4
.700	15.25	5.556	3231	2544	7577	.0095	4.7193	2.425	1.280	301.4
.800	13.60	6.349	3304	2699	7355	.0113	4.4299	2.472	1.282	293.2
.900	12.28	7.143	3336	2770	7134	.0121	4.1919	2.493	1.284	284.6
1.000	11.19	7.937	3341	2785	6925	.0122	3.9926	2.498	1.284	276.4
1.500	7.749	11.905	3219	2621	6120	.0103	3.3416	2.474	1.283	244.0
2.000	5.927	15.873	3045	2382	5592	.0079	2.9807	2.427	1.280	222.4
3.000	4.031	23.810	2695	1907	4882	.0032	2.5869	2.301	1.272	193.0
4.000	3.054	31.746	2363	1549	4369	.0007	2.3706	2.215	1.267	172.1
5.000	2.458	39.683	2066	1298	3972	.0000	2.2298	2.171	1.266	156.3
CHAMBER PRESSURE, 300 POUNDS PER SQUARE INCH ABSOLUTE, EQUILIBRIUM COMPOSITION										
0.150	45.65	1.190	1183	529	7247	0.0000	8.6565	3.020	1.379	310.6
.200	38.65	1.587	1514	703	7607	.0000	7.9040	3.088	1.382	326.7
.250	33.51	1.984	1816	862	7813	.0000	7.2831	3.168	1.386	336.5
.300	29.57	2.381	2093	1059	7929	.0000	6.7696	3.248	1.390	342.5
.350	26.47	2.778	2344	1232	7988	.0000	6.3404	3.329	1.393	345.9
.400	23.95	3.175	2565	1403	8008	.0003	5.9772	3.399	1.397	347.6
.450	21.87	3.571	2755	1569	7998	.0012	5.6664	3.474	1.401	348.1
.500	20.12	3.968	2915	1732	7956	.0025	5.3976	3.553	1.405	347.5
.600	17.35	4.762	3155	2047	7816	.0058	4.9564	3.726	1.416	343.9
.700	15.25	5.556	3307	2328	7625	.0087	4.6094	3.900	1.426	337.9
.800	13.60	6.349	3393	2544	7411	.0107	4.3293	4.042	1.433	330.1
.900	12.28	7.143	3430	2661	7193	.0117	4.0983	4.121	1.437	321.2
1.000	11.19	7.937	3437	2687	6983	.0118	3.9046	4.140	1.438	312.0
1.500	7.749	11.905	3297	2472	6163	.0097	3.2701	4.058	1.434	274.6
2.000	5.927	15.873	3103	2181	5621	.0076	2.9171	3.916	1.426	249.2
3.000	4.031	23.810	2723	1678	4892	.0027	2.5310	3.634	1.410	214.4
4.000	3.054	31.746	2372	1343	4371	.0005	2.3183	3.474	1.400	190.2
5.000	2.458	39.683	2069	1117	3972	.0000	2.1794	3.388	1.396	172.4
CHAMBER PRESSURE, 600 POUNDS PER SQUARE INCH ABSOLUTE, EQUILIBRIUM COMPOSITION										
0.150	45.65	1.190	1183	437	7247	0.0000	8.3448	4.682	1.469	330.9
.200	38.65	1.587	1514	585	7607	.0000	7.6399	4.802	1.474	348.6
.250	33.51	1.984	1817	731	7813	.0000	7.0341	4.949	1.481	359.6
.300	29.57	2.381	2094	891	7929	.0000	6.5675	5.106	1.488	366.6
.350	26.47	2.778	2347	1049	7988	.0000	6.1594	5.260	1.494	370.9
.400	23.95	3.175	2574	1199	8010	.0002	5.8131	5.409	1.500	373.4
.450	21.87	3.571	2775	1350	8001	.0008	5.5160	5.554	1.506	374.5
.500	20.12	3.968	2944	1501	7968	.0019	5.2585	5.701	1.512	374.5
.600	17.35	4.762	3208	1790	7844	.0048	4.8347	6.013	1.527	372.3
.700	15.25	5.556	3381	2081	7669	.0077	4.5004	6.330	1.542	367.6
.800	13.60	6.349	3481	2340	7485	.0100	4.2294	6.669	1.555	360.6
.900	12.28	7.143	3526	2523	7290	.0111	4.0056	6.947	1.565	352.3
1.000	11.19	7.937	3534	2575	7097	.0114	3.8175	7.322	1.569	342.5
1.500	7.749	11.905	3374	2291	6203	.0091	3.1998	8.760	1.557	300.2
2.000	5.927	15.873	3128	1959	5648	.0065	2.8539	8.416	1.544	271.1
3.000	4.031	23.810	2747	1484	4900	.0023	2.4736	5.862	1.520	231.4
4.000	3.054	31.746	2381	1159	4372	.0004	2.2609	5.572	1.509	204.7
5.000	2.458	39.683	2072	955	3972	.0000	2.1230	5.405	1.499	185.1

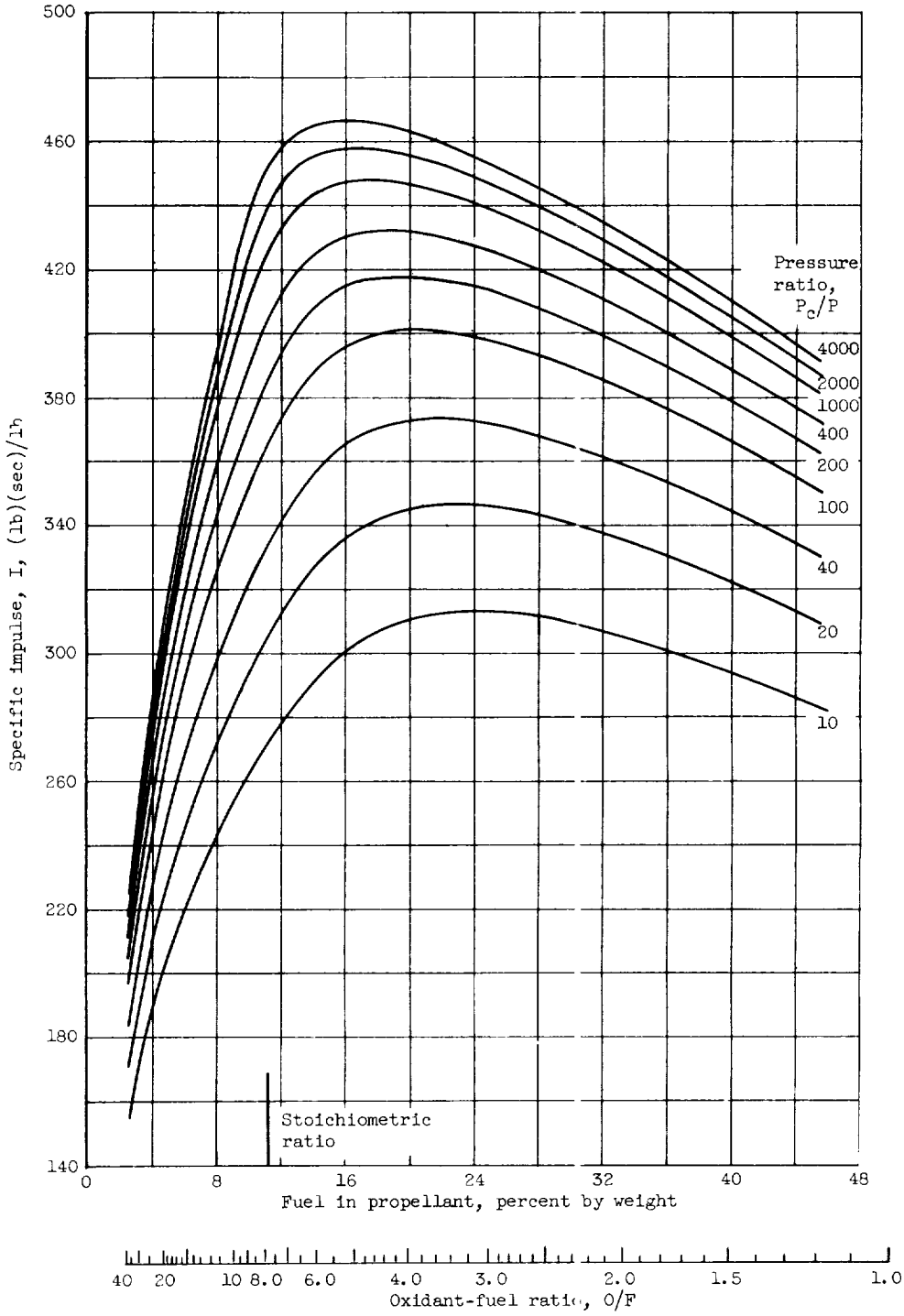
TABLE V. - Concluded. SUMMARY OF COMBUSTION PARAMETERS, CHARACTERISTIC VELOCITY, AND PERFORMANCE FOR EXPANSION TO SEA LEVEL FOR LIQUID HYDROGEN WITH LIQUID OXYGEN

Equivalence ratio, R, 2(O)/H	Fuel, percent by weight	Oxidant-fuel weight ratio, O/F	Combustion temperature, T_c, °K	Exit temperature, T_e, °K	Characteristic velocity, c^*, ft/sec	Entropy, s, $\frac{cal}{(g)(°K)}$	Area ratio, ϵ	Coefficient of thrust, C_F	Specific impulse, I_s, $\frac{(lb)(sec)}{lb}$
CHAMBER PRESSURE, 60 POUNDS PER SQUARE INCH ABS., FROZEN COMPOSITION									
0.150	45.65	1.190	1183	819	7247	9.3807	1.244	1.038	253.7
.200	38.65	1.587	1514	1073	7607	8.5172	1.256	1.035	244.7
.250	33.31	1.984	1816	1313	7811	7.8147	1.267	1.033	238.8
.300	29.37	2.381	2089	1540	7916	7.2590	1.278	1.032	233.8
.350	26.47	2.778	2329	1741	7948	6.7811	1.286	1.030	234.6
.400	23.95	3.175	2531	1914	7922	6.3190	1.292	1.030	233.5
.450	21.87	3.571	2696	2053	7856	6.0267	1.297	1.029	231.3
.500	20.12	3.968	2828	2166	7763	5.7222	1.301	1.029	228.2
.600	17.35	4.762	3015	2330	7542	5.2415	1.307	1.028	241.0
.700	15.25	5.556	3128	2429	7304	4.8859	1.310	1.028	233.3
.800	13.60	6.349	3188	2484	7070	4.5844	1.312	1.028	225.8
.900	12.28	7.143	3213	2500	6850	4.3169	1.313	1.028	218.8
1.000	11.19	7.937	3217	2514	6648	4.1101	1.313	1.027	212.3
1.500	7.749	11.905	3116	2433	5891	3.4871	1.313	1.028	188.1
2.000	5.927	15.873	2968	2308	5401	3.0693	1.311	1.028	172.5
3.000	4.031	23.810	2655	2040	4786	2.6610	1.305	1.028	152.3
4.000	3.054	31.746	2347	1789	4316	2.4299	1.298	1.029	138.1
5.000	2.458	39.683	2062	1554	3954	2.2965	1.292	1.030	126.6
CHAMBER PRESSURE, 150 POUNDS PER SQUARE INCH ABS., FROZEN COMPOSITION									
0.150	45.65	1.190	1183	839	7247	8.9884	1.997	1.261	284.0
.200	38.65	1.587	1514	847	7607	8.1681	2.033	1.261	298.2
.250	33.31	1.984	1816	1052	7812	7.5120	2.072	1.263	306.5
.300	29.37	2.381	2092	1240	7921	6.9718	2.110	1.264	311.2
.350	26.47	2.778	2339	1430	7961	6.5215	2.142	1.265	313.1
.400	23.95	3.175	2553	1592	7950	6.1415	2.168	1.267	313.0
.450	21.87	3.571	2733	1730	7899	5.8170	2.189	1.268	311.2
.500	20.12	3.968	2881	1846	7821	5.5271	2.205	1.268	308.3
.600	17.35	4.762	3097	2019	7621	5.0197	2.228	1.269	300.7
.700	15.25	5.556	3231	2128	7395	4.7193	2.242	1.270	291.9
.800	13.60	6.349	3304	2190	7166	4.4699	2.251	1.271	283.0
.900	12.28	7.143	3336	2219	6947	4.1919	2.256	1.271	274.4
1.000	11.19	7.937	3341	2226	6743	3.9526	2.258	1.271	266.3
1.500	7.749	11.905	3219	2140	5965	3.3416	2.255	1.271	235.6
2.000	5.927	15.873	3045	2009	5458	2.9607	2.244	1.270	215.5
3.000	4.031	23.810	2695	1745	4796	2.5859	2.219	1.269	189.2
4.000	3.054	31.746	2363	1498	4329	2.3706	2.192	1.268	170.6
5.000	2.458	39.683	2066	1284	3958	2.2298	2.166	1.267	155.8
CHAMBER PRESSURE, 300 POUNDS PER SQUARE INCH ABS., FROZEN COMPOSITION									
0.150	45.65	1.190	1183	929	7247	8.8655	3.020	1.379	310.6
.200	38.65	1.587	1514	705	7607	7.9040	3.088	1.382	326.7
.250	33.31	1.984	1817	884	7812	7.2831	3.167	1.386	336.5
.300	29.37	2.381	2093	1057	7923	6.7646	3.247	1.390	342.2
.350	26.47	2.778	2344	1223	7969	6.3404	3.319	1.394	345.1
.400	23.95	3.175	2565	1376	7966	5.9772	3.380	1.397	345.8
.450	21.87	3.571	2755	1511	7926	5.6654	3.431	1.399	344.7
.500	20.12	3.968	2915	1627	7856	5.3976	3.471	1.401	342.3
.600	17.35	4.762	3159	1803	7675	4.9554	3.530	1.404	335.0
.700	15.25	5.556	3307	1922	7461	4.6074	3.567	1.406	326.1
.800	13.60	6.349	3393	1990	7237	4.3273	3.590	1.408	316.6
.900	12.28	7.143	3430	2023	7019	4.0933	3.602	1.408	307.2
1.000	11.19	7.937	3437	2031	6813	3.8948	3.607	1.409	298.3
1.500	**7.749**	11.905	3297	1940	6019	3.2701	3.597	1.408	263.4
2.000	**5.927**	15.873	3103	1804	5498	2.9171	3.569	1.406	240.4
3.000	4.031	23.810	2723	1540	4816	2.5310	3.505	1.403	210.0
4.000	3.054	31.746	2372	1304	4337	2.3113	3.439	1.400	188.7
5.000	2.458	39.683	2064	1107	3960	2.1774	3.380	1.397	171.9
CHAMBER PRESSURE, 600 POUNDS PER SQUARE INCH ABS., FROZEN COMPOSITION									
0.150	45.65	1.190	1183	437	7247	8.3446	4.882	1.469	330.9
.200	38.65	**1.587**	1514	585	7607	7.6379	4.802	1.474	348.6
.250	33.31	1.984	1817	736	7813	7.0531	4.969	1.481	359.6
.300	29.37	2.381	2094	884	7924	6.5675	5.104	1.488	366.4
.350	26.47	2.778	2347	1037	7974	6.1594	5.252	1.494	370.3
.400	23.95	3.175	2574	1181	7976	5.8131	5.384	1.499	371.8
.450	21.87	3.571	2773	1310	7947	5.5130	5.497	1.504	371.5
.500	20.12	3.968	2944	1424	7890	5.2535	5.591	1.508	369.7
.600	17.35	4.762	3208	1607	7725	4.8637	5.730	1.513	363.3
.700	15.25	5.556	3381	1732	7522	4.5902	5.821	1.517	354.6
.800	13.60	6.349	3481	1807	7300	4.3274	5.876	1.519	344.9
.900	12.28	**7.143**	3528	1844	7089	4.0976	5.906	1.520	335.0
1.000	11.19	**7.937**	3534	1853	6882	3.8975	5.919	1.521	325.3
1.500	7.749	**11.905**	3374	1758	6071	3.1960	5.887	1.519	286.7
2.000	5.927	15.873	3150	1618	5536	2.8539	5.818	1.517	261.0
3.000	4.031	23.810	2747	1355	4834	2.4742	5.667	1.510	226.9
4.000	3.054	31.746	2381	1127	4343	2.2619	5.521	1.503	203.1
5.000	2.458	39.683	2070	943	3962	2.1270	5.393	1.499	184.6



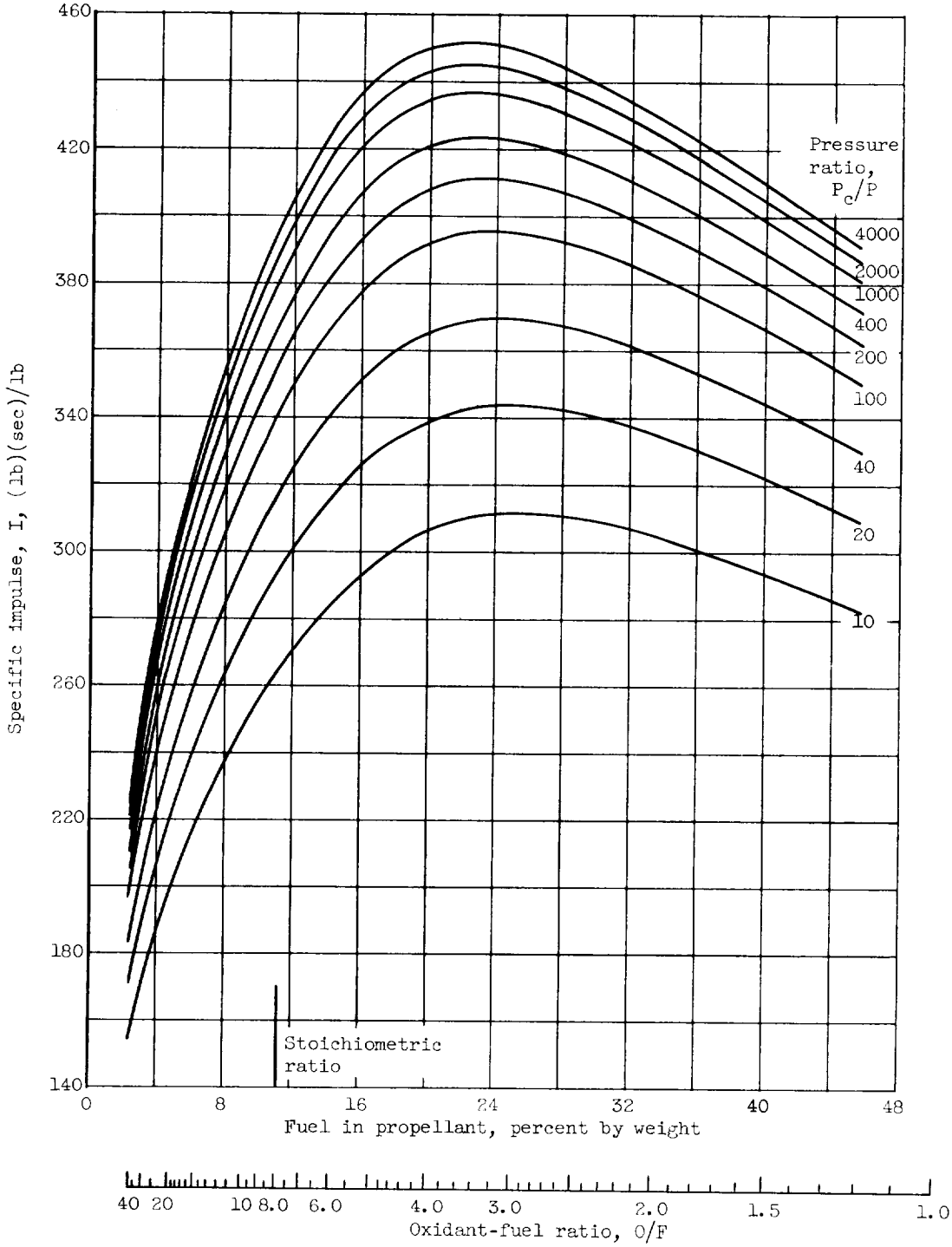
(a) Chamber pressure, 60 pounds per square inch absolute; frozen composition during expansion.

Figure 1. - Theoretical specific impulse of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



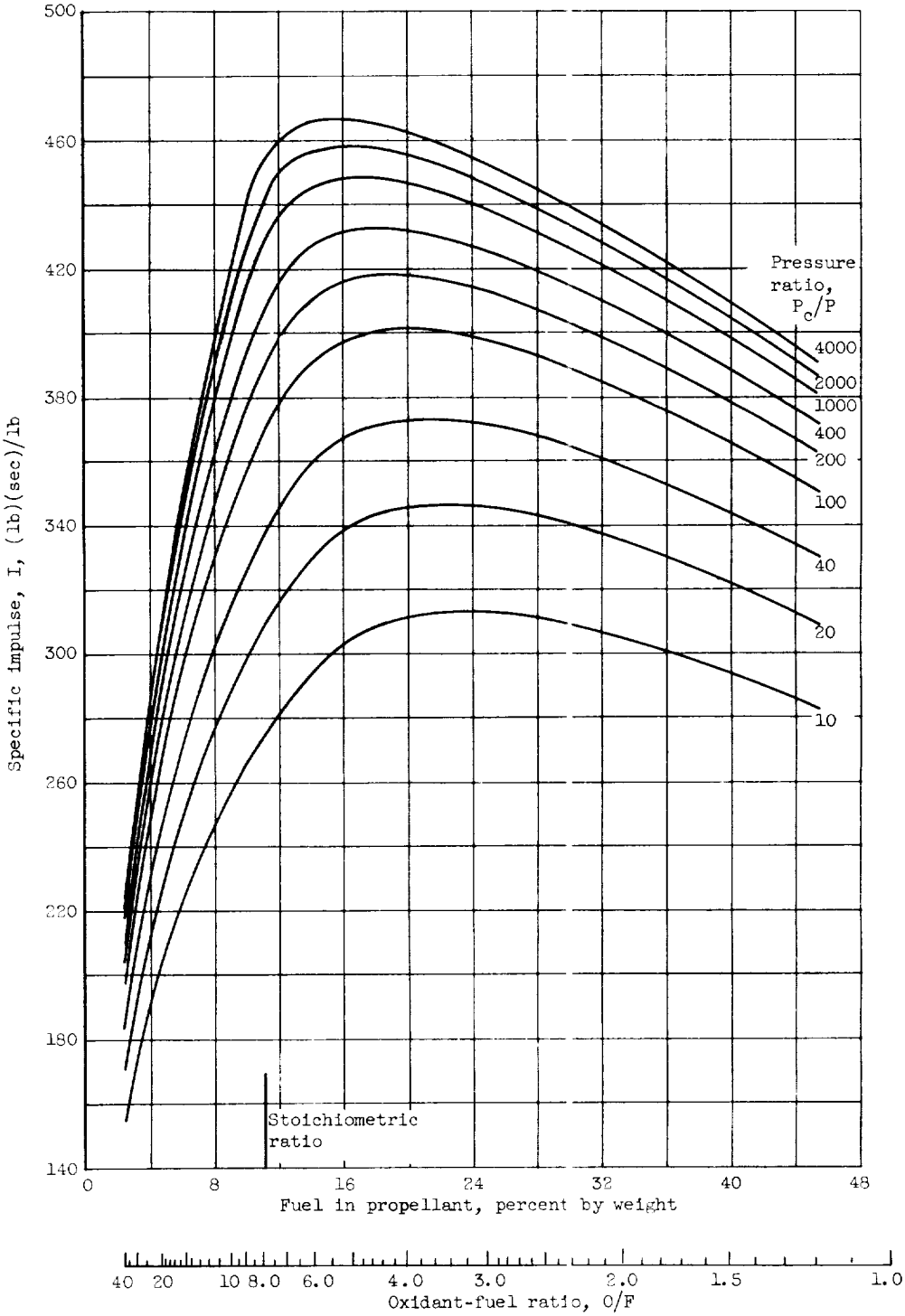
(b) Chamber pressure, 60 pounds per square inch absolute; equilibrium composition during expansion.

Figure 1. - Continued. Theoretical specific impulse of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



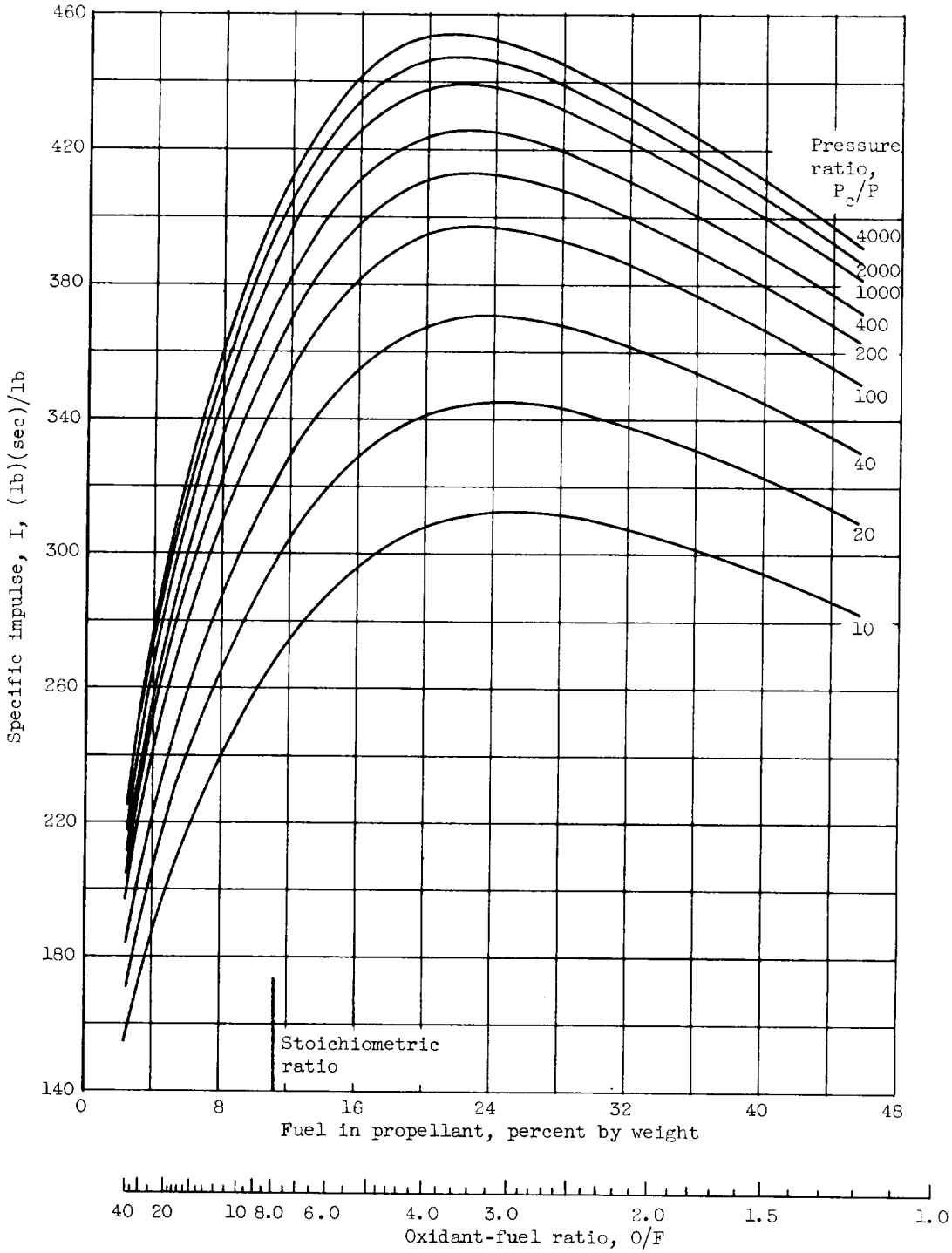
(c) Chamber pressure, 150 pounds per square inch absolute; frozen composition during expansion.

Figure 1. - Continued. Theoretical specific impulse of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



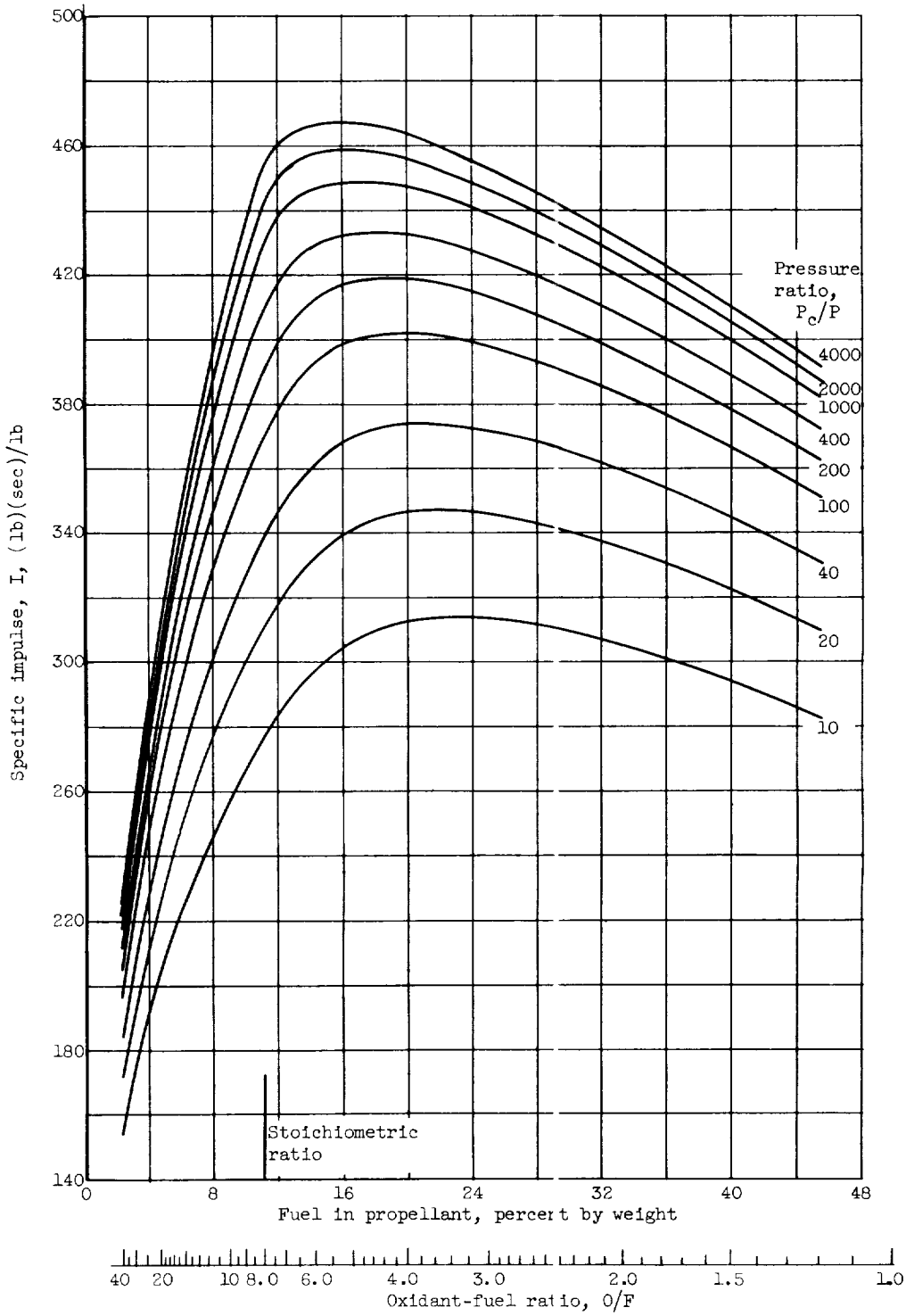
(d) Chamber pressure, 150 pounds per square inch absolute; equilibrium composition during expansion.

Figure 1. - Continued. Theoretical specific impulse of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



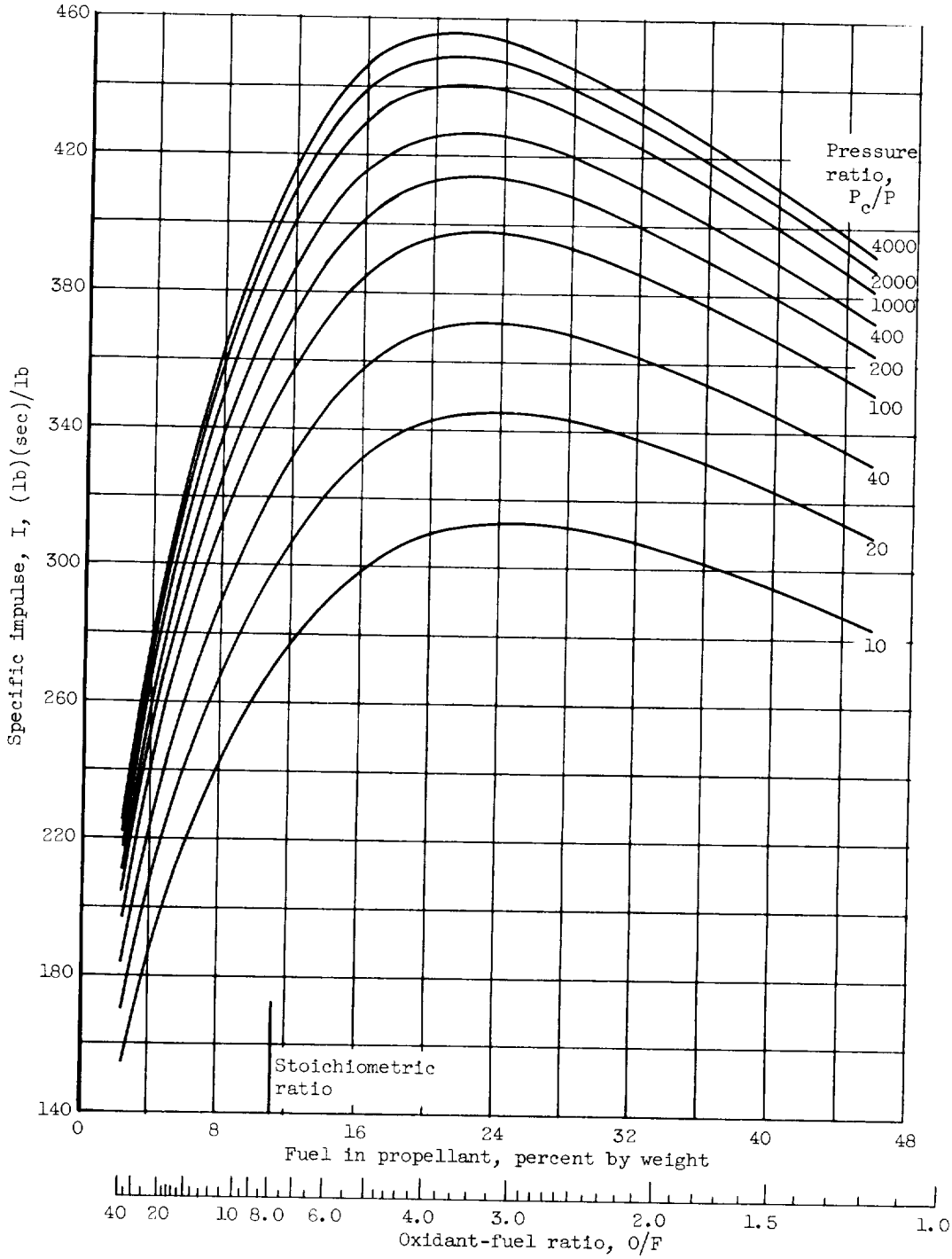
(e) Chamber pressure, 300 pounds per square inch absolute; frozen composition during expansion.

Figure 1. - Continued. Theoretical specific impulse of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



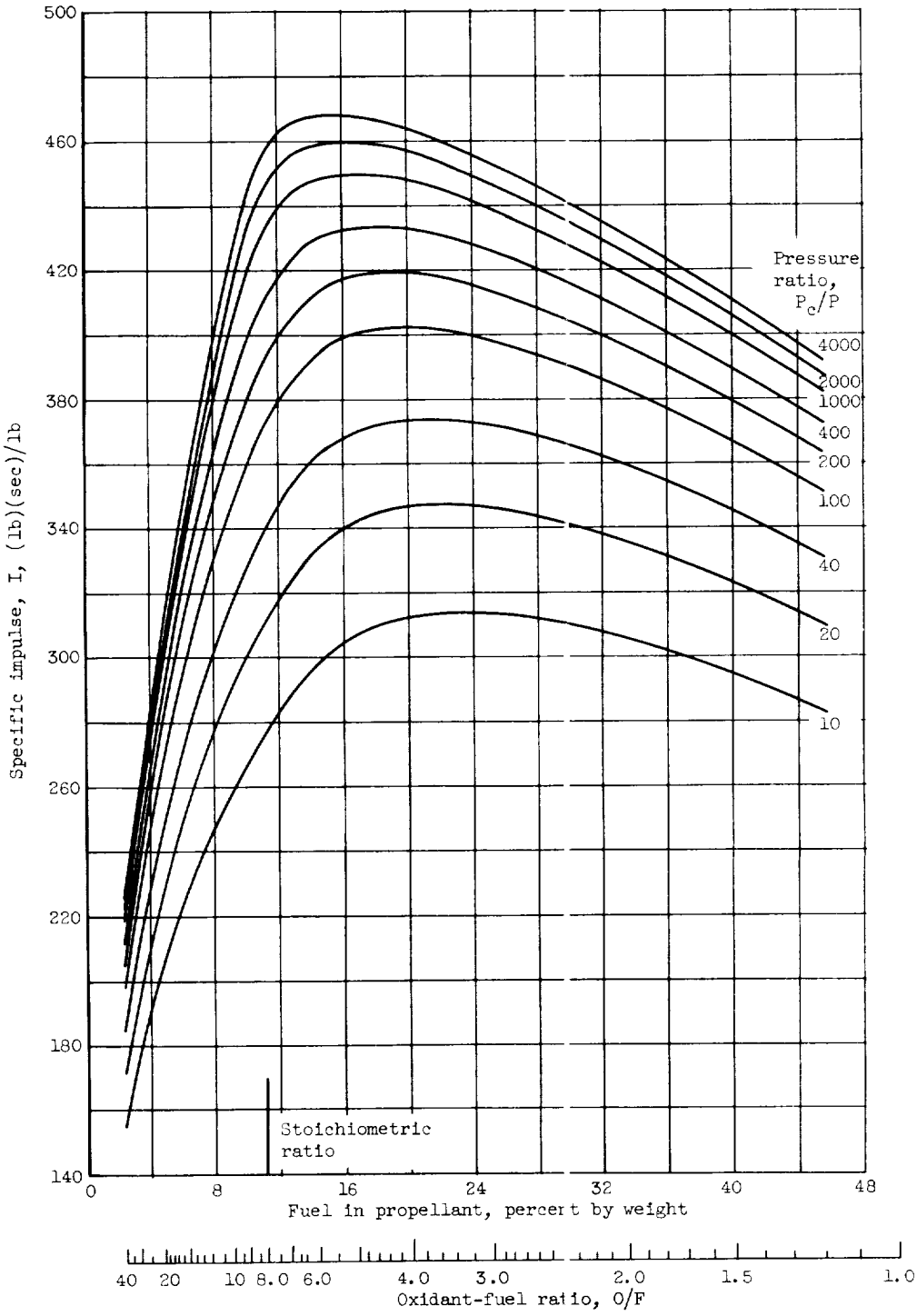
(f) Chamber pressure, 300 pounds per square inch absolute; equilibrium composition during expansion.

Figure 1. - Continued. Theoretical specific impulse of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



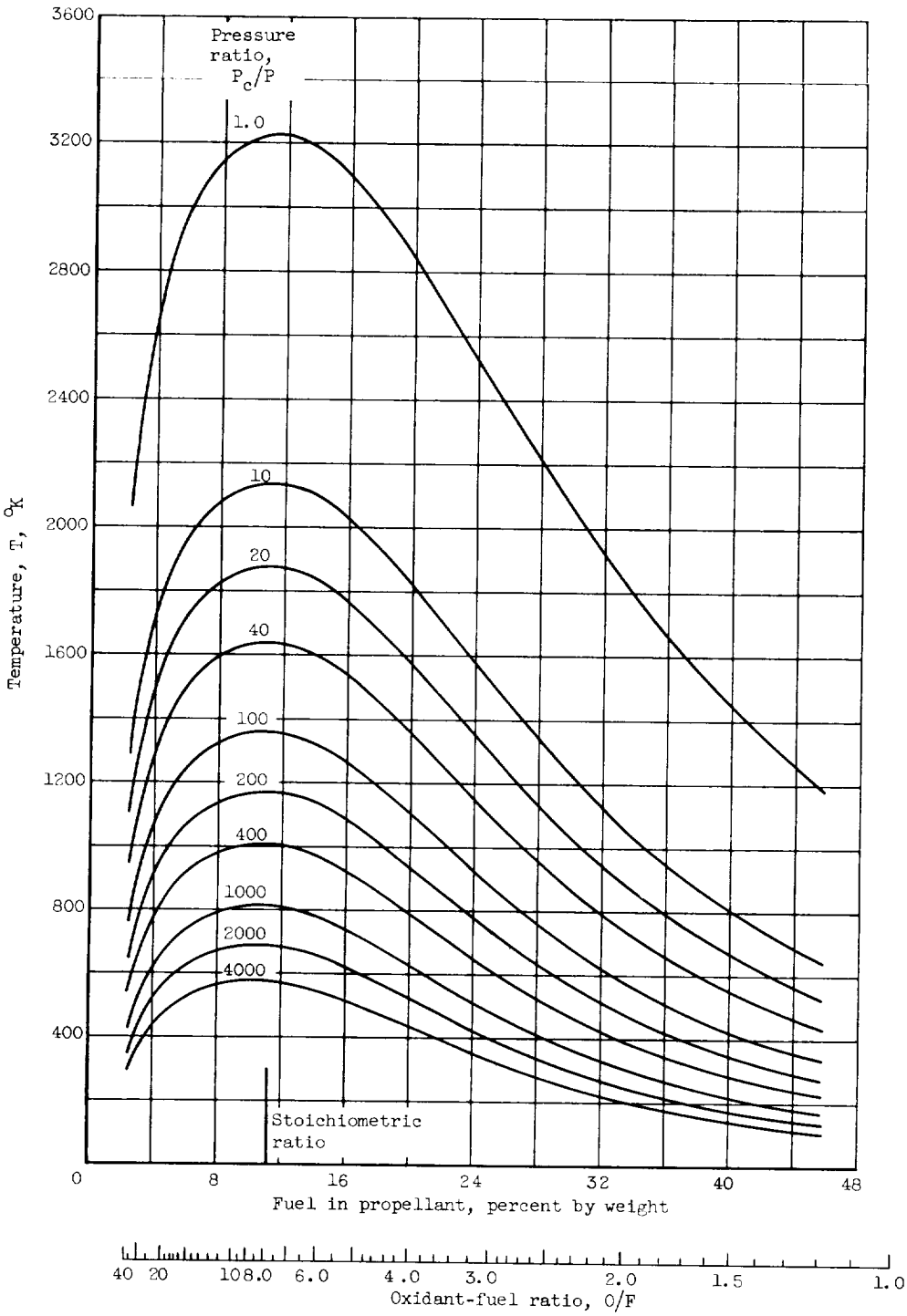
(g) Chamber pressure, 600 pounds per square inch absolute; frozen composition during expansion.

Figure 1. - Continued. Theoretical specific impulse of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



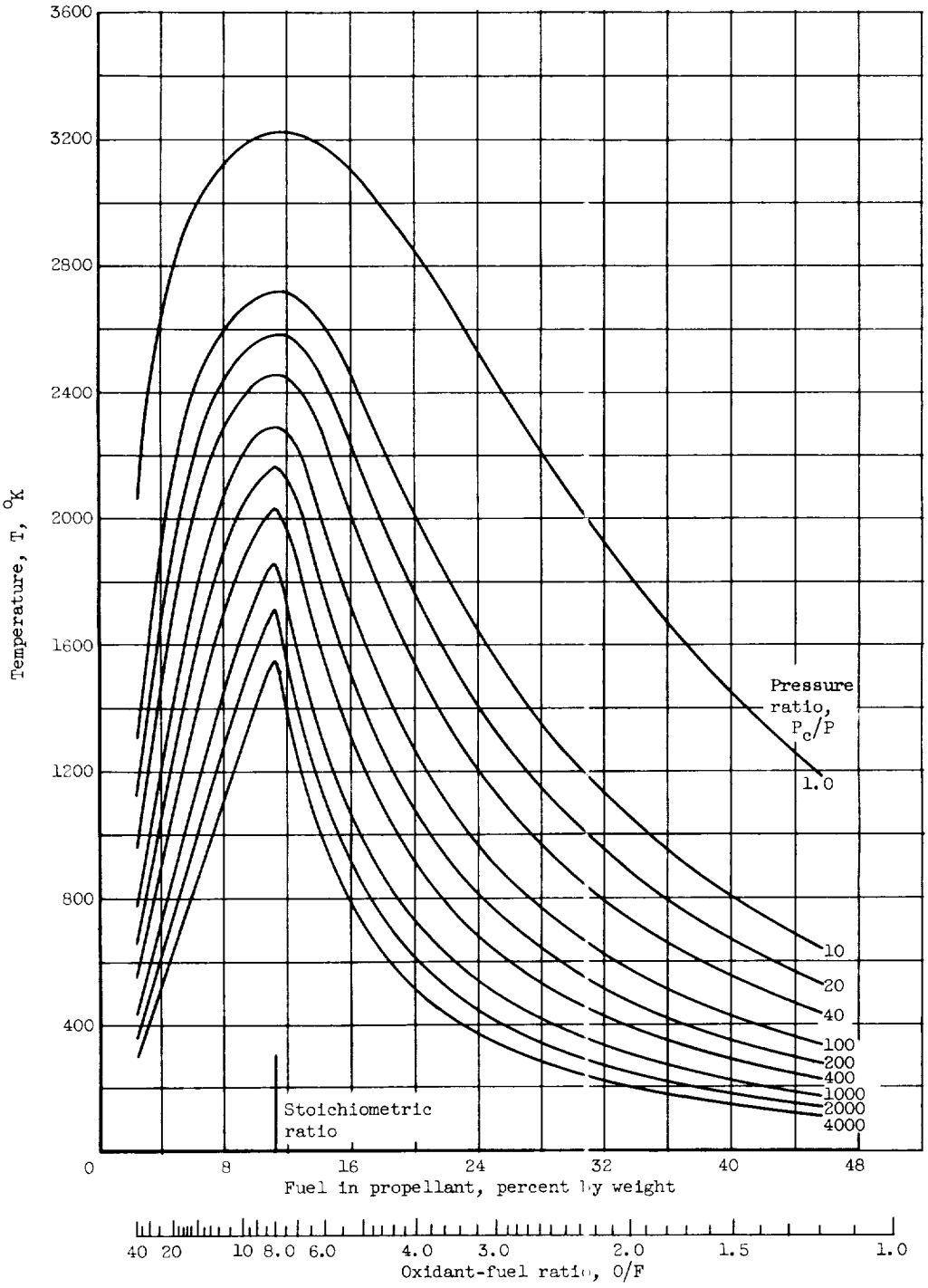
(h) Chamber pressure, 600 pounds per square inch absolute; equilibrium composition during expansion.

Figure 1. - Concluded. Theoretical specific impulse of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



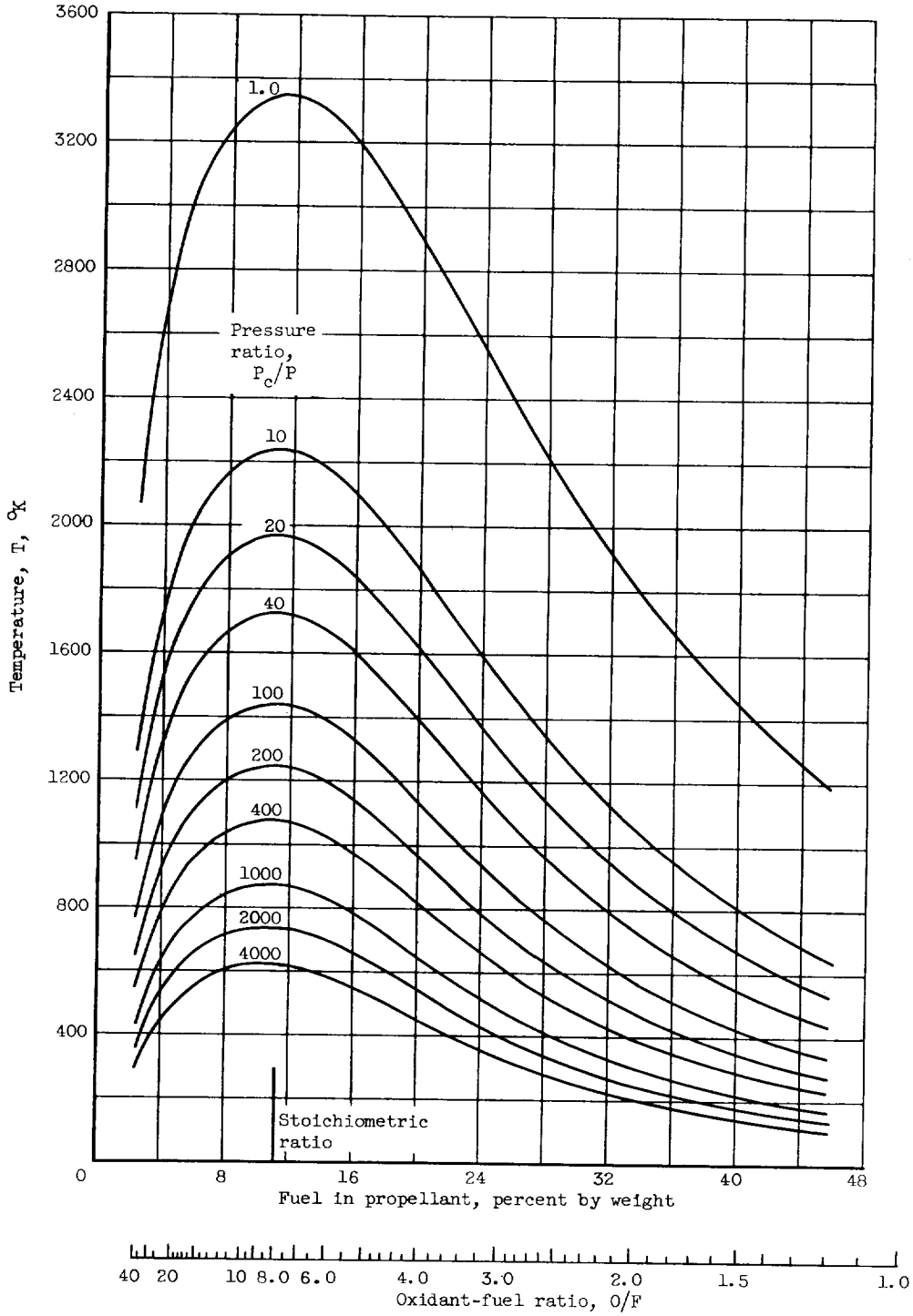
(a) Chamber pressure, 60 pounds per square inch absolute; frozen composition during expansion.

Figure 2. - Theoretical combustion chamber and nozzle-exit temperatures of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



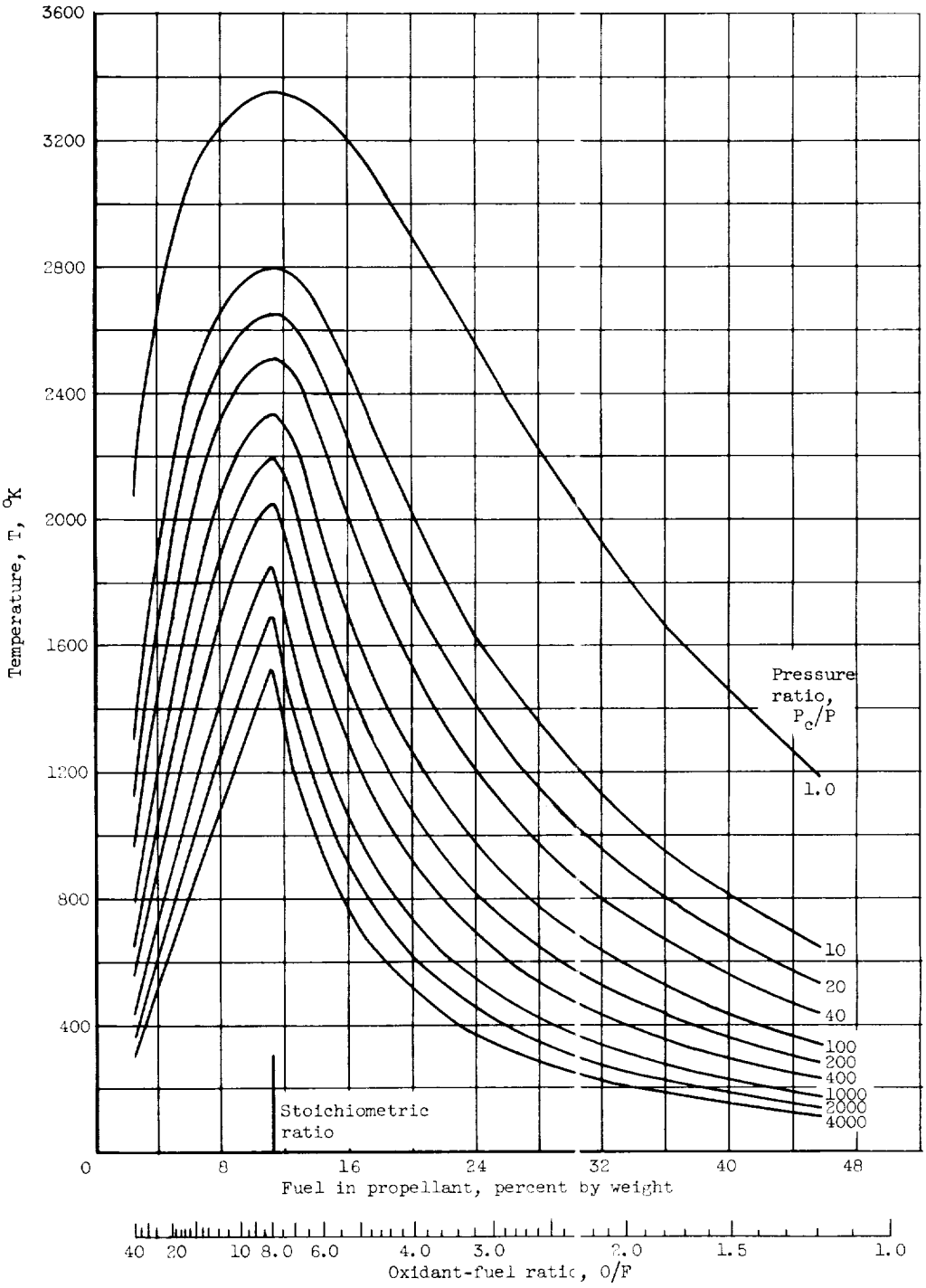
(b) Chamber pressure, 60 pounds per square inch absolute; equilibrium composition during expansion.

Figure 2. - Continued. Theoretical combustion chamber and nozzle-exit temperatures of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



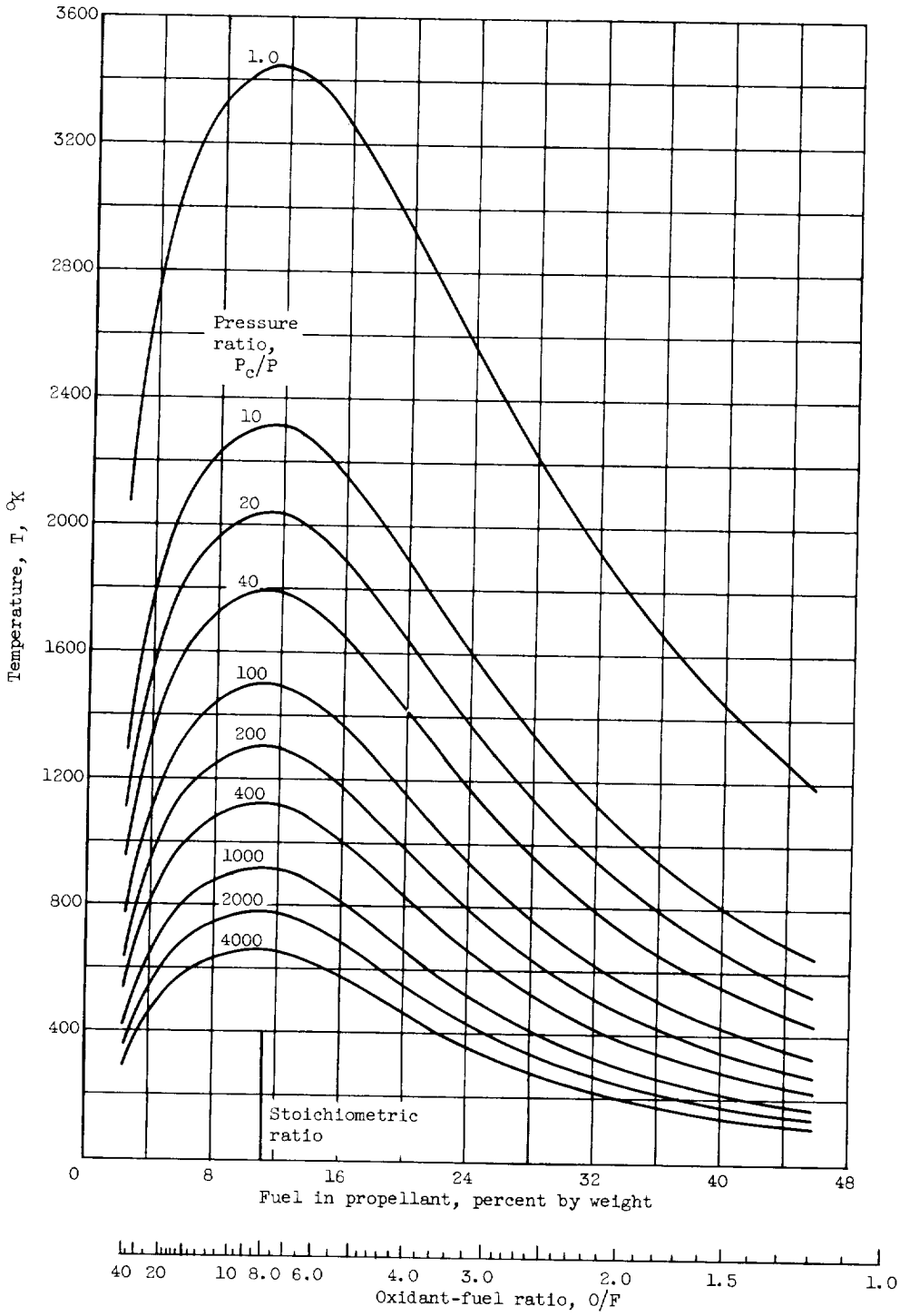
(c) Chamber pressure, 150 pounds per square inch absolute; frozen composition during expansion.

Figure 2. - Continued. Theoretical combustion chamber and nozzle-exit temperatures of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



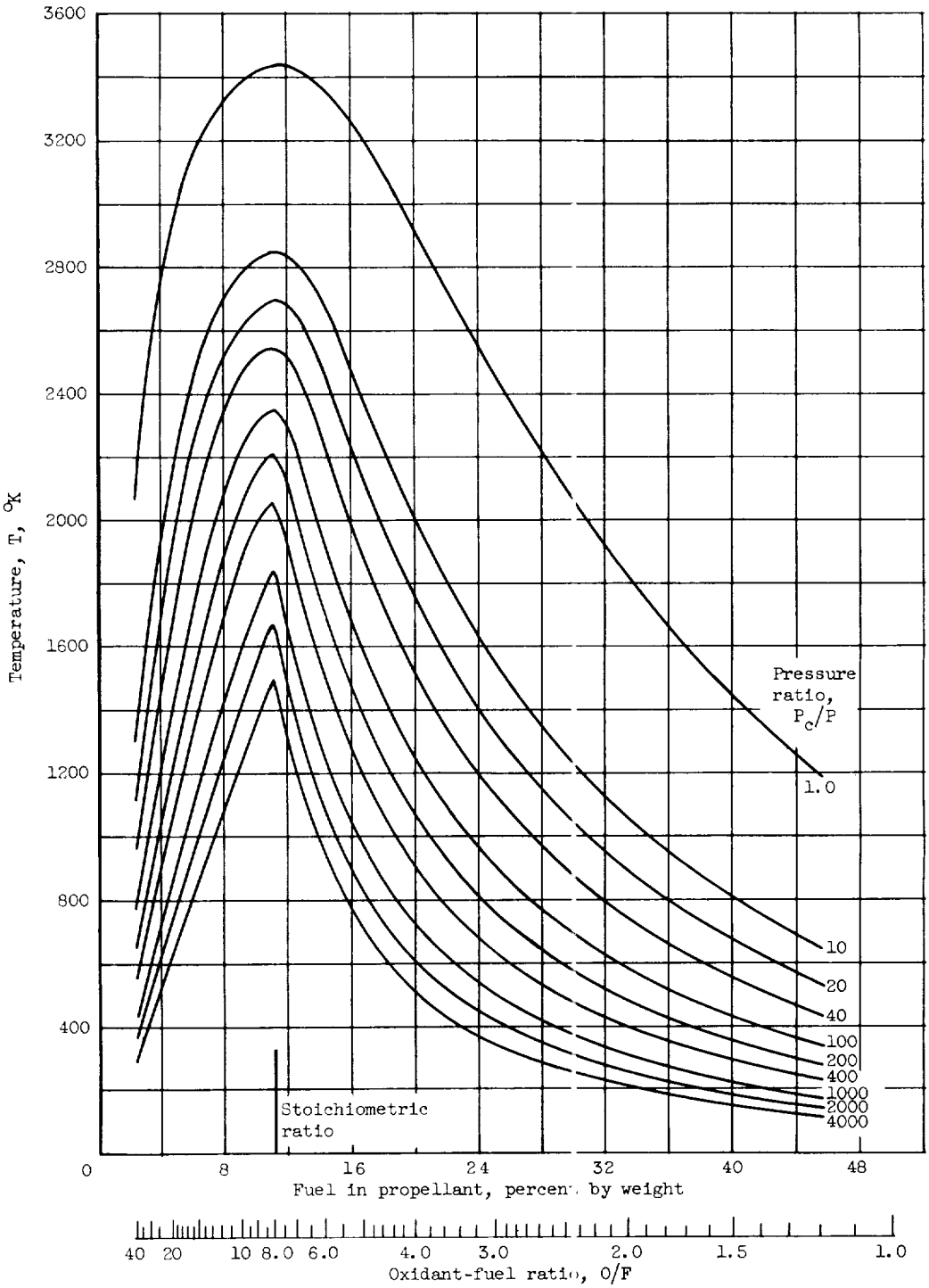
(d) Chamber pressure, 150 pounds per square inch absolute; equilibrium composition during expansion.

Figure 2. - Continued. Theoretical combustion chamber and nozzle-exit temperatures of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



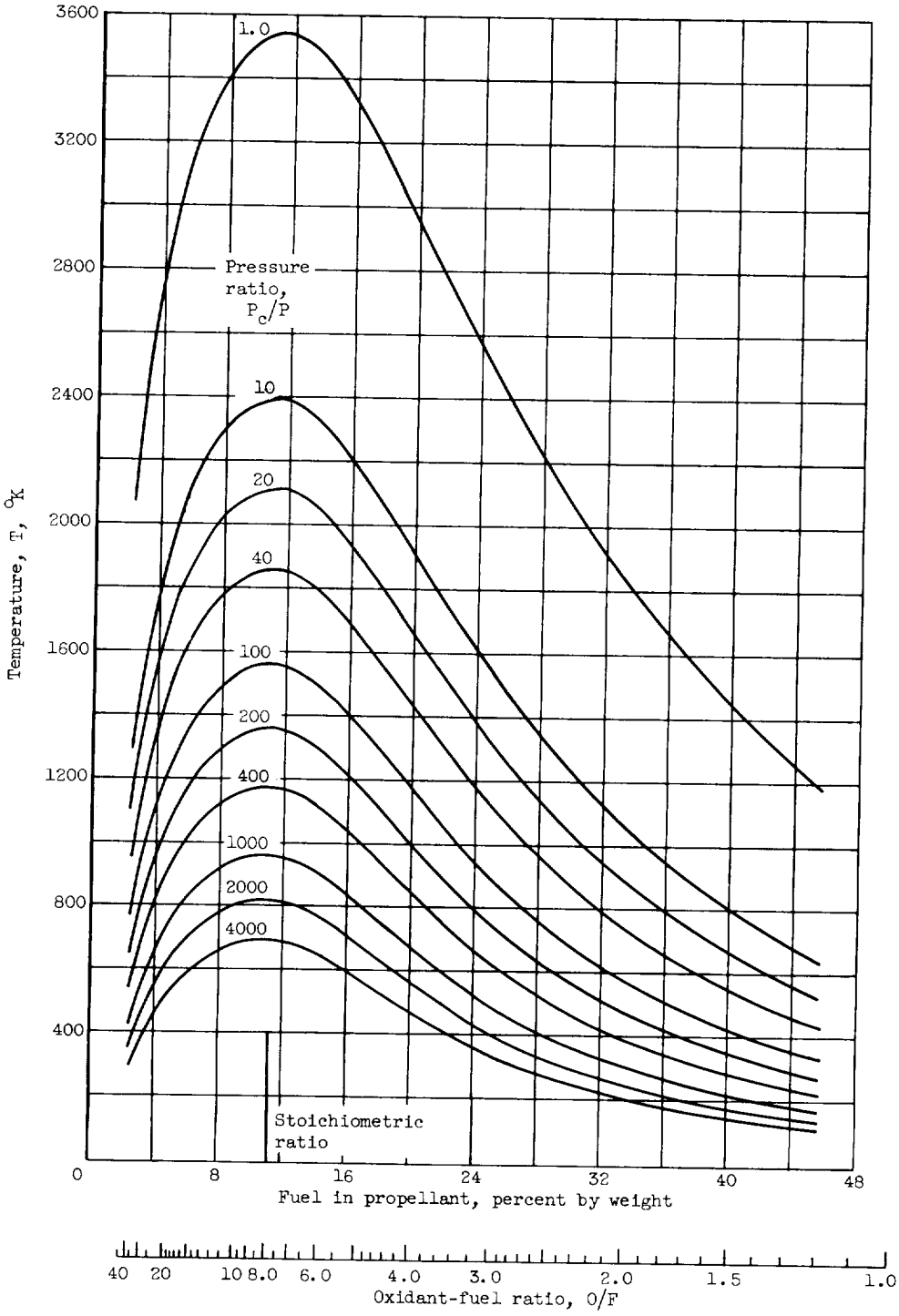
(e) Chamber pressure, 300 pounds per square inch absolute; frozen composition during expansion.

Figure 2. - Continued. Theoretical combustion chamber and nozzle-exit temperatures of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



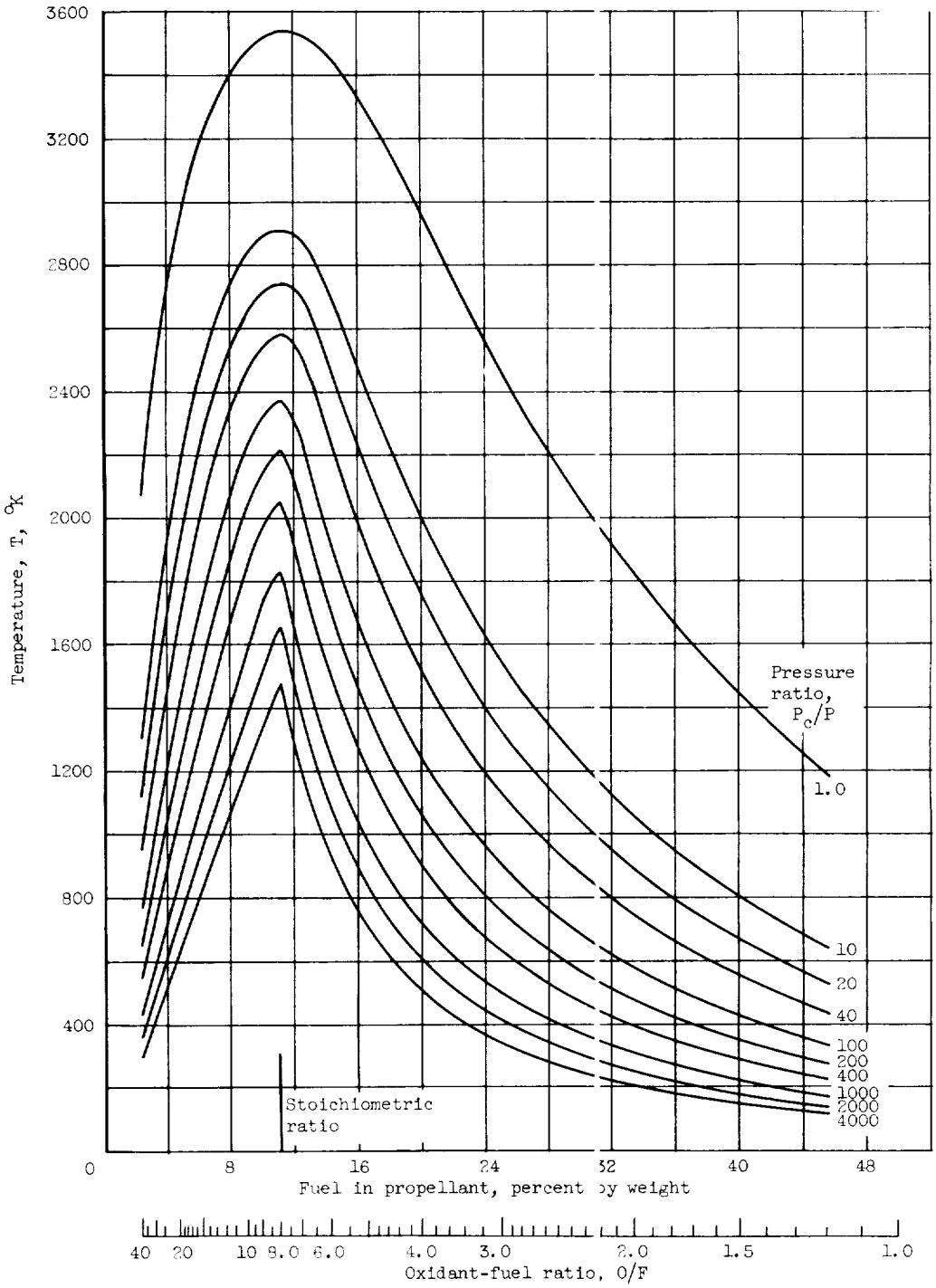
(f) Chamber pressure, 300 pounds per square inch absolute; equilibrium composition during expansion.

Figure 2. - Continued. Theoretical combustion chamber and nozzle-exit temperatures of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



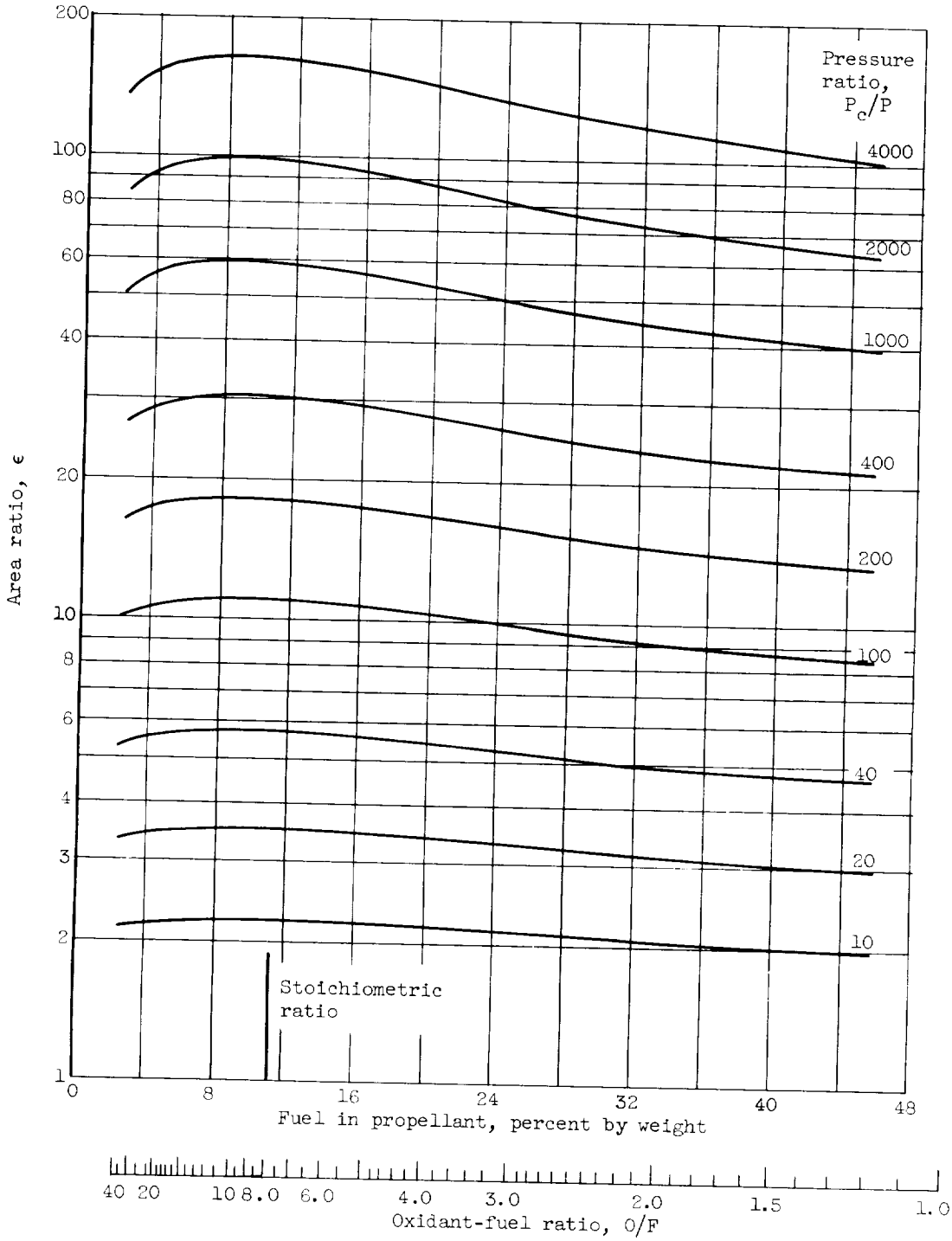
(g) Chamber pressure, 600 pounds per square inch absolute; frozen composition during expansion.

Figure 2. - Continued. Theoretical combustion chamber and nozzle-exit temperatures of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



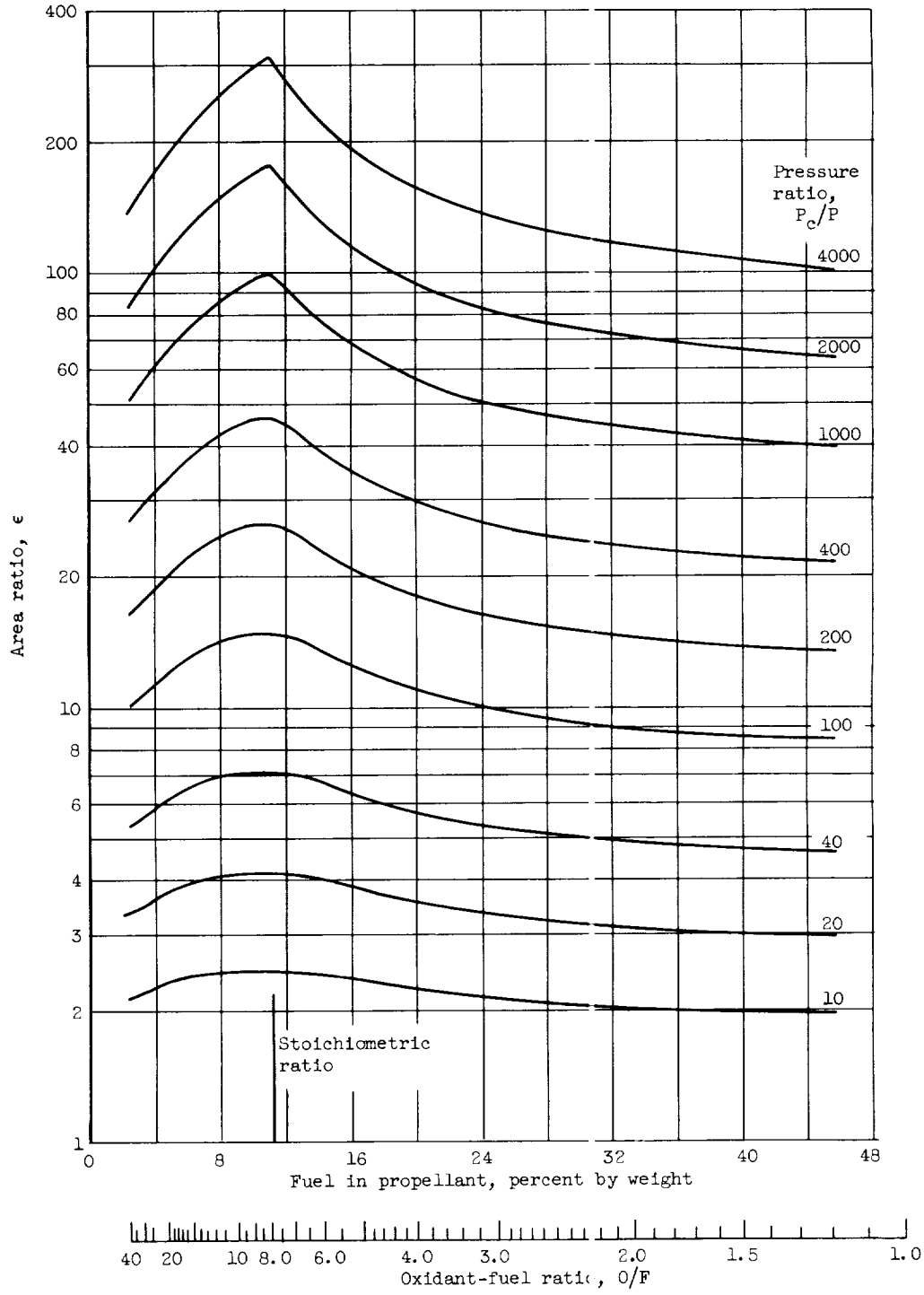
(h) Chamber pressure, 600 pounds per square inch absolute; equilibrium composition during expansion.

Figure 2. - Concluded. Theoretical combustion chamber and nozzle-exit temperatures of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



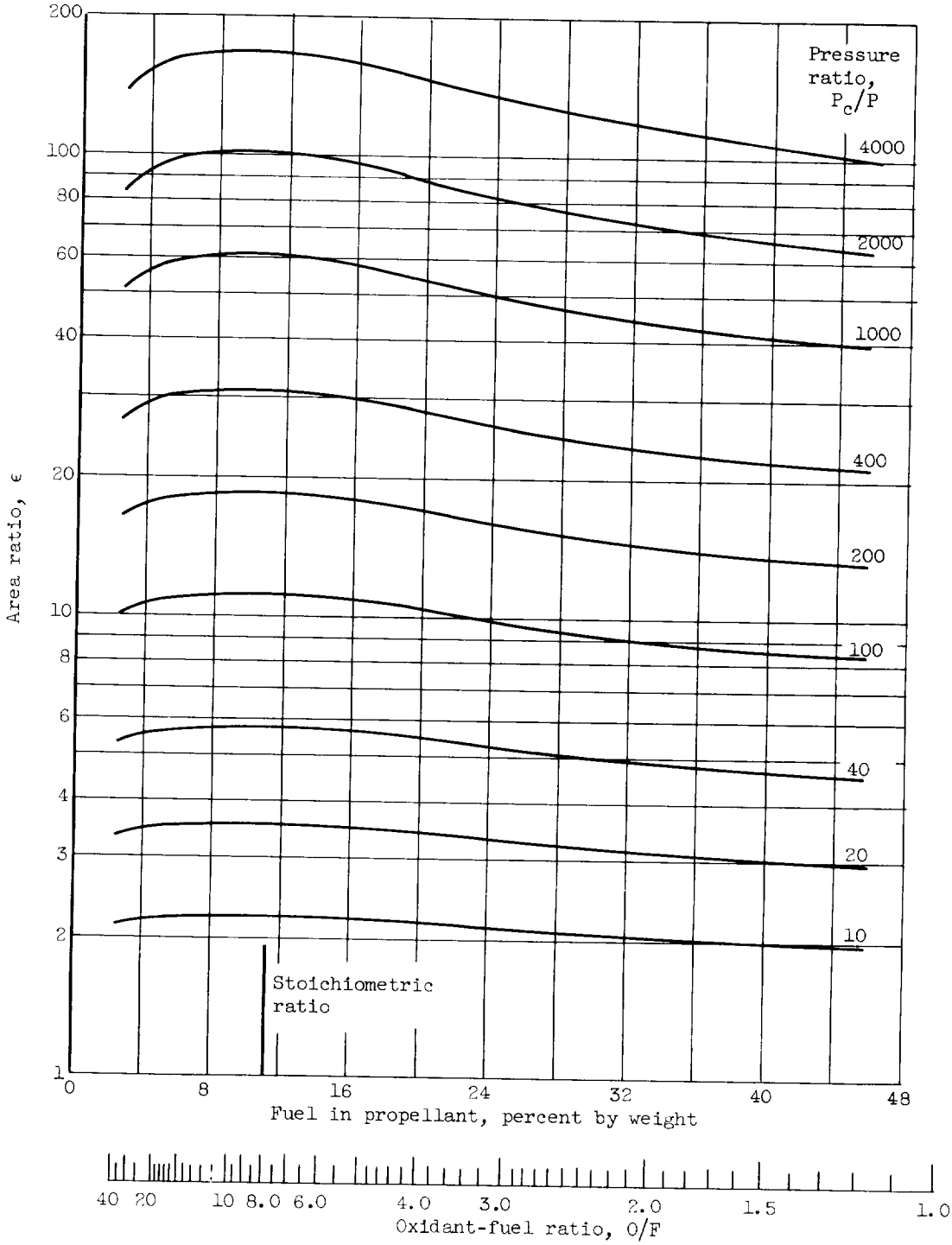
(a) Chamber pressure, 60 pounds per square inch absolute; frozen composition during expansion.

Figure 3. - Theoretical ratio of nozzle area to throat area for liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



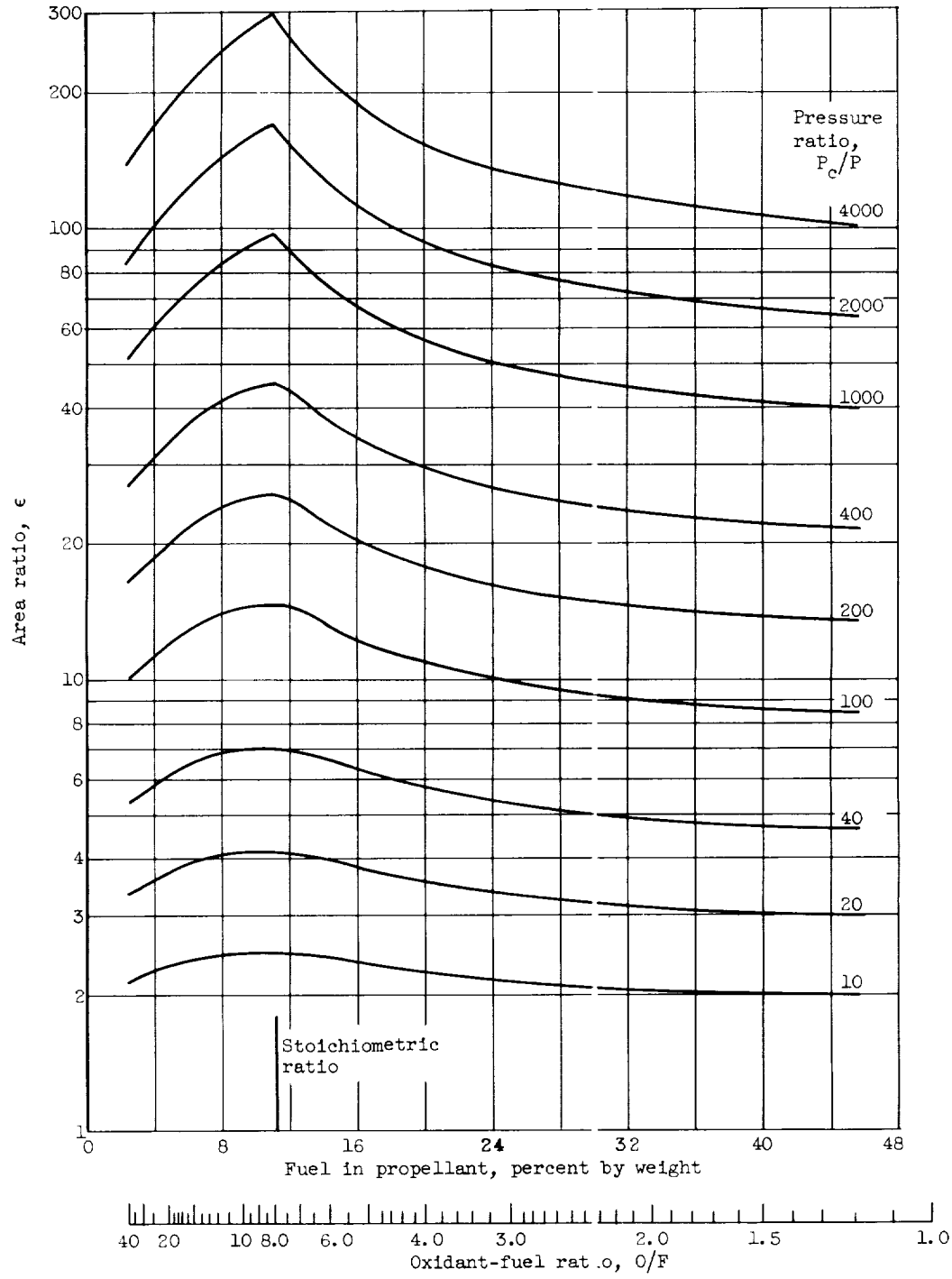
(b) Chamber pressure, 60 pounds per square inch absolute; equilibrium composition during expansion.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



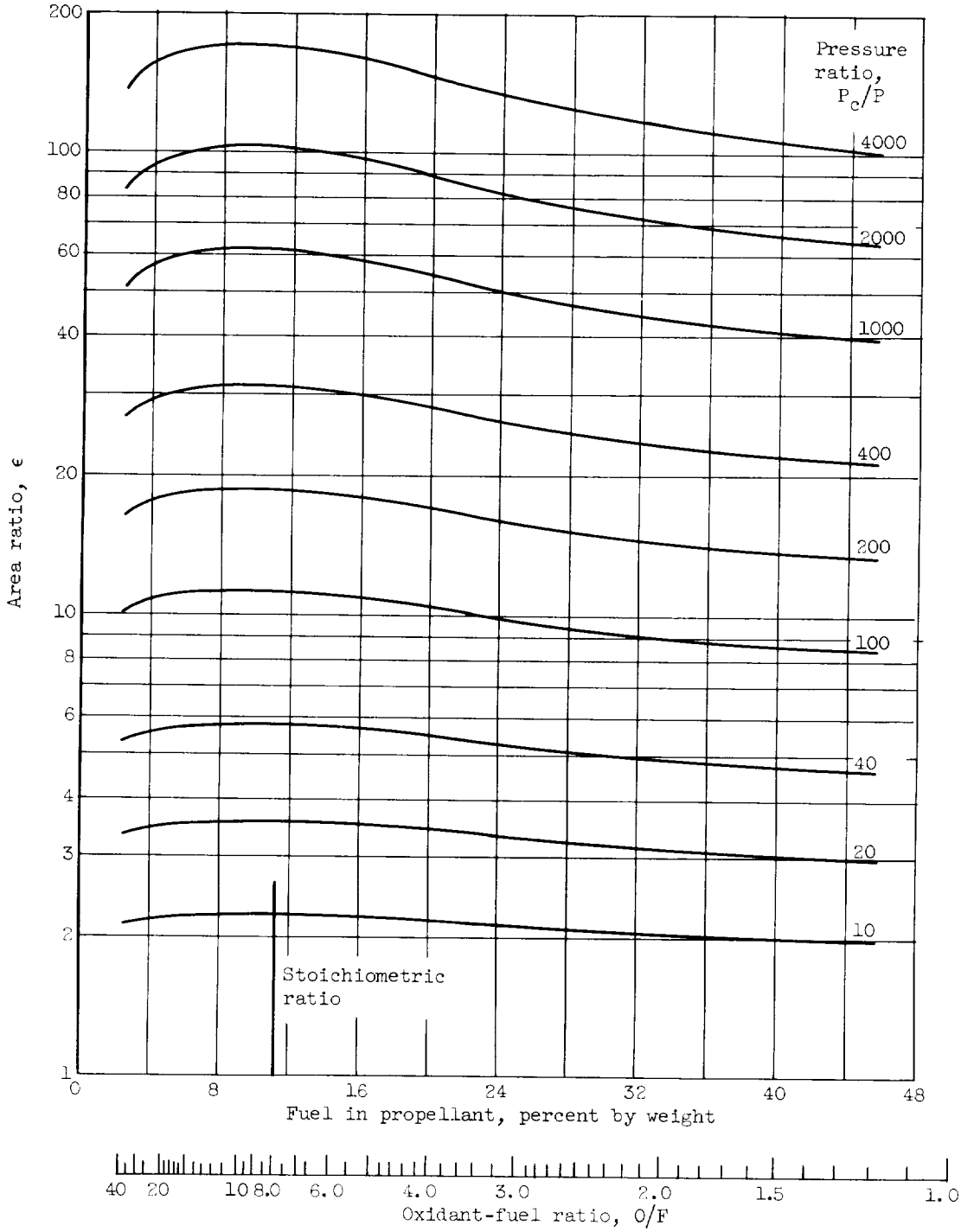
(c) Chamber pressure, 150 pounds per square inch absolute; frozen composition during expansion.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



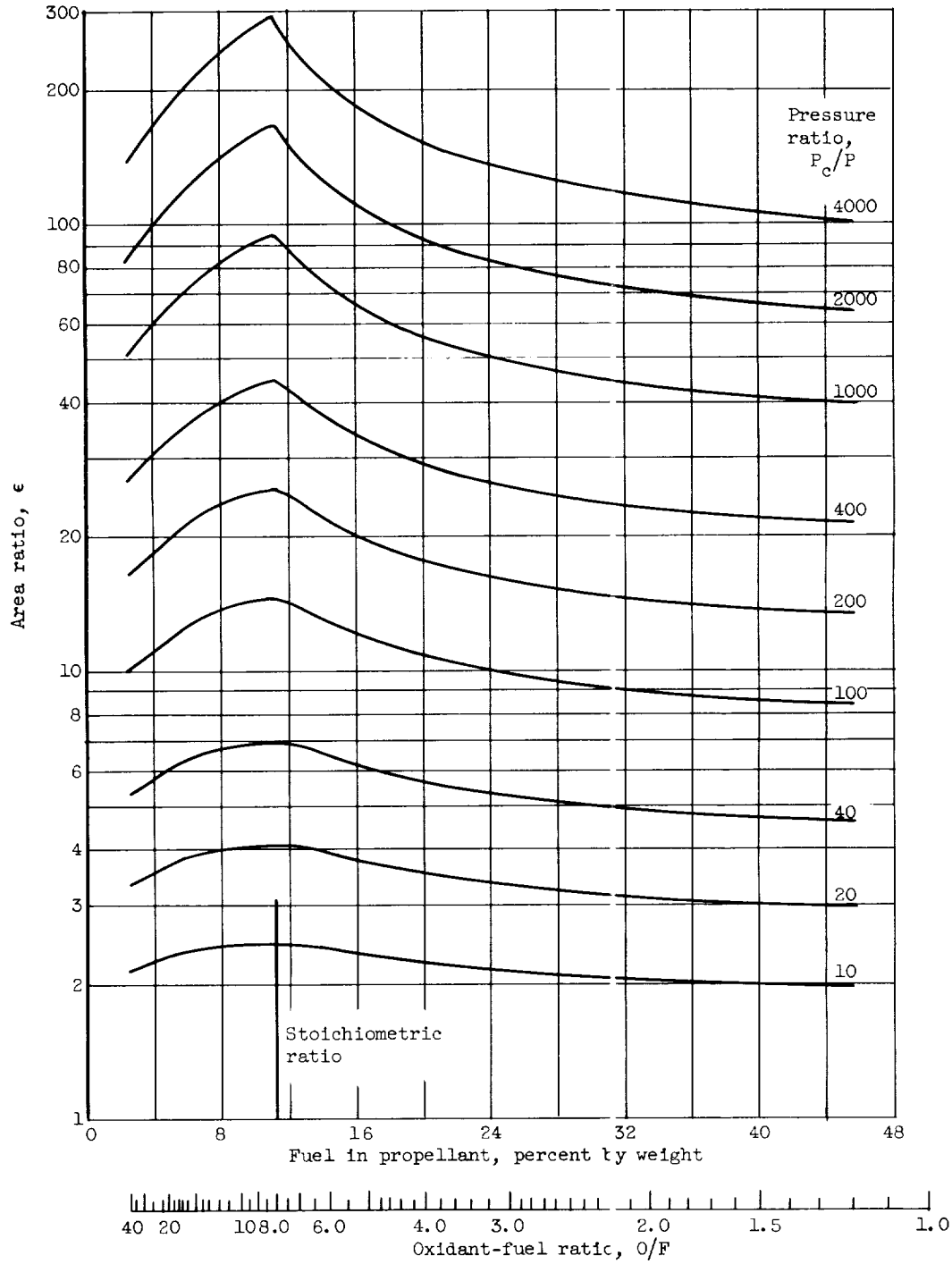
(d) Chamber pressure, 150 pounds per square inch absolute; equilibrium composition during expansion.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



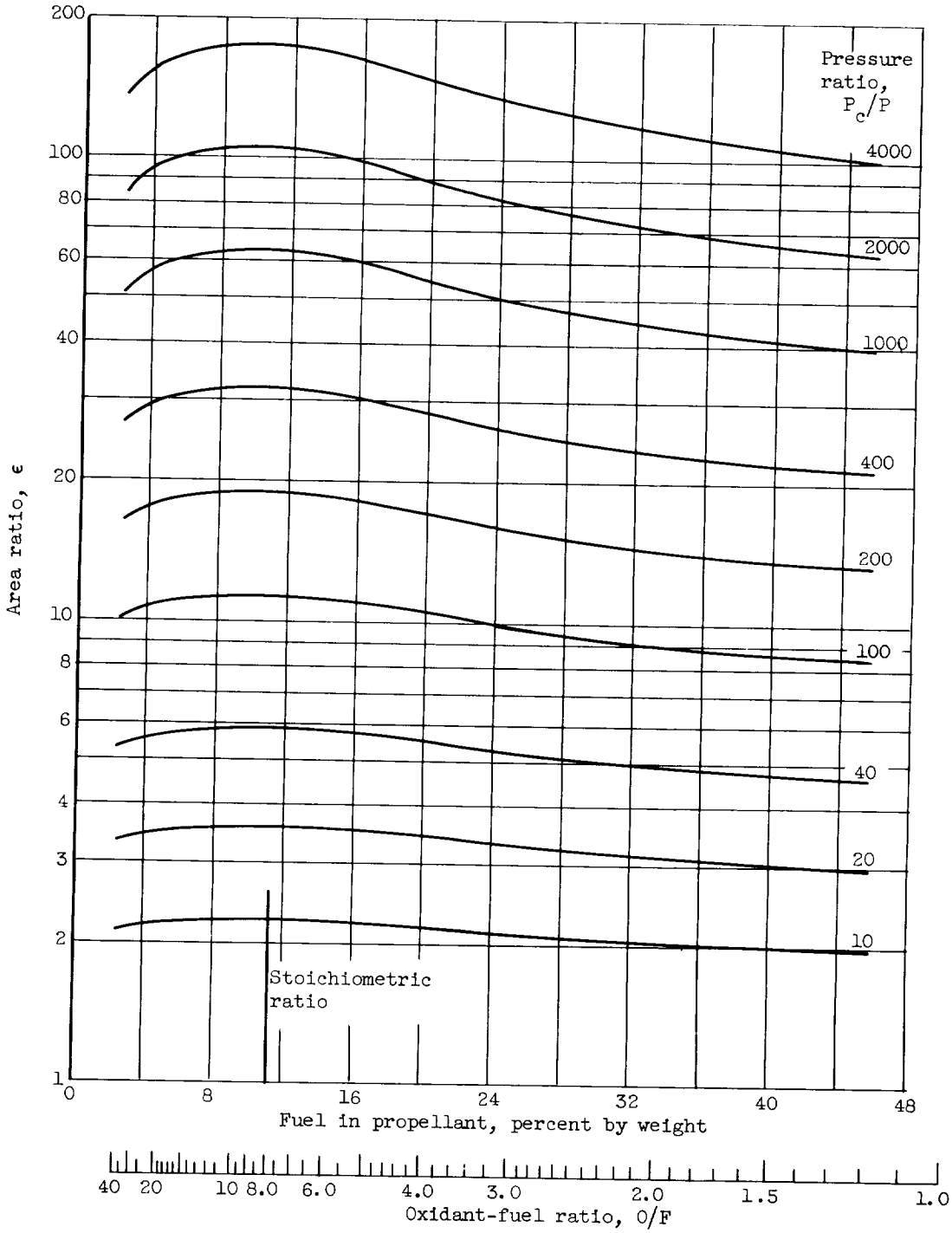
(e) Chamber pressure, 300 pounds per square inch absolute; frozen composition during expansion.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



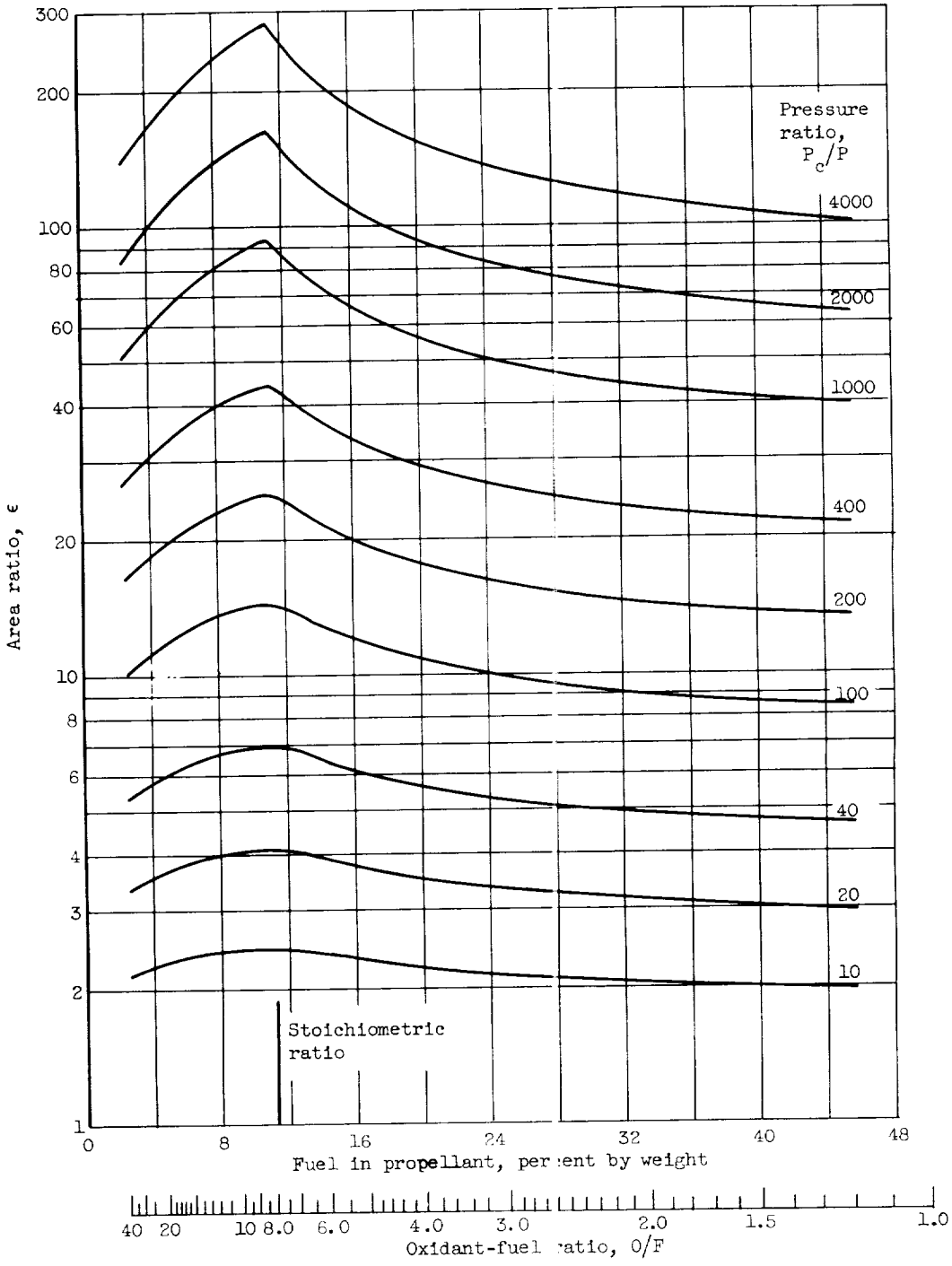
(f) Chamber pressure, 300 pounds per square inch absolute; equilibrium composition during expansion.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



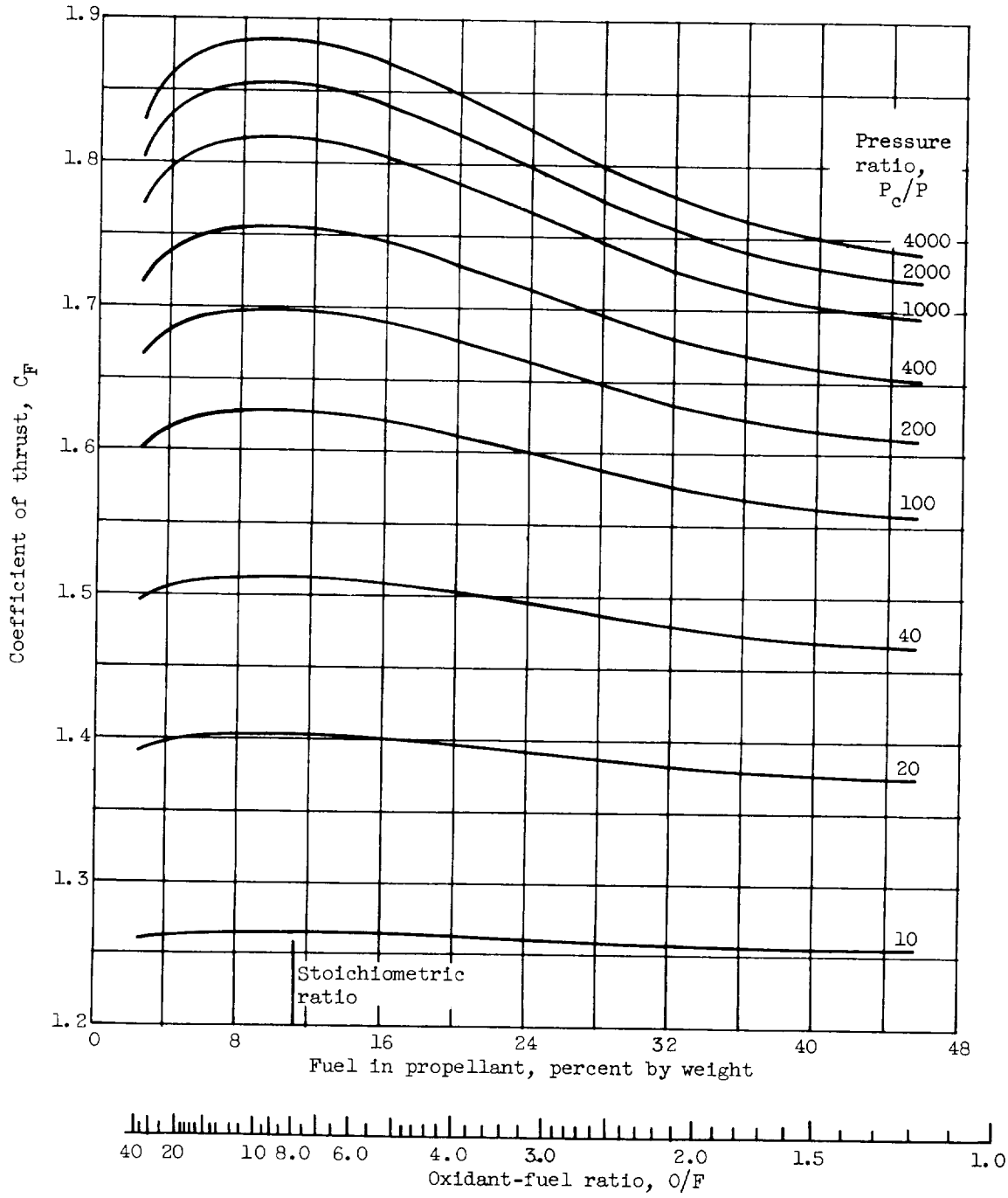
(g) Chamber pressure, 600 pounds per square inch absolute; frozen composition during expansion.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



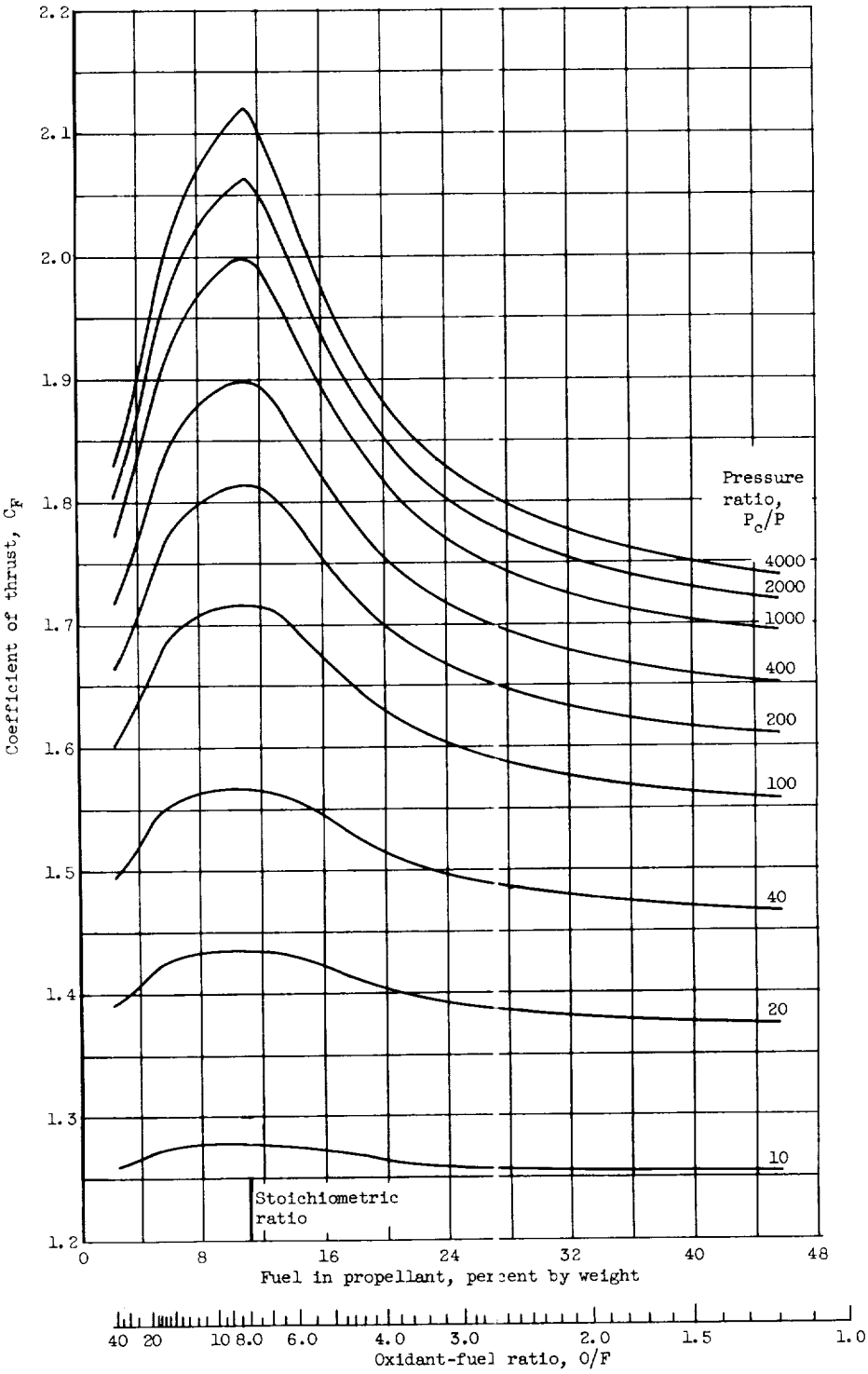
(h) Chamber pressure, 600 pounds per square inch absolute; equilibrium composition during expansion.

Figure 3. - Concluded. Theoretical ratio of nozzle area to throat area for liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



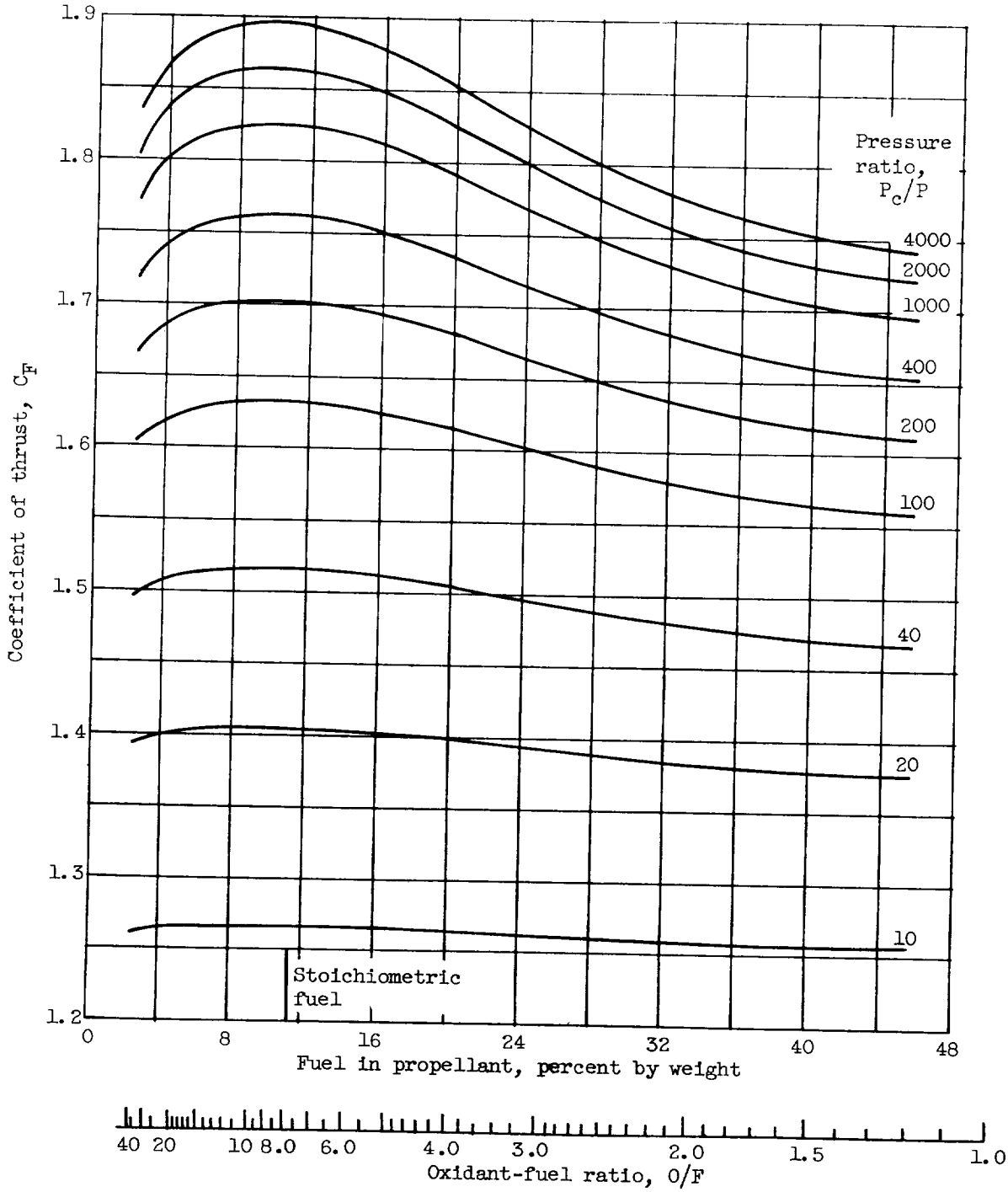
(a) Chamber pressure, 60 pounds per square inch absolute; frozen composition during expansion.

Figure 4. - Theoretical coefficient of thrust of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



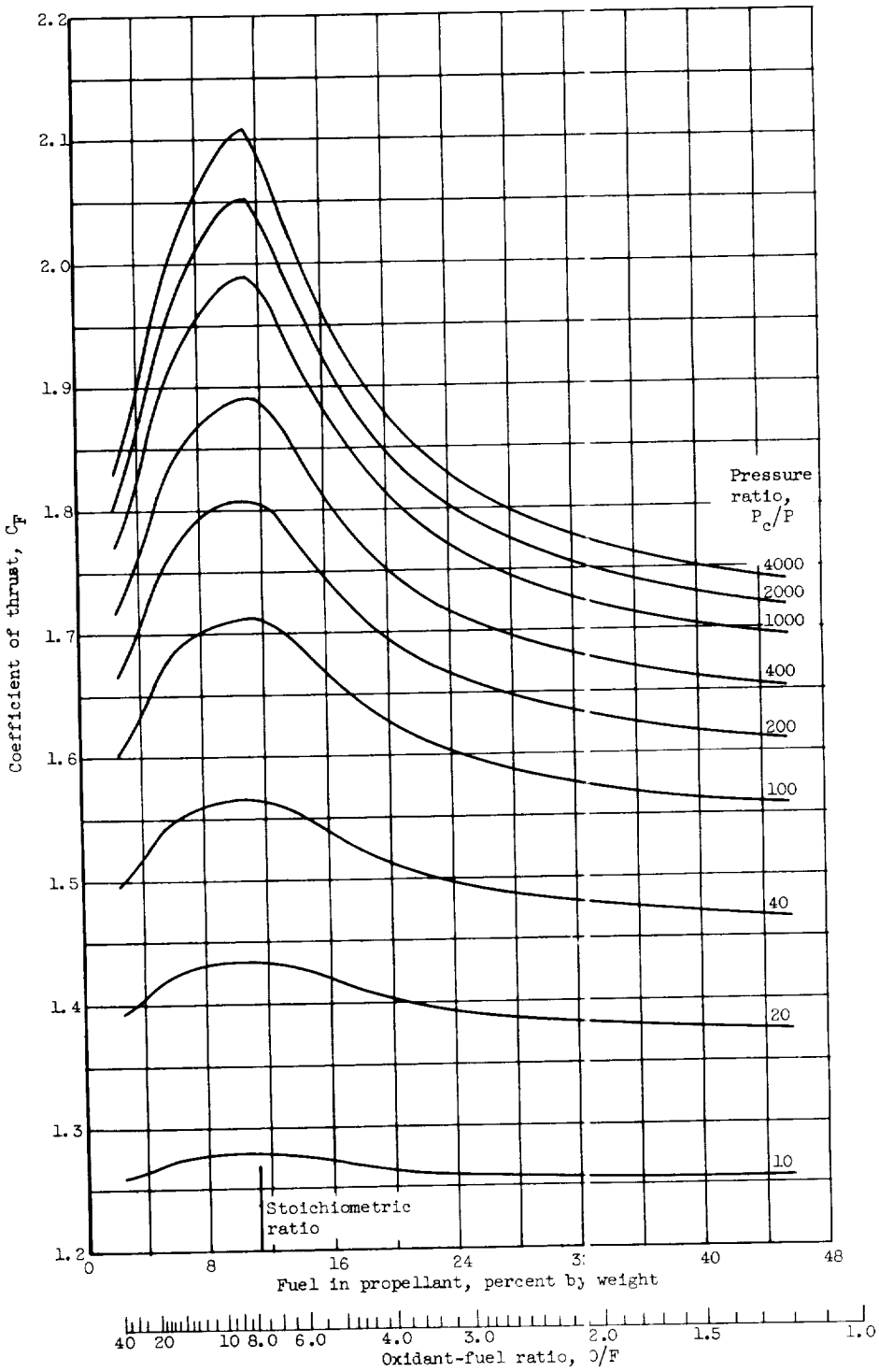
(b) Chamber pressure, 60 pounds per square inch absolute; equilibrium composition during expansion.

Figure 4. - Continued. Theoretical coefficient of thrust of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



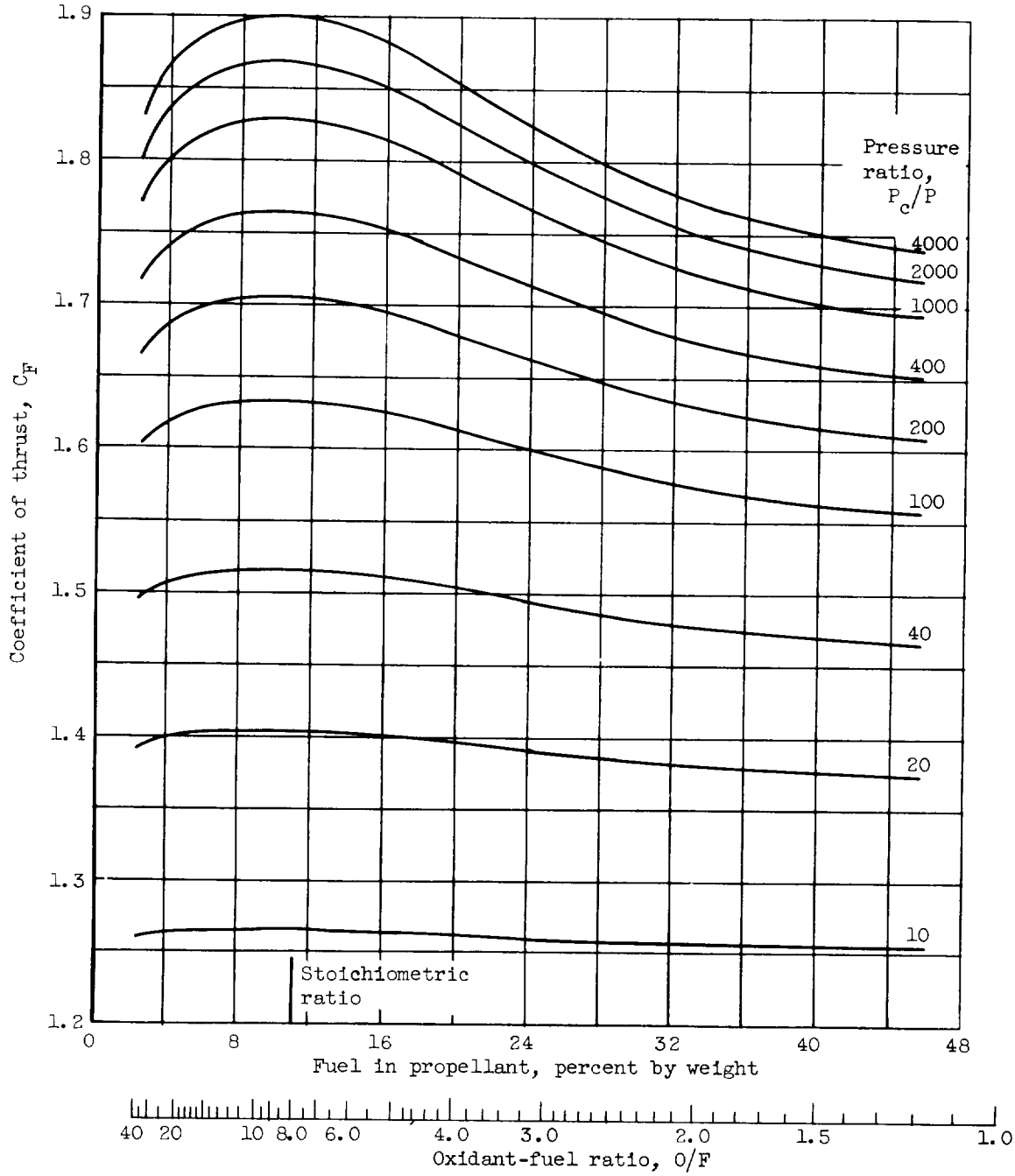
(c) Chamber pressure, 150 pounds per square inch absolute; frozen composition during expansion.

Figure 4. - Continued. Theoretical coefficient of thrust of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



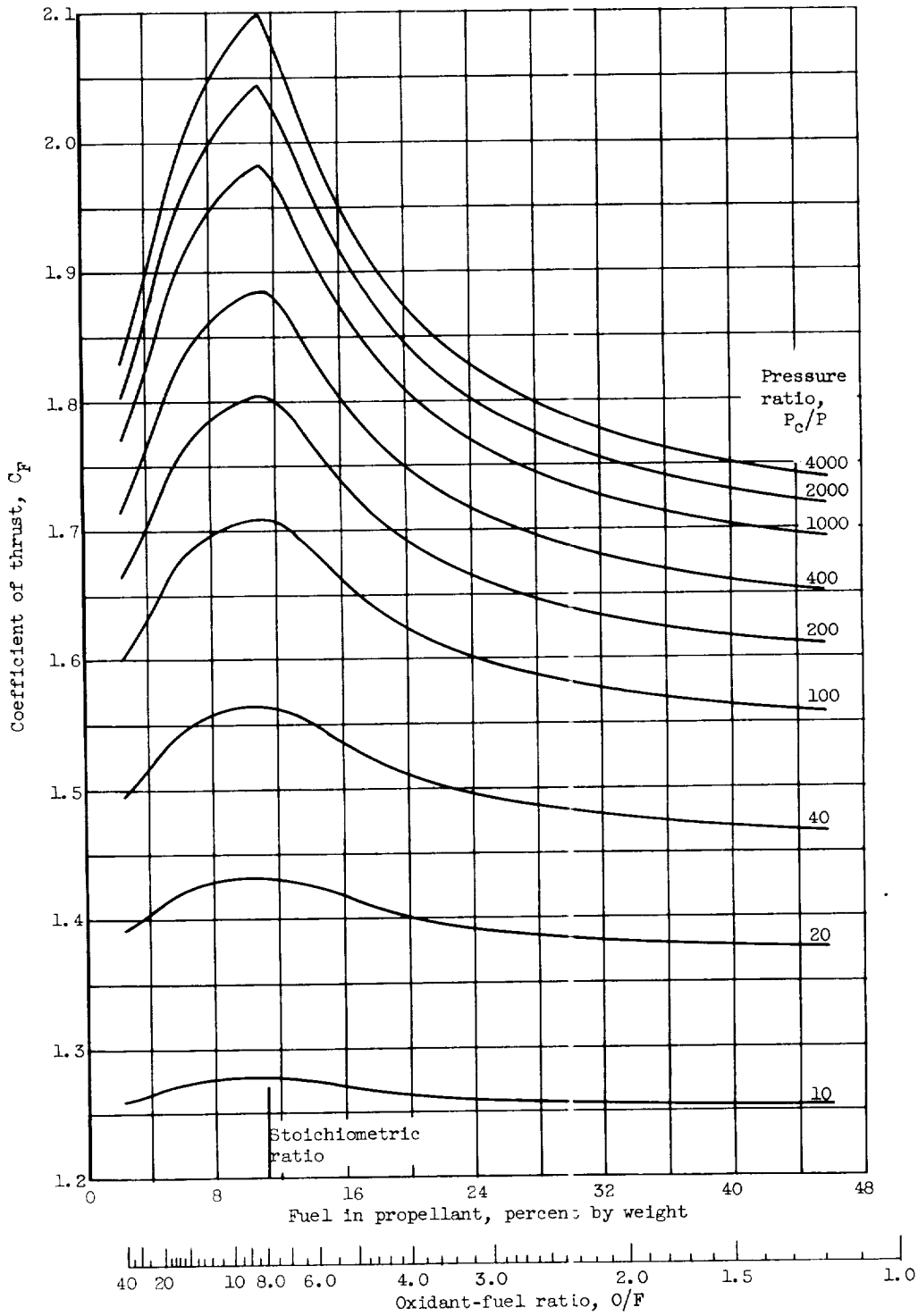
(d) Chamber pressure, 150 pounds per square inch absolute; equilibrium composition during expansion.

Figure 4. - Continued. Theoretical coefficient of thrust of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



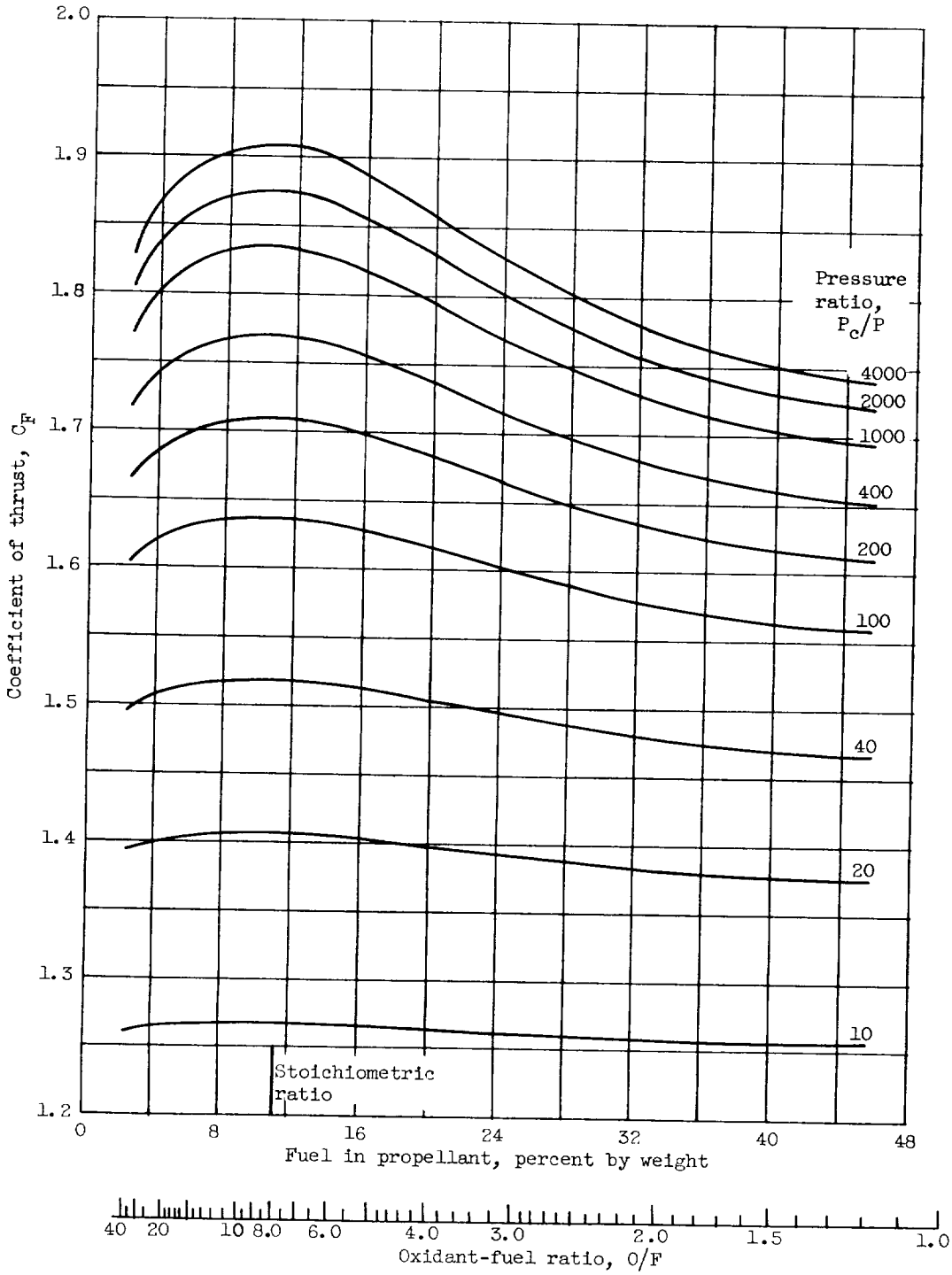
(e) Chamber pressure, 300 pounds per square inch absolute; frozen composition during expansion.

Figure 4. - Continued. Theoretical coefficient of thrust of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



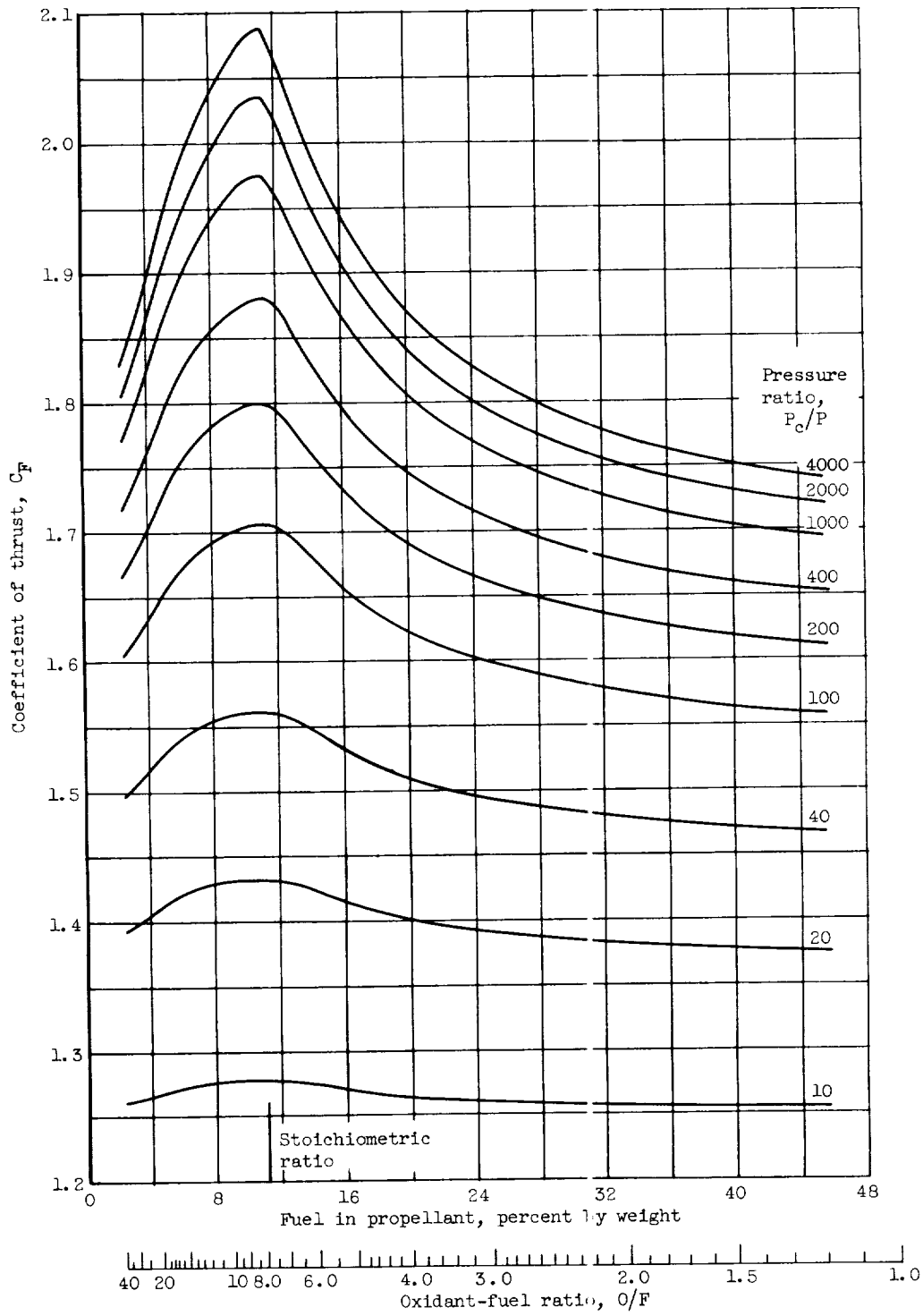
(f) Chamber pressure, 300 pounds per square inch absolute; equilibrium composition during expansion.

Figure 4. - Continued. Theoretical coefficient of thrust of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



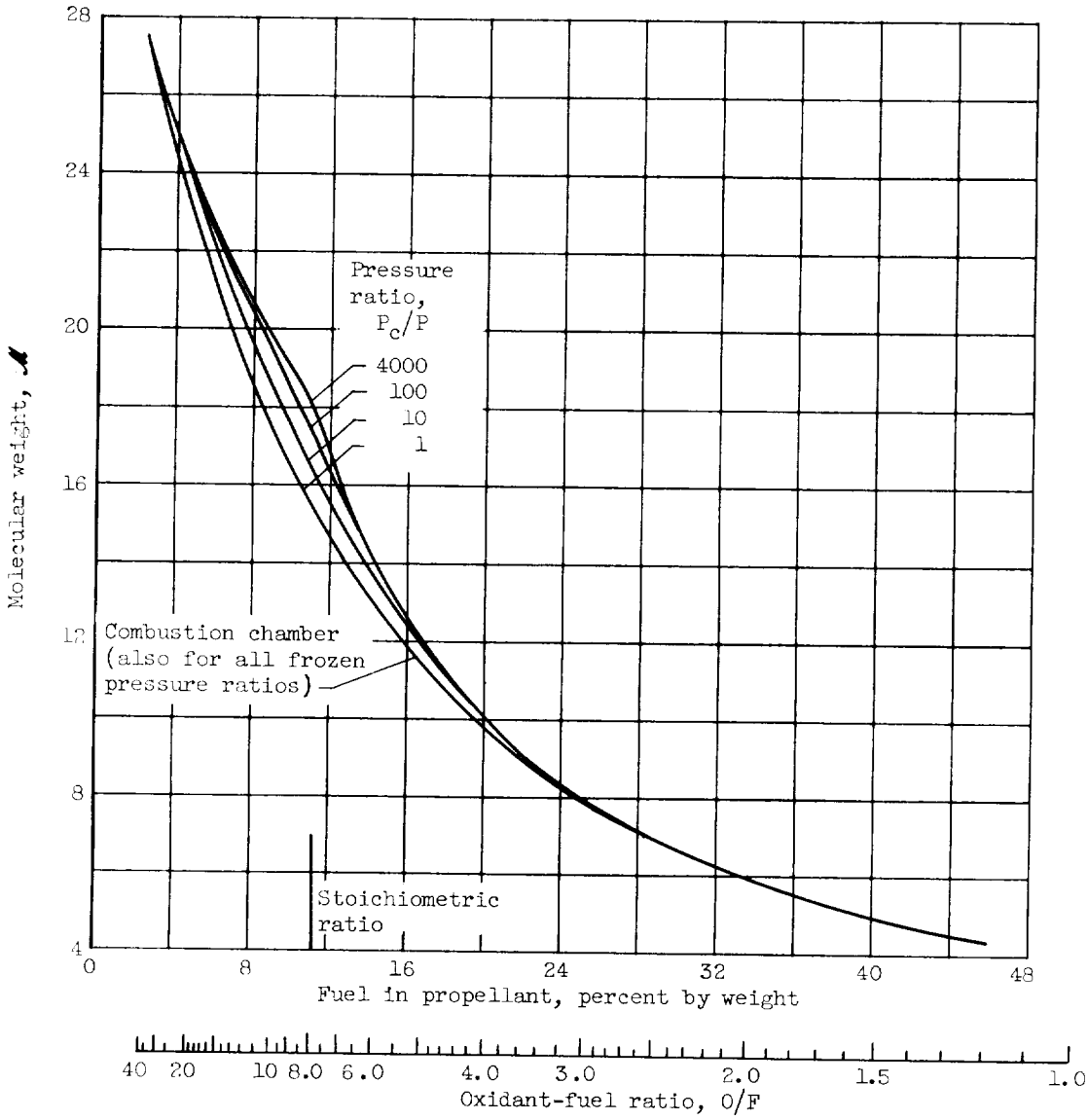
(g) Chamber pressure, 600 pounds per square inch absolute; frozen composition during expansion.

Figure 4. - Continued. Theoretical coefficient of thrust of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



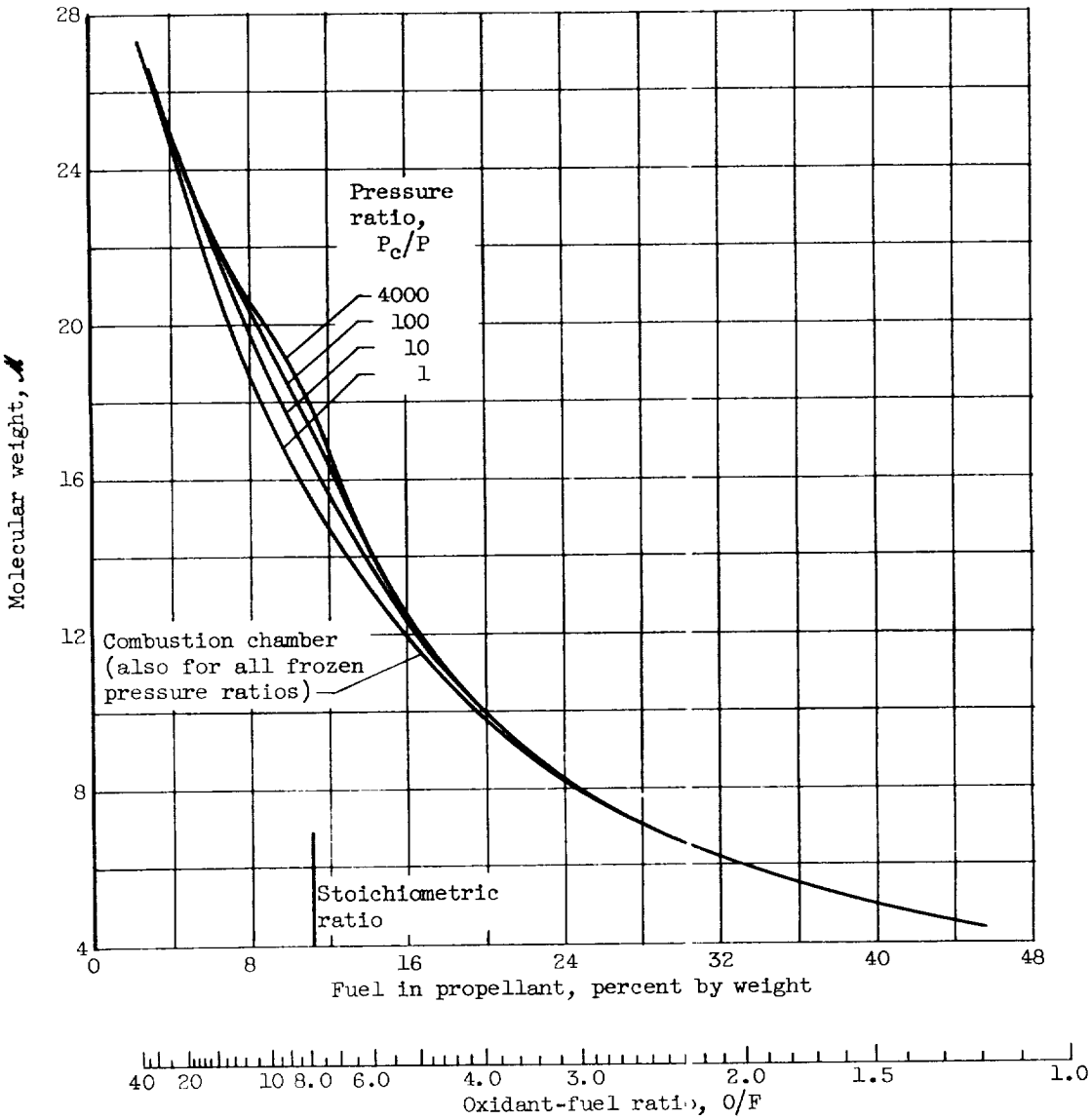
(h) Chamber pressure, 600 pounds per square inch absolute; equilibrium composition during expansion.

Figure 4. - Concluded. Theoretical coefficient of thrust of liquid hydrogen and liquid oxygen. Isentropic expansion to pressure ratio indicated.



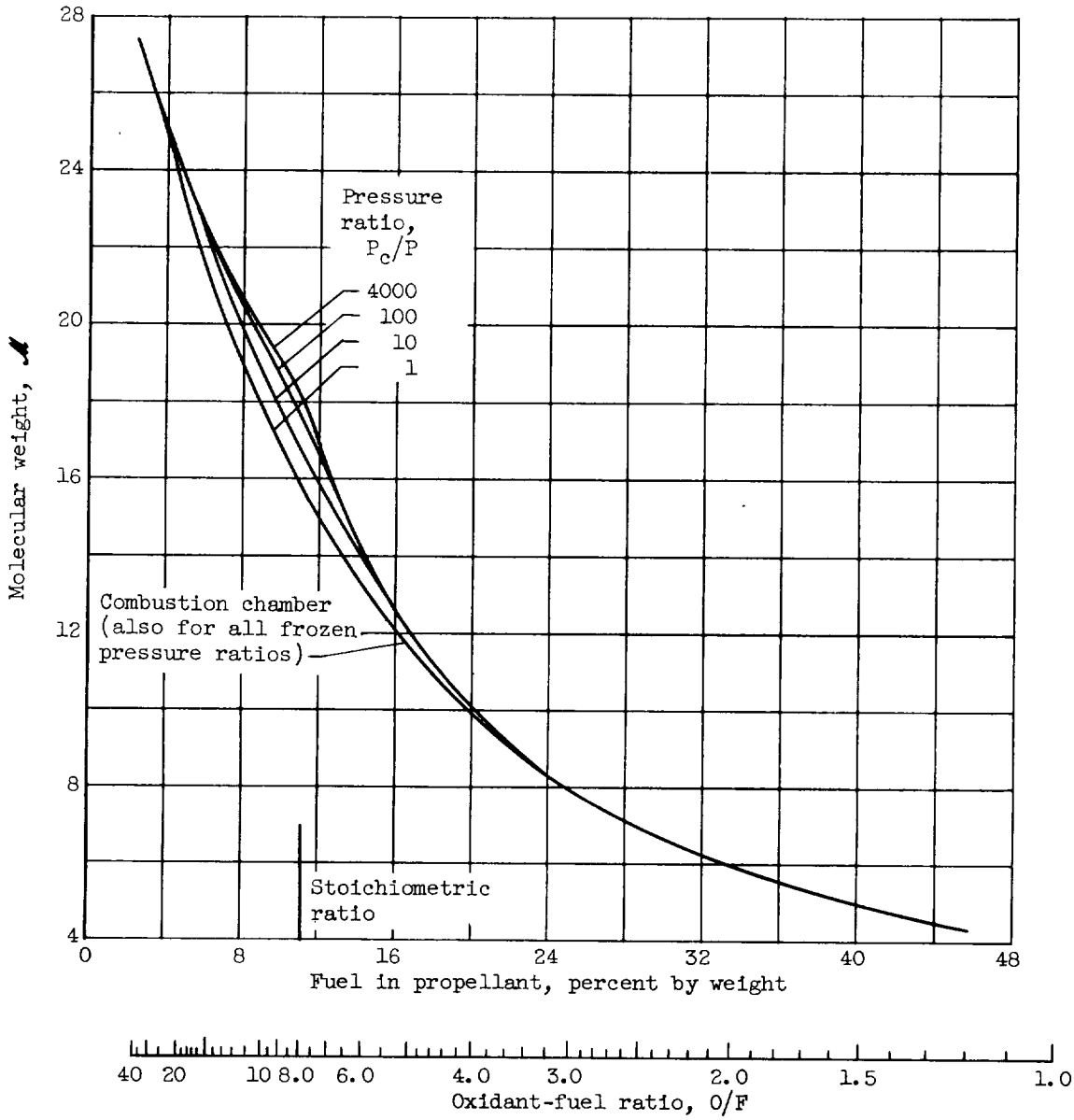
(a) Chamber pressure, 60 pounds per square inch absolute.

Figure 5. - Theoretical molecular weight of liquid hydrogen and liquid oxygen. Equilibrium composition during isentropic expansion to pressure ratio indicated.



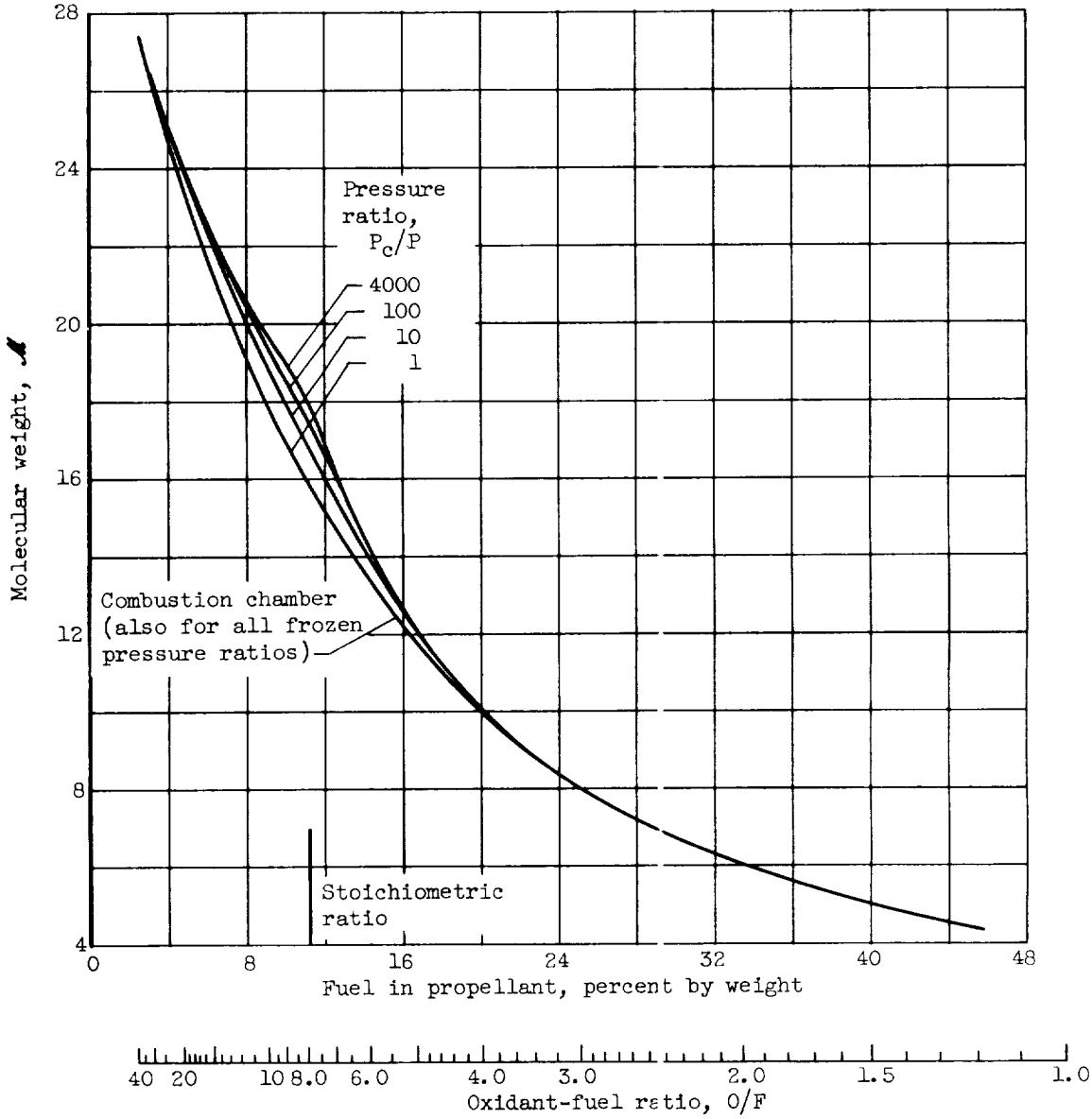
(b) Chamber pressure, 150 pounds per square inch absolute.

Figure 5. - Continued. Theoretical molecular weight of liquid hydrogen and liquid oxygen. Equilibrium composition during isentropic expansion to pressure ratio indicated.



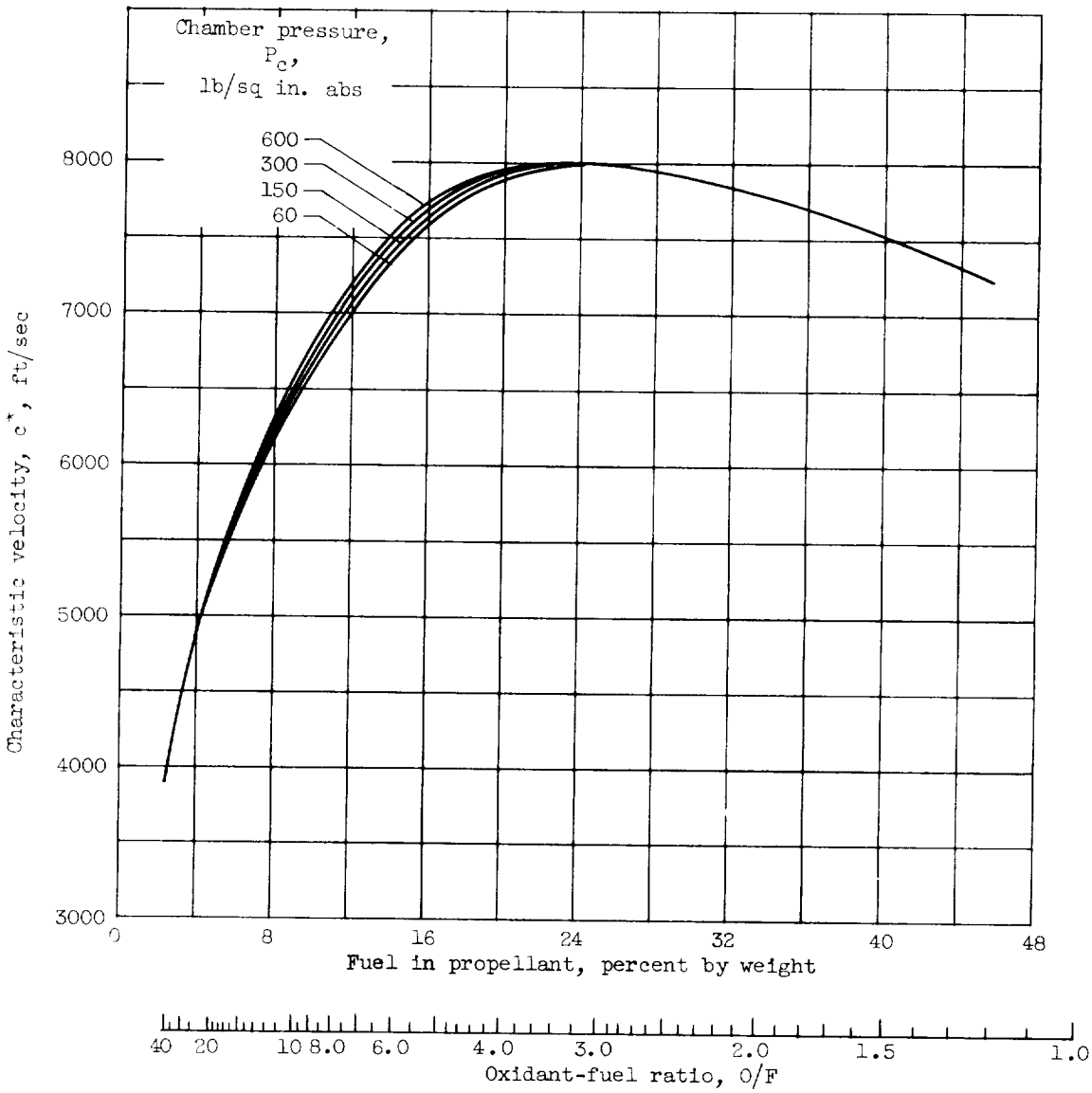
(c) Chamber pressure, 300 pounds per square inch absolute.

Figure 5. - Continued. Theoretical molecular weight of liquid hydrogen and liquid oxygen. Equilibrium composition during isentropic expansion to pressure ratio indicated.



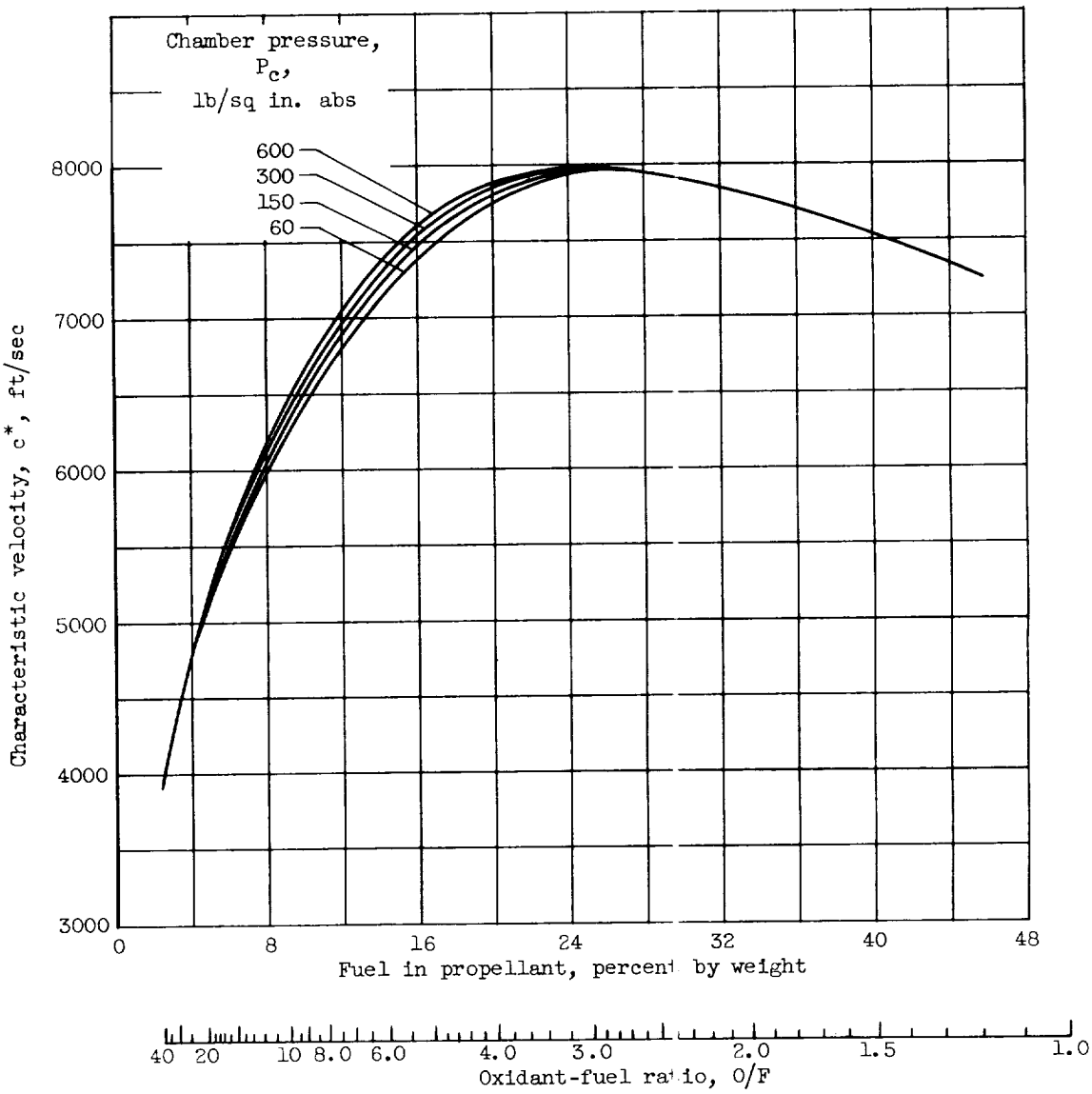
(d) Chamber pressure, 600 pounds per square inch absolute.

Figure 5. - Concluded. Theoretical molecular weight of liquid hydrogen and liquid oxygen. Equilibrium composition during isentropic expansion to pressure ratio indicated.



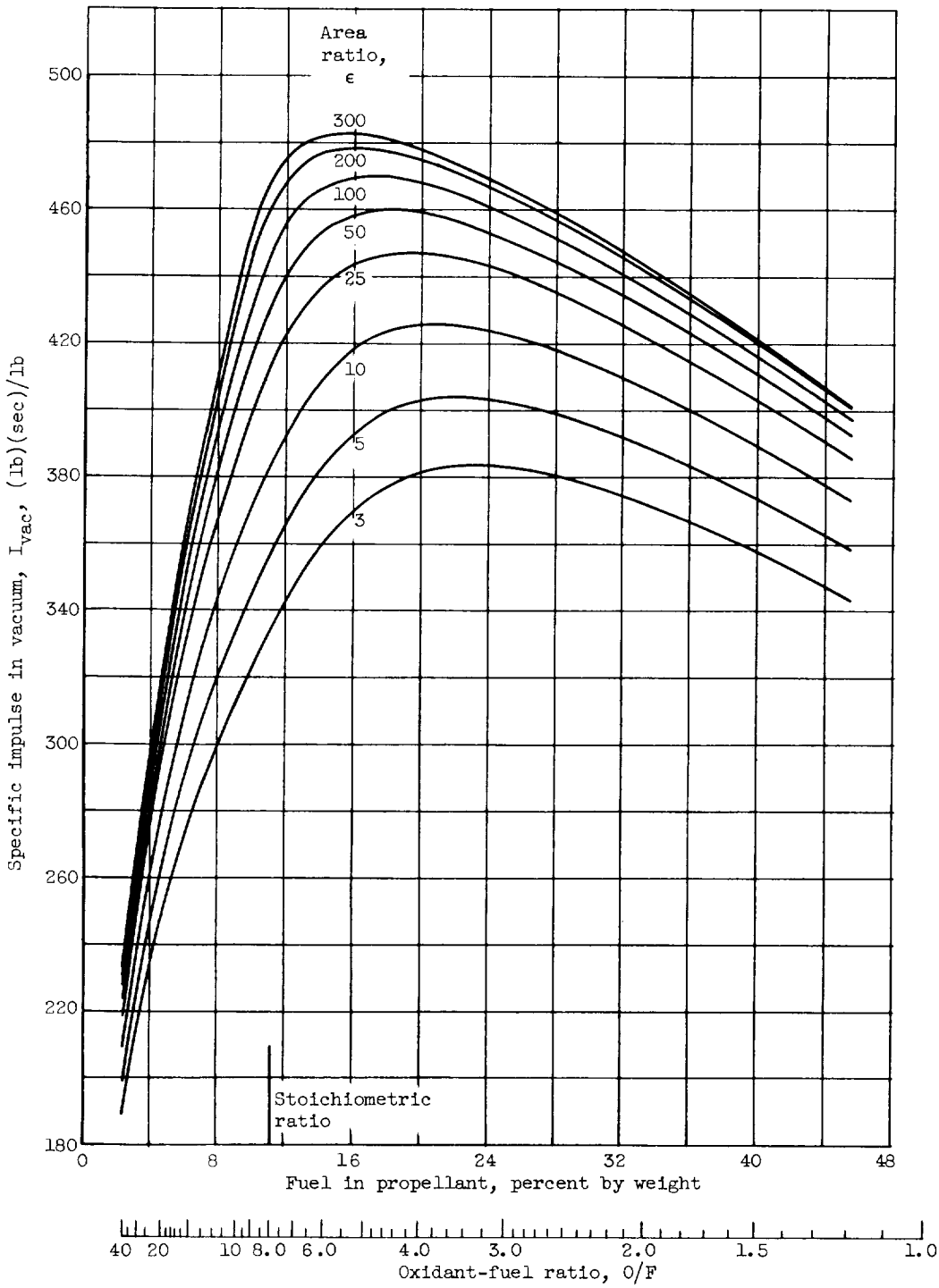
(a) Equilibrium composition during expansion.

Figure 6. - Theoretical characteristic velocity of liquid hydrogen and liquid oxygen.



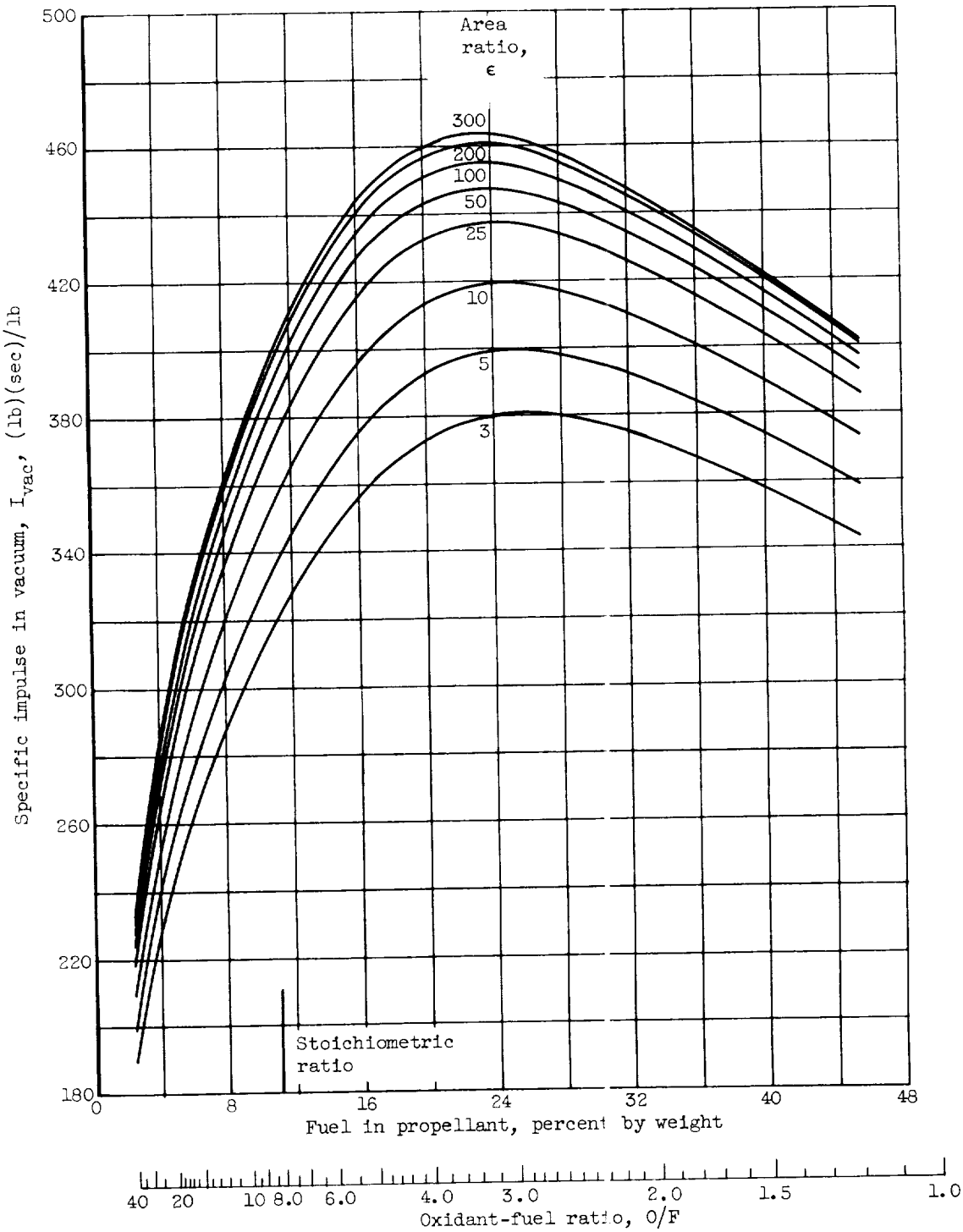
(b) Frozen composition during expansion.

Figure 6. - Concluded. Theoretical characteristic velocity of liquid hydrogen and liquid oxygen.



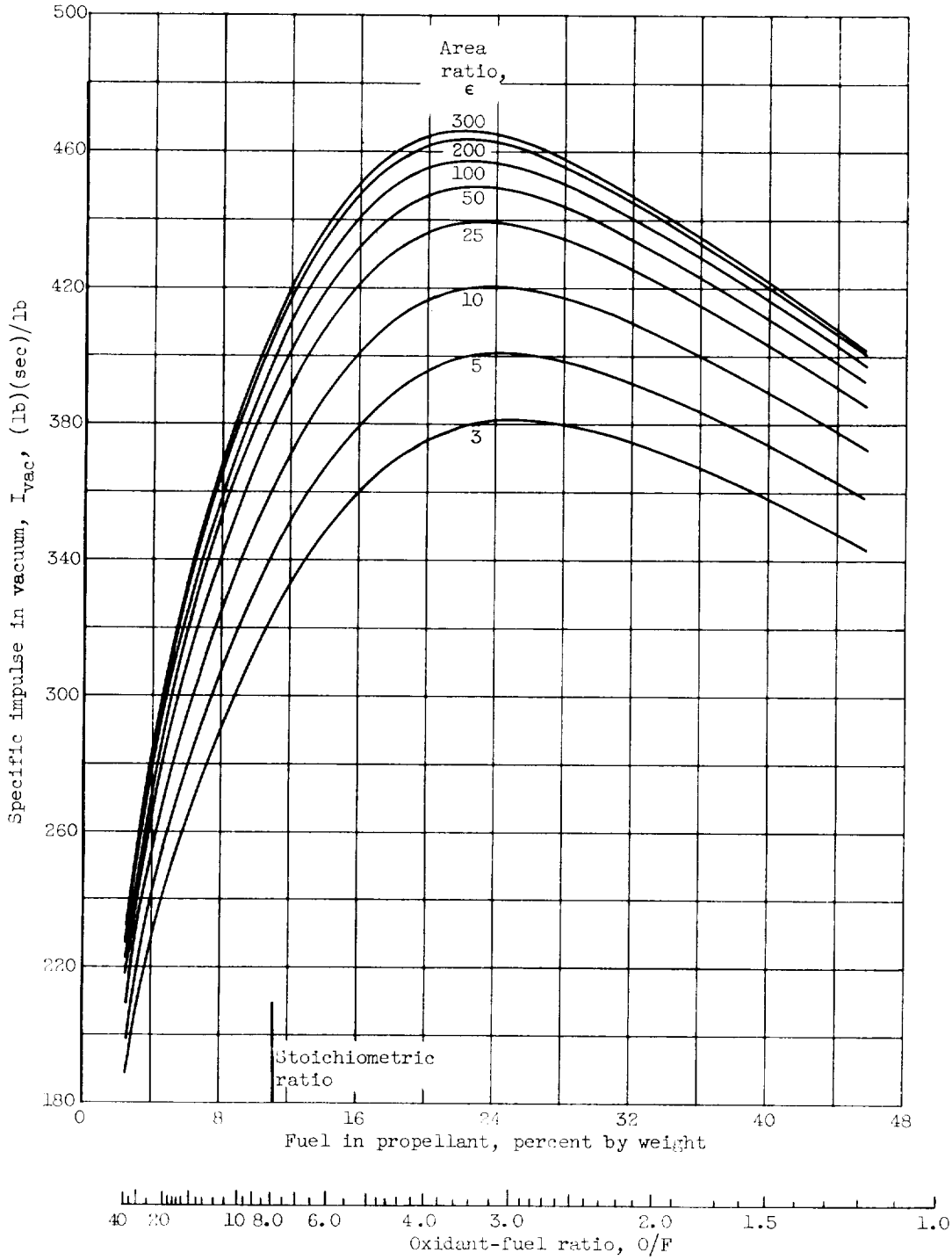
(b) Chamber pressure, 60 pounds per square inch absolute; equilibrium composition during expansion.

Figure 7. - Continued. Theoretical specific impulse in vacuum of liquid hydrogen and liquid oxygen. Isentropic expansion to area ratio indicated.



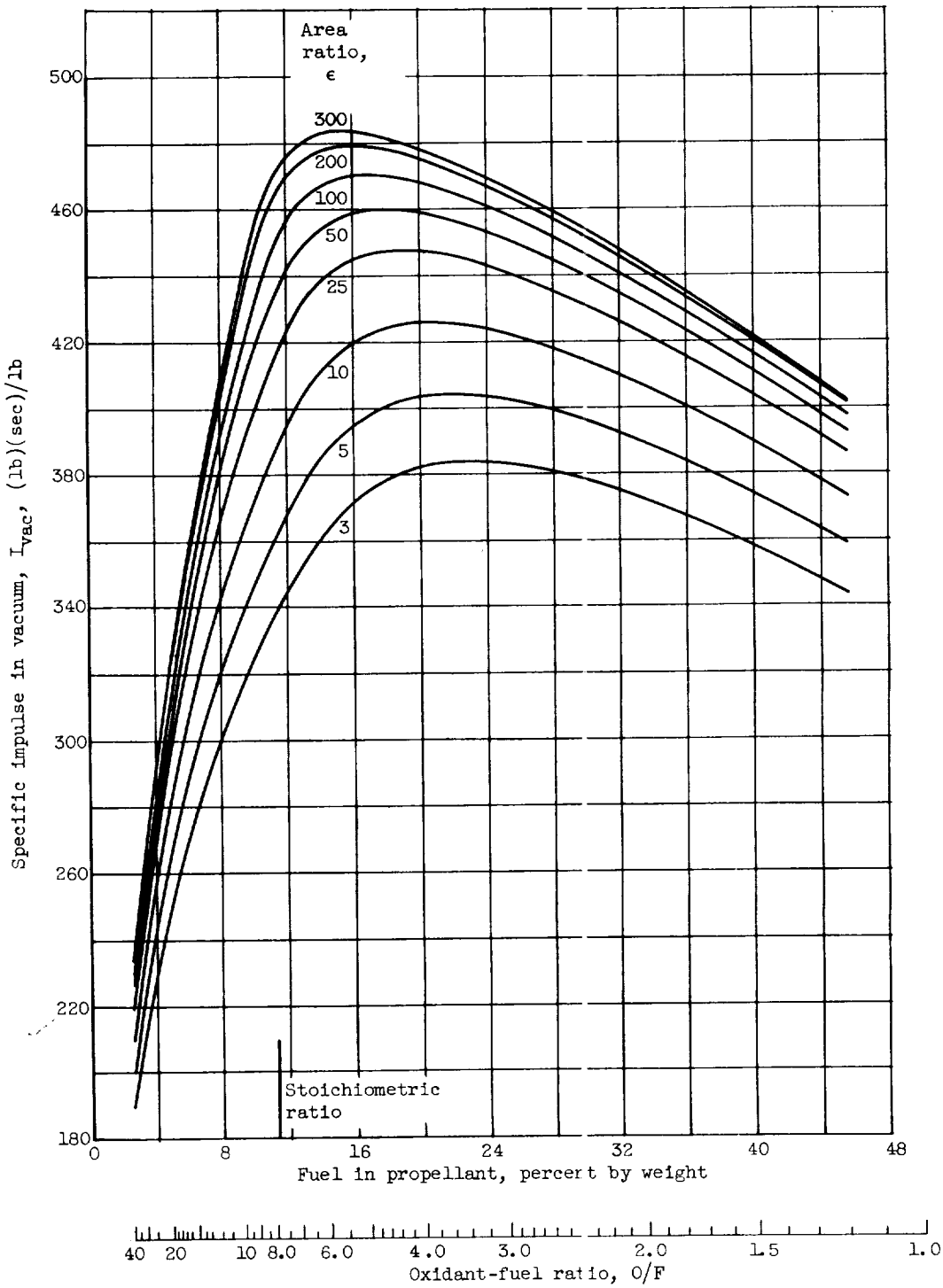
(a) Chamber pressure, 60 pounds per square inch absolute; frozen composition during expansion.

Figure 7. - Theoretical specific impulse in vacuum of liquid hydrogen and liquid oxygen. Isentropic expansion to area ratio indicated.



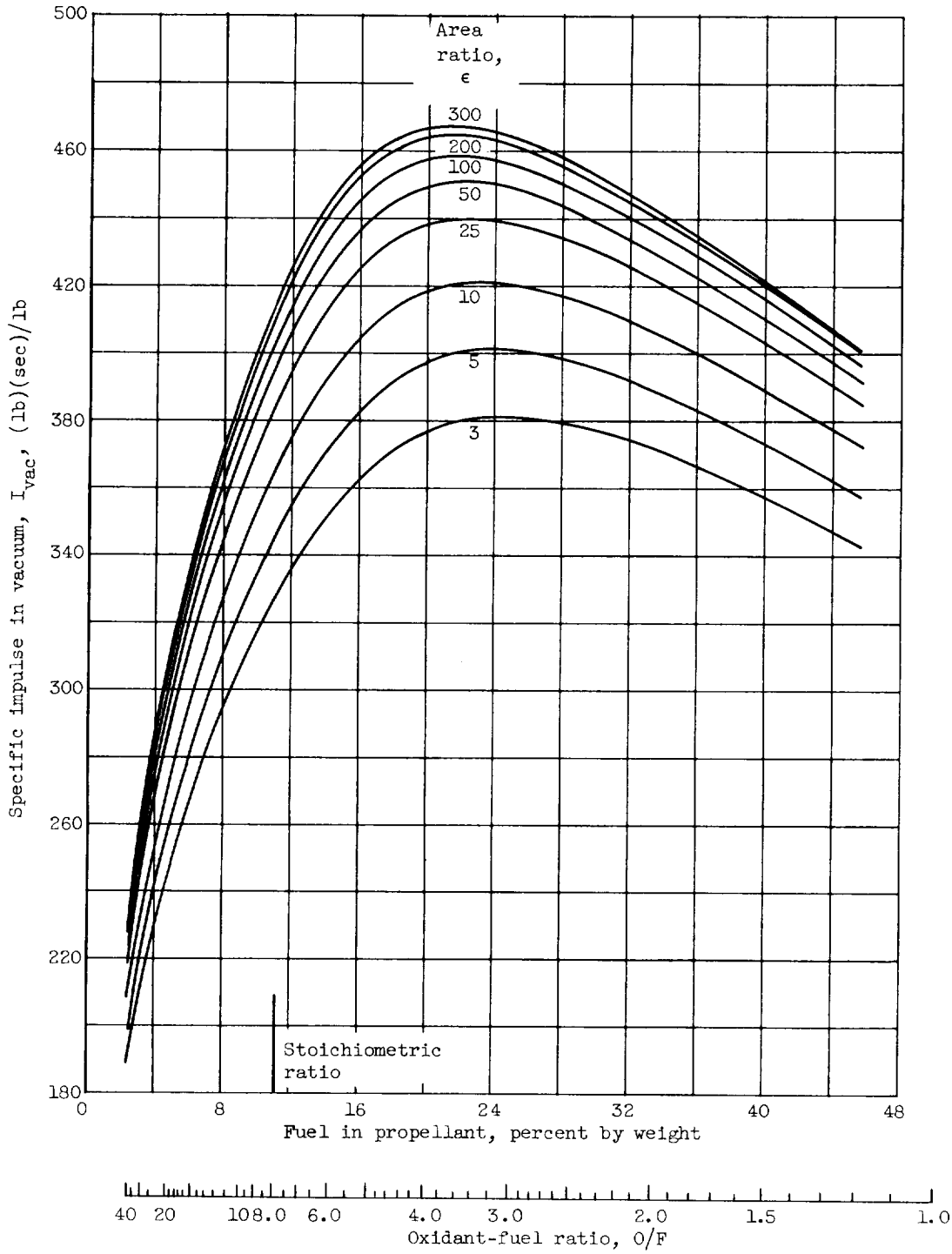
(c) Chamber pressure, 150 pounds per square inch absolute; frozen composition during expansion.

Figure 7. - Continued. Theoretical specific impulse in vacuum of liquid hydrogen and liquid oxygen. Isentropic expansion to area ratio indicated.



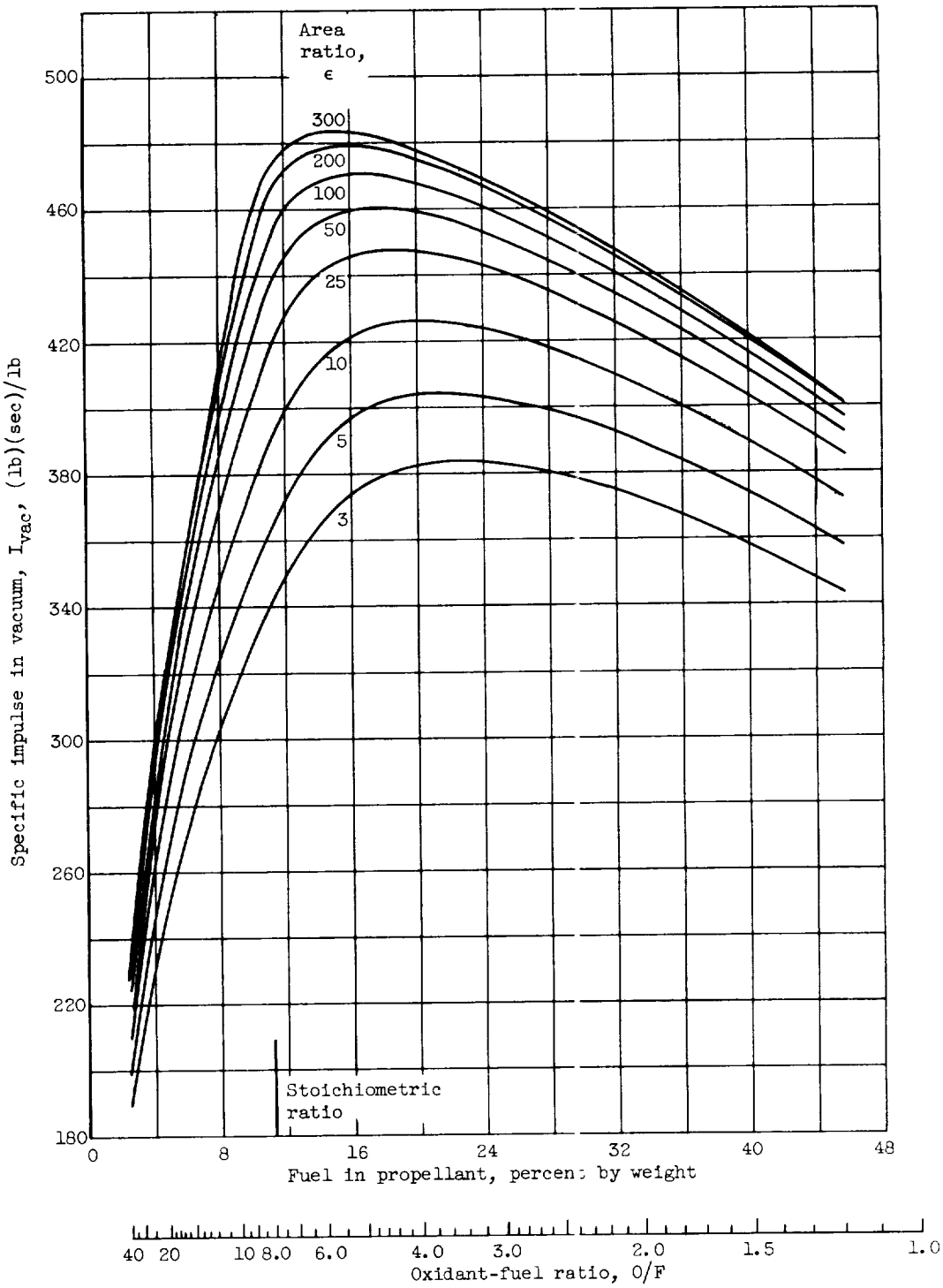
(d) Chamber pressure, 150 pounds per square inch absolute; equilibrium composition during expansion.

Figure 7. - Continued. Theoretical specific impulse in vacuum of liquid hydrogen and liquid oxygen. Isentropic expansion to area ratio indicated.



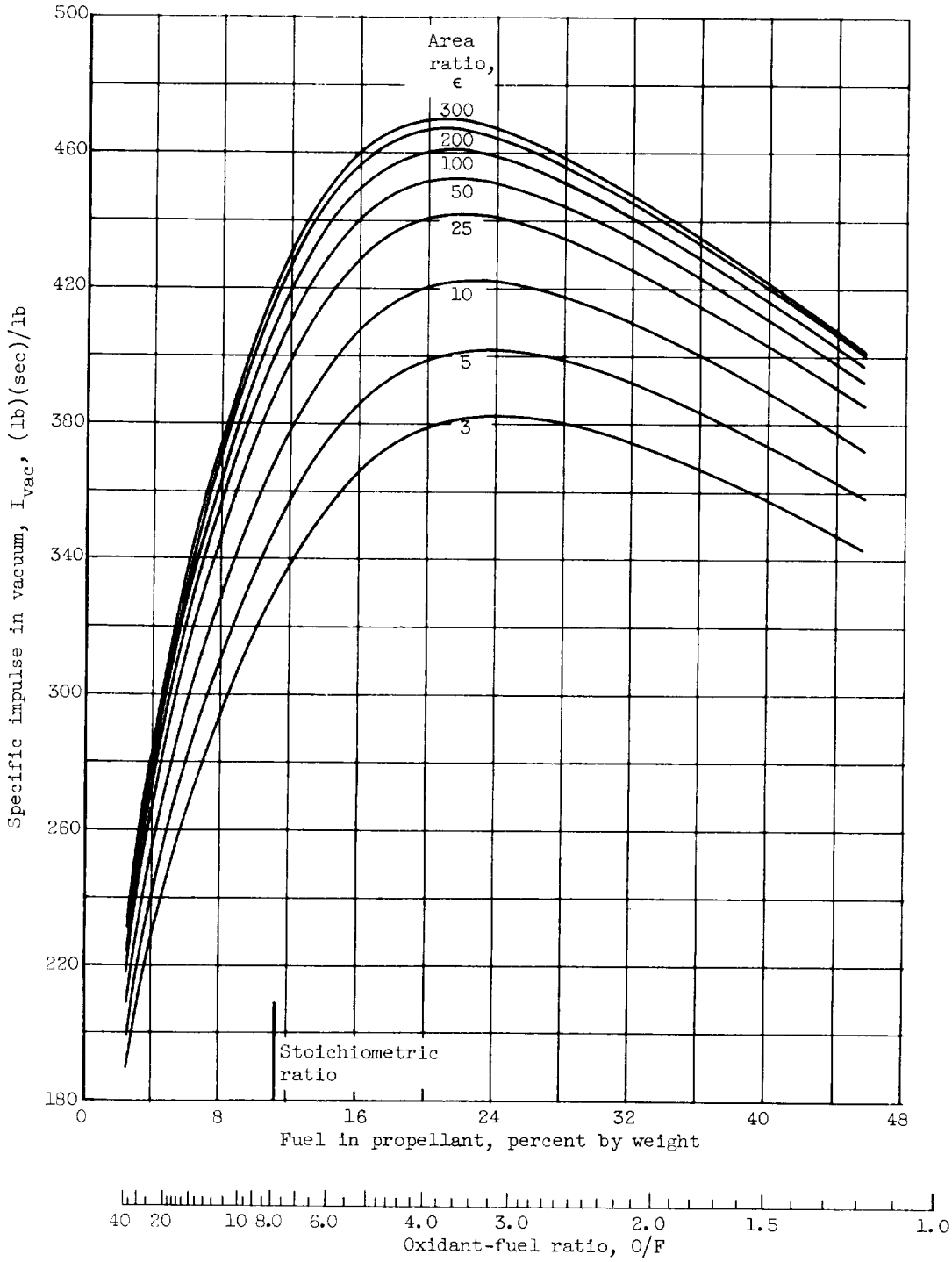
(e) Chamber pressure, 300 pounds per square inch absolute; frozen composition during expansion.

Figure 7. - Continued. Theoretical specific impulse in vacuum of liquid hydrogen and liquid oxygen. Isentropic expansion to area ratio indicated.



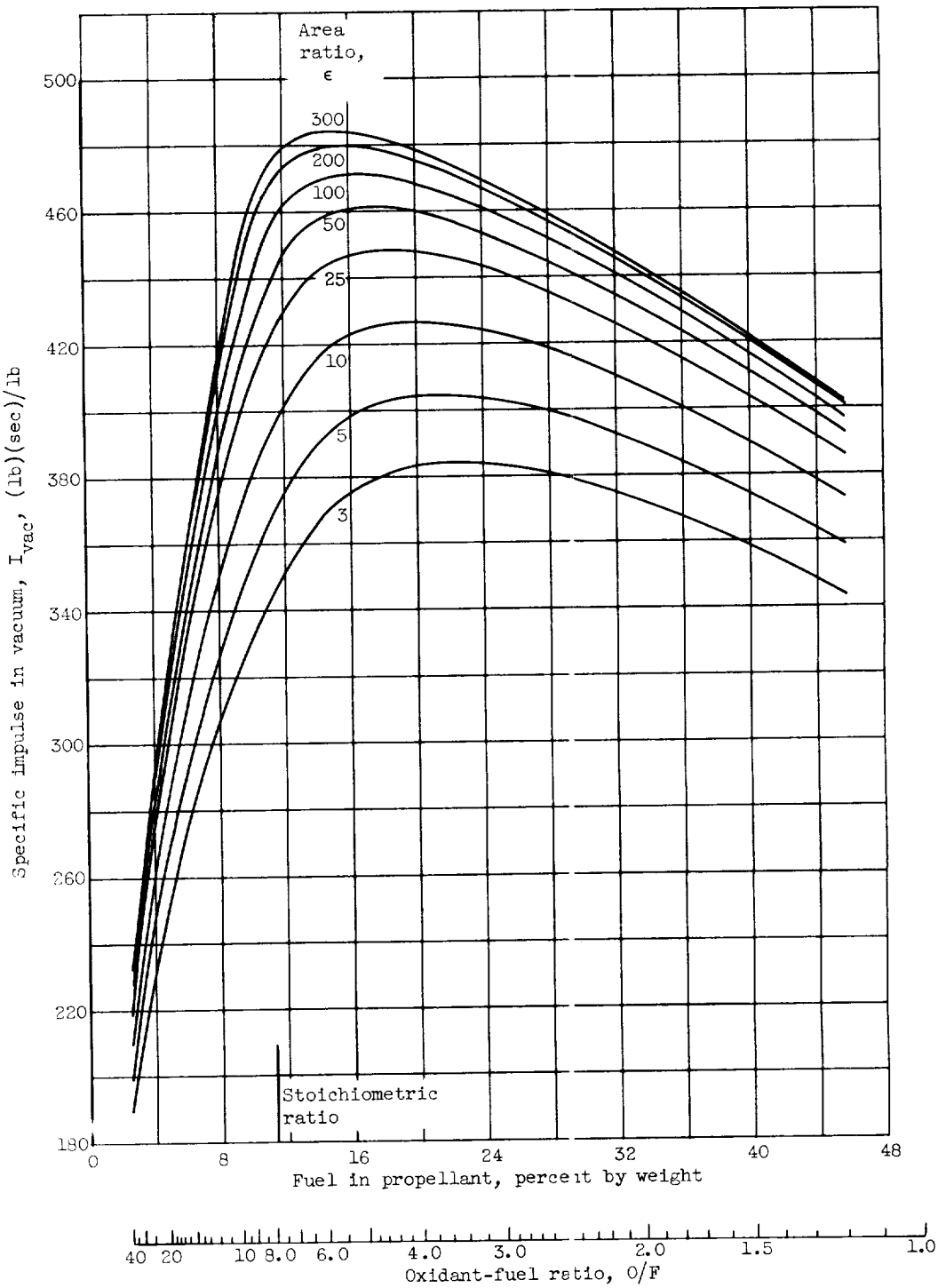
(f) Chamber pressure, 300 pounds per square inch absolute; equilibrium composition during expansion.

Figure 7. - Continued. Theoretical specific impulse in vacuum of liquid hydrogen and liquid oxygen. Isentropic expansion to area ratio indicated.



(g) Chamber pressure, 600 pounds per square inch absolute; frozen composition during expansion.

Figure 7. - Continued. Theoretical specific impulse in vacuum of liquid hydrogen and liquid oxygen. Isentropic expansion to area ratio indicated.



(h) Chamber pressure, 600 pounds per square inch absolute; equilibrium composition during expansion.

Figure 7. - Concluded. Theoretical specific impulse in vacuum of liquid hydrogen and liquid oxygen. Isentropic expansion to area ratio indicated.

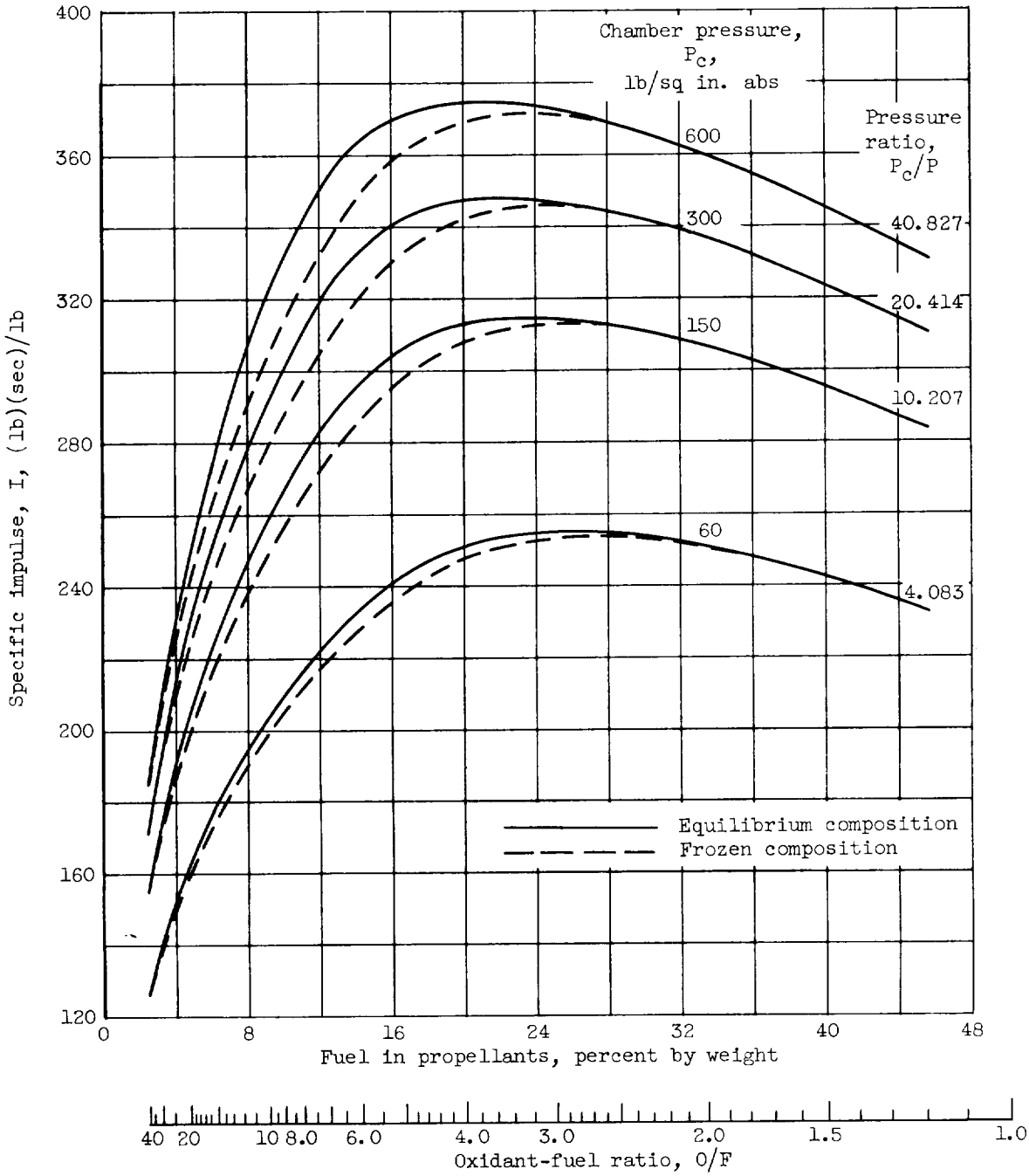


Figure 8. - Theoretical specific impulse for liquid hydrogen with liquid oxygen. Isentropic expansion to 1 atmosphere from chamber pressure indicated.