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# RESEARCH MEMORANDUM

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## THEORETICAL PERFORMANCE OF LIQUID AMMONIA WITH LIQUID OXYGEN AS A ROCKET PROPELLANT

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# THEORETICAL PERFORMANCE OF LIQUID AMMONIA WITH LIQUID OXYGEN AS A ROCKET PROPELLANT

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## SUMMARY

Theoretical rocket performance for both equilibrium and frozen composition during expansion was calculated for the propellant combination liquid ammonia with liquid oxygen at two chamber pressures (300 and 600 lb/sq in. abs) and a wide range of pressure ratios (1 to 1500) and oxidant-fuel ratios (0.564 to 7.046). Data are given to estimate performance parameters at chamber pressures other than 300 and 600 pounds per square inch absolute. 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 a chamber pressure of 600 pounds per square inch and an exit pressure of 1 atmosphere (pressure ratio, 40.827) is 278.7 and 269.3 assuming equilibrium and frozen composition, respectively.

## INTRODUCTION

The performance of ammonia and oxygen as a rocket propellant has been reported in the literature (e.g., refs. 1 to 3). However, additional performance calculations based on the latest thermodynamic data are needed for a wider range of conditions than were heretofore available. Calculations were therefore made at the NACA Lewis laboratory to provide rocket performance data for liquid ammonia and liquid oxygen for the following conditions:

(1) Equilibrium and frozen composition during expansion

(2) Two chamber pressures (300 and 600 lb/sq in. abs)

(3) A wide range of oxidant-fuel weight ratios (0.564 to 7.046)

(4) A wide range of pressure ratio (1 to 1500)

Data are given to permit estimates of performance parameters at chamber pressures other than 300 and 600 pounds per square inch absolute.

## SYMBOLS

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| | |
|---|---|
| $A$ | nozzle area, sq in. |
| $\mathscr{A}$ | number of formula weights (defined as $A$ in ref. 4) |
| $a$ | 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 force constant $\varepsilon/k$ and temperature $T$ |
| $g_c$ | gravitational conversion factor, 32.174 (lb mass/lb force)(ft/sec$^2$) |
| $H_T^o$ | sum of sensible enthalpy and chemical energy at temperature $T$, cal/mole |
| $h$ | sum of sensible enthalpy and chemical energy per unit mass, $\frac{\sum_i x_i (H_T^o)_i}{\mathscr{M}}$, 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)($^oK$) |

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| | |
|---|---|
| $M$ | Mach number |
| $\mathscr{M}$ | molecular weight, $\sum_i x_i \mathscr{M}_i$, g/g-mole or lb/lb-mole |
| $n_{c^*}$ | characteristic-velocity exponent, $\frac{\Delta \ln c^*}{\Delta \ln P_c}$ and $\frac{\partial \ln c^*}{\partial \ln P_c}$ for frozen and equilibrium composition, respectively |
| $n_I$ | specific-impulse exponent for fixed pressure ratio, $\left(\frac{\Delta \ln I}{\Delta \ln P_c}\right)_{P_c/P}$ and $\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{P_c/P}$ for frozen and equilibrium composition, respectively |
| $n_T$ | temperature exponent for fixed pressure ratio, $\left(\frac{\Delta \ln T}{\Delta \ln P_c}\right)_{P_c/P}$ and $\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{P_c/P}$ for frozen and equilibrium composition, respectively |
| $n_\varepsilon$ | area-ratio exponent for fixed pressure ratio, $\left(\frac{\Delta \ln \varepsilon}{\Delta \ln P_c}\right)_{P_c/P}$ and $\left(\frac{\partial \ln \varepsilon}{\partial \ln P_c}\right)_{P_c/P}$ for frozen and equilibrium composition, respectively |
| O/F | oxidant-fuel weight ratio |
| $P$ | static pressure (sum of partial pressures), lb/sq in. |
| $p$ | partial pressure, lb/sq in. |
| $Q$ | 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) |
| $S_T^o$ | entropy at a pressure of 1 atm, cal/(mole)($^o$K) |
| $s$ | entropy per unit mass, $\frac{\sum_i x_i \left[(S_T^o)_i - \mathscr{R} \ln(p_i/14.696)\right]}{\mathscr{M}}$, cal/(g)($^o$K) |

| | |
|---|---|
| $T$ | temperature, $^{\circ}K$ |
| $V$ | velocity, ft/sec |
| $v$ | specific volume |
| $w$ | mass-flow rate, lb/sec |
| $x$ | mole fraction |
| $\gamma$ | isentropic exponent, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$ |
| $\varepsilon$ | ratio of nozzle area to throat area |
| $\varepsilon/k$ | force constant for viscosity calculation |
| $\mu$ | absolute viscosity, g/(cm)(sec) or poises |
| $\rho$ | density, lb/cu in. |
| $\sigma$ | collision diameter for viscosity calculation |
| $\Omega^{(2,2)*}$ | function of force constant $\varepsilon/k$ and temperature $T$ |

Subscripts:

| | |
|---|---|
| c | combustion chamber |
| e | nozzle exit |
| i | product of combustion |
| inj | injector |
| $P_c/P$ | constant pressure ratio |
| p | constant pressure |
| s | constant entropy |
| T | constant temperature |
| t | nozzle throat |
| 1 | reference point |

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Superscript:

o thermodynamic standard reference state

## CALCULATION OF PERFORMANCE DATA

Performance data were obtained for liquid ammonia with liquid oxygen for two 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 4 with modifications to adapt it for use with an IBM 650 Magnetic Drum Data-Processing Machine. The machine was operated with floating-decimal-point notation and eight significant figures. 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 nitrogen N, nitrogen $N_2$, nitric oxide NO, 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 nitrogen, nitrogen, atomic oxygen, and oxygen were taken from reference 5. Data for water are also given in reference 5; however, the same data are given to more decimal places in reference 6, and therefore reference 6 data were used. Nitric oxide thermodynamic properties were taken from reference 7, and the hydroxyl radical data were taken from reference 8. 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 six 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 | 9 |
| $Q + N_2 \rightarrow 2N$ | [a]78,747 | 225,154 | 0 | 10 |
| $Q + O_2 \rightarrow 2O$ | 41,260 | 117,971 | 0 | 11 |
| $H_2 + \frac{1}{2}O_2 \rightarrow H_2O + Q$ | --------- | 57,797.9 | 298.16 | 12 |
| $Q + \frac{1}{2}N_2 + \frac{1}{2}O_2 \rightarrow NO$ | --------- | 21,600 | 298.16 | 12 |
| $Q + OH \rightarrow O + H$ | 37,340.25 | 106,764 | 0 | 13 |

[a]The value of 78,747 $cm^{-1}$ for $N_2$ was obtained from the difference in the predissociation limit in $c^3\Pi\mu$ of $N_2$ (97,970 $cm^{-1}$) and the $^2D$ term of N (19,223 $cm^{-1}$) given in reference 10.

Where values are given in $cm^{-1}$, the conversion factor used was 1 $cm^{-1}$ = 2.85921 cal/mole, calculated from data given in reference 14. The base used in this report for assigning absolute values to enthalpy is the same as in reference 4.

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. However, the extrapolated data must be considered only as estimates.

The derivations of various theoretical equations for viscosity are treated in detail in references 15 and 16. 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. 16):

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

The parameters $\Omega^{(2,2)*}$ and $f_\mu^{(k)}$ are tabulated in reference 16 as functions of the force constant $\varepsilon/k$ and temperature T.

The force constants $\varepsilon/k$ and $\sigma$ for $H_2$, $O_2$, $N_2$, NO, and H were taken from the literature or calculated from experimental viscosity data. No experimental viscosity data were found for N, O, and OH. Values of $\sigma$ for N and O were estimated from data in reference 17. The value of $\sigma$ for OH was estimated from

$$\sigma_{OH} = \sigma_O + \sigma_H \tag{2}$$

The values of $\varepsilon/k$ for N, O, and OH were estimated as follows:

$$\frac{(\varepsilon/k)_N}{(\varepsilon/k)_{N_2}} = \frac{(\varepsilon/k)_O}{(\varepsilon/k)_{O_2}} = \frac{(\varepsilon/k)_H}{(\varepsilon/k)_{H_2}} \tag{3}$$

and

$$(\varepsilon/k)_{OH} = \sqrt{(\varepsilon/k)_O(\varepsilon/k)_H} \tag{4}$$

Water is a polar molecule, and therefore the $\Omega^{(2,2)*}$ values based on the Lennard-Jones 6-12 potential are not very satisfactory for calculating the viscosity of water. The following equations from reference 18 were used to calculate the viscosity of water up to 1500° K:

$$\mu\times10^7 = 3.61T - 102 \qquad (T \leq 865^\circ\ K) \tag{5}$$

$$\mu\times10^7 = \frac{393.7T^{3/2}}{3315 - T + 0.001158T^2} \qquad (865^\circ\ K < T \leq 1500^\circ\ K) \tag{6}$$

Equation (6) is not satisfactory for high temperatures, since it reaches a maximum at about 2500° K after which it gives values of viscosity that decrease with temperature. In order to have a means of extrapolating to higher temperatures, values of $\sigma$ and $\varepsilon/k$ were calculated to be used in estimating viscosity above 1500° K by means of equation (1).

The force constants selected are summarized in the following table:

| Substance | $\sigma$, Å | $\varepsilon/k$, °K | Reference |
|---|---|---|---|
| H | 2.551 | 89.3 | [a]19 |
| $H_2$ | 2.775 | 70.2 | [a]5 |
| $H_2O$ | [b]3.031 | [b]302.2 | [a]18 |
| N | 3.355 | 93.0 | [c]17 |
| $N_2$ | 3.778 | 73.1 | [a]5 |
| NO | 3.593 | 94.3 | [a]20 |
| O | 3.088 | 127.2 | [c]17 |
| $O_2$ | 3.499 | 100.0 | 5 |
| OH | 2.820 | 106.6 | (d) |

[a]Calculated from data in reference given.
[b]To be used for $T > 1500^\circ$ K.
[c]$\sigma$ estimated from data in reference given, and $\varepsilon/k$ estimated by means of eq. (3).
[d]$\sigma$ estimated by means of eq. (2), and $\varepsilon/k$ by means of eq. (4).

Physical and thermochemical data. - Several physical and thermochemical properties of the propellants are listed in table I. Additional properties of ammonia may be found in references such as 21 and 22, and properties of oxygen may be found in reference 23.

## 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:

$$I = 294.98 \sqrt{\frac{h_c - h_e}{1000}} \tag{7}$$

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

$$I_{vac} = I + P\left(\frac{A}{w}\right) \tag{8}$$

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

$$\frac{A}{w} = \frac{86.4554T}{P\mathcal{M}I} \tag{9}$$

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

$$\frac{A_t}{w} = \frac{2781.6T_t}{P_t \mathscr{M}_t a} \tag{10}$$

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:

$$a = \sqrt{\left(\frac{\partial P}{\partial \rho}\right)_s} = \sqrt{\frac{P}{\rho}\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s} = 299.16\sqrt{\left(\frac{T}{\mathscr{M}}\right)\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s} \tag{11}$$

Characteristic velocity, ft/sec:

$$c^* = g_c P_c \frac{A_t}{w} = 32.174 P_c \frac{A_t}{w} \tag{12}$$

Coefficient of thrust:

$$C_F = \frac{g_c I}{c^*} = \frac{32.174 I}{c^*} \tag{13}$$

Ratio of nozzle area to throat area:

$$\varepsilon = \frac{A/w}{A_t/w} \tag{14}$$

Partial derivatives. - The derivatives of the fundamental thermodynamic quantities have many useful applications. Equations (29) to (32) 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:

$$c_p = \frac{1}{P\mathscr{M}T}\left[\sum_i p_i (H_T^o)_i \left(\frac{\partial \ln p_i}{\partial \ln T}\right)_p - \mathscr{A} h \left(\frac{\partial \ln \mathscr{A}}{\partial \ln T}\right)_p + T \sum_i p_i (C_p^o)_i\right] \tag{15}$$

$$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln P}\right)_T = \frac{P}{\sum_i p_i\left(\frac{\partial \ln p_i}{\partial \ln \mathscr{A}}\right)_T} - 1 \tag{16}$$

$$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_p = \left(\frac{\partial \ln \mathscr{A}}{\partial \ln T}\right)_p \tag{17}$$

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 4, and where $\mathscr{A}$ is $A$ in reference 4.

Reference 24 presents a convenient scheme for expressing all first derivatives in terms of $(\partial v/\partial T)_p$, $(\partial v/\partial P)_T$, and $(\partial h/\partial T)_p = c_p$. In order to make use of the tables in reference 24, $(\partial v/\partial T)_p$ and $(\partial v/\partial P)_T$ can be obtained from the derivatives given in this report by means of the following equations:

$$\left(\frac{\partial v}{\partial T}\right)_p = -\frac{v}{T}\left[\left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_p - 1\right] \tag{18}$$

$$\left(\frac{\partial v}{\partial P}\right)_T = -\frac{v}{T}\left[\left(\frac{\partial \ln \mathscr{M}}{\partial \ln P}\right)_T + 1\right] \tag{19}$$

With the aid of the tables in reference 24 and equations (18) and (19), other first derivatives can be expressed in terms of $c_p$, $(\partial \ln \mathscr{M}/\partial \ln T)_p$, and $(\partial \ln \mathscr{M}/\partial \ln P)_T$. As an example,

$$\gamma = \left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s = \frac{c_p}{c_p\left[1 + \left(\frac{\partial \ln \mathscr{M}}{\partial \ln P}\right)_T\right] - \frac{\mathscr{R}}{\mathscr{M}}\left[1 - \left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_p\right]^2} \tag{20}$$

When composition is frozen,

$$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln P}\right)_T = \left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_p = 0 \tag{21}$$

and

$$\gamma = \frac{c_p}{c_p - \frac{\mathscr{R}}{\mathscr{M}}} = \frac{c_p}{c_v} \tag{22}$$

Viscosity of mixtures. - Viscosities of multicomponent mixtures calculated by rigorous methods (refs. 16 and 25) show excellent agreement with experimental data. However, these calculations involve considerable effort and become increasingly more difficult with increasing number of components. A simpler technique, but one that still involves considerable calculations, is given in reference 26.

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

$$\mu = \frac{\mathscr{M}}{\sum_i \frac{x_i}{\mu_i \mathscr{M}_i}} \tag{23}$$

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 viscosities. Therefore, the Eucken relationship,

$$k = \mu\left(c_p + \frac{5}{4}\frac{\mathscr{R}}{\mathscr{M}}\right) \tag{24}$$

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 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 1500 for equivalence ratios from 0.40 to 5.00 (oxidant-fuel weight ratios from 0.564 to 7.046). Properties at the throat may be found where $\varepsilon = 1.00$. 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.

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## Curves

Performance parameters. - The performance parameters are plotted in figures 1 to 7. Curves of specific impulse are presented in figure 1 for assigned pressure ratios as a function 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, and 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 a function 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 a function of percent by weight of fuel.

Effect of assuming frozen or equilibrium composition during expansion. - Specific impulses based on equilibrium and on frozen composition during expansion to an exit pressure of 1 atmosphere are compared in figure 7. Maximum values of specific impulse based on equilibrium and on frozen composition during expansion are compared in the following table (taken from table II or V):

| 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 | Max. specific impulse, I, $\frac{\text{lb-sec}}{\text{lb}}$ | Difference in I, % |
|---|---|---|---|---|---|---|
| 300 | 20.414 | 0.95 | 1.339 | Equilibrium | 256.3 | 3.2 |
| | | .90 | 1.268 | Frozen | 248.4 | |
| | 1500 | 1.00 | 1.409 | Equilibrium | 345.3 | 6.5 |
| | | .90 | 1.268 | Frozen | 324.2 | |
| 600 | 40.827 | 0.975 | 1.374 | Equilibrium | 278.7 | 3.5 |
| | | .90 | 1.268 | Frozen | 269.3 | |
| | 1500 | 1.00 | 1.409 | Equilibrium | 345.7 | 5.8 |
| | | .90 | 1.268 | Frozen | 326.6 | |

The table shows that, for pressure ratios of about 20 to 40, the difference in maximum specific impulse due to equilibrium or frozen composition during expansion is about 3 to 4 percent, while for a pressure ratio of 1500 the difference increases to about 6 percent. The maximum specific impulse occurs nearer the stoichiometric point (R = 1.00) for equilibrium composition than for frozen composition. For frozen composition, maximum specific impulse remains at the same fuel-rich O/F ratio of 1.268 as pressure ratio increases. For equilibrium composition, the maximum specific impulse moves from a slightly fuel-rich ratio at the lower pressure ratios to the stoichiometric mixture ratio at the high pressure ratios.

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## Effect of Thermodynamic Data

New and revised thermodynamic data are constantly appearing in the literature. The reason for this may be the availability of better spectroscopic data, or a more rigorous use of the spectroscopic data in calculating thermodynamic functions, or possibly a more accurate determination of heat of formation, heat of dissociation, or heat of transition. In a comparison of the performance of various propellants, care must be taken to see that the same thermodynamic data are used, since different data may affect the results.

Several additional calculations were made to determine the effect on performance of using water data from reference 27 rather than that of reference 5 used in this report, and of the heat of dissociation of OH from reference 12 (100,206 cal/mole) rather than that of reference 13 (106,764 cal/mole) used in this report. The results of these calculations are shown in the following table ($P_c$ = 600 lb/sq in. abs):

| Equivalence ratio, R | Pressure ratio, $P_c/P$ | Thermodynamic data, this report | $H_2O$ thermodynamic data, ref. 27 | OH heat of dissociation, ref. 5 | Difference due to $H_2O$, percent | Difference due to OH, percent |
|---|---|---|---|---|---|---|
| | | Combustion temperature, T, °K | | | | |
| 0.7 | 1 | 2503.1 | 2513.4 | 2508.2 | 0.41 | 0.20 |
| 1.0 | 1 | 2980.5 | 3044.1 | 2984.4 | 2.13 | .13 |
| 1.5 | 1 | 2759.5 | 2841.0 | 2764.0 | 2.95 | .16 |
| | | Equilibrium specific impulse, I, lb-sec/lb | | | | |
| 0.7 | 40.827 | 262.04 | 262.09 | 262.11 | 0.02 | 0.03 |
| .7 | 1000 | 311.36 | 311.38 | 311.39 | .01 | .01 |
| 1.0 | 40.827 | 278.30 | 279.46 | 278.49 | .42 | .07 |
| 1.0 | 1000 | 340.79 | 341.34 | 340.88 | .16 | .03 |
| 1.5 | 40.827 | 250.32 | 251.56 | 250.44 | .50 | .05 |
| 1.5 | 1000 | 303.05 | 303.60 | 303.09 | .18 | .01 |
| | | Frozen specific impulse, I, lb-sec/lb | | | | |
| 0.7 | 40.827 | 260.91 | 261.40 | 260.95 | 0.19 | 0.02 |
| .7 | 1000 | 309.76 | 310.41 | 309.74 | .21 | .01 |
| 1.0 | 40.827 | 267.23 | 269.58 | 267.13 | .88 | .04 |
| 1.0 | 1000 | 320.54 | 323.83 | 320.23 | 1.03 | .10 |
| 1.5 | 40.827 | 242.74 | 245.81 | 242.69 | 1.26 | .02 |
| 1.5 | 1000 | 290.16 | 294.39 | 290.00 | 1.46 | .06 |

For the three equivalence ratios selected, the effect of the difference in the heat of dissociation of OH (6556 cal/mole) on both specific impulse and combustion temperature was very small. However, the different thermodynamic data for $H_2O$ made a difference of 82° K in the combustion temperature and 3 to 4 (lb)(sec)/lb in frozen specific impulse for the equivalence ratio of 1.5. The effect of different water data was greater on frozen specific impulse than on equilibrium specific impulse.

## 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, T, $\varepsilon$, and c* are very nearly linear with the logarithm of chamber pressure for a fixed equivalence ratio and pressure ratio. This linearity permits the data to be represented by means of exponential equations. For frozen composition the exponents can be calculated from data for two chamber pressures according to the following equations:

$$n_I = \left(\frac{\Delta \ln I}{\Delta \ln P_c}\right)_{P_c/P} \tag{25}$$

$$n_T = \left(\frac{\Delta \ln T}{\Delta \ln P_c}\right)_{P_c/P} \tag{26}$$

$$n_\varepsilon = \left(\frac{\Delta \ln \varepsilon}{\Delta \ln P_c}\right)_{P_c/P} \tag{27}$$

$$n_{c^*} = \frac{\Delta \ln c^*}{\Delta \ln P_c} \tag{28}$$

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

$$n_I = \left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{P_c/P} = 86.4554\ \frac{T}{I^2}\left(\frac{1}{\mathscr{M}_c} - \frac{1}{\mathscr{M}}\right) \tag{29}$$

$$n_T = \left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{P_c/P} = \frac{\mathscr{R}}{\mathscr{M} c_p}\left[1 - \left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_p\right] - \frac{\mathscr{R}}{c_p \mathscr{M}_c} \tag{30}$$

$$n_\varepsilon = \left(\frac{\partial \ln \varepsilon}{\partial \ln P_c}\right)_{P_c/P} = (n_{A/w})_e - (n_{A/w})_t \tag{31}$$

$$n_{c^*} = \frac{\partial \ln c^*}{\partial \ln P_c} = 1 + (n_{A/w})_t \tag{32}$$

where

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

Equations (25) to (28) and (29) to (32) may be written in the following approximate form:

$$I = I_1\left(\frac{P_c}{P_{c,1}}\right)^{n_{I,1}} \tag{33}$$

$$T = T_1\left(\frac{P_c}{P_{c,1}}\right)^{n_{T,1}} \tag{34}$$

$$\varepsilon = \varepsilon_1\left(\frac{P_c}{P_{c,1}}\right)^{n_{\varepsilon,1}} \tag{35}$$

$$c^* = c_1^*\left(\frac{P_c}{P_{c,1}}\right)^{n_{c^*,1}} \tag{36}$$

where $P_{c,1}$ may be selected to be either 300 or 600 pounds per square inch absolute if $I_1$, $T_1$, $\varepsilon_1$, $c_1^*$ and their derivatives are the corresponding values for the chamber pressure selected.

The exponents obtained by means of equations (25) to (32) are shown in tables III and V and are plotted in figures 1, 2, 3, and 6.

To illustrate the use of these derivatives, suppose the value of equilibrium specific impulse is desired for a chamber pressure $P_c$ of 1200 pounds per square inch absolute and a pressure ratio $P_c/P$ of 81.65 (exit pressure, 1 atm) for an equivalence ratio R of 0.95 (O/F, 1.339). From figure 1(c) and 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 295.8, and the value of $n_I$ is 0.0025. From equation (33),

$$I = 295.8\left(\frac{1200}{600}\right)^{0.0025}$$

$$= 295.8(1.0017)$$

$$= 296.3$$

The parameters obtained by the chamber-pressure correlation and by a direct calculation are compared in the following table (R = 0.95, equilibrium composition during expansion):

| Parameter | $P_c$ = 1200 lb/sq in. abs<br>$P_e$ = 1 atm | | |
|---|---|---|---|
| | Estimated by correlation | Direct calculation | Difference |
| I, lb-sec/lb | 296.34 | 296.32 | 0.02 |
| $T_c$, °K | 3012.8 | 3011.0 | 1.8 |
| $T_e$, °K | 1557.9 | 1558.2 | .3 |
| $\varepsilon$ | 10.272 | 10.266 | .006 |
| c*, ft/sec | 5843.0 | 5841.6 | 1.4 |

Values estimated for other equivalence ratios and for pressure ratios from about 150 to 1200 pounds per square inch absolute will probably have small errors of the order of magnitude shown in this table.

## 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 $P_{inj}$ may be found from the following equation for conservation of momentum:

$$P_{inj} = P_1 + \frac{w}{A_1 g_c}(V_1 - V_{inj}) \tag{37}$$

where $P_1$ and $V_1$ are the static pressure and velocity at the nozzle entrance, respectively, and $V_{inj}$ is the average velocity of propellant (liquid or gas) in the axial direction when injected. Equation (37) may be written

$$P_{inj} = P_c\left(\frac{P_1}{P_c}\right) + \frac{P_c}{c^*\varepsilon}(I_1 g_c - V_{inj}) \tag{38}$$

where $P_c$ is the stagnation pressure in the nozzle.

The data in tables II and V may be used to evaluate this expression. For example, consider a rocket operating at the stoichiometric ratio with a nozzle stagnation pressure of 600 pounds per square inch absolute and a chamber- to throat-area ratio $\varepsilon$ of 2.131 with $V_{inj}$ equal to 100 feet per second. From table II(c), corresponding to the area ratio of 2.131, $P_c/P_1$ is 1.05 and I is 35.7. From table V, c* is 5788. Therefore, for these conditions, the pressure at the injector face is

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$$P_{inj} = 600\left(\frac{1}{1.05}\right) + \frac{600}{5788(2.131)}[(35.7)(32.17) - 100]$$

$$= 571.43 + 0.04865(1048)$$

$$= 571.4 + 51.0$$

$$= 622.4 \text{ lb/sq in. abs}$$

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## SUMMARY OF RESULTS

A theoretical investigation of the performance of liquid ammonia with liquid oxygen was made for the following conditions: (1) equilibrium and frozen composition during expansion, (2) two chamber pressures (300 and 600 lb/sq in. abs), (3) a wide range of oxidant-fuel weight ratios (0.564 to 7.046), and (4) a wide range of pressure ratios (1 to 1500). The results of this investigation showed:

1. The maximum values of specific impulse for a chamber pressure of 300 pounds per square inch absolute and an exit pressure of 1 atmosphere (pressure ratio, 20.414) are 256.3 and 248.4 assuming equilibrium and frozen composition, respectively, a difference of 3.2 percent.

2. The maximum values of specific impulse for a chamber pressure of 600 pounds per square inch and an exit pressure of 1 atmosphere (pressure ratio, 40.827) are 278.7 and 269.3 assuming equilibrium and frozen composition, respectively, a difference of 3.5 percent.

3. The difference between values of specific impulse due to the assumption of equilibrium or frozen composition during expansion is about 6 percent for a pressure ratio of 1500.

4. The maximum value of specific impulse occurs on the slightly fuel-rich side of stoichiometric. For frozen composition during expansion, the maximum value of specific impulse occurs at the same oxidant-fuel weight ratio independent of pressure ratio. For equilibrium composition during

expansion, the maximum value of specific impulse shifts from the slightly fuel-rich side of stoichiometric to stoichiometric as pressure ratios increase.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, February 6, 1958

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TABLE I. - PROPERTIES OF LIQUID PROPELLANTS

| Properties | Ammonia | Oxygen |
|---|---|---|
| Molecular weight, $\mathscr{M}$ | 17.032 | 32.00 |
| Density, g/cc | [a]0.68 (at -33.4° C) | [b]1.1415 (at -182.0° C) |
| Freezing point, °C | [c]-77.76 | [c]-218.76 |
| Boiling point, °C | [c]-33.43 | [c]-182.97 |
| Enthalpy required to convert liquid at boiling point to gaseous elements at 25° C, kcal/mole | [d]17.14 | [d]3.080 |
| Enthalpy of vaporization, kcal/mole | [c]5.581 (at -33.43° C) | [c]1.630 (at -182.97° C) |
| Enthalpy of fusion, kcal/mole | [c]1.351 (at -77.76° C) | [c]0.106 (at -218.76° C) |

[a]Ref. 28.

[b]Ref. 29.

[c]Ref. 12.

[d]Ref. 4.

TABLE II. - THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500 FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(a) 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, $\mathcal{M}$ | Isentropic exponent, $\gamma$ | Specific heat, $c_p$, cal/(g)(°K) | Absolute viscosity, $\mu$, micropoises | Thermal conductivity, k, cal/(sec)(cm)(°K) | Mach number, M | Specific impulse, $I_{vac}$, (lb)(sec)/lb | Area ratio, $\epsilon$ | Thrust coefficient, $C_F$ | Specific impulse, I, (lb)(sec)/lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 0.40, PERCENT FUEL = 63.95, O/F = 0.564 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 1349 | 3350.2 | 13.316 | 1.2956 | 0.6541 | 453 | 0.00038 | | | | | |
| 1.05 | 285.71 | 1334 | 3340.4 | 13.316 | 1.2966 | .6524 | 450 | .00036 | 0.275 | 326.2 | 2.226 | 0.208 | 29.1 |
| 1.60 | 187.50 | 1210 | 3260.5 | 13.316 | 1.3053 | .6381 | 421 | .00035 | .872 | 177.3 | 1.019 | .630 | 88.3 |
| 1.84 | 163.21 | 1171 | 3235.9 | 13.316 | 1.3082 | .6335 | 412 | .00034 | 1.000 | 176.0 | 1.000 | .712 | 99.7 |
| 2.00 | 150.00 | 1148 | 3221.3 | 13.316 | 1.3100 | .6306 | 406 | .00033 | 1.072 | 176.3 | 1.004 | .756 | 105.9 |
| 10.00 | 30.00 | 772 | 2993.1 | 13.316 | 1.3421 | .5855 | 309 | .00024 | 2.149 | 204.7 | 2.030 | 1.258 | 176.3 |
| 20.00 | 15.00 | 646 | 2919.9 | 13.316 | 1.3530 | .5720 | 272 | .00021 | 2.569 | 215.2 | 3.093 | 1.381 | 193.5 |
| 20.41 | 14.70 | 643 | 2917.9 | 13.316 | 1.3532 | .5718 | 271 | .00021 | 2.581 | 215.4 | 3.133 | 1.384 | 193.9 |
| 40.00 | 7.50 | 538 | 2858.8 | 13.316 | 1.3618 | .5617 | 237 | .00018 | 2.998 | 223.7 | 4.823 | 1.476 | 206.8 |
| 40.83 | 7.35 | 535 | 2857.1 | 13.316 | 1.3621 | .5614 | 236 | .00018 | 3.010 | 223.9 | 4.888 | 1.478 | 207.1 |
| 80.00 | 3.75 | 447 | 2807.9 | 13.316 | 1.3680 | .5547 | 206 | .00015 | 3.447 | 230.6 | 7.629 | 1.550 | 217.2 |
| 100.00 | 3.00 | 421 | 2793.5 | 13.316 | 1.3696 | .5530 | 196 | .00015 | 3.597 | 232.5 | 8.863 | 1.571 | 220.1 |
| 200.00 | 1.50 | 349 | 2753.8 | 13.316 | 1.3744 | .5479 | 168 | .00012 | 4.083 | 237.7 | 14.191 | 1.626 | 227.8 |
| 300.00 | 1.00 | 312 | 2733.8 | 13.316 | 1.3767 | .5454 | 154 | .00011 | 4.383 | 240.3 | 18.744 | 1.653 | 231.6 |
| 500.00 | .60 | 271 | 2711.6 | 13.316 | 1.3791 | .5429 | 136 | .00010 | 4.781 | 243.2 | 26.680 | 1.682 | 235.7 |
| 800.00 | .37 | 238 | 2693.7 | 13.316 | 1.3842 | .5377 | 122 | .00009 | 5.163 | 245.5 | 36.978 | 1.705 | 239.0 |
| 1000.00 | .30 | 224 | 2686.0 | 13.316 | 1.3872 | .5347 | 115 | .00008 | 5.351 | 246.4 | 43.187 | 1.715 | 240.4 |
| 1500.00 | .20 | 200 | 2673.2 | 13.316 | 1.3928 | .5291 | 104 | .00007 | 5.707 | 248.0 | 57.266 | 1.732 | 242.7 |
| R = 0.50, PERCENT FUEL = 58.67, O/F = 0.705 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 1784 | 3075.9 | 14.516 | 1.2616 | 0.6607 | 555 | 0.00046 | | | | | |
| 1.05 | 285.71 | 1766 | 3064.0 | 14.516 | 1.2624 | .6590 | 551 | .00046 | 0.279 | 359.6 | 2.206 | 0.206 | 32.1 |
| 1.60 | 187.50 | 1617 | 2966.5 | 14.516 | 1.2695 | .6450 | 520 | .00042 | .882 | 196.3 | 1.013 | .626 | 97.5 |
| 1.82 | 165.20 | 1574 | 2938.9 | 14.516 | 1.2717 | .6408 | 511 | .00041 | 1.000 | 195.0 | 1.000 | .700 | 109.2 |
| 2.00 | 150.00 | 1542 | 2918.3 | 14.516 | 1.2735 | .6375 | 503 | .00041 | 1.083 | 195.5 | 1.006 | .731 | 117.1 |
| 10.00 | 30.00 | 1075 | 2632.4 | 14.516 | 1.3057 | .5847 | 394 | .00030 | 2.149 | 229.0 | 2.090 | 1.260 | 196.4 |
| 20.00 | 15.00 | 911 | 2538.4 | 14.516 | 1.3200 | .5647 | 351 | .00026 | 2.555 | 241.3 | 3.218 | 1.387 | 216.3 |
| 20.41 | 14.70 | 906 | 2535.8 | 14.516 | 1.3203 | .5641 | 350 | .00026 | 2.567 | 241.7 | 3.261 | 1.390 | 216.8 |
| 40.00 | 7.50 | 768 | 2458.9 | 14.516 | 1.3335 | .5474 | 311 | .00022 | 2.967 | 251.4 | 5.065 | 1.486 | 231.7 |
| 40.83 | 7.35 | 764 | 2456.7 | 14.516 | 1.3339 | .5469 | 310 | .00022 | 2.979 | 251.7 | 5.134 | 1.489 | 232.1 |
| 80.00 | 3.75 | 644 | 2392.0 | 14.516 | 1.3449 | .5338 | 274 | .00019 | 3.396 | 259.7 | 8.071 | 1.565 | 243.9 |
| 100.00 | 3.00 | 608 | 2372.9 | 14.516 | 1.3482 | .5301 | 262 | .00018 | 3.539 | 262.0 | 9.396 | 1.586 | 247.3 |
| 200.00 | 1.50 | 508 | 2320.1 | 14.516 | 1.3571 | .5203 | 228 | .00016 | 4.003 | 268.2 | 15.126 | 1.645 | 256.4 |
| 300.00 | 1.00 | 456 | 2293.4 | 14.516 | 1.3609 | .5162 | 210 | .00014 | 4.292 | 271.3 | 20.033 | 1.674 | 260.9 |
| 500.00 | .60 | 398 | 2263.6 | 14.516 | 1.3652 | .5118 | 188 | .00013 | 4.673 | 274.8 | 28.602 | 1.705 | 265.9 |
| 800.00 | .37 | 351 | 2239.5 | 14.516 | 1.3682 | .5087 | 169 | .00012 | 5.045 | 277.5 | 39.757 | 1.730 | 269.8 |
| 1000.00 | .30 | 330 | 2229.1 | 14.516 | 1.3696 | .5073 | 161 | .00011 | 5.228 | 278.7 | 46.508 | 1.741 | 271.4 |
| 1500.00 | .20 | 296 | 2211.7 | 14.516 | 1.3718 | .5051 | 146 | .00010 | 5.575 | 280.6 | 61.884 | 1.759 | 274.2 |
| R = 0.60, PERCENT FUEL = 54.19, O/F = 0.845 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2169 | 2843.5 | 15.708 | 1.2334 | 0.6765 | 639 | 0.00053 | | | | | |
| 1.05 | 285.71 | 2149 | 2830.1 | 15.709 | 1.2344 | .6734 | 635 | .00053 | 0.282 | 381.5 | 2.191 | 0.204 | 34.0 |
| 1.60 | 187.50 | 1982 | 2720.1 | 15.713 | 1.2423 | .6514 | 603 | .00049 | .890 | 208.9 | 1.012 | .622 | 103.6 |
| 1.80 | 166.72 | 1937 | 2691.0 | 15.714 | 1.2444 | .6461 | 594 | .00048 | 1.000 | 207.7 | 1.000 | .692 | 115.2 |
| 2.00 | 150.00 | 1897 | 2665.4 | 15.714 | 1.2463 | .6417 | 586 | .00047 | 1.091 | 208.3 | 1.007 | .748 | 124.5 |
| 10.00 | 30.00 | 1361 | 2336.0 | 15.716 | 1.2746 | .5870 | 469 | .00035 | 2.151 | 245.8 | 2.140 | 1.262 | 210.1 |
| 20.00 | 15.00 | 1169 | 2225.3 | 15.716 | 1.2883 | .5650 | 422 | .00031 | 2.548 | 259.7 | 3.331 | 1.393 | 231.9 |
| 20.41 | 14.70 | 1164 | 2222.3 | 15.716 | 1.2888 | .5643 | 421 | .00030 | 2.560 | 260.0 | 3.376 | 1.396 | 232.5 |
| 40.00 | 7.50 | 998 | 2130.5 | 15.716 | 1.3029 | .5439 | 378 | .00027 | 2.945 | 271.1 | 5.295 | 1.496 | 249.1 |
| 40.83 | 7.35 | 993 | 2127.9 | 15.716 | 1.3033 | .5433 | 377 | .00026 | 2.957 | 271.4 | 5.369 | 1.498 | 249.5 |
| 80.00 | 3.75 | 847 | 2049.8 | 15.716 | 1.3171 | .5252 | 337 | .00023 | 3.354 | 280.5 | 8.519 | 1.578 | 262.8 |
| 100.00 | 3.00 | 803 | 2026.5 | 15.716 | 1.3215 | .5198 | 324 | .00022 | 3.491 | 283.2 | 9.944 | 1.601 | 266.6 |
| 200.00 | 1.50 | 676 | 1961.8 | 15.716 | 1.3341 | .5049 | 286 | .00019 | 3.932 | 290.4 | 16.132 | 1.663 | 277.0 |
| 300.00 | 1.00 | 611 | 1928.9 | 15.716 | 1.3404 | .4979 | 265 | .00017 | 4.204 | 294.0 | 21.449 | 1.694 | 282.1 |
| 500.00 | .60 | 536 | 1891.9 | 15.716 | 1.3476 | .4902 | 239 | .00016 | 4.566 | 298.0 | 30.751 | 1.728 | 287.8 |
| 800.00 | .37 | 474 | 1861.9 | 15.716 | 1.3531 | .4846 | 217 | .00014 | 4.919 | 301.2 | 42.881 | 1.755 | 292.2 |
| 1000.00 | .30 | 447 | 1848.9 | 15.716 | 1.3552 | .4824 | 207 | .00013 | 5.094 | 302.5 | 50.232 | 1.767 | 294.2 |
| 1500.00 | .20 | 402 | 1827.2 | 15.716 | 1.3589 | .4788 | 190 | .00012 | 5.424 | 304.8 | 66.995 | 1.786 | 297.4 |
| R = 0.70, PERCENT FUEL = 50.34, O/F = 0.986 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2494 | 2644.0 | 16.862 | 1.2004 | 0.7547 | 709 | 0.00064 | | | | | |
| 1.05 | 285.71 | 2474 | 2629.8 | 16.866 | 1.2017 | .7474 | 705 | .00063 | 0.286 | 395.0 | 2.172 | 0.203 | 35.3 |
| 1.60 | 187.50 | 2305 | 2511.3 | 16.891 | 1.2130 | .6937 | 673 | .00057 | .898 | 217.2 | 1.010 | .618 | 107.5 |
| 1.78 | 168.33 | 2262 | 2482.3 | 16.895 | 1.2157 | .6824 | 665 | .00055 | 1.000 | 216.2 | 1.000 | .682 | 118.6 |
| 2.00 | 150.00 | 2216 | 2451.9 | 16.899 | 1.2186 | .6714 | 656 | .00054 | 1.100 | 217.0 | 1.009 | .743 | 129.3 |
| 10.00 | 30.00 | 1633 | 2089.7 | 16.916 | 1.2497 | .5884 | 536 | .00039 | 2.151 | 257.6 | 2.185 | 1.263 | 219.6 |
| 20.00 | 15.00 | 1418 | 1965.6 | 16.916 | 1.2618 | .5662 | 487 | .00035 | 2.541 | 272.8 | 3.431 | 1.397 | 243.0 |
| 20.41 | 14.70 | 1412 | 1962.2 | 16.916 | 1.2622 | .5656 | 486 | .00035 | 2.552 | 273.2 | 3.478 | 1.401 | 243.6 |
| 40.00 | 7.50 | 1225 | 1858.1 | 16.916 | 1.2749 | .5447 | 440 | .00030 | 2.927 | 285.4 | 5.306 | 1.504 | 261.5 |
| 40.83 | 7.35 | 1219 | 1855.2 | 16.916 | 1.2753 | .5441 | 439 | .00030 | 2.939 | 285.8 | 5.585 | 1.507 | 262.0 |
| 80.00 | 3.75 | 1052 | 1765.6 | 16.916 | 1.2892 | .5236 | 396 | .00027 | 3.321 | 295.9 | 8.943 | 1.590 | 276.5 |
| 100.00 | 3.00 | 1000 | 1738.7 | 16.916 | 1.2939 | .5172 | 382 | .00025 | 3.452 | 298.9 | 10.470 | 1.614 | 280.7 |
| 200.00 | 1.50 | 852 | 1663.4 | 16.916 | 1.3082 | .4986 | 341 | .00022 | 3.871 | 307.0 | 17.139 | 1.680 | 292.1 |
| 300.00 | 1.00 | 773 | 1624.8 | 16.916 | 1.3163 | .4889 | 318 | .00020 | 4.129 | 311.1 | 22.897 | 1.713 | 297.8 |
| 500.00 | .60 | 683 | 1581.1 | 16.916 | 1.3257 | .4781 | 290 | .00018 | 4.470 | 315.6 | 33.006 | 1.749 | 304.1 |
| 800.00 | .37 | 608 | 1545.5 | 16.916 | 1.3334 | .4698 | 265 | .00016 | 4.803 | 319.2 | 46.234 | 1.778 | 309.2 |
| 1000.00 | .30 | 575 | 1530.0 | 16.916 | 1.3369 | .4662 | 254 | .00016 | 4.968 | 320.8 | 54.262 | 1.790 | 311.3 |
| 1500.00 | .20 | 519 | 1504.0 | 16.916 | 1.3426 | .4604 | 235 | .00014 | 5.280 | 323.4 | 72.597 | 1.811 | 315.0 |

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TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(a) 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, $\mathcal{M}$ | Isentropic exponent, $\gamma$ | Specific heat, $c_p$, $\frac{cal}{(g)(°K)}$ | Absolute viscosity, $\mu$, micropoises | Thermal conductivity, k, cal/(sec)(cm)(°K) | Mach number, M | Specific impulse, $I_{vac}$, $\frac{(lb)(sec)}{lb}$ | Area ratio, $\epsilon$ | Thrust coefficient, $C_F$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 0.80, PERCENT FUEL = 47.01, O/F = 1.127 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2734 | 2471.0 | 17.915 | 1.1669 | 0.9466 | 762 | 0.00083 | | | | | |
| 1.05 | 285.71 | 2717 | 2456.3 | 17.924 | 1.1679 | .9345 | 759 | .00081 | 0.290 | 401.6 | 2.151 | 0.201 | 35.8 |
| 1.60 | 187.50 | 2563 | 2333.2 | 17.996 | 1.1777 | .8356 | 730 | .00071 | .909 | 222.0 | 1.008 | .613 | 109.5 |
| 1.76 | 170.41 | 2528 | 2306.4 | 18.009 | 1.1802 | .8150 | 723 | .00069 | 1.000 | 221.1 | 1.000 | .670 | 119.7 |
| 2.00 | 150.00 | 2482 | 2271.1 | 18.026 | 1.1837 | .7886 | 714 | .00066 | 1.111 | 222.1 | 1.011 | .739 | 131.9 |
| 10.00 | 30.00 | 1893 | 1884.7 | 18.112 | 1.2269 | .5974 | 597 | .00044 | 2.145 | 265.9 | 2.241 | 1.265 | 225.9 |
| 20.00 | 15.00 | 1661 | 1749.8 | 18.115 | 1.2396 | .5683 | 547 | .00039 | 2.528 | 282.2 | 3.544 | 1.403 | 250.5 |
| 20.41 | 14.70 | 1654 | 1746.0 | 18.115 | 1.2399 | .5676 | 546 | .00038 | 2.539 | 282.6 | 3.594 | 1.407 | 251.2 |
| 40.00 | 7.50 | 1449 | 1631.7 | 18.116 | 1.2514 | .5461 | 499 | .00034 | 2.906 | 295.8 | 5.731 | 1.514 | 270.2 |
| 40.83 | 7.35 | 1443 | 1628.4 | 18.116 | 1.2518 | .5455 | 497 | .00034 | 2.917 | 296.2 | 5.815 | 1.517 | 270.8 |
| 80.00 | 3.75 | 1257 | 1529.0 | 18.116 | 1.2640 | .5251 | 452 | .00030 | 3.288 | 307.3 | 9.387 | 1.604 | 286.3 |
| 100.00 | 3.00 | 1199 | 1498.9 | 18.116 | 1.2684 | .5184 | 438 | .00029 | 3.414 | 310.5 | 11.022 | 1.629 | 290.8 |
| 200.00 | 1.50 | 1033 | 1414.2 | 18.116 | 1.2826 | .4979 | 394 | .00025 | 3.815 | 319.5 | 18.203 | 1.699 | 303.2 |
| 300.00 | 1.00 | 943 | 1370.3 | 18.116 | 1.2909 | .4867 | 370 | .00023 | 4.060 | 324.0 | 24.443 | 1.734 | 309.5 |
| 500.00 | .60 | 839 | 1320.4 | 18.116 | 1.3015 | .4735 | 340 | .00021 | 4.382 | 329.1 | 35.455 | 1.772 | 316.4 |
| 800.00 | .37 | 752 | 1279.4 | 18.116 | 1.3109 | .4625 | 314 | .00019 | 4.695 | 333.2 | 49.927 | 1.804 | 322.0 |
| 1000.00 | .30 | 713 | 1261.5 | 18.116 | 1.3151 | .4578 | 301 | .00018 | 4.850 | 334.9 | 58.736 | 1.817 | 324.4 |
| 1500.00 | .20 | 646 | 1231.3 | 18.116 | 1.3223 | .4500 | 284 | .00017 | 5.143 | 337.8 | 78.899 | 1.840 | 328.4 |
| R = 0.90, PERCENT FUEL = 44.09, O/F = 1.268 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2877 | 2319.5 | 18.816 | 1.1439 | 1.2266 | 798 | 0.00108 | | | | | |
| 1.05 | 285.71 | 2862 | 2304.7 | 18.831 | 1.1443 | 1.2148 | 795 | .00107 | 0.292 | 402.3 | 2.134 | 0.199 | 35.9 |
| 1.60 | 187.50 | 2731 | 2180.9 | 18.956 | 1.1481 | 1.1072 | 770 | .00095 | .919 | 223.2 | 1.006 | .609 | 109.8 |
| 1.74 | 172.33 | 2704 | 2156.8 | 18.979 | 1.1491 | 1.0847 | 765 | .00093 | 1.000 | 222.5 | 1.000 | .660 | 119.0 |
| 2.00 | 150.00 | 2661 | 2117.9 | 19.015 | 1.1510 | 1.0470 | 757 | .00089 | 1.122 | 223.8 | 1.013 | .735 | 132.5 |
| 10.00 | 30.00 | 2135 | 1717.1 | 19.278 | 1.1950 | .6645 | 653 | .00052 | 2.140 | 270.8 | 2.320 | 1.270 | 229.0 |
| 20.00 | 15.00 | 1900 | 1573.1 | 19.307 | 1.2156 | .5881 | 604 | .00043 | 2.506 | 288.2 | 3.704 | 1.414 | 254.8 |
| 20.41 | 14.70 | 1893 | 1569.1 | 19.308 | 1.2161 | .5866 | 602 | .00043 | 2.517 | 288.7 | 3.757 | 1.418 | 255.5 |
| 40.00 | 7.50 | 1675 | 1445.7 | 19.315 | 1.2303 | .5510 | 555 | .00038 | 2.871 | 302.9 | 6.033 | 1.530 | 275.7 |
| 40.83 | 7.35 | 1668 | 1442.2 | 19.315 | 1.2306 | .5502 | 554 | .00038 | 2.882 | 303.3 | 6.122 | 1.533 | 276.3 |
| 80.00 | 3.75 | 1467 | 1333.8 | 19.316 | 1.2422 | .5277 | 507 | .00033 | 3.243 | 315.3 | 9.951 | 1.625 | 292.9 |
| 100.00 | 3.00 | 1404 | 1300.9 | 19.316 | 1.2461 | .5209 | 492 | .00032 | 3.364 | 318.8 | 11.711 | 1.652 | 297.7 |
| 200.00 | 1.50 | 1221 | 1207.4 | 19.316 | 1.2587 | .5006 | 447 | .00028 | 3.751 | 328.6 | 19.495 | 1.726 | 311.1 |
| 300.00 | 1.00 | 1122 | 1158.5 | 19.316 | 1.2666 | .4887 | 421 | .00026 | 3.985 | 333.6 | 26.305 | 1.763 | 317.8 |
| 500.00 | .60 | 1006 | 1102.6 | 19.316 | 1.2771 | .4741 | 390 | .00024 | 4.291 | 339.2 | 38.394 | 1.805 | 325.4 |
| 800.00 | .37 | 907 | 1056.4 | 19.316 | 1.2868 | .4616 | 362 | .00021 | 4.586 | 343.8 | 54.374 | 1.839 | 331.5 |
| 1000.00 | .30 | 863 | 1036.1 | 19.316 | 1.2914 | .4559 | 349 | .00020 | 4.731 | 345.7 | 64.136 | 1.854 | 334.2 |
| 1500.00 | .20 | 787 | 1001.7 | 19.316 | 1.2997 | .4461 | 338 | .00019 | 5.005 | 349.0 | 86.552 | 1.879 | 338.6 |
| R = 0.95, PERCENT FUEL = 42.76, O/F = 1.339 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2913 | 2250.6 | 19.201 | 1.1381 | 1.3349 | 810 | 0.00119 | | | | | |
| 1.05 | 285.71 | 2899 | 2235.9 | 19.218 | 1.1382 | 1.3256 | 807 | .00117 | 0.293 | 400.7 | 2.130 | 0.199 | 35.7 |
| 1.60 | 187.50 | 2774 | 2112.9 | 19.361 | 1.1395 | 1.2397 | 783 | .00107 | .921 | 222.6 | 1.006 | .608 | 109.5 |
| 1.73 | 172.91 | 2751 | 2089.9 | 19.387 | 1.1399 | 1.2220 | 778 | .00105 | 1.000 | 222.0 | 1.000 | .657 | 118.2 |
| 2.00 | 150.00 | 2709 | 2050.2 | 19.432 | 1.1408 | 1.1901 | 770 | .00102 | 1.126 | 223.3 | 1.014 | .734 | 132.1 |
| 10.00 | 30.00 | 2234 | 1647.3 | 19.815 | 1.1704 | .7776 | 676 | .00061 | 2.145 | 271.7 | 2.364 | 1.273 | 229.1 |
| 20.00 | 15.00 | 2015 | 1499.8 | 19.885 | 1.1957 | .6375 | 631 | .00048 | 2.498 | 289.9 | 3.808 | 1.420 | 255.6 |
| 20.41 | 14.70 | 2008 | 1495.7 | 19.887 | 1.1964 | .6345 | 629 | .00048 | 2.508 | 290.4 | 3.863 | 1.424 | 256.3 |
| 40.00 | 7.50 | 1791 | 1368.1 | 19.910 | 1.2173 | .5646 | 583 | .00040 | 2.848 | 305.2 | 6.237 | 1.540 | 277.1 |
| 40.83 | 7.35 | 1784 | 1364.5 | 19.910 | 1.2178 | .5633 | 582 | .00040 | 2.859 | 305.6 | 6.330 | 1.543 | 277.7 |
| 80.00 | 3.75 | 1577 | 1251.7 | 19.915 | 1.2316 | .5315 | 535 | .00035 | 3.210 | 318.0 | 10.324 | 1.638 | 294.8 |
| 100.00 | 3.00 | 1512 | 1217.3 | 19.916 | 1.2355 | .5238 | 520 | .00034 | 3.330 | 321.7 | 12.164 | 1.666 | 299.8 |
| 200.00 | 1.50 | 1321 | 1119.5 | 19.916 | 1.2477 | .5026 | 474 | .00030 | 3.709 | 332.0 | 20.318 | 1.743 | 313.7 |
| 300.00 | 1.00 | 1218 | 1068.1 | 19.916 | 1.2551 | .4910 | 448 | .00028 | 3.938 | 337.3 | 27.476 | 1.782 | 320.8 |
| 500.00 | .60 | 1096 | 1009.2 | 19.916 | 1.2651 | .4762 | 416 | .00025 | 4.236 | 343.1 | 40.222 | 1.826 | 328.7 |
| 800.00 | .37 | 992 | 960.2 | 19.916 | 1.2747 | .4630 | 387 | .00023 | 4.523 | 347.9 | 57.122 | 1.862 | 335.1 |
| 1000.00 | .30 | 945 | 938.7 | 19.916 | 1.2792 | .4571 | 374 | .00022 | 4.664 | 350.0 | 67.468 | 1.877 | 337.9 |
| 1500.00 | .20 | 864 | 902.1 | 19.916 | 1.2877 | .4466 | 368 | .00021 | 4.929 | 353.5 | 91.270 | 1.903 | 342.5 |

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(a) 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, $\mathcal{M}$ | Isentropic exponent, γ | Specific heat, $c_p$, cal/(g)(°K) | Absolute viscosity, μ, micropoises | Thermal conductivity, k, cal/(sec)(cm)(°K) | Mach number, M | Specific impulse, $I_{vac}$, (lb)(sec)/lb | Area ratio, ε | Thrust coefficient, $C_F$ | Specific impulse, I, (lb)(sec)/lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 1.00, PERCENT FUEL = 41.51, O/F = 1.409 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2928 | 2185.7 | 19.542 | 1.1360 | 1.3651 | 817 | 0.00122 | | | | | |
| 1.05 | 285.71 | 2914 | 2171.2 | 19.560 | 1.1360 | 1.3572 | 814 | .00121 | 0.294 | 398.3 | 2.128 | 0.198 | 83.5 |
| 1.60 | 187.50 | 2792 | 2049.6 | 19.711 | 1.1365 | 1.2845 | 791 | .00112 | .922 | 221.3 | 1.006 | .608 | 108.8 |
| 1.74 | 172.87 | 2769 | 2027.3 | 19.738 | 1.1367 | 1.2700 | 786 | .00110 | 1.000 | 220.7 | 1.000 | .656 | 117.4 |
| 2.00 | 150.00 | 2728 | 1987.7 | 19.787 | 1.1371 | 1.2432 | 778 | .00107 | 1.128 | 222.1 | 1.015 | .739 | 131.9 |
| 10.00 | 30.00 | 2283 | 1587.6 | 20.239 | 1.1520 | .9129 | 689 | .00071 | 2.153 | 270.9 | 2.388 | 1.275 | 228.1 |
| 20.00 | 15.00 | 2089 | 1439.3 | 20.368 | 1.1665 | .7746 | 649 | .00058 | 2.506 | 289.6 | 3.887 | 1.424 | 254.9 |
| 20.41 | 14.70 | 2083 | 1438.1 | 20.371 | 1.1670 | .7708 | 648 | .00058 | 2.516 | 290.2 | 3.945 | 1.428 | 255.6 |
| 40.00 | 7.50 | 1891 | 1305.0 | 20.451 | 1.1861 | .6592 | 607 | .00047 | 2.843 | 305.7 | 6.453 | 1.547 | 276.8 |
| 40.83 | 7.35 | 1885 | 1301.2 | 20.453 | 1.1868 | .6562 | 606 | .00047 | 2.853 | 306.1 | 6.551 | 1.550 | 277.4 |
| 80.00 | 3.75 | 1691 | 1184.5 | 20.494 | 1.2080 | .5771 | 563 | .00039 | 3.180 | 319.3 | 10.799 | 1.649 | 295.2 |
| 100.00 | 3.00 | 1627 | 1148.7 | 20.502 | 1.2145 | .5580 | 549 | .00037 | 3.291 | 323.2 | 12.756 | 1.678 | 300.4 |
| 200.00 | 1.50 | 1434 | 1046.0 | 20.513 | 1.2327 | .5153 | 503 | .00032 | 3.649 | 334.1 | 21.438 | 1.739 | 314.9 |
| 300.00 | 1.00 | 1326 | 991.8 | 20.515 | 1.2418 | .4983 | 477 | .00030 | 3.869 | 339.7 | 29.067 | 1.801 | 322.3 |
| 500.00 | .60 | 1199 | 929.3 | 20.516 | 1.2523 | .4810 | 445 | .00027 | 4.157 | 345.9 | 42.681 | 1.847 | 330.6 |
| 800.00 | .37 | 1089 | 877.3 | 20.516 | 1.2619 | .4668 | 415 | .00024 | 4.434 | 351.0 | 60.786 | 1.885 | 337.4 |
| 1000.00 | .30 | 1039 | 854.3 | 20.516 | 1.2664 | .4604 | 402 | .00023 | 4.570 | 353.2 | 71.892 | 1.902 | 340.4 |
| 1500.00 | .20 | 953 | 815.2 | 20.516 | 1.2747 | .4494 | 402 | .00023 | 4.825 | 357.0 | 97.495 | 1.929 | 345.3 |
| R = 1.10, PERCENT FUEL = 39.22, O/F = 1.550 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2913 | 2066.7 | 20.113 | 1.1386 | 1.2483 | 823 | 0.00113 | | | | | |
| 1.05 | 285.71 | 2898 | 2052.7 | 20.131 | 1.1387 | 1.2393 | 820 | .00112 | 0.293 | 391.5 | 2.130 | 0.199 | 34.9 |
| 1.60 | 187.50 | 2773 | 1935.3 | 20.275 | 1.1402 | 1.1574 | 795 | .00102 | .921 | 217.5 | 1.006 | .608 | 107.0 |
| 1.74 | 172.87 | 2749 | 1913.3 | 20.302 | 1.1406 | 1.1409 | 791 | .00100 | 1.000 | 216.8 | 1.000 | .657 | 115.3 |
| 2.00 | 150.00 | 2707 | 1875.4 | 20.347 | 1.1415 | 1.1117 | 782 | .00097 | 1.126 | 218.2 | 1.014 | .734 | 129.0 |
| 10.00 | 30.00 | 2236 | 1490.9 | 20.739 | 1.1633 | .7848 | 686 | .00062 | 2.150 | 265.5 | 2.368 | 1.273 | 223.8 |
| 20.00 | 15.00 | 2030 | 1349.6 | 20.834 | 1.1794 | .6769 | 643 | .00051 | 2.506 | 283.5 | 3.836 | 1.421 | 249.8 |
| 20.41 | 14.70 | 2023 | 1345.6 | 20.836 | 1.1800 | .6741 | 642 | .00051 | 2.517 | 284.0 | 3.892 | 1.425 | 250.5 |
| 40.00 | 7.50 | 1823 | 1222.4 | 20.889 | 1.1979 | .5972 | 598 | .00043 | 2.851 | 298.9 | 6.334 | 1.542 | 271.0 |
| 40.83 | 7.35 | 1817 | 1218.9 | 20.890 | 1.1984 | .5952 | 597 | .00043 | 2.861 | 299.3 | 6.430 | 1.545 | 271.6 |
| 80.00 | 3.75 | 1621 | 1109.0 | 20.916 | 1.2162 | .5421 | 552 | .00036 | 3.198 | 311.9 | 10.560 | 1.642 | 288.7 |
| 100.00 | 3.00 | 1557 | 1075.3 | 20.921 | 1.2219 | .5284 | 537 | .00035 | 3.312 | 315.6 | 12.464 | 1.671 | 293.7 |
| 200.00 | 1.50 | 1368 | 979.1 | 20.928 | 1.2385 | .4945 | 492 | .00030 | 3.677 | 326.0 | 20.903 | 1.750 | 307.6 |
| 300.00 | 1.00 | 1264 | 928.5 | 20.930 | 1.2474 | .4794 | 466 | .00028 | 3.900 | 331.3 | 28.314 | 1.790 | 314.7 |
| 500.00 | .60 | 1140 | 870.2 | 20.931 | 1.2582 | .4628 | 433 | .00025 | 4.191 | 337.3 | 41.518 | 1.835 | 322.7 |
| 800.00 | .37 | 1034 | 821.7 | 20.931 | 1.2681 | .4491 | 404 | .00023 | 4.472 | 342.1 | 59.048 | 1.872 | 329.1 |
| 1000.00 | .30 | 986 | 800.3 | 20.931 | 1.2727 | .4431 | 391 | .00022 | 4.611 | 344.2 | 69.789 | 1.888 | 332.0 |
| 1500.00 | .20 | 903 | 764.0 | 20.931 | 1.2811 | .4327 | 388 | .00021 | 4.871 | 347.8 | 94.528 | 1.915 | 336.7 |
| R = 1.20, PERCENT FUEL = 37.16, O/F = 1.691 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2871 | 1960.2 | 20.593 | 1.1425 | 1.1178 | 822 | 0.00102 | | | | | |
| 1.05 | 285.71 | 2856 | 1946.7 | 20.609 | 1.1427 | 1.1093 | 819 | .00101 | 0.293 | 384.1 | 2.133 | 0.199 | 34.2 |
| 1.60 | 187.50 | 2726 | 1833.7 | 20.742 | 1.1448 | 1.0346 | 793 | .00092 | .920 | 213.2 | 1.006 | .609 | 104.9 |
| 1.74 | 172.57 | 2701 | 1812.2 | 20.767 | 1.1454 | 1.0197 | 788 | .00090 | 1.000 | 212.6 | 1.000 | .659 | 113.5 |
| 2.00 | 150.00 | 2659 | 1776.2 | 20.807 | 1.1464 | .9945 | 780 | .00087 | 1.124 | 213.8 | 1.014 | .734 | 126.5 |
| 10.00 | 30.00 | 2173 | 1408.1 | 21.154 | 1.1691 | .7271 | 679 | .00057 | 2.150 | 259.7 | 2.355 | 1.272 | 219.2 |
| 20.00 | 15.00 | 1968 | 1275.5 | 21.235 | 1.1851 | .6378 | 635 | .00048 | 2.509 | 277.2 | 3.805 | 1.419 | 244.4 |
| 20.41 | 14.70 | 1962 | 1269.7 | 21.237 | 1.1856 | .6355 | 633 | .00048 | 2.519 | 277.7 | 3.861 | 1.423 | 245.1 |
| 40.00 | 7.50 | 1762 | 1152.7 | 21.283 | 1.2035 | .5686 | 589 | .00040 | 2.856 | 292.1 | 6.270 | 1.539 | 265.1 |
| 40.83 | 7.35 | 1756 | 1149.3 | 21.284 | 1.2041 | .5669 | 588 | .00040 | 2.866 | 292.5 | 6.364 | 1.542 | 265.6 |
| 80.00 | 3.75 | 1562 | 1045.5 | 21.305 | 1.2220 | .5192 | 543 | .00035 | 3.206 | 304.6 | 10.432 | 1.638 | 282.2 |
| 100.00 | 3.00 | 1499 | 1013.4 | 21.309 | 1.2278 | .5067 | 528 | .00033 | 3.321 | 308.2 | 12.304 | 1.666 | 287.0 |
| 200.00 | 1.50 | 1314 | 922.6 | 21.315 | 1.2443 | .4759 | 482 | .00029 | 3.690 | 318.2 | 20.590 | 1.744 | 300.5 |
| 300.00 | 1.00 | 1212 | 874.9 | 21.316 | 1.2531 | .4620 | 456 | .00026 | 3.916 | 323.3 | 27.856 | 1.784 | 307.3 |
| 500.00 | .60 | 1091 | 820.1 | 21.317 | 1.2640 | .4445 | 424 | .00024 | 4.211 | 329.0 | 40.785 | 1.829 | 315.0 |
| 800.00 | .37 | 988 | 774.6 | 21.317 | 1.2738 | .4358 | 395 | .00022 | 4.497 | 333.7 | 57.925 | 1.865 | 321.2 |
| 1000.00 | .30 | 941 | 754.5 | 21.317 | 1.2783 | .4281 | 382 | .00021 | 4.637 | 335.7 | 68.417 | 1.880 | 323.9 |
| 1500.00 | .20 | 861 | 720.5 | 21.317 | 1.2867 | .4183 | 376 | .00020 | 4.900 | 339.1 | 92.559 | 1.907 | 328.4 |
| R = 1.50, PERCENT FUEL = 32.12, O/F = 2.114 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2728 | 1698.4 | 21.784 | 1.1504 | 0.9074 | 809 | 0.00083 | | | | | |
| 1.05 | 285.71 | 2712 | 1686.3 | 21.797 | 1.1507 | .9009 | 806 | .00082 | 0.292 | 364.0 | 2.138 | 0.199 | 32.5 |
| 1.60 | 187.50 | 2579 | 1585.0 | 21.908 | 1.1540 | .8450 | 779 | .00075 | .917 | 201.8 | 1.007 | .610 | 99.3 |
| 1.74 | 172.00 | 2551 | 1564.9 | 21.929 | 1.1548 | .8335 | 773 | .00073 | 1.000 | 201.1 | 1.000 | .662 | 107.8 |
| 2.00 | 150.00 | 2509 | 1533.6 | 21.962 | 1.1562 | .8152 | 764 | .00071 | 1.121 | 202.2 | 1.013 | .736 | 119.8 |
| 10.00 | 30.00 | 2013 | 1206.6 | 22.230 | 1.1845 | .6144 | 658 | .00048 | 2.148 | 244.7 | 2.325 | 1.271 | 206.9 |
| 20.00 | 15.00 | 1804 | 1088.6 | 22.286 | 1.2028 | .5472 | 611 | .00040 | 2.511 | 260.7 | 3.732 | 1.415 | 230.4 |
| 20.41 | 14.70 | 1798 | 1085.3 | 22.287 | 1.2033 | .5455 | 609 | .00040 | 2.521 | 261.2 | 3.786 | 1.419 | 231.0 |
| 40.00 | 7.50 | 1600 | 983.5 | 22.314 | 1.2219 | .4971 | 563 | .00034 | 2.866 | 274.3 | 6.106 | 1.532 | 249.4 |
| 40.83 | 7.35 | 1594 | 980.6 | 22.314 | 1.2225 | .4959 | 562 | .00034 | 2.877 | 274.6 | 6.197 | 1.535 | 249.9 |
| 80.00 | 3.75 | 1405 | 890.8 | 22.325 | 1.2400 | .4620 | 515 | .00030 | 3.227 | 285.6 | 10.088 | 1.628 | 265.1 |
| 100.00 | 3.00 | 1345 | 863.5 | 22.327 | 1.2453 | .4532 | 500 | .00028 | 3.346 | 288.9 | 11.874 | 1.656 | 269.5 |
| 200.00 | 1.50 | 1170 | 786.0 | 22.329 | 1.2604 | .4310 | 455 | .00025 | 3.729 | 297.8 | 19.750 | 1.731 | 281.8 |
| 300.00 | 1.00 | 1075 | 745.5 | 22.329 | 1.2690 | .4199 | 429 | .00023 | 3.943 | 302.4 | 26.630 | 1.769 | 288.0 |
| 500.00 | .60 | 963 | 699.2 | 22.329 | 1.2794 | .4075 | 397 | .00021 | 4.270 | 307.5 | 38.831 | 1.811 | 294.9 |
| 800.00 | .37 | 868 | 661.0 | 22.329 | 1.2890 | .3969 | 368 | .00019 | 4.566 | 311.6 | 54.950 | 1.846 | 300.5 |
| 1000.00 | .30 | 825 | 644.2 | 22.329 | 1.2936 | .3922 | 355 | .00018 | 4.711 | 313.4 | 64.794 | 1.860 | 302.9 |
| 1500.00 | .20 | 752 | 615.7 | 22.329 | 1.3017 | .3840 | 345 | .00017 | 4.988 | 316.4 | 87.389 | 1.885 | 306.9 |

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(a) 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, $\mathcal{M}$ | Isentropic exponent, $\gamma$ | Specific heat, $c_p$, cal/(g)(°K) | Absolute viscosity, $\mu$, micropoises | Thermal conductivity, k, cal/(sec)(cm)(°K) | Mach number, M | Specific impulse, $I_{vac}$, (lb)(sec)/lb | Area ratio, $\epsilon$ | Thrust coefficient, $C_F$ | Specific impulse, $I_s$, (lb)(sec)/lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 2.00, PERCENT FUEL = 26.19, O/F = 2.818 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2515 | 1391.0 | 23.307 | 1.1630 | 0.7201 | 783 | 0.00065 | | | | | |
| 1.05 | 285.71 | 2499 | 1380.5 | 23.318 | 1.1635 | .7148 | 779 | .00064 | 0.290 | 337.8 | 2.147 | 0.200 | 30.1 |
| 1.60 | 187.50 | 2362 | 1293.5 | 23.403 | 1.1694 | .6684 | 750 | .00058 | .912 | 186.8 | 1.008 | .612 | 92.1 |
| 1.75 | 171.00 | 2332 | 1275.1 | 23.419 | 1.1709 | .6584 | 744 | .00057 | 1.000 | 186.2 | 1.000 | .667 | 100.4 |
| 2.00 | 150.00 | 2290 | 1249.4 | 23.442 | 1.1731 | .6441 | 734 | .00055 | 1.115 | 187.1 | 1.012 | .738 | 111.0 |
| 10.00 | 30.00 | 1782 | 973.0 | 23.611 | 1.2117 | .4949 | 620 | .00037 | 2.145 | 224.9 | 2.275 | 1.268 | 190.7 |
| 20.00 | 15.00 | 1574 | 875.2 | 23.636 | 1.2308 | .4530 | 570 | .00032 | 2.517 | 239.0 | 3.612 | 1.408 | 211.8 |
| 20.41 | 14.70 | 1568 | 872.5 | 23.636 | 1.2314 | .4520 | 569 | .00032 | 2.528 | 239.4 | 3.663 | 1.412 | 212.4 |
| 40.00 | 7.50 | 1377 | 789.3 | 23.645 | 1.2484 | .4238 | 521 | .00028 | 2.886 | 250.8 | 5.849 | 1.521 | 228.8 |
| 40.83 | 7.35 | 1371 | 787.0 | 23.645 | 1.2488 | .4230 | 520 | .00027 | 2.897 | 251.1 | 5.934 | 1.524 | 229.3 |
| 80.00 | 3.75 | 1195 | 714.5 | 23.647 | 1.2634 | .4033 | 473 | .00024 | 3.265 | 260.6 | 9.579 | 1.613 | 242.6 |
| 100.00 | 3.00 | 1141 | 692.6 | 23.648 | 1.2680 | .3977 | 458 | .00023 | 3.390 | 263.4 | 11.245 | 1.639 | 246.5 |
| 200.00 | 1.50 | 982 | 630.9 | 23.648 | 1.2820 | .3821 | 414 | .00020 | 3.790 | 271.1 | 18.564 | 1.709 | 257.2 |
| 300.00 | 1.00 | 898 | 598.8 | 23.648 | 1.2900 | .3738 | 388 | .00019 | 4.035 | 275.0 | 24.925 | 1.745 | 262.5 |
| 500.00 | .60 | 799 | 562.5 | 23.648 | 1.3003 | .3639 | 357 | .00017 | 4.357 | 279.4 | 36.156 | 1.785 | 268.5 |
| 800.00 | .37 | 716 | 532.6 | 23.648 | 1.3095 | .3556 | 330 | .00015 | 4.668 | 282.9 | 50.923 | 1.817 | 273.3 |
| 1000.00 | .30 | 679 | 519.5 | 23.648 | 1.3138 | .3519 | 317 | .00015 | 4.822 | 284.4 | 59.913 | 1.830 | 275.4 |
| 1500.00 | .20 | 616 | 497.5 | 23.648 | 1.3214 | .3455 | 302 | .00014 | 5.113 | 286.9 | 80.490 | 1.853 | 278.8 |
| R = 3.00, PERCENT FUEL = 19.13, O/F = 4.227 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2163 | 1024.7 | 25.320 | 1.1942 | 0.5151 | 727 | 0.00045 | | | | | |
| 1.05 | 285.71 | 2146 | 1016.4 | 25.326 | 1.1953 | .5112 | 723 | .00044 | 0.286 | 300.3 | 2.168 | 0.202 | 26.8 |
| 1.60 | 187.50 | 2004 | 947.9 | 25.367 | 1.2055 | .4795 | 690 | .00040 | .901 | 165.3 | 1.009 | .617 | 81.7 |
| 1.78 | 168.77 | 1969 | 931.6 | 25.376 | 1.2083 | .4721 | 682 | .00039 | 1.000 | 164.5 | 1.000 | .680 | 90.0 |
| 2.00 | 150.00 | 1929 | 913.6 | 25.384 | 1.2114 | .4641 | 673 | .00038 | 1.102 | 165.2 | 1.009 | .742 | 98.3 |
| 10.00 | 30.00 | 1427 | 703.2 | 25.434 | 1.2533 | .3878 | 550 | .00027 | 2.146 | 196.3 | 2.189 | 1.263 | 167.3 |
| 20.00 | 15.00 | 1236 | 631.1 | 25.437 | 1.2679 | .3700 | 499 | .00023 | 2.535 | 207.8 | 3.429 | 1.397 | 185.1 |
| 20.41 | 14.70 | 1231 | 629.2 | 25.437 | 1.2683 | .3696 | 498 | .00023 | 2.547 | 208.1 | 3.476 | 1.401 | 185.5 |
| 40.00 | 7.50 | 1065 | 568.9 | 25.438 | 1.2814 | .3558 | 452 | .00020 | 2.925 | 217.3 | 5.488 | 1.504 | 199.1 |
| 40.83 | 7.35 | 1060 | 567.2 | 25.438 | 1.2818 | .3554 | 450 | .00020 | 2.936 | 217.6 | 5.566 | 1.506 | 199.5 |
| 80.00 | 3.75 | 912 | 515.5 | 25.438 | 1.2944 | .3434 | 406 | .00018 | 3.323 | 225.2 | 8.893 | 1.589 | 210.5 |
| 100.00 | 3.00 | 866 | 500.0 | 25.438 | 1.2988 | .3396 | 392 | .00017 | 3.455 | 227.5 | 10.406 | 1.613 | 213.7 |
| 200.00 | 1.50 | 737 | 456.7 | 25.438 | 1.3123 | .3282 | 350 | .00015 | 3.878 | 233.6 | 17.008 | 1.679 | 222.3 |
| 300.00 | 1.00 | 668 | 434.4 | 25.438 | 1.3202 | .3221 | 326 | .00014 | 4.139 | 236.6 | 22.703 | 1.711 | 226.6 |
| 500.00 | .60 | 590 | 409.4 | 25.438 | 1.3300 | .3148 | 297 | .00012 | 4.482 | 240.0 | 32.694 | 1.747 | 231.4 |
| 800.00 | .37 | 524 | 388.9 | 25.438 | 1.3385 | .3089 | 272 | .00011 | 4.817 | 242.8 | 45.747 | 1.776 | 235.2 |
| 1000.00 | .30 | 495 | 380.1 | 25.438 | 1.3423 | .3063 | 261 | .00011 | 4.983 | 243.9 | 53.660 | 1.788 | 236.8 |
| 1500.00 | .20 | 446 | 365.2 | 25.438 | 1.3491 | .3019 | 242 | .00010 | 5.296 | 245.9 | 71.702 | 1.809 | 239.6 |
| R = 4.00, PERCENT FUEL = 15.07, O/F = 5.636 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 1875 | 814.0 | 26.561 | 1.2253 | 0.4158 | 672 | 0.00034 | | | | | |
| 1.05 | 285.71 | 1858 | 807.1 | 26.563 | 1.2266 | .4133 | 668 | .00034 | 0.283 | 272.7 | 2.187 | 0.204 | 24.3 |
| 1.60 | 187.50 | 1717 | 750.8 | 26.579 | 1.2377 | .3939 | 633 | .00031 | .891 | 149.5 | 1.011 | .621 | 74.1 |
| 1.80 | 166.91 | 1680 | 736.1 | 26.582 | 1.2406 | .3893 | 624 | .00030 | 1.000 | 148.7 | 1.000 | .690 | 82.3 |
| 2.00 | 150.00 | 1645 | 722.8 | 26.584 | 1.2433 | .3853 | 616 | .00029 | 1.092 | 149.1 | 1.007 | .747 | 89.1 |
| 10.00 | 30.00 | 1179 | 554.0 | 26.595 | 1.2773 | .3442 | 493 | .00022 | 2.149 | 175.9 | 2.197 | 1.261 | 150.4 |
| 20.00 | 15.00 | 1012 | 497.3 | 26.596 | 1.2901 | .3322 | 445 | .00019 | 2.548 | 185.8 | 3.323 | 1.392 | 166.0 |
| 20.41 | 14.70 | 1007 | 495.8 | 26.596 | 1.2905 | .3319 | 444 | .00019 | 2.560 | 186.1 | 3.368 | 1.395 | 166.4 |
| 40.00 | 7.50 | 864 | 448.9 | 26.596 | 1.3028 | .3215 | 399 | .00017 | 2.947 | 194.0 | 5.282 | 1.494 | 178.2 |
| 40.83 | 7.35 | 859 | 447.5 | 26.596 | 1.3032 | .3211 | 398 | .00016 | 2.959 | 194.2 | 5.356 | 1.497 | 178.6 |
| 80.00 | 3.75 | 733 | 407.6 | 26.596 | 1.3163 | .3110 | 356 | .00014 | 3.358 | 200.7 | 8.500 | 1.577 | 188.0 |
| 100.00 | 3.00 | 695 | 395.7 | 26.596 | 1.3205 | .3078 | 343 | .00014 | 3.494 | 202.6 | 9.924 | 1.600 | 190.8 |
| 200.00 | 1.50 | 585 | 362.6 | 26.596 | 1.3341 | .2983 | 303 | .00012 | 3.933 | 207.8 | 16.104 | 1.662 | 198.2 |
| 300.00 | 1.00 | 528 | 345.8 | 26.596 | 1.3416 | .2934 | 281 | .00011 | 4.204 | 210.4 | 21.408 | 1.692 | 201.8 |
| 500.00 | .60 | 463 | 326.9 | 26.596 | 1.3509 | .2877 | 254 | .00010 | 4.564 | 213.2 | 30.675 | 1.726 | 205.9 |
| 800.00 | .37 | 410 | 311.5 | 26.596 | 1.3580 | .2834 | 231 | .00009 | 4.916 | 215.5 | 42.731 | 1.753 | 209.1 |
| 1000.00 | .30 | 386 | 304.9 | 26.596 | 1.3608 | .2818 | 221 | .00008 | 5.091 | 216.4 | 50.025 | 1.765 | 210.5 |
| 1500.00 | .20 | 347 | 293.8 | 26.596 | 1.3650 | .2794 | 203 | .00008 | 5.424 | 218.0 | 66.635 | 1.784 | 212.7 |
| R = 5.00, PERCENT FUEL = 12.43, O/F = 7.046 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 1640 | 677.0 | 27.397 | 1.2496 | 0.3655 | 621 | 0.00028 | | | | | |
| 1.05 | 285.71 | 1624 | 671.3 | 27.398 | 1.2507 | .3640 | 617 | .00028 | 0.280 | 251.0 | 2.200 | 0.205 | 22.4 |
| 1.60 | 187.50 | 1491 | 623.7 | 27.403 | 1.2601 | .3523 | 583 | .00026 | .885 | 137.2 | 1.013 | .624 | 68.1 |
| 1.81 | 165.69 | 1453 | 610.5 | 27.404 | 1.2628 | .3493 | 573 | .00025 | 1.000 | 136.4 | 1.000 | .697 | 76.1 |
| 2.00 | 150.00 | 1424 | 600.1 | 27.404 | 1.2648 | .3470 | 565 | .00025 | 1.085 | 136.7 | 1.006 | .750 | 81.8 |
| 10.00 | 30.00 | 1002 | 459.7 | 27.406 | 1.2941 | .3191 | 448 | .00018 | 2.151 | 160.5 | 2.106 | 1.260 | 137.5 |
| 20.00 | 15.00 | 853 | 413.2 | 27.406 | 1.3064 | .3091 | 402 | .00016 | 2.555 | 169.3 | 3.257 | 1.389 | 151.5 |
| 20.41 | 14.70 | 849 | 411.9 | 27.406 | 1.3068 | .3088 | 400 | .00016 | 2.567 | 169.5 | 3.301 | 1.392 | 151.9 |
| 40.00 | 7.50 | 723 | 373.6 | 27.406 | 1.3198 | .2993 | 358 | .00014 | 2.961 | 176.5 | 5.149 | 1.489 | 162.5 |
| 40.83 | 7.35 | 720 | 372.6 | 27.406 | 1.3201 | .2990 | 357 | .00014 | 2.973 | 176.7 | 5.221 | 1.492 | 162.8 |
| 80.00 | 3.75 | 610 | 340.2 | 27.406 | 1.3335 | .2899 | 317 | .00012 | 3.380 | 182.4 | 8.241 | 1.569 | 171.2 |
| 100.00 | 3.00 | 577 | 330.6 | 27.406 | 1.3378 | .2871 | 305 | .00012 | 3.519 | 184.1 | 9.603 | 1.591 | 173.6 |
| 200.00 | 1.50 | 483 | 304.0 | 27.406 | 1.3509 | .2792 | 267 | .00010 | 3.972 | 188.6 | 15.499 | 1.651 | 180.2 |
| 300.00 | 1.00 | 434 | 290.5 | 27.406 | 1.3579 | .2751 | 247 | .00009 | 4.252 | 190.9 | 20.540 | 1.681 | 183.4 |
| 500.00 | .60 | 379 | 275.5 | 27.406 | 1.3649 | .2712 | 222 | .00008 | 4.626 | 193.3 | 29.326 | 1.713 | 186.9 |
| 800.00 | .37 | 334 | 263.4 | 27.406 | 1.3697 | .2687 | 201 | .00007 | 4.993 | 195.2 | 40.744 | 1.739 | 189.7 |
| 1000.00 | .30 | 315 | 258.1 | 27.406 | 1.3715 | .2677 | 191 | .00007 | 5.175 | 196.1 | 47.646 | 1.750 | 190.9 |
| 1500.00 | .20 | 282 | 249.4 | 27.406 | 1.3740 | .2664 | 175 | .00006 | 5.520 | 197.5 | 63.359 | 1.768 | 192.9 |

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TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(b) 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, M | Isentropic exponent, γ | Specific heat, $c_p$, $\frac{cal}{(g)(°K)}$ | Absolute viscosity, μ, micropoises | Thermal conductivity, k, $\frac{cal}{(sec)(cm)(°K)}$ | Mach number, M | Specific impulse, $I_{vac}$, $\frac{(lb)(sec)}{lb}$ | Area ratio, ε | Thrust coefficient, $C_F$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 0.40, PERCENT FUEL = 63.95, O/F = 0.564 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 1949 | 3350.2 | 13.316 | 1.2956 | 0.6540 | 453 | 0.00038 | | | | | |
| 1.05 | 285.71 | 1934 | 3340.4 | 13.316 | 1.2966 | .6524 | 450 | .00038 | 0.275 | 326.2 | 2.226 | 0.208 | 29.1 |
| 1.60 | 187.50 | 1210 | 3260.5 | 13.316 | 1.3053 | .6381 | 421 | .00035 | .872 | 177.3 | 1.015 | .630 | 88.3 |
| 1.84 | 163.20 | 1171 | 3235.9 | 13.316 | 1.3082 | .6335 | 412 | .00034 | 1.000 | 176.0 | 1.000 | .712 | 99.7 |
| 2.00 | 150.00 | 1148 | 3221.3 | 13.316 | 1.3100 | .6307 | 406 | .00033 | 1.072 | 176.3 | 1.004 | .756 | 105.9 |
| 10.00 | 30.00 | 772 | 2993.1 | 13.316 | 1.3421 | .5855 | 309 | .00024 | 2.149 | 204.7 | 2.030 | 1.258 | 176.3 |
| 20.00 | 15.00 | 646 | 2919.9 | 13.316 | 1.3530 | .5720 | 272 | .00021 | 2.569 | 215.2 | 3.093 | 1.381 | 193.5 |
| 20.41 | 14.70 | 643 | 2917.9 | 13.316 | 1.3532 | .5717 | 271 | .00021 | 2.581 | 215.4 | 3.133 | 1.384 | 193.9 |
| 40.00 | 7.50 | 538 | 2858.8 | 13.316 | 1.3618 | .5617 | 237 | .00018 | 2.998 | 223.7 | 4.823 | 1.476 | 206.8 |
| 40.83 | 7.35 | 535 | 2857.1 | 13.316 | 1.3620 | .5615 | 236 | .00018 | 3.011 | 223.9 | 4.888 | 1.478 | 207.1 |
| 80.00 | 3.75 | 447 | 2807.9 | 13.316 | 1.3680 | .5548 | 206 | .00015 | 3.447 | 230.6 | 7.629 | 1.550 | 217.2 |
| 100.00 | 3.00 | 421 | 2793.5 | 13.316 | 1.3696 | .5530 | 196 | .00015 | 3.597 | 232.5 | 8.863 | 1.571 | 220.1 |
| 200.00 | 1.50 | 349 | 2753.8 | 13.316 | 1.3744 | .5478 | 168 | .00012 | 4.083 | 237.7 | 14.191 | 1.626 | 227.8 |
| 300.00 | 1.00 | 312 | 2733.8 | 13.316 | 1.3768 | .5453 | 154 | .00011 | 4.383 | 240.3 | 18.744 | 1.653 | 231.6 |
| 500.00 | .60 | 271 | 2711.6 | 13.316 | 1.3793 | .5427 | 136 | .00010 | 4.781 | 243.2 | 26.680 | 1.682 | 235.7 |
| 800.00 | .37 | 238 | 2693.7 | 13.316 | 1.3842 | .5377 | 122 | .00009 | 5.163 | 245.5 | 36.978 | 1.705 | 239.0 |
| 1000.00 | .30 | 224 | 2686.0 | 13.316 | 1.3871 | .5348 | 115 | .00008 | 5.351 | 246.4 | 43.187 | 1.715 | 240.4 |
| 1500.00 | .20 | 200 | 2673.2 | 13.316 | 1.3927 | .5293 | 104 | .00007 | 5.707 | 248.0 | 57.266 | 1.732 | 242.7 |
| R = 0.50, PERCENT FUEL = 58.67, O/F = 0.705 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 1784 | 3075.9 | 14.516 | 1.2623 | 0.6588 | 555 | 0.00046 | | | | | |
| 1.05 | 285.71 | 1766 | 3064.0 | 14.516 | 1.2630 | .6573 | 551 | .00046 | 0.279 | 359.6 | 2.206 | 0.206 | 32.1 |
| 1.60 | 187.50 | 1617 | 2966.5 | 14.516 | 1.2697 | .6444 | 520 | .00042 | .882 | 196.3 | 1.013 | .626 | 97.5 |
| 1.82 | 165.20 | 1574 | 2938.9 | 14.516 | 1.2719 | .6404 | 510 | .00041 | 1.000 | 195.0 | 1.000 | .700 | 109.2 |
| 2.00 | 150.00 | 1541 | 2918.3 | 14.516 | 1.2736 | .6372 | 503 | .00041 | 1.083 | 195.5 | 1.006 | .751 | 117.1 |
| 10.00 | 30.00 | 1074 | 2632.5 | 14.516 | 1.3057 | .5847 | 394 | .00030 | 2.149 | 229.0 | 2.090 | 1.260 | 196.4 |
| 20.00 | 15.00 | 911 | 2538.5 | 14.516 | 1.3201 | .5646 | 351 | .00026 | 2.555 | 241.3 | 3.218 | 1.387 | 216.2 |
| 20.41 | 14.70 | 906 | 2535.9 | 14.516 | 1.3205 | .5641 | 350 | .00026 | 2.568 | 241.7 | 3.261 | 1.390 | 216.8 |
| 40.00 | 7.50 | 768 | 2459.0 | 14.516 | 1.3335 | .5474 | 311 | .00022 | 2.967 | 251.4 | 5.064 | 1.486 | 231.7 |
| 40.83 | 7.35 | 764 | 2456.9 | 14.516 | 1.3339 | .5469 | 310 | .00022 | 2.979 | 251.7 | 5.134 | 1.489 | 232.1 |
| 80.00 | 3.75 | 644 | 2392.2 | 14.516 | 1.3450 | .5338 | 273 | .00019 | 3.396 | 259.6 | 8.071 | 1.565 | 243.9 |
| 100.00 | 3.00 | 608 | 2373.0 | 14.516 | 1.3482 | .5301 | 262 | .00018 | 3.539 | 261.9 | 9.395 | 1.586 | 247.3 |
| 200.00 | 1.50 | 508 | 2320.2 | 14.516 | 1.3571 | .5203 | 228 | .00016 | 4.003 | 268.2 | 15.125 | 1.645 | 256.4 |
| 300.00 | 1.00 | 456 | 2293.5 | 14.516 | 1.3609 | .5163 | 210 | .00014 | 4.292 | 271.3 | 20.032 | 1.674 | 260.9 |
| 500.00 | .60 | 398 | 2263.7 | 14.516 | 1.3650 | .5120 | 188 | .00013 | 4.673 | 274.8 | 28.600 | 1.705 | 265.8 |
| 800.00 | .37 | 351 | 2239.6 | 14.516 | 1.3683 | .5086 | 169 | .00012 | 5.045 | 277.5 | 39.755 | 1.730 | 269.7 |
| 1000.00 | .30 | 330 | 2229.2 | 14.516 | 1.3696 | .5073 | 161 | .00011 | 5.228 | 278.7 | 46.505 | 1.741 | 271.4 |
| 1500.00 | .20 | 296 | 2211.9 | 14.516 | 1.3717 | .5053 | 146 | .00010 | 5.575 | 280.6 | 61.880 | 1.759 | 274.2 |
| R = 0.60, PERCENT FUEL = 54.19, O/F = 0.845 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2169 | 2843.5 | 15.708 | 1.2400 | 0.6535 | 639 | 0.00052 | | | | | |
| 1.05 | 285.71 | 2149 | 2830.1 | 15.708 | 1.2406 | .6523 | 635 | .00051 | 0.281 | 381.4 | 2.193 | 0.205 | 34.0 |
| 1.60 | 187.50 | 1979 | 2720.2 | 15.708 | 1.2456 | .6416 | 602 | .00048 | .889 | 208.7 | 1.012 | .623 | 103.6 |
| 1.80 | 166.59 | 1933 | 2691.0 | 15.708 | 1.2472 | .6383 | 593 | .00047 | 1.000 | 207.6 | 1.000 | .693 | 115.2 |
| 2.00 | 150.00 | 1893 | 2665.6 | 15.708 | 1.2486 | .6354 | 585 | .00046 | 1.091 | 208.2 | 1.007 | .748 | 124.4 |
| 10.00 | 30.00 | 1357 | 2337.0 | 15.708 | 1.2750 | .5865 | 468 | .00035 | 2.151 | 245.5 | 2.139 | 1.262 | 209.9 |
| 20.00 | 15.00 | 1165 | 2226.6 | 15.708 | 1.2888 | .5646 | 421 | .00030 | 2.548 | 259.4 | 3.328 | 1.393 | 231.7 |
| 20.41 | 14.70 | 1160 | 2223.6 | 15.708 | 1.2892 | .5639 | 420 | .00030 | 2.560 | 259.7 | 3.373 | 1.396 | 232.2 |
| 40.00 | 7.50 | 994 | 2132.1 | 15.708 | 1.3034 | .5435 | 377 | .00026 | 2.946 | 270.8 | 5.291 | 1.498 | 248.8 |
| 40.83 | 7.35 | 990 | 2129.5 | 15.708 | 1.3038 | .5429 | 376 | .00026 | 2.958 | 271.1 | 5.365 | 1.499 | 249.2 |
| 80.00 | 3.75 | 844 | 2051.6 | 15.708 | 1.3175 | .5249 | 336 | .00023 | 3.356 | 280.2 | 8.510 | 1.578 | 262.5 |
| 100.00 | 3.00 | 799 | 2028.4 | 15.708 | 1.3219 | .5194 | 323 | .00022 | 3.492 | 282.8 | 9.934 | 1.601 | 266.3 |
| 200.00 | 1.50 | 674 | 1964.0 | 15.708 | 1.3345 | .5048 | 285 | .00019 | 3.933 | 290.0 | 16.114 | 1.663 | 276.6 |
| 300.00 | 1.00 | 608 | 1931.1 | 15.708 | 1.3408 | .4977 | 264 | .00017 | 4.206 | 293.6 | 21.423 | 1.694 | 281.8 |
| 500.00 | .60 | 533 | 1894.3 | 15.708 | 1.3479 | .4901 | 239 | .00015 | 4.568 | 297.6 | 30.711 | 1.728 | 287.4 |
| 800.00 | .37 | 472 | 1864.4 | 15.708 | 1.3534 | .4845 | 216 | .00014 | 4.922 | 300.8 | 42.823 | 1.755 | 291.9 |
| 1000.00 | .30 | 445 | 1851.5 | 15.708 | 1.3555 | .4823 | 206 | .00013 | 5.097 | 302.1 | 50.162 | 1.766 | 293.8 |
| 1500.00 | .20 | 400 | 1829.8 | 15.708 | 1.3590 | .4789 | 189 | .00012 | 5.428 | 304.4 | 66.899 | 1.786 | 297.0 |
| R = 0.70, PERCENT FUEL = 50.34, O/F = 0.986 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2494 | 2644.0 | 16.862 | 1.2247 | 0.6424 | 709 | 0.00056 | | | | | |
| 1.05 | 285.71 | 2472 | 2629.8 | 16.862 | 1.2251 | .6414 | 705 | .00056 | 0.281 | 394.8 | 2.183 | 0.204 | 35.2 |
| 1.60 | 187.50 | 2286 | 2511.7 | 16.862 | 1.2291 | .6321 | 670 | .00052 | .894 | 216.5 | 1.011 | .620 | 107.3 |
| 1.79 | 167.56 | 2239 | 2481.7 | 16.862 | 1.2303 | .6295 | 661 | .00051 | 1.000 | 215.4 | 1.000 | .687 | 118.8 |
| 2.00 | 150.00 | 2193 | 2452.8 | 16.862 | 1.2315 | .6270 | 652 | .00050 | 1.096 | 216.1 | 1.008 | .746 | 129.0 |
| 10.00 | 30.00 | 1604 | 2095.0 | 16.862 | 1.2525 | .5846 | 530 | .00039 | 2.154 | 256.2 | 2.175 | 1.264 | 218.6 |
| 20.00 | 15.00 | 1391 | 1972.9 | 16.862 | 1.2643 | .5635 | 481 | .00034 | 2.545 | 271.2 | 3.418 | 1.397 | 241.7 |
| 20.41 | 14.70 | 1385 | 1969.5 | 16.862 | 1.2648 | .5628 | 480 | .00034 | 2.556 | 271.6 | 3.460 | 1.401 | 242.3 |
| 40.00 | 7.50 | 1200 | 1867.2 | 16.862 | 1.2777 | .5422 | 435 | .00030 | 2.932 | 283.7 | 5.473 | 1.503 | 260.0 |
| 40.83 | 7.35 | 1195 | 1864.3 | 16.862 | 1.2781 | .5415 | 433 | .00030 | 2.944 | 284.0 | 5.551 | 1.506 | 260.5 |
| 80.00 | 3.75 | 1029 | 1776.3 | 16.862 | 1.2922 | .5212 | 390 | .00026 | 3.328 | 294.0 | 8.882 | 1.589 | 274.8 |
| 100.00 | 3.00 | 978 | 1749.9 | 16.862 | 1.2968 | .5149 | 377 | .00025 | 3.459 | 296.9 | 10.396 | 1.615 | 278.9 |
| 200.00 | 1.50 | 832 | 1676.1 | 16.862 | 1.3111 | .4967 | 336 | .00022 | 3.880 | 304.9 | 17.002 | 1.678 | 290.2 |
| 300.00 | 1.00 | 755 | 1638.2 | 16.862 | 1.3191 | .4872 | 313 | .00020 | 4.140 | 308.9 | 22.701 | 1.711 | 295.8 |
| 500.00 | .60 | 666 | 1595.5 | 16.862 | 1.3283 | .4769 | 285 | .00018 | 4.484 | 313.4 | 32.704 | 1.747 | 302.1 |
| 800.00 | .37 | 593 | 1560.6 | 16.862 | 1.3358 | .4688 | 261 | .00016 | 4.819 | 316.9 | 45.786 | 1.775 | 307.0 |
| 1000.00 | .30 | 560 | 1545.5 | 16.862 | 1.3391 | .4653 | 249 | .00015 | 4.985 | 318.5 | 53.725 | 1.788 | 309.2 |
| 1500.00 | .20 | 505 | 1520.0 | 16.862 | 1.3446 | .4598 | 230 | .00014 | 5.299 | 321.0 | 71.849 | 1.808 | 312.7 |

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CQ-4 back

TABLE II. - Continued THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(b) 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, $\mathscr{M}$ | Isentropic exponent, $\gamma$ | Specific heat, $c_p$, $\frac{cal}{(g)(°K)}$ | Absolute viscosity, $\mu$, micropoises | Thermal conductivity, k, cal/(sec)(cm)(°K) | Mach number, M | Specific impulse, $I_{vac}$, $\frac{(lb)(sec)}{lb}$ | Area ratio, $\varepsilon$ | Thrust coefficient, $C_F$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 0.80, PERCENT FUEL = 47.01, O/F = 1.127 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2734 | 2471.0 | 17.915 | 1.2149 | 0.6272 | 762 | 0.00058 | | | | | |
| 1.05 | 285.71 | 2711 | 2456.3 | 17.915 | 1.2152 | .6263 | 758 | .00058 | 0.284 | 401.1 | 2.177 | 0.203 | 35.8 |
| 1.60 | 187.50 | 2515 | 2334.3 | 17.915 | 1.2185 | .6186 | 722 | .00055 | .897 | 220.3 | 1.010 | .619 | 109.1 |
| 1.78 | 168.19 | 2466 | 2304.3 | 17.915 | 1.2194 | .6166 | 713 | .00054 | 1.000 | 219.3 | 1.000 | .684 | 120.5 |
| 2.00 | 150.00 | 2416 | 2273.3 | 17.915 | 1.2204 | .6143 | 703 | .00053 | 1.100 | 220.1 | 1.009 | .744 | 131.2 |
| 10.00 | 30.00 | 1790 | 1900.0 | 17.915 | 1.2382 | .5766 | 577 | .00041 | 2.155 | 261.7 | 2.200 | 1.265 | 222.9 |
| 20.00 | 15.00 | 1564 | 1771.2 | 17.915 | 1.2482 | .5578 | 527 | .00037 | 2.543 | 277.3 | 3.471 | 1.400 | 246.8 |
| 20.41 | 14.70 | 1557 | 1767.7 | 17.915 | 1.2486 | .5572 | 525 | .00037 | 2.554 | 277.8 | 3.519 | 1.404 | 247.4 |
| 40.00 | 7.50 | 1359 | 1659.0 | 17.915 | 1.2602 | .5373 | 479 | .00032 | 2.924 | 290.5 | 5.599 | 1.508 | 265.8 |
| 40.83 | 7.35 | 1353 | 1655.9 | 17.915 | 1.2606 | .5367 | 477 | .00032 | 2.936 | 290.8 | 5.680 | 1.511 | 266.3 |
| 80.00 | 3.75 | 1174 | 1561.8 | 17.915 | 1.2734 | .5166 | 433 | .00028 | 3.311 | 301.4 | 9.146 | 1.596 | 281.3 |
| 100.00 | 3.00 | 1119 | 1533.4 | 17.915 | 1.2780 | .5100 | 419 | .00027 | 3.438 | 304.5 | 10.728 | 1.621 | 285.6 |
| 200.00 | 1.50 | 959 | 1453.6 | 17.915 | 1.2924 | .4903 | 375 | .00024 | 3.846 | 313.1 | 17.662 | 1.689 | 297.5 |
| 300.00 | 1.00 | 874 | 1412.4 | 17.915 | 1.3009 | .4796 | 351 | .00022 | 4.096 | 317.4 | 23.671 | 1.722 | 303.5 |
| 500.00 | .60 | 776 | 1365.7 | 17.915 | 1.3112 | .4673 | 322 | .00020 | 4.426 | 322.2 | 34.253 | 1.768 | 310.1 |
| 800.00 | .37 | 693 | 1327.4 | 17.915 | 1.3201 | .4574 | 296 | .00018 | 4.747 | 326.1 | 48.133 | 1.790 | 315.5 |
| 1000.00 | .30 | 656 | 1310.7 | 17.915 | 1.3241 | .4532 | 284 | .00017 | 4.906 | 327.7 | 56.572 | 1.803 | 317.7 |
| 1500.00 | .20 | 594 | 1282.6 | 17.915 | 1.3308 | .4463 | 263 | .00015 | 5.207 | 330.5 | 75.868 | 1.825 | 321.6 |
| R = 0.90, PERCENT FUEL = 44.09, O/F = 1.268 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2877 | 2319.5 | 18.816 | 1.2093 | 0.6102 | 798 | 0.00059 | | | | | |
| 1.05 | 285.71 | 2853 | 2304.8 | 18.816 | 1.2096 | .6094 | 794 | .00059 | 0.285 | 401.6 | 2.174 | 0.203 | 35.8 |
| 1.60 | 187.50 | 2651 | 2182.4 | 18.816 | 1.2127 | .6023 | 757 | .00056 | .899 | 220.8 | 1.010 | .618 | 109.2 |
| 1.78 | 168.54 | 2602 | 2152.8 | 18.816 | 1.2134 | .6004 | 747 | .00055 | 1.000 | 219.7 | 1.000 | .682 | 120.4 |
| 2.00 | 150.00 | 2549 | 2121.1 | 18.816 | 1.2143 | .5984 | 737 | .00054 | 1.102 | 220.5 | 1.009 | .744 | 131.4 |
| 10.00 | 30.00 | 1904 | 1744.8 | 18.816 | 1.2301 | .5645 | 608 | .00042 | 2.156 | 262.7 | 2.214 | 1.266 | 223.6 |
| 20.00 | 15.00 | 1669 | 1614.2 | 18.816 | 1.2393 | .5469 | 557 | .00038 | 2.541 | 278.7 | 3.503 | 1.402 | 247.7 |
| 20.41 | 14.70 | 1662 | 1610.6 | 18.816 | 1.2396 | .5464 | 556 | .00038 | 2.553 | 279.1 | 3.553 | 1.406 | 248.4 |
| 40.00 | 7.50 | 1456 | 1499.9 | 18.816 | 1.2502 | .5278 | 508 | .00034 | 2.920 | 292.1 | 5.672 | 1.511 | 267.0 |
| 40.83 | 7.35 | 1450 | 1496.8 | 18.816 | 1.2505 | .5272 | 507 | .00033 | 2.931 | 292.5 | 5.755 | 1.514 | 267.6 |
| 80.00 | 3.75 | 1264 | 1400.5 | 18.816 | 1.2626 | .5079 | 461 | .00030 | 3.302 | 303.3 | 9.300 | 1.600 | 282.8 |
| 100.00 | 3.00 | 1206 | 1371.4 | 18.816 | 1.2669 | .5014 | 447 | .00028 | 3.427 | 306.5 | 10.923 | 1.626 | 287.2 |
| 200.00 | 1.50 | 1039 | 1289.3 | 18.816 | 1.2810 | .4814 | 402 | .00025 | 3.828 | 315.4 | 18.057 | 1.695 | 299.4 |
| 300.00 | 1.00 | 950 | 1246.7 | 18.816 | 1.2894 | .4705 | 377 | .00023 | 4.072 | 319.8 | 24.258 | 1.729 | 305.5 |
| 500.00 | .60 | 846 | 1198.3 | 18.816 | 1.3001 | .4575 | 347 | .00020 | 4.394 | 324.8 | 35.206 | 1.768 | 312.3 |
| 800.00 | .37 | 758 | 1158.5 | 18.816 | 1.3096 | .4468 | 320 | .00019 | 4.707 | 328.8 | 49.600 | 1.799 | 317.8 |
| 1000.00 | .30 | 719 | 1141.2 | 18.816 | 1.3139 | .4421 | 308 | .00018 | 4.862 | 330.5 | 58.362 | 1.812 | 320.2 |
| 1500.00 | .20 | 652 | 1111.8 | 18.816 | 1.3212 | .4344 | 286 | .00016 | 5.154 | 333.4 | 78.422 | 1.835 | 324.2 |
| R = 0.95, PERCENT FUEL = 42.76, O/F = 1.339 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2913 | 2250.6 | 19.201 | 1.2079 | 0.6014 | 810 | 0.00059 | | | | | |
| 1.05 | 285.71 | 2889 | 2236.0 | 19.201 | 1.2082 | .6006 | 805 | .00059 | 0.285 | 400.0 | 2.173 | 0.203 | 35.7 |
| 1.60 | 187.50 | 2686 | 2114.5 | 19.201 | 1.2111 | .5936 | 768 | .00056 | .899 | 219.9 | 1.010 | .618 | 108.8 |
| 1.78 | 168.62 | 2636 | 2085.3 | 19.201 | 1.2119 | .5918 | 759 | .00055 | 1.000 | 218.9 | 1.000 | .681 | 119.9 |
| 2.00 | 150.00 | 2583 | 2053.7 | 19.201 | 1.2128 | .5899 | 748 | .00054 | 1.102 | 219.7 | 1.009 | .743 | 130.9 |
| 10.00 | 30.00 | 1932 | 1679.7 | 19.201 | 1.2281 | .5572 | 618 | .00042 | 2.156 | 261.9 | 2.217 | 1.266 | 222.9 |
| 20.00 | 15.00 | 1696 | 1549.7 | 19.201 | 1.2371 | .5400 | 567 | .00038 | 2.541 | 277.9 | 3.512 | 1.403 | 247.0 |
| 20.41 | 14.70 | 1689 | 1546.1 | 19.201 | 1.2374 | .5395 | 565 | .00038 | 2.552 | 278.3 | 3.561 | 1.406 | 247.6 |
| 40.00 | 7.50 | 1481 | 1435.9 | 19.201 | 1.2476 | .5215 | 517 | .00034 | 2.919 | 291.3 | 5.691 | 1.512 | 266.3 |
| 40.83 | 7.35 | 1475 | 1432.8 | 19.201 | 1.2479 | .5209 | 516 | .00034 | 2.930 | 291.7 | 5.774 | 1.515 | 266.8 |
| 80.00 | 3.75 | 1287 | 1336.7 | 19.201 | 1.2598 | .5019 | 470 | .00030 | 3.300 | 302.6 | 9.341 | 1.602 | 282.0 |
| 100.00 | 3.00 | 1229 | 1307.7 | 19.201 | 1.2640 | .4956 | 455 | .00028 | 3.425 | 305.8 | 10.974 | 1.627 | 286.4 |
| 200.00 | 1.50 | 1060 | 1225.6 | 19.201 | 1.2780 | .4758 | 410 | .00025 | 3.823 | 314.6 | 18.161 | 1.696 | 298.6 |
| 300.00 | 1.00 | 970 | 1183.1 | 19.201 | 1.2864 | .4649 | 385 | .00023 | 4.066 | 319.1 | 24.414 | 1.731 | 304.8 |
| 500.00 | .60 | 864 | 1134.6 | 19.201 | 1.2970 | .4519 | 355 | .00021 | 4.386 | 324.1 | 35.461 | 1.770 | 311.6 |
| 800.00 | .37 | 775 | 1094.8 | 19.201 | 1.3066 | .4410 | 328 | .00019 | 4.697 | 328.1 | 49.995 | 1.801 | 317.1 |
| 1000.00 | .30 | 735 | 1077.4 | 19.201 | 1.3110 | .4363 | 315 | .00018 | 4.850 | 329.9 | 58.846 | 1.815 | 319.5 |
| 1500.00 | .20 | 667 | 1047.9 | 19.201 | 1.3185 | .4284 | 293 | .00016 | 5.140 | 332.8 | 79.117 | 1.837 | 323.5 |

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(b) 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, M | Isentropic exponent, γ | Specific heat, $c_p$, cal/(g)(°K) | Absolute viscosity, μ, micropoises | Thermal conductivity, k, cal/(sec)(cm)(°K) | Mach number, M, | Specific impulse, $I_{vac}$, (lb)(sec)/lb | Area ratio, ε | Thrust coefficient, $C_F$ | Specific impulse, $I_s$, (lb)(sec)/lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 1.00, PERCENT FUEL = 41.51, O/F = 1.409 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2928 | 2185.7 | 19.542 | 1.2072 | 0.5924 | 817 | 0.00059 | | | | | |
| 1.05 | 285.71 | 2904 | 2171.3 | 19.542 | 1.2075 | .5917 | 813 | .00058 | 0.285 | 397.5 | 2.172 | 0.203 | 35.5 |
| 1.60 | 187.50 | 2700 | 2051.3 | 19.542 | 1.2104 | .5849 | 775 | .00055 | .899 | 228.6 | 1.010 | .618 | 108.2 |
| 1.78 | 168.67 | 2650 | 2022.5 | 19.542 | 1.2112 | .5831 | 766 | .00054 | 1.000 | 217.6 | 1.000 | .681 | 119.2 |
| 2.00 | 150.00 | 2597 | 1991.2 | 19.542 | 1.2121 | .5812 | 756 | .00054 | 1.102 | 218.4 | 1.009 | .743 | 130.1 |
| 10.00 | 30.00 | 1945 | 1621.7 | 19.542 | 1.2271 | .5494 | 625 | .00042 | 2.156 | 260.4 | 2.219 | 1.266 | 221.5 |
| 20.00 | 15.00 | 1707 | 1493.1 | 19.542 | 1.2360 | .5325 | 573 | .00038 | 2.541 | 276.3 | 3.516 | 1.403 | 245.5 |
| 20.41 | 14.70 | 1700 | 1489.6 | 19.542 | 1.2363 | .5320 | 571 | .00038 | 2.552 | 276.7 | 3.565 | 1.406 | 246.1 |
| 40.00 | 7.50 | 1492 | 1380.5 | 19.542 | 1.2463 | .5145 | 523 | .00034 | 2.918 | 289.6 | 5.700 | 1.515 | 264.7 |
| 40.83 | 7.35 | 1486 | 1377.4 | 19.542 | 1.2467 | .5139 | 522 | .00033 | 2.929 | 290.0 | 5.783 | 1.515 | 265.2 |
| 80.00 | 3.75 | 1298 | 1282.3 | 19.542 | 1.2584 | .4952 | 475 | .00030 | 3.299 | 300.9 | 9.360 | 1.602 | 280.4 |
| 100.00 | 3.00 | 1239 | 1253.5 | 19.542 | 1.2626 | .4890 | 460 | .00028 | 3.423 | 304.1 | 10.999 | 1.627 | 284.8 |
| 200.00 | 1.50 | 1070 | 1172.2 | 19.542 | 1.2764 | .4695 | 416 | .00025 | 3.821 | 312.9 | 18.211 | 1.697 | 297.0 |
| 300.00 | 1.00 | 979 | 1130.0 | 19.542 | 1.2849 | .4587 | 390 | .00023 | 4.063 | 317.4 | 24.489 | 1.732 | 303.1 |
| 500.00 | .60 | 872 | 1082.0 | 19.542 | 1.2955 | .4458 | 359 | .00021 | 4.382 | 322.4 | 35.585 | 1.771 | 309.9 |
| 800.00 | .37 | 783 | 1042.5 | 19.542 | 1.3051 | .4350 | 332 | .00019 | 4.692 | 326.4 | 50.188 | 1.802 | 315.4 |
| 1000.00 | .30 | 743 | 1025.2 | 19.542 | 1.3095 | .4302 | 319 | .00018 | 4.844 | 328.1 | 59.083 | 1.816 | 317.8 |
| 1500.00 | .20 | 674 | 996.0 | 19.542 | 1.3171 | .4224 | 297 | .00016 | 5.135 | 331.0 | 79.460 | 1.838 | 321.8 |
| R = 1.10, PERCENT FUEL = 39.22, O/F = 1.550 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2913 | 2066.7 | 20.113 | 1.2075 | 0.5750 | 823 | 0.00057 | | | | | |
| 1.05 | 285.71 | 2889 | 2052.7 | 20.113 | 1.2078 | .5743 | 818 | .00057 | 0.285 | 390.9 | 2.172 | 0.203 | 34.9 |
| 1.60 | 187.50 | 2686 | 1936.8 | 20.113 | 1.2107 | .5677 | 780 | .00054 | .899 | 214.9 | 1.010 | .618 | 106.3 |
| 1.78 | 168.65 | 2637 | 1908.9 | 20.113 | 1.2115 | .5660 | 771 | .00053 | 1.000 | 213.9 | 1.000 | .681 | 117.2 |
| 2.00 | 150.00 | 2583 | 1878.7 | 20.113 | 1.2123 | .5641 | 761 | .00052 | 1.102 | 214.7 | 1.009 | .743 | 127.9 |
| 10.00 | 30.00 | 1934 | 1521.6 | 20.113 | 1.2274 | .5332 | 629 | .00041 | 2.156 | 256.0 | 2.218 | 1.266 | 217.8 |
| 20.00 | 15.00 | 1697 | 1397.4 | 20.113 | 1.2363 | .5169 | 577 | .00037 | 2.541 | 271.6 | 3.514 | 1.403 | 241.3 |
| 20.41 | 14.70 | 1691 | 1394.0 | 20.113 | 1.2366 | .5164 | 575 | .00037 | 2.552 | 272.0 | 3.564 | 1.406 | 241.9 |
| 40.00 | 7.50 | 1483 | 1288.6 | 20.113 | 1.2466 | .4994 | 526 | .00033 | 2.919 | 284.7 | 5.697 | 1.512 | 260.2 |
| 40.83 | 7.35 | 1477 | 1285.6 | 20.113 | 1.2470 | .4988 | 525 | .00033 | 2.930 | 285.1 | 5.780 | 1.515 | 260.7 |
| 80.00 | 3.75 | 1290 | 1193.7 | 20.113 | 1.2587 | .4808 | 478 | .00029 | 3.299 | 295.7 | 9.354 | 1.602 | 275.6 |
| 100.00 | 3.00 | 1232 | 1166.0 | 20.113 | 1.2628 | .4748 | 463 | .00028 | 3.424 | 298.9 | 10.992 | 1.627 | 280.0 |
| 200.00 | 1.50 | 1063 | 1087.5 | 20.113 | 1.2766 | .4559 | 418 | .00024 | 3.822 | 307.6 | 18.199 | 1.697 | 291.9 |
| 300.00 | 1.00 | 973 | 1046.7 | 20.113 | 1.2850 | .4455 | 393 | .00022 | 4.064 | 312.0 | 24.472 | 1.732 | 297.9 |
| 500.00 | .60 | 867 | 1000.3 | 20.113 | 1.2956 | .4330 | 362 | .00020 | 4.383 | 316.9 | 35.559 | 1.771 | 304.6 |
| 800.00 | .37 | 778 | 962.2 | 20.113 | 1.3052 | .4225 | 334 | .00018 | 4.693 | 320.8 | 50.151 | 1.802 | 310.0 |
| 1000.00 | .30 | 738 | 945.4 | 20.113 | 1.3096 | .4179 | 322 | .00017 | 4.846 | 322.5 | 59.040 | 1.815 | 312.4 |
| 1500.00 | .20 | 670 | 917.3 | 20.113 | 1.3172 | .4103 | 299 | .00016 | 5.135 | 325.4 | 79.401 | 1.838 | 316.3 |
| R = 1.20, PERCENT FUEL = 37.16, O/F = 1.691 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2871 | 1960.2 | 20.593 | 1.2087 | 0.5589 | 822 | 0.00056 | | | | | |
| 1.05 | 285.71 | 2847 | 1946.7 | 20.593 | 1.2090 | .5582 | 816 | .00055 | 0.285 | 383.5 | 2.173 | 0.203 | 34.2 |
| 1.60 | 187.50 | 2646 | 1835.1 | 20.593 | 1.2120 | .5517 | 779 | .00052 | .899 | 210.8 | 1.010 | .618 | 104.3 |
| 1.78 | 168.57 | 2597 | 1808.2 | 20.593 | 1.2128 | .5500 | 770 | .00052 | 1.000 | 209.8 | 1.000 | .681 | 115.0 |
| 2.00 | 150.00 | 2545 | 1779.2 | 20.593 | 1.2136 | .5483 | 760 | .00051 | 1.102 | 210.6 | 1.009 | .744 | 125.5 |
| 10.00 | 30.00 | 1902 | 1435.9 | 20.593 | 1.2291 | .5177 | 627 | .00040 | 2.156 | 251.0 | 2.215 | 1.266 | 213.6 |
| 20.00 | 15.00 | 1668 | 1316.6 | 20.593 | 1.2381 | .5019 | 575 | .00036 | 2.541 | 266.2 | 3.507 | 1.402 | 236.6 |
| 20.41 | 14.70 | 1662 | 1313.5 | 20.593 | 1.2383 | .5014 | 573 | .00036 | 2.553 | 266.6 | 3.557 | 1.406 | 237.2 |
| 40.00 | 7.50 | 1457 | 1212.2 | 20.593 | 1.2486 | .4846 | 524 | .00032 | 2.920 | 279.1 | 5.682 | 1.512 | 255.1 |
| 40.83 | 7.35 | 1451 | 1209.4 | 20.593 | 1.2490 | .4841 | 523 | .00032 | 2.931 | 279.4 | 5.765 | 1.515 | 255.6 |
| 80.00 | 3.75 | 1265 | 1121.3 | 20.593 | 1.2607 | .4667 | 476 | .00028 | 3.301 | 289.8 | 9.322 | 1.601 | 270.2 |
| 100.00 | 3.00 | 1208 | 1094.7 | 20.593 | 1.2649 | .4608 | 461 | .00027 | 3.426 | 292.9 | 10.952 | 1.626 | 274.4 |
| 200.00 | 1.50 | 1042 | 1019.5 | 20.593 | 1.2787 | .4427 | 416 | .00023 | 3.826 | 301.4 | 18.119 | 1.695 | 288.1 |
| 300.00 | 1.00 | 953 | 980.6 | 20.593 | 1.2870 | .4327 | 391 | .00022 | 4.069 | 305.7 | 24.354 | 1.730 | 292.0 |
| 500.00 | .60 | 849 | 936.2 | 20.593 | 1.2976 | .4207 | 360 | .00019 | 4.390 | 310.4 | 35.368 | 1.769 | 298.5 |
| 800.00 | .37 | 761 | 899.7 | 20.593 | 1.3071 | .4107 | 332 | .00018 | 4.701 | 314.3 | 49.859 | 1.808 | 303.8 |
| 1000.00 | .30 | 722 | 883.8 | 20.593 | 1.3114 | .4064 | 319 | .00017 | 4.855 | 315.9 | 58.683 | 1.814 | 306.0 |
| 1500.00 | .20 | 655 | 856.8 | 20.593 | 1.3189 | .3991 | 297 | .00015 | 5.145 | 318.7 | 78.894 | 1.836 | 309.8 |
| R = 1.50, PERCENT FUEL = 32.12, O/F = 2.114 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2728 | 1698.4 | 21.784 | 1.2133 | 0.5189 | 809 | 0.00051 | | | | | |
| 1.05 | 285.71 | 2705 | 1686.3 | 21.784 | 1.2137 | .5182 | 805 | .00051 | 0.284 | 363.4 | 2.176 | 0.203 | 32.4 |
| 1.60 | 187.50 | 2510 | 1586.2 | 21.784 | 1.2168 | .5120 | 767 | .00048 | .898 | 199.6 | 1.010 | .619 | 98.8 |
| 1.78 | 168.29 | 2462 | 1561.7 | 21.784 | 1.2177 | .5103 | 757 | .00047 | 1.000 | 198.7 | 1.000 | .683 | 109.1 |
| 2.00 | 150.00 | 2412 | 1536.1 | 21.784 | 1.2186 | .5085 | 747 | .00046 | 1.100 | 199.4 | 1.009 | .744 | 118.9 |
| 10.00 | 30.00 | 1792 | 1229.3 | 21.784 | 1.2355 | .4786 | 614 | .00036 | 2.155 | 237.2 | 2.204 | 1.265 | 202.0 |
| 20.00 | 15.00 | 1567 | 1123.2 | 21.784 | 1.2449 | .4638 | 561 | .00032 | 2.543 | 251.5 | 3.481 | 1.401 | 223.7 |
| 20.41 | 14.70 | 1561 | 1120.3 | 21.784 | 1.2452 | .4633 | 560 | .00032 | 2.554 | 251.9 | 3.530 | 1.404 | 224.3 |
| 40.00 | 7.50 | 1364 | 1030.6 | 21.784 | 1.2560 | .4476 | 511 | .00029 | 2.923 | 263.5 | 5.625 | 1.509 | 241.1 |
| 40.83 | 7.35 | 1358 | 1028.1 | 21.784 | 1.2564 | .4471 | 509 | .00029 | 2.935 | 263.8 | 5.706 | 1.512 | 241.5 |
| 80.00 | 3.75 | 1181 | 950.3 | 21.784 | 1.2683 | .4312 | 463 | .00025 | 3.309 | 273.5 | 9.203 | 1.598 | 255.1 |
| 100.00 | 3.00 | 1126 | 926.8 | 21.784 | 1.2726 | .4258 | 448 | .00024 | 3.435 | 276.4 | 10.802 | 1.623 | 259.1 |
| 200.00 | 1.50 | 968 | 860.7 | 21.784 | 1.2864 | .4097 | 403 | .00021 | 3.840 | 284.2 | 17.821 | 1.691 | 270.0 |
| 300.00 | 1.00 | 884 | 826.5 | 21.784 | 1.2946 | .4008 | 378 | .00019 | 4.088 | 288.2 | 23.916 | 1.725 | 275.5 |
| 500.00 | .60 | 785 | 787.6 | 21.784 | 1.3050 | .3904 | 347 | .00018 | 4.414 | 292.6 | 34.666 | 1.763 | 281.5 |
| 800.00 | .37 | 703 | 755.7 | 21.784 | 1.3140 | .3817 | 320 | .00016 | 4.731 | 296.1 | 48.787 | 1.793 | 286.4 |
| 1000.00 | .30 | 666 | 741.8 | 21.784 | 1.3182 | .3779 | 308 | .00015 | 4.887 | 297.7 | 57.379 | 1.807 | 288.5 |
| 1500.00 | .20 | 604 | 718.3 | 21.784 | 1.3254 | .3715 | 285 | .00014 | 5.183 | 300.2 | 77.038 | 1.829 | 292.0 |

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TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(b) 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, $\mathcal{M}$ | Isentropic exponent, $\gamma$ | Specific heat, $c_p$, cal/(g)(°K) | Absolute viscosity, $\mu$, micropoises | Thermal conductivity, k, cal/(sec)(cm)(°K) | Mach number, M | Specific impulse, $I_{vac}$, (lb)(sec)/lb | Area ratio, $\epsilon$ | Thrust coefficient, $C_F$ | Specific impulse, I, (lb)(sec)/lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 2.00, PERCENT FUEL = 26.19, O/F = 2.818 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2515 | 1391.0 | 23.307 | 1.2208 | 0.4714 | 783 | 0.00045 | | | | | |
| 1.05 | 285.71 | 2493 | 1380.6 | 23.307 | 1.2212 | .4707 | 778 | .00045 | 0.283 | 337.3 | 2.181 | 0.204 | 30.1 |
| 1.60 | 187.50 | 2309 | 1294.4 | 23.307 | 1.2249 | .4643 | 740 | .00042 | .895 | 185.1 | 1.010 | .620 | 91.7 |
| 1.79 | 167.81 | 2262 | 1272.7 | 23.307 | 1.2260 | .4626 | 730 | .00042 | 1.000 | 184.2 | 1.000 | .686 | 101.4 |
| 2.00 | 150.00 | 2216 | 1251.3 | 23.307 | 1.2270 | .4608 | 720 | .00041 | 1.098 | 184.8 | 1.088 | .745 | 110.2 |
| 10.00 | 30.00 | 1630 | 989.1 | 23.307 | 1.2455 | .4325 | 588 | .00032 | 2.155 | 219.3 | 2.186 | 1.264 | 187.0 |
| 20.00 | 15.00 | 1419 | 899.1 | 23.307 | 1.2558 | .4185 | 536 | .00028 | 2.545 | 232.3 | 3.440 | 1.399 | 206.9 |
| 20.41 | 14.70 | 1413 | 896.6 | 23.307 | 1.2562 | .4181 | 534 | .00028 | 2.556 | 232.7 | 3.487 | 1.402 | 207.4 |
| 40.00 | 7.50 | 1229 | 821.0 | 23.307 | 1.2675 | .4042 | 486 | .00025 | 2.930 | 243.2 | 5.535 | 1.506 | 222.7 |
| 40.83 | 7.35 | 1224 | 818.8 | 23.307 | 1.2677 | .4038 | 485 | .00025 | 2.942 | 243.5 | 5.615 | 1.509 | 223.1 |
| 80.00 | 3.75 | 1059 | 753.5 | 23.307 | 1.2802 | .3896 | 439 | .00022 | 3.322 | 252.2 | 9.020 | 1.592 | 235.5 |
| 100.00 | 3.00 | 1008 | 733.8 | 23.307 | 1.2845 | .3850 | 424 | .00021 | 3.450 | 254.8 | 10.572 | 1.617 | 239.1 |
| 200.00 | 1.50 | 862 | 678.6 | 23.307 | 1.2980 | .3714 | 380 | .00018 | 3.864 | 261.8 | 17.371 | 1.683 | 249.0 |
| 300.00 | 1.00 | 785 | 650.2 | 23.307 | 1.3061 | .3638 | 356 | .00017 | 4.117 | 265.4 | 25.257 | 1.717 | 253.9 |
| 500.00 | .60 | 695 | 618.0 | 23.307 | 1.3159 | .3552 | 326 | .00015 | 4.452 | 269.3 | 33.615 | 1.753 | 259.3 |
| 800.00 | .37 | 620 | 591.6 | 23.307 | 1.3247 | .3478 | 299 | .00014 | 4.777 | 272.5 | 47.191 | 1.783 | 263.7 |
| 1000.00 | .30 | 587 | 580.2 | 23.307 | 1.3287 | .3447 | 287 | .00013 | 4.938 | 273.8 | 55.438 | 1.796 | 265.6 |
| 1500.00 | .20 | 531 | 560.9 | 23.307 | 1.3354 | .3394 | 266 | .00012 | 5.242 | 276.1 | 74.282 | 1.817 | 268.8 |
| R = 3.00, PERCENT FUEL = 19.13, O/F = 4.227 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 2163 | 1024.7 | 25.320 | 1.2354 | 0.4119 | 727 | 0.00037 | | | | | |
| 1.05 | 285.71 | 2143 | 1016.4 | 25.320 | 1.2359 | .4112 | 722 | .00037 | 0.282 | 300.0 | 2.189 | 0.204 | 26.8 |
| 1.60 | 187.50 | 1976 | 948.4 | 25.320 | 1.2402 | .4053 | 685 | .00034 | .891 | 164.3 | 1.011 | .622 | 81.5 |
| 1.80 | 166.92 | 1932 | 930.6 | 25.320 | 1.2415 | .4035 | 675 | .00034 | 1.000 | 163.4 | 1.000 | .691 | 90.5 |
| 2.00 | 150.00 | 1892 | 914.5 | 25.320 | 1.2427 | .4019 | 665 | .00033 | 1.093 | 163.9 | 1.007 | .747 | 97.9 |
| 10.00 | 30.00 | 1368 | 710.1 | 25.320 | 1.2641 | .3757 | 536 | .00025 | 2.154 | 193.7 | 2.154 | 1.263 | 165.5 |
| 20.00 | 15.00 | 1180 | 640.9 | 25.320 | 1.2751 | .3638 | 485 | .00022 | 2.549 | 204.8 | 3.347 | 1.395 | 182.8 |
| 20.41 | 14.70 | 1175 | 639.0 | 25.320 | 1.2754 | .3634 | 484 | .00022 | 2.561 | 205.1 | 3.413 | 1.398 | 183.2 |
| 40.00 | 7.50 | 1014 | 581.3 | 25.320 | 1.2874 | .3515 | 438 | .00020 | 2.942 | 214.0 | 5.381 | 1.499 | 196.4 |
| 40.83 | 7.35 | 1009 | 579.6 | 25.320 | 1.2878 | .3512 | 437 | .00020 | 2.954 | 214.3 | 5.457 | 1.502 | 196.8 |
| 80.00 | 3.75 | 866 | 530.2 | 25.320 | 1.3003 | .3398 | 393 | .00017 | 3.345 | 221.7 | 8.707 | 1.583 | 207.4 |
| 100.00 | 3.00 | 822 | 515.4 | 25.320 | 1.3045 | .3361 | 379 | .00016 | 3.478 | 223.8 | 10.183 | 1.607 | 210.5 |
| 200.00 | 1.50 | 698 | 474.2 | 25.320 | 1.3180 | .3253 | 337 | .00014 | 3.906 | 229.8 | 16.615 | 1.671 | 218.9 |
| 300.00 | 1.00 | 632 | 453.0 | 25.320 | 1.3259 | .3193 | 314 | .00013 | 4.169 | 232.7 | 22.157 | 1.702 | 223.0 |
| 500.00 | .60 | 557 | 429.2 | 25.320 | 1.3354 | .3125 | 286 | .00012 | 4.518 | 236.0 | 31.869 | 1.737 | 227.6 |
| 800.00 | .37 | 494 | 409.9 | 25.320 | 1.3435 | .3070 | 261 | .00011 | 4.858 | 238.6 | 44.547 | 1.765 | 231.3 |
| 1000.00 | .30 | 467 | 401.4 | 25.320 | 1.3473 | .3044 | 250 | .00010 | 5.026 | 239.7 | 52.227 | 1.777 | 232.9 |
| 1500.00 | .20 | 420 | 387.3 | 25.320 | 1.3533 | .3006 | 230 | .00009 | 5.345 | 241.6 | 69.732 | 1.797 | 235.5 |
| R = 4.00, PERCENT FUEL = 15.07, O/F = 5.636 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 1875 | 814.0 | 26.561 | 1.2489 | 0.3754 | 672 | 0.00031 | | | | | |
| 1.05 | 285.71 | 1857 | 807.1 | 26.561 | 1.2494 | .3747 | 667 | .00031 | 0.280 | 272.6 | 2.198 | 0.205 | 24.3 |
| 1.60 | 187.50 | 1706 | 751.0 | 26.561 | 1.2545 | .3688 | 631 | .00029 | .887 | 149.0 | 1.012 | .624 | 74.0 |
| 1.81 | 166.11 | 1664 | 735.8 | 26.561 | 1.2559 | .3672 | 621 | .00029 | 1.000 | 148.2 | 1.000 | .695 | 82.5 |
| 2.00 | 150.00 | 1630 | 723.2 | 26.561 | 1.2571 | .3658 | 612 | .00028 | 1.088 | 148.6 | 1.007 | .749 | 88.9 |
| 10.00 | 30.00 | 1160 | 556.5 | 26.561 | 1.2804 | .3417 | 488 | .00021 | 2.153 | 174.9 | 2.126 | 1.262 | 149.7 |
| 20.00 | 15.00 | 994 | 500.8 | 26.561 | 1.2923 | .3308 | 440 | .00019 | 2.553 | 184.7 | 3.304 | 1.392 | 165.1 |
| 20.41 | 14.70 | 989 | 499.2 | 26.561 | 1.2926 | .3305 | 439 | .00019 | 2.565 | 184.9 | 3.349 | 1.395 | 165.5 |
| 40.00 | 7.50 | 848 | 453.1 | 26.561 | 1.3048 | .3203 | 395 | .00016 | 2.953 | 192.8 | 5.250 | 1.494 | 177.2 |
| 40.83 | 7.35 | 844 | 451.8 | 26.561 | 1.3052 | .3200 | 393 | .00016 | 2.965 | 193.0 | 5.324 | 1.497 | 177.5 |
| 80.00 | 3.75 | 719 | 412.5 | 26.561 | 1.3182 | .3100 | 352 | .00014 | 3.365 | 199.4 | 8.445 | 1.576 | 186.9 |
| 100.00 | 3.00 | 681 | 400.9 | 26.561 | 1.3225 | .3068 | 338 | .00014 | 3.502 | 201.3 | 9.857 | 1.598 | 189.6 |
| 200.00 | 1.50 | 574 | 368.4 | 26.561 | 1.3360 | .2975 | 299 | .00012 | 3.942 | 206.4 | 15.988 | 1.660 | 196.9 |
| 300.00 | 1.00 | 518 | 351.9 | 26.561 | 1.3434 | .2927 | 277 | .00011 | 4.215 | 208.9 | 21.247 | 1.690 | 200.5 |
| 500.00 | .60 | 454 | 333.3 | 26.561 | 1.3525 | .2870 | 251 | .00010 | 4.576 | 211.7 | 30.433 | 1.724 | 204.5 |
| 800.00 | .37 | 401 | 318.3 | 26.561 | 1.3593 | .2830 | 228 | .00009 | 4.931 | 214.0 | 42.383 | 1.751 | 207.7 |
| 1000.00 | .30 | 378 | 311.8 | 26.561 | 1.3619 | .2815 | 217 | .00008 | 5.107 | 214.9 | 49.612 | 1.762 | 209.0 |
| 1500.00 | .20 | 339 | 301.0 | 26.561 | 1.3659 | .2793 | 199 | .00007 | 5.441 | 216.5 | 66.074 | 1.781 | 211.3 |
| R = 5.00, PERCENT FUEL = 12.43, O/F = 7.046 | | | | | | | | | | | | | |
| 1.00 | 300.00 | 1640 | 677.0 | 27.397 | 1.2611 | 0.3504 | 621 | 0.00027 | | | | | |
| 1.05 | 285.71 | 1624 | 671.3 | 27.397 | 1.2617 | .3497 | 617 | .00027 | 0.279 | 251.0 | 2.205 | 0.206 | 22.4 |
| 1.60 | 187.50 | 1487 | 623.8 | 27.397 | 1.2671 | .3441 | 582 | .00025 | .885 | 137.0 | 1.013 | .625 | 68.1 |
| 1.81 | 165.38 | 1448 | 610.4 | 27.397 | 1.2688 | .3424 | 572 | .00025 | 1.000 | 136.1 | 1.000 | .699 | 76.1 |
| 2.00 | 150.00 | 1418 | 600.3 | 27.397 | 1.2701 | .3410 | 564 | .00024 | 1.084 | 136.5 | 1.006 | .751 | 81.7 |
| 10.00 | 30.00 | 995 | 460.6 | 27.397 | 1.2949 | .3185 | 446 | .00018 | 2.152 | 160.1 | 2.103 | 1.261 | 137.2 |
| 20.00 | 15.00 | 848 | 414.3 | 27.397 | 1.3071 | .3087 | 400 | .00016 | 2.557 | 168.9 | 3.252 | 1.389 | 151.2 |
| 20.41 | 14.70 | 844 | 413.0 | 27.397 | 1.3075 | .3084 | 399 | .00016 | 2.568 | 169.1 | 3.295 | 1.392 | 151.6 |
| 40.00 | 7.50 | 719 | 375.0 | 27.397 | 1.3204 | .2989 | 357 | .00014 | 2.963 | 176.1 | 5.140 | 1.489 | 162.1 |
| 40.83 | 7.35 | 715 | 373.9 | 27.397 | 1.3208 | .2987 | 355 | .00014 | 2.975 | 176.3 | 5.211 | 1.492 | 162.4 |
| 80.00 | 3.75 | 606 | 341.8 | 27.397 | 1.3341 | .2896 | 316 | .00012 | 3.382 | 182.0 | 8.225 | 1.569 | 170.8 |
| 100.00 | 3.00 | 573 | 332.2 | 27.397 | 1.3385 | .2868 | 303 | .00011 | 3.522 | 183.6 | 9.584 | 1.591 | 173.2 |
| 200.00 | 1.50 | 479 | 305.8 | 27.397 | 1.3515 | .2789 | 266 | .00010 | 3.975 | 188.1 | 15.466 | 1.651 | 179.7 |
| 300.00 | 1.00 | 431 | 292.5 | 27.397 | 1.3584 | .2749 | 245 | .00009 | 4.255 | 190.4 | 20.494 | 1.680 | 182.9 |
| 500.00 | .60 | 376 | 277.5 | 27.397 | 1.3652 | .2711 | 221 | .00008 | 4.630 | 192.8 | 29.258 | 1.713 | 186.4 |
| 800.00 | .37 | 332 | 265.5 | 27.397 | 1.3699 | .2686 | 200 | .00007 | 4.998 | 194.8 | 40.647 | 1.738 | 189.2 |
| 1000.00 | .30 | 312 | 260.3 | 27.397 | 1.3717 | .2677 | 190 | .00007 | 5.180 | 195.6 | 47.533 | 1.749 | 190.4 |
| 1500.00 | .20 | 280 | 251.6 | 27.397 | 1.3741 | .2664 | 174 | .00006 | 5.525 | 197.0 | 63.206 | 1.768 | 192.4 |

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(c) 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, $\mathcal{M}$ | Isentropic exponent, γ | Specific heat, $c_p$, cal/(g)(°K) | Absolute viscosity, μ, micropoises | Thermal conductivity, k, cal/(sec)(cm)(°K) | Mach number, M | Specific impulse, $I_{vac}$, (lb)(sec)/lb | Area ratio, ε | Thrust coefficient, $C_F$ | Specific impulse, I, (lb)(sec)/lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 0.40, PERCENT FUEL = 63.95, O/F = 0.564 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 1349 | 3350.2 | 13.316 | 1.2956 | 0.6540 | 453 | 0.00038 | | | | | |
| 1.05 | 571.43 | 1334 | 3340.4 | 13.316 | 1.2966 | .6524 | 450 | .00038 | 0.275 | 326.2 | 2.226 | 0.208 | 29.1 |
| 1.60 | 375.00 | 1210 | 3260.5 | 13.316 | 1.3052 | .6381 | 421 | .00035 | .872 | 177.3 | 1.015 | .630 | 88.3 |
| 1.84 | 326.41 | 1171 | 3235.9 | 13.316 | 1.3082 | .6335 | 412 | .00034 | 1.000 | 176.0 | 1.000 | .712 | 99.7 |
| 2.00 | 300.00 | 1148 | 3221.3 | 13.316 | 1.3100 | .6307 | 406 | .00033 | 1.072 | 176.3 | 1.004 | .756 | 105.9 |
| 10.00 | 60.00 | 772 | 2993.1 | 13.316 | 1.3421 | .5855 | 309 | .00024 | 2.149 | 204.7 | 2.030 | 1.258 | 176.3 |
| 20.00 | 30.00 | 646 | 2919.9 | 13.316 | 1.3530 | .5720 | 272 | .00021 | 2.569 | 215.2 | 3.093 | 1.381 | 193.5 |
| 20.41 | 29.39 | 643 | 2917.9 | 13.316 | 1.3532 | .5717 | 271 | .00021 | 2.581 | 215.4 | 3.133 | 1.384 | 193.9 |
| 40.00 | 15.00 | 538 | 2858.8 | 13.316 | 1.3617 | .5618 | 237 | .00018 | 2.998 | 223.7 | 4.823 | 1.476 | 206.8 |
| 40.83 | 14.70 | 535 | 2857.1 | 13.316 | 1.3619 | .5616 | 236 | .00018 | 3.011 | 223.9 | 4.888 | 1.478 | 207.1 |
| 80.00 | 7.50 | 447 | 2807.9 | 13.316 | 1.3680 | .5547 | 206 | .00015 | 3.447 | 230.6 | 7.629 | 1.550 | 217.2 |
| 100.00 | 6.00 | 421 | 2793.5 | 13.316 | 1.3696 | .5530 | 196 | .00015 | 3.597 | 232.5 | 8.863 | 1.571 | 220.1 |
| 200.00 | 3.00 | 349 | 2753.8 | 13.316 | 1.3745 | .5478 | 168 | .00012 | 4.083 | 237.7 | 14.191 | 1.626 | 227.8 |
| 300.00 | 2.00 | 312 | 2733.8 | 13.316 | 1.3767 | .5454 | 154 | .00011 | 4.383 | 240.3 | 18.744 | 1.653 | 231.6 |
| 500.00 | 1.20 | 271 | 2711.6 | 13.316 | 1.3793 | .5427 | 136 | .00010 | 4.781 | 243.2 | 26.680 | 1.682 | 235.7 |
| 800.00 | .75 | 238 | 2693.7 | 13.316 | 1.3842 | .5377 | 122 | .00009 | 5.163 | 245.5 | 36.978 | 1.705 | 239.0 |
| 1000.00 | .60 | 224 | 2686.0 | 13.316 | 1.3874 | .5344 | 115 | .00008 | 5.351 | 246.4 | 43.187 | 1.715 | 240.4 |
| 1500.00 | .40 | 200 | 2673.2 | 13.316 | 1.3925 | .5294 | 104 | .00007 | 5.708 | 248.0 | 57.266 | 1.732 | 242.7 |
| R = 0.50, PERCENT FUEL = 58.67, O/F = 0.705 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 1784 | 3075.9 | 14.516 | 1.2618 | 0.6602 | 555 | 0.00046 | | | | | |
| 1.05 | 571.43 | 1766 | 3064.0 | 14.516 | 1.2626 | .6585 | 551 | .00046 | 0.279 | 359.6 | 2.206 | 0.206 | 32.1 |
| 1.60 | 375.00 | 1617 | 2966.5 | 14.516 | 1.2696 | .6448 | 520 | .00042 | .882 | 196.3 | 1.013 | .626 | 97.5 |
| 1.82 | 330.41 | 1574 | 2938.9 | 14.516 | 1.2718 | .6407 | 511 | .00041 | 1.000 | 195.0 | 1.000 | .700 | 109.2 |
| 2.00 | 300.00 | 1542 | 2918.3 | 14.516 | 1.2735 | .6375 | 503 | .00041 | 1.083 | 195.5 | 1.006 | .751 | 117.1 |
| 10.00 | 60.00 | 1075 | 2632.4 | 14.516 | 1.3057 | .5847 | 394 | .00030 | 2.149 | 229.0 | 2.090 | 1.260 | 196.4 |
| 20.00 | 30.00 | 911 | 2538.4 | 14.516 | 1.3200 | .5646 | 351 | .00026 | 2.555 | 241.3 | 3.218 | 1.387 | 216.3 |
| 20.41 | 29.39 | 906 | 2535.8 | 14.516 | 1.3205 | .5641 | 350 | .00026 | 2.567 | 241.7 | 3.261 | 1.390 | 216.8 |
| 40.00 | 15.00 | 768 | 2458.9 | 14.516 | 1.3335 | .5474 | 311 | .00022 | 2.967 | 251.4 | 5.065 | 1.486 | 231.7 |
| 40.83 | 14.70 | 764 | 2456.7 | 14.516 | 1.3339 | .5469 | 310 | .00022 | 2.979 | 251.7 | 5.134 | 1.489 | 232.1 |
| 80.00 | 7.50 | 644 | 2592.0 | 14.516 | 1.3450 | .5337 | 274 | .00019 | 3.396 | 259.7 | 8.071 | 1.565 | 243.9 |
| 100.00 | 6.00 | 608 | 2572.9 | 14.516 | 1.3482 | .5301 | 262 | .00018 | 3.539 | 262.0 | 9.396 | 1.586 | 247.3 |
| 200.00 | 3.00 | 508 | 2520.1 | 14.516 | 1.3571 | .5202 | 228 | .00016 | 4.003 | 268.2 | 15.126 | 1.645 | 256.4 |
| 300.00 | 2.00 | 456 | 2293.4 | 14.516 | 1.3609 | .5162 | 210 | .00014 | 4.292 | 271.3 | 20.033 | 1.674 | 260.9 |
| 500.00 | 1.20 | 398 | 2263.5 | 14.516 | 1.3649 | .5121 | 188 | .00013 | 4.673 | 274.8 | 28.602 | 1.705 | 265.9 |
| 800.00 | .75 | 351 | 2239.5 | 14.516 | 1.3682 | .5087 | 169 | .00012 | 5.045 | 277.5 | 39.757 | 1.730 | 269.8 |
| 1000.00 | .60 | 330 | 2229.1 | 14.516 | 1.3697 | .5072 | 161 | .00011 | 5.228 | 278.7 | 46.508 | 1.741 | 271.4 |
| 1500.00 | .40 | 296 | 2211.7 | 14.516 | 1.3715 | .5054 | 146 | .00010 | 5.576 | 280.6 | 61.884 | 1.759 | 274.2 |
| R = 0.60, PERCENT FUEL = 54.19, O/F = 0.845 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2171 | 2843.5 | 15.710 | 1.2352 | 0.6700 | 640 | 0.00053 | | | | | |
| 1.05 | 571.43 | 2151 | 2830.1 | 15.711 | 1.2361 | .6675 | 636 | .00052 | 0.282 | 381.6 | 2.191 | 0.205 | 34.1 |
| 1.60 | 375.00 | 1983 | 2720.1 | 15.714 | 1.2432 | .6486 | 603 | .00049 | .890 | 208.9 | 1.012 | .622 | 103.6 |
| 1.80 | 333.38 | 1938 | 2690.9 | 15.715 | 1.2451 | .6440 | 594 | .00048 | 1.000 | 207.7 | 1.000 | .692 | 115.2 |
| 2.00 | 300.00 | 1898 | 2665.3 | 15.715 | 1.2469 | .6399 | 586 | .00047 | 1.091 | 208.4 | 1.007 | .748 | 124.5 |
| 10.00 | 60.00 | 1361 | 2536.0 | 15.716 | 1.2746 | .5870 | 469 | .00035 | 2.151 | 245.8 | 2.140 | 1.262 | 210.1 |
| 20.00 | 30.00 | 1169 | 2225.3 | 15.716 | 1.2883 | .5650 | 422 | .00031 | 2.548 | 259.7 | 3.330 | 1.393 | 231.9 |
| 20.41 | 29.39 | 1164 | 2222.2 | 15.716 | 1.2887 | .5643 | 421 | .00030 | 2.560 | 260.0 | 3.375 | 1.396 | 232.5 |
| 40.00 | 15.00 | 998 | 2130.4 | 15.716 | 1.3029 | .5439 | 378 | .00027 | 2.945 | 271.1 | 5.295 | 1.496 | 249.1 |
| 40.83 | 14.70 | 993 | 2127.9 | 15.716 | 1.3033 | .5433 | 377 | .00026 | 2.957 | 271.4 | 5.369 | 1.498 | 249.5 |
| 80.00 | 7.50 | 847 | 2049.7 | 15.716 | 1.3171 | .5252 | 337 | .00023 | 3.355 | 280.5 | 8.518 | 1.578 | 262.8 |
| 100.00 | 6.00 | 803 | 2026.5 | 15.716 | 1.3215 | .5197 | 324 | .00022 | 3.491 | 283.2 | 9.943 | 1.601 | 266.6 |
| 200.00 | 3.00 | 676 | 1961.8 | 15.716 | 1.3340 | .5050 | 286 | .00019 | 3.932 | 290.4 | 16.131 | 1.663 | 277.0 |
| 300.00 | 2.00 | 611 | 1928.8 | 15.716 | 1.3404 | .4979 | 265 | .00017 | 4.205 | 294.0 | 21.448 | 1.694 | 282.1 |
| 500.00 | 1.20 | 536 | 1891.9 | 15.716 | 1.3476 | .4902 | 239 | .00016 | 4.566 | 298.0 | 30.749 | 1.728 | 287.8 |
| 800.00 | .75 | 474 | 1861.9 | 15.716 | 1.3531 | .4845 | 217 | .00014 | 4.919 | 301.2 | 42.879 | 1.755 | 292.3 |
| 1000.00 | .60 | 447 | 1848.9 | 15.716 | 1.3552 | .4824 | 207 | .00013 | 5.094 | 302.5 | 50.228 | 1.767 | 294.2 |
| 1500.00 | .40 | 402 | 1827.1 | 15.716 | 1.3588 | .4789 | 190 | .00012 | 5.425 | 304.8 | 66.991 | 1.786 | 297.4 |
| R = 0.70, PERCENT FUEL = 50.24, O/F = 0.986 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2503 | 2644.0 | 16.876 | 1.2058 | 0.7252 | 711 | 0.00062 | | | | | |
| 1.05 | 571.43 | 2483 | 2629.7 | 16.879 | 1.2069 | .7195 | 707 | .00061 | 0.285 | 395.5 | 2.175 | 0.203 | 35.5 |
| 1.60 | 375.00 | 2309 | 2511.0 | 16.898 | 1.2167 | .6770 | 674 | .00056 | .897 | 217.4 | 1.010 | .619 | 107.6 |
| 1.78 | 336.30 | 2265 | 2481.7 | 16.901 | 1.2192 | .6680 | 665 | .00054 | 1.000 | 216.3 | 1.000 | .683 | 118.9 |
| 2.00 | 300.00 | 2219 | 2451.6 | 16.904 | 1.2216 | .6593 | 657 | .00053 | 1.099 | 217.1 | 1.009 | .744 | 129.4 |
| 10.00 | 60.00 | 1633 | 2089.3 | 16.916 | 1.2499 | .5879 | 536 | .00039 | 2.151 | 257.7 | 2.184 | 1.265 | 219.7 |
| 20.00 | 30.00 | 1418 | 1965.3 | 16.916 | 1.2619 | .5661 | 487 | .00035 | 2.542 | 272.8 | 3.428 | 1.397 | 243.0 |
| 20.41 | 29.39 | 1412 | 1961.9 | 16.916 | 1.2622 | .5655 | 486 | .00035 | 2.553 | 273.2 | 3.476 | 1.401 | 243.6 |
| 40.00 | 15.00 | 1224 | 1857.9 | 16.916 | 1.2750 | .5447 | 440 | .00030 | 2.928 | 285.5 | 5.502 | 1.504 | 261.6 |
| 40.83 | 14.70 | 1219 | 1854.9 | 16.916 | 1.2754 | .5441 | 439 | .00030 | 2.940 | 285.8 | 5.580 | 1.507 | 262.0 |
| 80.00 | 7.50 | 1051 | 1765.4 | 16.916 | 1.2899 | .5236 | 396 | .00027 | 3.323 | 295.9 | 8.936 | 1.590 | 276.5 |
| 100.00 | 6.00 | 999 | 1738.5 | 16.916 | 1.2940 | .5171 | 382 | .00025 | 3.453 | 298.9 | 10.463 | 1.614 | 280.7 |
| 200.00 | 3.00 | 851 | 1663.3 | 16.916 | 1.3083 | .4986 | 341 | .00022 | 3.872 | 307.0 | 17.127 | 1.680 | 292.1 |
| 300.00 | 2.00 | 773 | 1624.6 | 16.916 | 1.3164 | .4888 | 318 | .00020 | 4.130 | 311.1 | 22.881 | 1.712 | 297.8 |
| 500.00 | 1.20 | 683 | 1581.0 | 16.916 | 1.3257 | .4781 | 290 | .00018 | 4.472 | 315.6 | 32.983 | 1.749 | 304.1 |
| 800.00 | .75 | 608 | 1545.4 | 16.916 | 1.3334 | .4698 | 265 | .00016 | 4.805 | 319.2 | 46.201 | 1.778 | 309.2 |
| 1000.00 | .60 | 575 | 1529.9 | 16.916 | 1.3369 | .4662 | 254 | .00016 | 4.970 | 320.8 | 54.224 | 1.790 | 311.4 |
| 1500.00 | .40 | 518 | 1503.9 | 16.916 | 1.3426 | .4604 | 235 | .00014 | 5.281 | 323.4 | 72.546 | 1.811 | 315.0 |

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TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(c) 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, $\mathcal{M}$ | Isentropic exponent, $\gamma$ | Specific heat, $c_p$, cal/(g)(°K) | Absolute viscosity, $\mu$, micropoises | Thermal conductivity, k, cal/(sec)(cm)(°K) | Mach number, M | Specific impulse, $I_{vac}$, (lb)(sec)/lb | Area ratio, $\varepsilon$ | Thrust coefficient, $C_F$ | Specific impulse, I, (lb)(sec)/lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 0.80, PERCENT FUEL = 47.01, O/F = 1.127 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2760 | 2471.0 | 17.957 | 1.1740 | 0.8755 | 767 | 0.00078 | | | | | |
| 1.05 | 571.43 | 2741 | 2456.2 | 17.965 | 1.1750 | .8653 | 763 | .00077 | 0.289 | 403.0 | 2.156 | 0.201 | 35.9 |
| 1.60 | 375.00 | 2580 | 2332.4 | 18.024 | 1.1847 | .7831 | 733 | .00067 | .907 | 222.5 | 1.008 | .614 | 109.8 |
| 1.76 | 340.01 | 2542 | 2304.8 | 18.035 | 1.1872 | .7659 | 726 | .00066 | 1.000 | 221.6 | 1.000 | .673 | 120.3 |
| 2.00 | 300.00 | 2493 | 2270.1 | 18.048 | 1.1904 | .7451 | 717 | .00063 | 1.109 | 222.6 | 1.011 | .740 | 132.2 |
| 10.00 | 60.00 | 1891 | 1883.3 | 18.113 | 1.2283 | .5932 | 597 | .00044 | 2.147 | 266.1 | 2.233 | 1.265 | 226.1 |
| 20.00 | 30.00 | 1658 | 1748.5 | 18.116 | 1.2400 | .5673 | 547 | .00039 | 2.531 | 282.3 | 3.531 | 1.403 | 250.7 |
| 20.41 | 29.39 | 1652 | 1744.8 | 18.116 | 1.2403 | .5666 | 545 | .00038 | 2.542 | 282.7 | 3.581 | 1.406 | 251.4 |
| 40.00 | 15.00 | 1447 | 1630.6 | 18.116 | 1.2516 | .5458 | 498 | .00034 | 2.909 | 296.0 | 5.712 | 1.513 | 270.4 |
| 40.83 | 14.70 | 1441 | 1627.3 | 18.116 | 1.2519 | .5452 | 497 | .00034 | 2.920 | 296.3 | 5.795 | 1.516 | 270.9 |
| 80.00 | 7.50 | 1255 | 1528.0 | 18.116 | 1.2642 | .5249 | 452 | .00030 | 3.292 | 307.4 | 9.356 | 1.602 | 286.5 |
| 100.00 | 6.00 | 1197 | 1498.0 | 18.116 | 1.2685 | .5182 | 438 | .00029 | 3.418 | 310.6 | 10.986 | 1.628 | 291.0 |
| 200.00 | 3.00 | 1031 | 1413.4 | 18.116 | 1.2827 | .4977 | 394 | .00025 | 3.819 | 319.6 | 18.144 | 1.697 | 303.4 |
| 300.00 | 2.00 | 942 | 1369.5 | 18.116 | 1.2911 | .4865 | 369 | .00023 | 4.064 | 324.1 | 24.364 | 1.732 | 309.6 |
| 500.00 | 1.20 | 838 | 1319.7 | 18.116 | 1.3017 | .4733 | 340 | .00021 | 4.387 | 329.1 | 35.340 | 1.770 | 316.5 |
| 800.00 | .75 | 751 | 1278.8 | 18.116 | 1.3110 | .4624 | 313 | .00019 | 4.700 | 333.2 | 49.765 | 1.802 | 322.1 |
| 1000.00 | .60 | 712 | 1260.9 | 18.116 | 1.3153 | .4576 | 301 | .00018 | 4.855 | 335.0 | 58.545 | 1.815 | 324.5 |
| 1500.00 | .40 | 645 | 1230.8 | 18.116 | 1.3225 | .4499 | 283 | .00017 | 5.148 | 337.9 | 78.642 | 1.838 | 328.5 |
| R = 0.90, PERCENT FUEL = 44.09, O/F = 1.268 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2922 | 2319.5 | 18.893 | 1.1494 | 1.1223 | 805 | 0.00101 | | | | | |
| 1.05 | 571.43 | 2905 | 2304.6 | 18.907 | 1.1498 | 1.1114 | 802 | .00100 | 0.292 | 404.4 | 2.138 | 0.199 | 36.1 |
| 1.60 | 375.00 | 2765 | 2179.4 | 19.020 | 1.1544 | 1.0129 | 776 | .00089 | .917 | 224.2 | 1.007 | .610 | 110.4 |
| 1.74 | 343.86 | 2736 | 2154.6 | 19.041 | 1.1556 | .9919 | 770 | .00086 | 1.000 | 223.5 | 1.000 | .662 | 119.8 |
| 2.00 | 300.00 | 2690 | 2116.0 | 19.073 | 1.1578 | .9586 | 762 | .00083 | 1.120 | 224.7 | 1.013 | .736 | 133.1 |
| 10.00 | 60.00 | 2135 | 1713.6 | 19.289 | 1.2006 | .6391 | 653 | .00050 | 2.142 | 271.3 | 2.304 | 1.269 | 229.6 |
| 20.00 | 30.00 | 1896 | 1569.8 | 19.310 | 1.2181 | .5800 | 603 | .00043 | 2.512 | 288.6 | 3.674 | 1.412 | 255.4 |
| 20.41 | 29.39 | 1889 | 1565.9 | 19.310 | 1.2186 | .5788 | 602 | .00043 | 2.523 | 289.1 | 3.726 | 1.416 | 256.1 |
| 40.00 | 15.00 | 1670 | 1442.8 | 19.315 | 1.2311 | .5490 | 554 | .00038 | 2.880 | 303.3 | 5.982 | 1.527 | 276.2 |
| 40.83 | 14.70 | 1663 | 1439.3 | 19.315 | 1.2314 | .5483 | 553 | .00037 | 2.890 | 303.6 | 6.071 | 1.530 | 276.7 |
| 80.00 | 7.50 | 1462 | 1331.3 | 19.316 | 1.2426 | .5270 | 506 | .00033 | 3.252 | 315.6 | 9.869 | 1.621 | 293.2 |
| 100.00 | 6.00 | 1399 | 1298.4 | 19.316 | 1.2465 | .5203 | 491 | .00032 | 3.373 | 319.1 | 11.616 | 1.648 | 298.1 |
| 200.00 | 3.00 | 1217 | 1205.3 | 19.316 | 1.2590 | .5001 | 441 | .00028 | 3.760 | 328.9 | 19.337 | 1.721 | 311.4 |
| 300.00 | 2.00 | 1118 | 1156.6 | 19.316 | 1.2670 | .4882 | 410 | .00025 | 3.995 | 333.8 | 26.094 | 1.758 | 318.1 |
| 500.00 | 1.20 | 1003 | 1100.9 | 19.316 | 1.2774 | .4737 | 371 | .00022 | 4.301 | 339.4 | 38.086 | 1.800 | 325.6 |
| 800.00 | .75 | 904 | 1054.8 | 19.316 | 1.2872 | .4611 | 335 | .00020 | 4.597 | 343.9 | 53.938 | 1.834 | 331.7 |
| 1000.00 | .60 | 860 | 1034.6 | 19.316 | 1.2918 | .4555 | 319 | .00019 | 4.742 | 345.9 | 63.621 | 1.848 | 334.4 |
| 1500.00 | .40 | 784 | 1000.3 | 19.316 | 1.3000 | .4458 | 303 | .00017 | 5.017 | 349.2 | 85.855 | 1.873 | 338.8 |
| R = 0.95, PERCENT FUEL = 42.76, O/F = 1.339 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2963 | 2250.6 | 19.291 | 1.1426 | 1.2294 | 818 | 0.00111 | | | | | |
| 1.05 | 571.43 | 2948 | 2235.8 | 19.307 | 1.1427 | 1.2208 | 815 | .00110 | 0.293 | 403.2 | 2.133 | 0.199 | 35.9 |
| 1.60 | 375.00 | 2815 | 2111.3 | 19.440 | 1.1445 | 1.1408 | 790 | .00100 | .920 | 223.8 | 1.006 | .609 | 110.1 |
| 1.74 | 345.19 | 2790 | 2087.6 | 19.465 | 1.1450 | 1.1240 | 785 | .00098 | 1.000 | 223.1 | 1.000 | .659 | 119.1 |
| 2.00 | 300.00 | 2746 | 2048.0 | 19.506 | 1.1461 | 1.0946 | 776 | .00095 | 1.124 | 224.4 | 1.014 | .734 | 132.8 |
| 10.00 | 60.00 | 2241 | 1642.6 | 19.841 | 1.1784 | .7248 | 677 | .00058 | 2.144 | 272.5 | 2.348 | 1.272 | 230.0 |
| 20.00 | 30.00 | 2012 | 1495.1 | 19.895 | 1.2015 | .6138 | 630 | .00047 | 2.502 | 290.5 | 3.772 | 1.418 | 256.4 |
| 20.41 | 29.39 | 2005 | 1491.0 | 19.896 | 1.2021 | .6115 | 629 | .00046 | 2.512 | 291.0 | 3.826 | 1.422 | 257.1 |
| 40.00 | 15.00 | 1784 | 1363.9 | 19.912 | 1.2197 | .5578 | 581 | .00040 | 2.858 | 305.7 | 6.170 | 1.536 | 277.8 |
| 40.83 | 14.70 | 1778 | 1360.2 | 19.912 | 1.2201 | .5567 | 580 | .00040 | 2.868 | 306.1 | 6.262 | 1.539 | 278.3 |
| 80.00 | 7.50 | 1570 | 1247.9 | 19.915 | 1.2324 | .5297 | 534 | .00035 | 3.223 | 318.5 | 10.212 | 1.634 | 295.4 |
| 100.00 | 6.00 | 1505 | 1213.7 | 19.916 | 1.2362 | .5225 | 518 | .00034 | 3.342 | 322.1 | 12.031 | 1.661 | 300.4 |
| 200.00 | 3.00 | 1315 | 1116.3 | 19.916 | 1.2481 | .5019 | 472 | .00030 | 3.722 | 332.3 | 20.099 | 1.738 | 314.2 |
| 300.00 | 2.00 | 1212 | 1065.2 | 19.916 | 1.2555 | .4903 | 446 | .00027 | 3.952 | 337.5 | 27.182 | 1.776 | 321.2 |
| 500.00 | 1.20 | 1091 | 1006.5 | 19.916 | 1.2656 | .4755 | 415 | .00025 | 4.251 | 343.4 | 39.792 | 1.820 | 329.0 |
| 800.00 | .75 | 987 | 957.9 | 19.916 | 1.2752 | .4624 | 386 | .00023 | 4.538 | 348.2 | 56.511 | 1.855 | 335.4 |
| 1000.00 | .60 | 940 | 936.4 | 19.916 | 1.2798 | .4564 | 373 | .00022 | 4.679 | 350.2 | 66.746 | 1.870 | 338.2 |
| 1500.00 | .40 | 859 | 900.0 | 19.916 | 1.2882 | .4460 | 364 | .00021 | 4.945 | 353.7 | 90.290 | 1.896 | 342.8 |
| R = 0.975, PERCENT FUEL = 42.13, O/F = 1.374 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2975 | 2217.7 | 19.471 | 1.1409 | 1.2570 | 823 | 0.00114 | | | | | |
| 1.05 | 571.43 | 2960 | 2202.9 | 19.488 | 1.1409 | 1.2494 | 820 | .00113 | 0.293 | 402.1 | 2.131 | 0.199 | 35.8 |
| 1.60 | 375.00 | 2829 | 2079.1 | 19.627 | 1.1419 | 1.1792 | 795 | .00104 | .921 | 223.3 | 1.006 | .609 | 109.8 |
| 1.74 | 345.55 | 2804 | 2055.8 | 19.653 | 1.1422 | 1.1647 | 790 | .00102 | 1.000 | 222.6 | 1.000 | .658 | 118.7 |
| 2.00 | 300.00 | 2761 | 2016.0 | 19.697 | 1.1428 | 1.1390 | 782 | .00099 | 1.126 | 224.0 | 1.014 | .734 | 132.5 |
| 10.00 | 60.00 | 2280 | 1611.0 | 20.086 | 1.1650 | .8037 | 686 | .00064 | 2.149 | 272.5 | 2.367 | 1.273 | 229.8 |
| 20.00 | 30.00 | 2064 | 1462.3 | 20.172 | 1.1874 | .6626 | 642 | .00050 | 2.501 | 290.9 | 3.825 | 1.421 | 256.4 |
| 20.41 | 29.39 | 2058 | 1458.1 | 20.173 | 1.1881 | .6591 | 641 | .00050 | 2.511 | 291.4 | 3.881 | 1.425 | 257.1 |
| 40.00 | 15.00 | 1843 | 1329.0 | 20.206 | 1.2108 | .5737 | 595 | .00041 | 2.846 | 306.4 | 6.285 | 1.541 | 278.1 |
| 40.83 | 14.70 | 1836 | 1325.3 | 20.207 | 1.2114 | .5719 | 594 | .00041 | 2.856 | 306.8 | 6.379 | 1.544 | 278.7 |
| 80.00 | 7.50 | 1627 | 1210.9 | 20.215 | 1.2266 | .5334 | 548 | .00036 | 3.203 | 319.5 | 10.425 | 1.640 | 296.0 |
| 100.00 | 6.00 | 1561 | 1175.9 | 20.215 | 1.2307 | .5251 | 532 | .00035 | 3.321 | 323.3 | 12.290 | 1.669 | 301.1 |
| 200.00 | 3.00 | 1367 | 1076.2 | 20.216 | 1.2428 | .5032 | 486 | .00030 | 3.697 | 333.7 | 20.564 | 1.747 | 315.2 |
| 300.00 | 2.00 | 1262 | 1023.8 | 20.216 | 1.2499 | .4916 | 460 | .00028 | 3.924 | 339.1 | 27.839 | 1.786 | 322.3 |
| 500.00 | 1.20 | 1138 | 963.6 | 20.216 | 1.2597 | .4768 | 428 | .00026 | 4.220 | 345.1 | 40.811 | 1.831 | 330.3 |
| 800.00 | .75 | 1031 | 913.6 | 20.216 | 1.2692 | .4636 | 399 | .00023 | 4.503 | 350.0 | 58.039 | 1.867 | 336.9 |
| 1000.00 | .60 | 983 | 891.5 | 20.216 | 1.2737 | .4575 | 386 | .00022 | 4.642 | 352.1 | 68.596 | 1.883 | 339.7 |
| 1500.00 | .40 | 900 | 854.0 | 20.216 | 1.2820 | .4468 | 380 | .00022 | 4.903 | 355.7 | 92.907 | 1.909 | 344.5 |

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(c) 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, $\mathcal{M}$ | Isentropic exponent, γ | Specific heat, $c_p$, cal/(g)(°K) | Absolute viscosity, μ, micropoises | Thermal conductivity, k, cal/(sec)(cm)(°K) | Mach number, M | Specific impulse, $I_{vac}$, (lb)(sec)/lb | Area ratio, ε | Thrust coefficient, $C_F$ | Specific impulse, I, (lb)(sec)/lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 1.00, PERCENT FUEL = 41.51, O/F = 1.409 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2980 | 2185.7 | 19.638 | 1.1402 | 1.2619 | 826 | 0.00115 | | | | | |
| 1.05 | 571.43 | 2965 | 2171.1 | 19.655 | 1.1402 | 1.2547 | 823 | .00114 | 0.293 | 400.8 | 2.131 | 0.199 | 35.7 |
| 1.60 | 375.00 | 2836 | 2048.0 | 19.798 | 1.1409 | 1.1885 | 798 | .00105 | .921 | 222.6 | 1.806 | .609 | 109.5 |
| 1.74 | 345.69 | 2811 | 2025.0 | 19.824 | 1.1411 | 1.1750 | 794 | .00103 | 1.000 | 221.9 | 1.000 | .657 | 118.3 |
| 2.00 | 300.00 | 2768 | 1985.4 | 19.869 | 1.1416 | 1.1510 | 785 | .00100 | 1.126 | 223.3 | 1.014 | .734 | 132.0 |
| 10.00 | 60.00 | 2297 | 1582.3 | 20.284 | 1.1579 | .8538 | 692 | .00068 | 2.152 | 271.9 | 2.375 | 1.274 | 229.2 |
| 20.00 | 30.00 | 2094 | 1433.6 | 20.396 | 1.1727 | .7326 | 650 | .00056 | 2.508 | 290.5 | 3.857 | 1.422 | 255.8 |
| 20.41 | 29.39 | 2088 | 1429.4 | 20.399 | 1.1732 | .7294 | 649 | .00055 | 2.518 | 291.0 | 3.914 | 1.426 | 256.5 |
| 40.00 | 15.00 | 1888 | 1299.4 | 20.465 | 1.1917 | .6340 | 606 | .00046 | 2.848 | 306.4 | 6.387 | 1.544 | 277.7 |
| 40.83 | 14.70 | 1882 | 1295.6 | 20.467 | 1.1923 | .6315 | 605 | .00046 | 2.858 | 308.9 | 6.484 | 1.547 | 278.3 |
| 80.00 | 7.50 | 1684 | 1179.3 | 20.499 | 1.2118 | .5650 | 561 | .00039 | 3.190 | 319.9 | 10.670 | 1.645 | 295.9 |
| 100.00 | 6.00 | 1619 | 1143.6 | 20.505 | 1.2177 | .5490 | 547 | .00037 | 3.303 | 323.8 | 12.600 | 1.674 | 301.1 |
| 200.00 | 3.00 | 1425 | 1041.4 | 20.514 | 1.2343 | .5119 | 501 | .00032 | 3.665 | 334.6 | 21.162 | 1.754 | 315.5 |
| 300.00 | 2.00 | 1318 | 987.6 | 20.515 | 1.2428 | .4963 | 473 | .00029 | 3.886 | 340.1 | 28.690 | 1.795 | 322.9 |
| 500.00 | 1.20 | 1191 | 925.5 | 20.516 | 1.2530 | .4798 | 436 | .00026 | 4.176 | 346.3 | 42.126 | 1.841 | 331.1 |
| 800.00 | .75 | 1082 | 873.8 | 20.516 | 1.2626 | .4658 | 400 | .00023 | 4.454 | 351.4 | 59.993 | 1.878 | 337.9 |
| 1000.00 | .60 | 1032 | 851.0 | 20.516 | 1.2671 | .4595 | 383 | .00022 | 4.590 | 353.6 | 70.953 | 1.894 | 340.8 |
| 1500.00 | .40 | 947 | 812.1 | 20.516 | 1.2754 | .4485 | 375 | .00021 | 4.847 | 357.3 | 96.219 | 1.922 | 345.7 |
| R = 1.10, PERCENT FUEL = 39.22, O/F = 1.550 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2962 | 2066.7 | 20.207 | 1.1432 | 1.1481 | 831 | 0.00106 | | | | | |
| 1.05 | 571.43 | 2946 | 2052.6 | 20.229 | 1.1433 | 1.1398 | 828 | .00105 | 0.293 | 393.8 | 2.133 | 0.199 | 35.1 |
| 1.60 | 375.00 | 2812 | 1933.8 | 20.357 | 1.1452 | 1.0656 | 802 | .00095 | .920 | 218.6 | 1.806 | .609 | 107.6 |
| 1.74 | 345.11 | 2786 | 1911.1 | 20.381 | 1.1457 | 1.0505 | 797 | .00093 | 1.000 | 217.9 | 1.000 | .659 | 116.4 |
| 2.00 | 300.00 | 2742 | 1873.4 | 20.422 | 1.1466 | 1.0246 | 788 | .00090 | 1.124 | 219.2 | 1.014 | .735 | 129.7 |
| 10.00 | 60.00 | 2245 | 1486.5 | 20.771 | 1.1691 | .7419 | 688 | .00059 | 2.150 | 266.3 | 2.355 | 1.272 | 224.7 |
| 20.00 | 30.00 | 2031 | 1345.1 | 20.851 | 1.1844 | .6513 | 643 | .00050 | 2.509 | 284.2 | 3.806 | 1.419 | 250.6 |
| 20.41 | 29.39 | 2024 | 1341.1 | 20.853 | 1.1849 | .6490 | 642 | .00049 | 2.520 | 284.7 | 3.861 | 1.423 | 251.3 |
| 40.00 | 15.00 | 1819 | 1218.1 | 20.897 | 1.2016 | .5836 | 597 | .00042 | 2.857 | 299.4 | 6.274 | 1.539 | 271.7 |
| 40.83 | 14.70 | 1813 | 1214.5 | 20.898 | 1.2021 | .5820 | 596 | .00042 | 2.868 | 299.9 | 6.369 | 1.542 | 272.3 |
| 80.00 | 7.50 | 1615 | 1105.0 | 20.919 | 1.2186 | .5356 | 551 | .00036 | 3.208 | 312.3 | 10.451 | 1.638 | 289.3 |
| 100.00 | 6.00 | 1551 | 1071.5 | 20.923 | 1.2239 | .5234 | 536 | .00034 | 3.323 | 316.1 | 12.333 | 1.667 | 294.3 |
| 200.00 | 3.00 | 1362 | 975.7 | 20.929 | 1.2397 | .4923 | 489 | .00030 | 3.690 | 326.4 | 20.676 | 1.745 | 308.1 |
| 300.00 | 2.00 | 1258 | 925.3 | 20.930 | 1.2482 | .4779 | 460 | .00027 | 3.914 | 331.6 | 28.004 | 1.785 | 315.2 |
| 500.00 | 1.20 | 1134 | 867.3 | 20.931 | 1.2589 | .4618 | 422 | .00025 | 4.207 | 337.6 | 41.063 | 1.830 | 323.1 |
| 800.00 | .75 | 1028 | 819.1 | 20.931 | 1.2687 | .4483 | 386 | .00022 | 4.489 | 342.4 | 58.399 | 1.866 | 329.5 |
| 1000.00 | .60 | 980 | 797.8 | 20.931 | 1.2733 | .4424 | 369 | .00021 | 4.627 | 344.5 | 69.021 | 1.882 | 332.3 |
| 1500.00 | .40 | 898 | 761.7 | 20.931 | 1.2817 | .4320 | 357 | .00020 | 4.888 | 348.0 | 93.482 | 1.908 | 337.0 |
| R = 1.20, PERCENT FUEL = 37.16, O/F = 1.691 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2914 | 1960.2 | 20.677 | 1.1473 | 1.0323 | 829 | 0.00096 | | | | | |
| 1.05 | 571.43 | 2898 | 1946.6 | 20.692 | 1.1475 | 1.0248 | 826 | .00095 | 0.292 | 386.1 | 2.136 | 0.199 | 34.4 |
| 1.60 | 375.00 | 2761 | 1832.5 | 20.813 | 1.1498 | .9596 | 799 | .00086 | .918 | 214.2 | 1.807 | .610 | 105.4 |
| 1.74 | 344.53 | 2733 | 1810.2 | 20.836 | 1.1504 | .9464 | 794 | .00085 | 1.000 | 213.5 | 1.000 | .661 | 114.2 |
| 2.00 | 300.00 | 2689 | 1774.5 | 20.872 | 1.1515 | .9249 | 785 | .00082 | 1.122 | 214.7 | 1.013 | .735 | 127.1 |
| 10.00 | 60.00 | 2182 | 1404.4 | 21.179 | 1.1741 | .6953 | 680 | .00055 | 2.150 | 260.4 | 2.343 | 1.272 | 219.9 |
| 20.00 | 30.00 | 1968 | 1269.7 | 21.249 | 1.1894 | .6184 | 635 | .00047 | 2.512 | 277.8 | 3.779 | 1.418 | 245.1 |
| 20.41 | 29.39 | 1962 | 1266.0 | 21.251 | 1.1899 | .6163 | 633 | .00046 | 2.522 | 278.3 | 3.834 | 1.421 | 245.8 |
| 40.00 | 15.00 | 1758 | 1149.1 | 21.289 | 1.2068 | .5580 | 588 | .00040 | 2.862 | 292.5 | 6.218 | 1.536 | 265.7 |
| 40.83 | 14.70 | 1752 | 1145.8 | 21.290 | 1.2073 | .5564 | 587 | .00040 | 2.872 | 292.9 | 6.312 | 1.540 | 266.2 |
| 80.00 | 7.50 | 1556 | 1042.0 | 21.308 | 1.2241 | .5141 | 542 | .00034 | 3.215 | 305.0 | 10.337 | 1.635 | 282.7 |
| 100.00 | 6.00 | 1494 | 1010.5 | 21.311 | 1.2295 | .5028 | 527 | .00033 | 3.331 | 308.6 | 12.190 | 1.663 | 287.5 |
| 200.00 | 3.00 | 1308 | 919.8 | 21.316 | 1.2452 | .4742 | 481 | .00028 | 3.702 | 318.5 | 20.395 | 1.740 | 300.9 |
| 300.00 | 2.00 | 1206 | 872.3 | 21.317 | 1.2538 | .4609 | 455 | .00026 | 3.928 | 323.6 | 27.591 | 1.779 | 307.7 |
| 500.00 | 1.20 | 1086 | 817.7 | 21.317 | 1.2645 | .4457 | 422 | .00024 | 4.225 | 329.3 | 40.395 | 1.823 | 315.3 |
| 800.00 | .75 | 983 | 772.4 | 21.317 | 1.2743 | .4331 | 394 | .00022 | 4.511 | 333.9 | 57.370 | 1.859 | 321.5 |
| 1000.00 | .60 | 937 | 752.3 | 21.317 | 1.2788 | .4275 | 380 | .00021 | 4.651 | 335.9 | 67.761 | 1.875 | 324.2 |
| 1500.00 | .40 | 856 | 718.6 | 21.317 | 1.2872 | .4178 | 373 | .00020 | 4.916 | 339.3 | 91.669 | 1.901 | 328.7 |
| R = 1.50, PERCENT FUEL = 32.12, O/F = 2.114 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2759 | 1698.4 | 21.847 | 1.1548 | 0.8534 | 815 | 0.00079 | | | | | |
| 1.05 | 571.43 | 2743 | 1686.2 | 21.859 | 1.1551 | .8478 | 811 | .00078 | 0.291 | 365.5 | 2.141 | 0.200 | 32.6 |
| 1.60 | 375.00 | 2603 | 1584.1 | 21.960 | 1.1585 | .7989 | 783 | .00071 | .915 | 202.5 | 1.807 | .611 | 99.7 |
| 1.75 | 343.44 | 2574 | 1563.5 | 21.979 | 1.1593 | .7887 | 777 | .00070 | 1.000 | 201.8 | 1.000 | .664 | 108.3 |
| 2.00 | 300.00 | 2530 | 1532.4 | 22.008 | 1.1607 | .7729 | 768 | .00068 | 1.119 | 202.9 | 1.013 | .736 | 120.2 |
| 10.00 | 60.00 | 2017 | 1204.2 | 22.246 | 1.1886 | .5962 | 658 | .00047 | 2.148 | 245.2 | 2.315 | 1.270 | 207.4 |
| 20.00 | 30.00 | 1803 | 1086.1 | 22.293 | 1.2061 | .5367 | 610 | .00040 | 2.513 | 261.1 | 3.711 | 1.414 | 230.8 |
| 20.41 | 29.39 | 1797 | 1082.9 | 22.294 | 1.2066 | .5352 | 609 | .00039 | 2.524 | 261.5 | 3.764 | 1.418 | 231.4 |
| 40.00 | 15.00 | 1596 | 981.2 | 22.316 | 1.2241 | .4920 | 562 | .00034 | 2.871 | 274.6 | 6.066 | 1.530 | 249.8 |
| 40.83 | 14.70 | 1591 | 978.3 | 22.317 | 1.2246 | .4909 | 561 | .00034 | 2.882 | 274.9 | 6.156 | 1.533 | 250.3 |
| 80.00 | 7.50 | 1401 | 888.8 | 22.326 | 1.2411 | .4598 | 514 | .00029 | 3.234 | 285.9 | 10.018 | 1.626 | 265.4 |
| 100.00 | 6.00 | 1341 | 861.6 | 22.327 | 1.2462 | .4516 | 499 | .00028 | 3.354 | 289.1 | 11.790 | 1.653 | 269.8 |
| 200.00 | 3.00 | 1166 | 784.3 | 22.329 | 1.2609 | .4303 | 454 | .00025 | 3.738 | 298.0 | 19.610 | 1.727 | 282.0 |
| 300.00 | 2.00 | 1071 | 744.0 | 22.329 | 1.2694 | .4194 | 428 | .00023 | 3.972 | 302.6 | 26.441 | 1.765 | 288.2 |
| 500.00 | 1.20 | 959 | 697.8 | 22.329 | 1.2798 | .4071 | 396 | .00021 | 4.280 | 307.7 | 38.535 | 1.807 | 295.1 |
| 800.00 | .75 | 865 | 659.7 | 22.329 | 1.2893 | .3966 | 367 | .00019 | 4.576 | 311.8 | 54.560 | 1.841 | 300.6 |
| 1000.00 | .60 | 822 | 643.0 | 22.329 | 1.2939 | .3918 | 354 | .00018 | 4.722 | 313.6 | 64.332 | 1.856 | 303.0 |
| 1500.00 | .40 | 749 | 614.7 | 22.329 | 1.3020 | .3837 | 343 | .00017 | 4.998 | 316.5 | 86.765 | 1.881 | 307.1 |

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(c) 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, $\mathcal{M}$ | Isentropic exponent, $\gamma$ | Specific heat, $c_p$, $\frac{cal}{(g)(°K)}$ | Absolute viscosity, $\mu$, micropoises | Thermal conductivity, k, $\frac{cal}{(sec)(cm)(°K)}$ | Mach number, M | Specific impulse, $I_{vac}$, $\frac{(lb)(sec)}{lb}$ | Area ratio, $\varepsilon$ | Thrust coefficient, $C_F$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 2.00, PERCENT FUEL = 26.19, O/F = 2.818 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2536 | 1391.0 | 23.349 | 1.1672 | 0.6880 | 786 | 0.00062 | | | | | |
| 1.05 | 571.43 | 2519 | 1380.5 | 23.359 | 1.1678 | .6833 | 783 | .00062 | 0.290 | 338.8 | 2.150 | 0.200 | 30.2 |
| 1.60 | 375.00 | 2377 | 1292.9 | 23.434 | 1.1736 | .6421 | 753 | .00056 | .911 | 187.3 | 1.008 | .613 | 92.4 |
| 1.76 | 341.52 | 2345 | 1274.2 | 23.450 | 1.1751 | .6330 | 746 | .00055 | 1.000 | 186.6 | 1.000 | .669 | 100.8 |
| 2.00 | 300.00 | 2302 | 1248.7 | 23.469 | 1.1773 | .6205 | 737 | .00053 | 1.114 | 187.5 | 1.011 | .738 | 111.3 |
| 10.00 | 60.00 | 1783 | 971.7 | 23.617 | 1.2145 | .4873 | 620 | .00037 | 2.145 | 225.2 | 2.267 | 1.267 | 191.0 |
| 20.00 | 30.00 | 1572 | 874.0 | 23.638 | 1.2325 | .4495 | 570 | .00032 | 2.520 | 239.2 | 3.597 | 1.407 | 212.1 |
| 20.41 | 29.39 | 1566 | 871.3 | 23.638 | 1.2331 | .4486 | 568 | .00031 | 2.530 | 239.6 | 3.648 | 1.411 | 212.6 |
| 40.00 | 15.00 | 1374 | 788.2 | 23.645 | 1.2492 | .4224 | 520 | .00027 | 2.890 | 251.0 | 5.824 | 1.519 | 229.0 |
| 40.83 | 14.70 | 1369 | 785.9 | 23.646 | 1.2496 | .4217 | 519 | .00027 | 2.901 | 251.3 | 5.908 | 1.522 | 229.5 |
| 80.00 | 7.50 | 1193 | 713.6 | 23.648 | 1.2638 | .4028 | 473 | .00024 | 3.270 | 260.8 | 9.537 | 1.611 | 242.8 |
| 100.00 | 6.00 | 1138 | 691.7 | 23.648 | 1.2683 | .3973 | 458 | .00023 | 3.395 | 263.5 | 11.195 | 1.637 | 246.7 |
| 200.00 | 3.00 | 980 | 630.1 | 23.648 | 1.2822 | .3818 | 413 | .00020 | 3.796 | 271.2 | 18.482 | 1.707 | 257.3 |
| 300.00 | 2.00 | 896 | 598.1 | 23.648 | 1.2902 | .3736 | 388 | .00019 | 4.041 | 275.1 | 24.816 | 1.743 | 262.7 |
| 500.00 | 1.20 | 797 | 561.8 | 23.648 | 1.3005 | .3637 | 357 | .00017 | 4.363 | 279.5 | 35.998 | 1.782 | 268.6 |
| 800.00 | .75 | 714 | 532.0 | 23.648 | 1.3097 | .3554 | 329 | .00015 | 4.675 | 282.9 | 50.700 | 1.814 | 273.4 |
| 1000.00 | .60 | 677 | 519.0 | 23.648 | 1.3139 | .3517 | 317 | .00014 | 4.829 | 284.4 | 59.650 | 1.828 | 275.5 |
| 1500.00 | .40 | 614 | 497.0 | 23.648 | 1.3216 | .3453 | 301 | .00014 | 5.120 | 287.0 | 80.136 | 1.851 | 278.9 |
| R = 3.00, PERCENT FUEL = 19.13, O/F = 4.227 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2171 | 1024.7 | 25.337 | 1.1977 | 0.5023 | 728 | 0.00044 | | | | | |
| 1.05 | 571.43 | 2154 | 1016.4 | 25.342 | 1.1988 | .4988 | 724 | .00043 | 0.286 | 300.7 | 2.170 | 0.202 | 26.8 |
| 1.60 | 375.00 | 2008 | 947.7 | 25.377 | 1.2087 | .4704 | 691 | .00039 | .900 | 165.4 | 1.010 | .618 | 81.8 |
| 1.78 | 337.20 | 1972 | 931.2 | 25.385 | 1.2113 | .4637 | 683 | .00038 | 1.000 | 164.7 | 1.000 | .681 | 90.2 |
| 2.00 | 300.00 | 1933 | 913.3 | 25.392 | 1.2143 | .4565 | 674 | .00037 | 1.101 | 165.3 | 1.009 | .743 | 98.4 |
| 10.00 | 60.00 | 1426 | 702.8 | 25.435 | 1.2540 | .3868 | 550 | .00027 | 2.147 | 194.3 | 2.186 | 1.263 | 167.4 |
| 20.00 | 30.00 | 1235 | 630.9 | 25.437 | 1.2681 | .3697 | 499 | .00023 | 2.537 | 207.8 | 3.424 | 1.397 | 185.1 |
| 20.41 | 29.39 | 1230 | 628.9 | 25.437 | 1.2685 | .3693 | 498 | .00023 | 2.548 | 208.1 | 3.471 | 1.401 | 185.6 |
| 40.00 | 15.00 | 1064 | 568.7 | 25.438 | 1.2815 | .3557 | 451 | .00020 | 2.926 | 217.3 | 5.480 | 1.503 | 199.2 |
| 40.83 | 14.70 | 1059 | 567.0 | 25.438 | 1.2819 | .3553 | 450 | .00020 | 2.938 | 217.6 | 5.558 | 1.506 | 199.6 |
| 80.00 | 7.50 | 911 | 515.3 | 25.438 | 1.2945 | .3434 | 406 | .00018 | 3.325 | 225.2 | 8.881 | 1.589 | 210.5 |
| 100.00 | 6.00 | 866 | 499.8 | 25.438 | 1.2988 | .3395 | 392 | .00017 | 3.457 | 227.5 | 10.392 | 1.613 | 213.7 |
| 200.00 | 3.00 | 736 | 456.5 | 25.438 | 1.3124 | .3282 | 350 | .00015 | 3.880 | 233.6 | 16.984 | 1.678 | 222.3 |
| 300.00 | 2.00 | 668 | 434.3 | 25.438 | 1.3203 | .3220 | 326 | .00014 | 4.140 | 236.7 | 22.672 | 1.711 | 226.7 |
| 500.00 | 1.20 | 589 | 409.2 | 25.438 | 1.3301 | .3148 | 297 | .00012 | 4.484 | 240.1 | 32.650 | 1.746 | 231.4 |
| 800.00 | .75 | 524 | 388.8 | 25.438 | 1.3385 | .3089 | 272 | .00011 | 4.819 | 242.8 | 45.684 | 1.775 | 235.2 |
| 1000.00 | .60 | 495 | 379.9 | 25.438 | 1.3423 | .3063 | 260 | .00011 | 4.985 | 244.0 | 53.587 | 1.788 | 236.9 |
| 1500.00 | .40 | 446 | 365.1 | 25.438 | 1.3491 | .3019 | 242 | .00010 | 5.298 | 245.9 | 71.604 | 1.808 | 239.6 |
| R = 4.00, PERCENT FUEL = 15.07, O/F = 5.636 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 1877 | 814.0 | 26.566 | 1.2276 | 0.4111 | 672 | 0.00034 | | | | | |
| 1.05 | 571.43 | 1861 | 807.1 | 26.568 | 1.2288 | .4088 | 668 | .00034 | 0.282 | 272.9 | 2.188 | 0.204 | 24.4 |
| 1.60 | 375.00 | 1719 | 750.8 | 26.581 | 1.2393 | .3911 | 634 | .00031 | .891 | 149.5 | 1.011 | .622 | 74.1 |
| 1.80 | 333.68 | 1680 | 735.9 | 26.584 | 1.2421 | .3868 | 624 | .00030 | 1.000 | 148.7 | 1.000 | .691 | 82.4 |
| 2.00 | 300.00 | 1646 | 722.7 | 26.586 | 1.2446 | .3831 | 616 | .00029 | 1.092 | 149.2 | 1.007 | .747 | 89.1 |
| 10.00 | 60.00 | 1179 | 553.9 | 26.596 | 1.2775 | .3441 | 493 | .00022 | 2.150 | 175.9 | 2.136 | 1.261 | 150.4 |
| 20.00 | 30.00 | 1012 | 497.3 | 26.596 | 1.2902 | .3322 | 445 | .00019 | 2.549 | 185.8 | 3.322 | 1.392 | 166.0 |
| 20.41 | 29.39 | 1007 | 495.7 | 26.596 | 1.2906 | .3319 | 444 | .00019 | 2.560 | 186.1 | 3.367 | 1.395 | 166.4 |
| 40.00 | 15.00 | 863 | 448.8 | 26.596 | 1.3028 | .3215 | 399 | .00017 | 2.948 | 194.0 | 5.280 | 1.494 | 178.2 |
| 40.83 | 14.70 | 859 | 447.5 | 26.596 | 1.3032 | .3211 | 398 | .00016 | 2.960 | 194.2 | 5.354 | 1.497 | 178.6 |
| 80.00 | 7.50 | 733 | 407.5 | 26.596 | 1.3162 | .3110 | 356 | .00014 | 3.358 | 200.7 | 8.497 | 1.577 | 188.0 |
| 100.00 | 6.00 | 694 | 395.7 | 26.596 | 1.3205 | .3078 | 343 | .00014 | 3.494 | 202.6 | 9.920 | 1.600 | 190.8 |
| 200.00 | 3.00 | 585 | 362.6 | 26.596 | 1.3341 | .2983 | 303 | .00012 | 3.934 | 207.8 | 16.099 | 1.662 | 198.2 |
| 300.00 | 2.00 | 528 | 345.7 | 26.596 | 1.3417 | .2934 | 281 | .00011 | 4.205 | 210.4 | 21.402 | 1.692 | 201.8 |
| 500.00 | 1.20 | 463 | 326.8 | 26.596 | 1.3509 | .2877 | 254 | .00010 | 4.565 | 213.2 | 30.665 | 1.726 | 205.9 |
| 800.00 | .75 | 410 | 311.5 | 26.596 | 1.3580 | .2834 | 231 | .00009 | 4.917 | 215.5 | 42.718 | 1.753 | 209.1 |
| 1000.00 | .60 | 386 | 304.9 | 26.596 | 1.3608 | .2818 | 221 | .00008 | 5.092 | 216.4 | 50.009 | 1.765 | 210.5 |
| 1500.00 | .40 | 347 | 293.8 | 26.596 | 1.3650 | .2794 | 203 | .00008 | 5.425 | 218.0 | 66.614 | 1.784 | 212.7 |
| R = 5.00, PERCENT FUEL = 12.43, O/F = 7.046 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 1641 | 677.0 | 27.398 | 1.2506 | 0.3639 | 621 | 0.00028 | | | | | |
| 1.05 | 571.43 | 1625 | 671.3 | 27.399 | 1.2517 | .3625 | 617 | .00028 | 0.280 | 251.1 | 2.201 | 0.206 | 22.4 |
| 1.60 | 375.00 | 1491 | 623.7 | 27.403 | 1.2607 | .3515 | 583 | .00026 | .885 | 137.2 | 1.013 | .624 | 68.1 |
| 1.81 | 331.33 | 1454 | 610.5 | 27.404 | 1.2632 | .3487 | 573 | .00025 | 1.000 | 136.4 | 1.000 | .698 | 76.1 |
| 2.00 | 300.00 | 1424 | 600.1 | 27.404 | 1.2652 | .3465 | 566 | .00025 | 1.085 | 136.7 | 1.006 | .750 | 81.8 |
| 10.00 | 60.00 | 1001 | 459.7 | 27.406 | 1.2941 | .3191 | 448 | .00018 | 2.151 | 160.5 | 2.106 | 1.260 | 137.5 |
| 20.00 | 30.00 | 853 | 413.2 | 27.406 | 1.3065 | .3091 | 402 | .00016 | 2.555 | 169.3 | 3.257 | 1.389 | 151.5 |
| 20.41 | 29.39 | 849 | 411.9 | 27.406 | 1.3068 | .3088 | 400 | .00016 | 2.567 | 169.5 | 3.300 | 1.392 | 151.9 |
| 40.00 | 15.00 | 723 | 373.6 | 27.406 | 1.3197 | .2993 | 358 | .00014 | 2.961 | 176.5 | 5.149 | 1.489 | 162.5 |
| 40.83 | 14.70 | 720 | 372.5 | 27.406 | 1.3201 | .2990 | 357 | .00014 | 2.973 | 176.7 | 5.220 | 1.492 | 162.8 |
| 80.00 | 7.50 | 610 | 340.2 | 27.406 | 1.3335 | .2900 | 317 | .00012 | 3.380 | 182.4 | 8.240 | 1.569 | 171.2 |
| 100.00 | 6.00 | 577 | 330.6 | 27.406 | 1.3378 | .2871 | 305 | .00012 | 3.520 | 184.1 | 9.603 | 1.591 | 173.6 |
| 200.00 | 3.00 | 483 | 304.0 | 27.406 | 1.3509 | .2792 | 267 | .00010 | 3.972 | 188.6 | 15.498 | 1.651 | 180.2 |
| 300.00 | 2.00 | 434 | 290.5 | 27.406 | 1.3579 | .2751 | 247 | .00009 | 4.252 | 190.9 | 20.539 | 1.681 | 183.4 |
| 500.00 | 1.20 | 379 | 275.5 | 27.406 | 1.3649 | .2712 | 222 | .00008 | 4.626 | 193.3 | 29.324 | 1.712 | 186.9 |
| 800.00 | .75 | 334 | 263.4 | 27.406 | 1.3697 | .2687 | 201 | .00007 | 4.993 | 195.3 | 40.741 | 1.739 | 189.7 |
| 1000.00 | .60 | 315 | 258.1 | 27.406 | 1.3715 | .2677 | 191 | .00007 | 5.175 | 196.1 | 47.644 | 1.750 | 190.9 |
| 1500.00 | .40 | 282 | 249.3 | 27.406 | 1.3739 | .2664 | 175 | .00006 | 5.520 | 197.5 | 63.255 | 1.768 | 192.9 |

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(d) 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, $\mathcal{M}$ | Isentropic exponent, γ | Specific heat, $c_p$, $\frac{cal}{(g)(°K)}$ | Absolute viscosity, μ, micropoises | Thermal conductivity, k, $\frac{cal}{(sec)(cm)(°K)}$ | Mach number, M | Specific impulse, $I_{vac}$, $\frac{(lb)(sec)}{lb}$ | Area ratio, ε | Thrust coefficient, $C_F$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 0.40, PERCENT FUEL = 63.95, O/F = 0.564 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 1349 | 3350.2 | 13.316 | 1.2956 | 0.6540 | 453 | 0.00038 | | | | | |
| 1.05 | 571.43 | 1334 | 3340.4 | 13.316 | 1.2966 | .6524 | 450 | .00038 | 0.275 | 326.2 | 2.226 | 0.208 | 29.1 |
| 1.60 | 375.00 | 1210 | 3260.5 | 13.316 | 1.3059 | .6381 | 421 | .00035 | .872 | 177.3 | 1.015 | .630 | 88.3 |
| 1.84 | 326.41 | 1171 | 3235.9 | 13.316 | 1.3082 | .6335 | 412 | .00034 | 1.000 | 176.0 | 1.000 | .712 | 99.7 |
| 2.00 | 300.00 | 1148 | 3221.3 | 13.316 | 1.3100 | .6307 | 406 | .00033 | 1.072 | 176.3 | 1.004 | .756 | 105.9 |
| 10.00 | 60.00 | 772 | 2993.1 | 13.316 | 1.3421 | .5855 | 309 | .00024 | 2.149 | 204.7 | 2.030 | 1.258 | 176.3 |
| 20.00 | 30.00 | 646 | 2919.9 | 13.316 | 1.3530 | .5720 | 272 | .00021 | 2.569 | 215.2 | 3.093 | 1.381 | 193.5 |
| 20.41 | 29.39 | 643 | 2917.9 | 13.316 | 1.3532 | .5717 | 271 | .00021 | 2.581 | 215.4 | 3.133 | 1.384 | 193.9 |
| 40.00 | 15.00 | 538 | 2858.8 | 13.316 | 1.3618 | .5617 | 237 | .00018 | 2.998 | 223.7 | 4.823 | 1.476 | 206.8 |
| 40.83 | 14.70 | 535 | 2857.1 | 13.316 | 1.3620 | .5615 | 236 | .00018 | 3.011 | 223.9 | 4.888 | 1.478 | 207.1 |
| 80.00 | 7.50 | 447 | 2807.9 | 13.316 | 1.3680 | .5548 | 206 | .00015 | 3.447 | 230.6 | 7.629 | 1.550 | 217.2 |
| 100.00 | 6.00 | 421 | 2793.5 | 13.316 | 1.3696 | .5530 | 196 | .00015 | 3.597 | 232.5 | 8.863 | 1.571 | 220.1 |
| 200.00 | 3.00 | 349 | 2753.8 | 13.316 | 1.3744 | .5478 | 168 | .00012 | 4.083 | 237.7 | 14.191 | 1.626 | 227.8 |
| 300.00 | 2.00 | 312 | 2733.8 | 13.316 | 1.3768 | .5453 | 154 | .00011 | 4.383 | 240.3 | 18.744 | 1.653 | 231.6 |
| 500.00 | 1.20 | 271 | 2711.6 | 13.316 | 1.3793 | .5427 | 136 | .00010 | 4.781 | 243.2 | 26.680 | 1.682 | 235.7 |
| 800.00 | .75 | 238 | 2693.7 | 13.316 | 1.3842 | .5377 | 122 | .00009 | 5.163 | 245.5 | 36.978 | 1.705 | 239.0 |
| 1000.00 | .60 | 224 | 2686.0 | 13.316 | 1.3871 | .5348 | 115 | .00008 | 5.351 | 246.4 | 43.187 | 1.715 | 240.4 |
| 1500.00 | .40 | 200 | 2673.2 | 13.316 | 1.3927 | .5293 | 104 | .00007 | 5.707 | 248.0 | 57.266 | 1.732 | 242.7 |
| R = 0.50, PERCENT FUEL = 58.67, O/F = 0.705 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 1784 | 3075.9 | 14.516 | 1.2623 | 0.6588 | 555 | 0.00046 | | | | | |
| 1.05 | 571.43 | 1766 | 3064.0 | 14.516 | 1.2630 | .6573 | 551 | .00046 | 0.279 | 359.6 | 2.206 | 0.206 | 32.1 |
| 1.60 | 375.00 | 1617 | 2966.5 | 14.516 | 1.2697 | .6444 | 520 | .00042 | .882 | 196.3 | 1.013 | .626 | 97.5 |
| 1.82 | 330.40 | 1574 | 2938.9 | 14.516 | 1.2719 | .6404 | 510 | .00041 | 1.000 | 195.0 | 1.000 | .700 | 109.2 |
| 2.00 | 300.00 | 1541 | 2918.3 | 14.516 | 1.2736 | .6372 | 503 | .00041 | 1.083 | 195.5 | 1.006 | .751 | 117.1 |
| 10.00 | 60.00 | 1074 | 2632.5 | 14.516 | 1.3057 | .5847 | 394 | .00030 | 2.149 | 229.0 | 2.090 | 1.260 | 196.4 |
| 20.00 | 30.00 | 911 | 2538.4 | 14.516 | 1.3201 | .5646 | 351 | .00026 | 2.555 | 241.3 | 3.218 | 1.387 | 216.2 |
| 20.41 | 29.39 | 906 | 2535.9 | 14.516 | 1.3205 | .5641 | 350 | .00026 | 2.568 | 241.7 | 3.261 | 1.390 | 216.8 |
| 40.00 | 15.00 | 768 | 2459.0 | 14.516 | 1.3335 | .5474 | 311 | .00022 | 2.967 | 251.4 | 5.065 | 1.486 | 231.7 |
| 40.83 | 14.70 | 764 | 2456.8 | 14.516 | 1.3339 | .5469 | 310 | .00022 | 2.979 | 251.7 | 5.134 | 1.489 | 232.1 |
| 80.00 | 7.50 | 644 | 2392.1 | 14.516 | 1.3450 | .5338 | 274 | .00019 | 3.396 | 259.6 | 8.071 | 1.565 | 243.9 |
| 100.00 | 6.00 | 608 | 2373.0 | 14.516 | 1.3482 | .5301 | 262 | .00018 | 3.539 | 261.9 | 9.395 | 1.586 | 247.3 |
| 200.00 | 3.00 | 508 | 2320.2 | 14.516 | 1.3571 | .5203 | 228 | .00016 | 4.003 | 268.2 | 15.126 | 1.645 | 256.4 |
| 300.00 | 2.00 | 456 | 2293.5 | 14.516 | 1.3609 | .5163 | 210 | .00014 | 4.292 | 271.3 | 20.032 | 1.674 | 260.9 |
| 500.00 | 1.20 | 398 | 2263.7 | 14.516 | 1.3650 | .5120 | 188 | .00013 | 4.673 | 274.8 | 28.601 | 1.705 | 265.8 |
| 800.00 | .75 | 351 | 2239.6 | 14.516 | 1.3683 | .5086 | 169 | .00012 | 5.045 | 277.5 | 39.755 | 1.730 | 269.8 |
| 1000.00 | .60 | 330 | 2229.2 | 14.516 | 1.3696 | .5073 | 161 | .00011 | 5.228 | 278.7 | 46.505 | 1.741 | 271.4 |
| 1500.00 | .40 | 296 | 2211.8 | 14.516 | 1.3717 | .5053 | 146 | .00010 | 5.575 | 280.6 | 61.881 | 1.759 | 274.2 |
| R = 0.60, PERCENT FUEL = 54.19, O/F = 0.845 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2171 | 2843.5 | 15.710 | 1.2400 | 0.6536 | 640 | 0.00052 | | | | | |
| 1.05 | 571.43 | 2150 | 2830.1 | 15.710 | 1.2405 | .6524 | 636 | .00052 | 0.281 | 381.5 | 2.193 | 0.205 | 34.1 |
| 1.60 | 375.00 | 1980 | 2720.2 | 15.710 | 1.2455 | .6417 | 602 | .00048 | .889 | 208.8 | 1.012 | .623 | 103.6 |
| 1.80 | 333.20 | 1935 | 2690.9 | 15.710 | 1.2471 | .6384 | 593 | .00047 | 1.000 | 207.6 | 1.000 | .693 | 115.2 |
| 2.00 | 300.00 | 1895 | 2665.5 | 15.710 | 1.2485 | .6355 | 585 | .00046 | 1.091 | 208.2 | 1.007 | .748 | 124.5 |
| 10.00 | 60.00 | 1358 | 2336.7 | 15.710 | 1.2749 | .5866 | 468 | .00035 | 2.151 | 245.6 | 2.189 | 1.262 | 210.0 |
| 20.00 | 30.00 | 1166 | 2226.2 | 15.710 | 1.2887 | .5647 | 421 | .00030 | 2.548 | 259.4 | 3.329 | 1.393 | 231.8 |
| 20.41 | 29.39 | 1161 | 2223.2 | 15.710 | 1.2891 | .5640 | 420 | .00030 | 2.560 | 259.8 | 3.374 | 1.396 | 232.3 |
| 40.00 | 15.00 | 995 | 2131.6 | 15.710 | 1.3032 | .5436 | 377 | .00026 | 2.946 | 270.9 | 5.292 | 1.496 | 248.9 |
| 40.83 | 14.70 | 991 | 2129.0 | 15.710 | 1.3037 | .5430 | 376 | .00026 | 2.957 | 271.2 | 5.366 | 1.499 | 249.3 |
| 80.00 | 7.50 | 845 | 2051.1 | 15.710 | 1.3174 | .5250 | 336 | .00023 | 3.355 | 280.3 | 8.512 | 1.578 | 262.6 |
| 100.00 | 6.00 | 800 | 2027.8 | 15.710 | 1.3218 | .5195 | 323 | .00022 | 3.492 | 282.9 | 9.986 | 1.601 | 266.4 |
| 200.00 | 3.00 | 674 | 1963.3 | 15.710 | 1.3343 | .5048 | 285 | .00019 | 3.933 | 290.1 | 16.118 | 1.663 | 276.7 |
| 300.00 | 2.00 | 609 | 1930.5 | 15.710 | 1.3407 | .4978 | 264 | .00017 | 4.206 | 293.7 | 21.429 | 1.694 | 281.9 |
| 500.00 | 1.20 | 534 | 1893.6 | 15.710 | 1.3478 | .4901 | 239 | .00015 | 4.568 | 297.7 | 30.721 | 1.728 | 287.5 |
| 800.00 | .75 | 473 | 1863.7 | 15.710 | 1.3533 | .4845 | 217 | .00014 | 4.921 | 300.9 | 42.837 | 1.755 | 292.0 |
| 1000.00 | .60 | 446 | 1850.7 | 15.710 | 1.3554 | .4824 | 207 | .00013 | 5.096 | 302.3 | 50.179 | 1.766 | 293.9 |
| 1500.00 | .40 | 401 | 1829.0 | 15.710 | 1.3589 | .4789 | 189 | .00012 | 5.427 | 304.5 | 66.923 | 1.786 | 297.1 |
| R = 0.70, PERCENT FUEL = 50.34, O/F = 0.986 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2503 | 2644.0 | 16.876 | 1.2243 | 0.6428 | 711 | 0.00056 | | | | | |
| 1.05 | 571.43 | 2481 | 2629.7 | 16.876 | 1.2247 | .6418 | 707 | .00056 | 0.283 | 395.4 | 2.183 | 0.204 | 35.3 |
| 1.60 | 375.00 | 2295 | 2511.3 | 16.876 | 1.2287 | .6326 | 671 | .00052 | .894 | 216.9 | 1.011 | .620 | 107.5 |
| 1.79 | 335.17 | 2247 | 2481.3 | 16.876 | 1.2299 | .6300 | 662 | .00051 | 1.000 | 215.8 | 1.000 | .687 | 119.0 |
| 2.00 | 300.00 | 2201 | 2452.3 | 16.876 | 1.2310 | .6274 | 653 | .00051 | 1.096 | 216.5 | 1.008 | .746 | 129.2 |
| 10.00 | 60.00 | 1611 | 2093.3 | 16.876 | 1.2519 | .5851 | 531 | .00039 | 2.154 | 256.6 | 2.176 | 1.264 | 218.9 |
| 20.00 | 30.00 | 1398 | 1970.7 | 16.876 | 1.2638 | .5641 | 482 | .00034 | 2.545 | 271.6 | 3.415 | 1.397 | 242.1 |
| 20.41 | 29.39 | 1392 | 1967.3 | 16.876 | 1.2642 | .5634 | 481 | .00034 | 2.556 | 272.0 | 3.462 | 1.401 | 242.7 |
| 40.00 | 15.00 | 1206 | 1864.6 | 16.876 | 1.2770 | .5428 | 436 | .00030 | 2.932 | 284.2 | 5.478 | 1.504 | 260.4 |
| 40.83 | 14.70 | 1201 | 1861.7 | 16.876 | 1.2775 | .5422 | 435 | .00030 | 2.944 | 284.5 | 5.556 | 1.506 | 260.9 |
| 80.00 | 7.50 | 1034 | 1773.3 | 16.876 | 1.2914 | .5218 | 392 | .00026 | 3.327 | 294.5 | 8.892 | 1.589 | 275.3 |
| 100.00 | 6.00 | 983 | 1746.8 | 16.876 | 1.2961 | .5155 | 378 | .00025 | 3.458 | 297.4 | 10.408 | 1.613 | 279.4 |
| 200.00 | 3.00 | 837 | 1672.6 | 16.876 | 1.3104 | .4971 | 337 | .00022 | 3.879 | 305.5 | 17.027 | 1.679 | 290.7 |
| 300.00 | 2.00 | 759 | 1634.5 | 16.876 | 1.3184 | .4876 | 314 | .00020 | 4.138 | 309.5 | 22.738 | 1.711 | 296.4 |
| 500.00 | 1.20 | 670 | 1591.6 | 16.876 | 1.3276 | .4772 | 286 | .00018 | 4.482 | 314.0 | 32.762 | 1.747 | 302.6 |
| 800.00 | .75 | 596 | 1556.6 | 16.876 | 1.3352 | .4690 | 262 | .00016 | 4.816 | 317.5 | 45.874 | 1.776 | 307.6 |
| 1000.00 | .60 | 564 | 1541.3 | 16.876 | 1.3386 | .4655 | 250 | .00015 | 4.982 | 319.1 | 53.831 | 1.788 | 309.8 |
| 1500.00 | .40 | 508 | 1515.7 | 16.876 | 1.3441 | .4599 | 231 | .00014 | 5.295 | 321.6 | 71.999 | 1.809 | 313.3 |

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TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(d) 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, $\mathcal{M}$ | Isentropic exponent, $\gamma$ | Specific heat, $c_p$, $\frac{cal}{(g)(°K)}$ | Absolute viscosity, $\mu$, micropoises | Thermal conductivity, k, $\frac{cal}{(sec)(cm)(°K)}$ | Mach number, M | Specific impulse, $I_{vac}$, $\frac{(lb)(sec)}{lb}$ | Area ratio, $\varepsilon$ | Thrust coefficient, $C_F$ | Specific impulse, $I_s$, $\frac{(lb)(sec)}{lb}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 0.80, PERCENT FUEL = 47.01, O/F = 1.127 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2760 | 2471.0 | 17.957 | 1.2139 | 0.6281 | 767 | 0.00059 | | | | | |
| 1.05 | 571.43 | 2737 | 2456.2 | 17.957 | 1.2142 | .6272 | 762 | .00058 | 0.284 | 402.6 | 2.176 | 0.203 | 35.9 |
| 1.60 | 375.00 | 2539 | 2333.3 | 17.957 | 1.2174 | .6196 | 726 | .00055 | .897 | 221.2 | 1.010 | .619 | 109.5 |
| 1.78 | 336.51 | 2491 | 2303.1 | 17.957 | 1.2183 | .6176 | 717 | .00054 | 1.000 | 220.1 | 1.000 | .683 | 120.9 |
| 2.00 | 300.00 | 2440 | 2271.8 | 17.957 | 1.2193 | .6153 | 707 | .00053 | 1.100 | 220.9 | 1.009 | .744 | 131.7 |
| 10.00 | 60.00 | 1811 | 1895.5 | 17.957 | 1.2368 | .5781 | 581 | .00042 | 2.155 | 262.7 | 2.202 | 1.265 | 223.8 |
| 20.00 | 30.00 | 1582 | 1765.5 | 17.957 | 1.2466 | .5593 | 531 | .00037 | 2.542 | 278.5 | 3.476 | 1.401 | 247.8 |
| 20.41 | 29.39 | 1576 | 1761.9 | 17.957 | 1.2470 | .5588 | 529 | .00037 | 2.554 | 278.9 | 3.525 | 1.404 | 248.4 |
| 40.00 | 15.00 | 1376 | 1652.2 | 17.957 | 1.2584 | .5389 | 483 | .00033 | 2.923 | 291.7 | 5.612 | 1.509 | 266.9 |
| 40.83 | 14.70 | 1370 | 1649.1 | 17.957 | 1.2588 | .5383 | 481 | .00033 | 2.935 | 292.1 | 5.693 | 1.512 | 267.4 |
| 80.00 | 7.50 | 1190 | 1553.9 | 17.957 | 1.2715 | .5183 | 437 | .00029 | 3.310 | 302.8 | 9.173 | 1.597 | 282.5 |
| 100.00 | 6.00 | 1134 | 1525.2 | 17.957 | 1.2760 | .5116 | 422 | .00027 | 3.436 | 305.9 | 10.762 | 1.622 | 286.9 |
| 200.00 | 3.00 | 973 | 1444.5 | 17.957 | 1.2904 | .4917 | 379 | .00024 | 3.843 | 314.6 | 17.730 | 1.690 | 298.9 |
| 300.00 | 2.00 | 888 | 1402.7 | 17.957 | 1.2989 | .4809 | 355 | .00022 | 4.092 | 318.9 | 23.773 | 1.724 | 304.9 |
| 500.00 | 1.20 | 788 | 1355.4 | 17.957 | 1.3093 | .4684 | 325 | .00020 | 4.421 | 325.7 | 34.418 | 1.761 | 311.6 |
| 800.00 | .75 | 704 | 1316.6 | 17.957 | 1.3183 | .4583 | 300 | .00018 | 4.740 | 327.6 | 48.386 | 1.792 | 316.9 |
| 1000.00 | .60 | 667 | 1299.7 | 17.957 | 1.3223 | .4540 | 288 | .00017 | 4.899 | 329.3 | 56.880 | 1.805 | 319.2 |
| 1500.00 | .40 | 604 | 1271.2 | 17.957 | 1.3291 | .4469 | 266 | .00016 | 5.198 | 332.1 | 76.307 | 1.827 | 323.1 |
| R = 0.90, PERCENT FUEL = 44.09, O/F = 1.268 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2922 | 2319.5 | 18.893 | 1.2077 | 0.6116 | 805 | 0.00060 | | | | | |
| 1.05 | 571.43 | 2897 | 2304.6 | 18.893 | 1.2080 | .6108 | 801 | .00059 | 0.285 | 403.8 | 2.173 | 0.203 | 36.0 |
| 1.60 | 375.00 | 2693 | 2180.8 | 18.893 | 1.2110 | .6038 | 764 | .00056 | .899 | 222.0 | 1.010 | .618 | 109.9 |
| 1.78 | 337.27 | 2644 | 2151.0 | 18.893 | 1.2117 | .6019 | 755 | .00055 | 1.000 | 221.0 | 1.000 | .681 | 121.1 |
| 2.00 | 300.00 | 2590 | 2118.8 | 18.893 | 1.2126 | .5999 | 745 | .00054 | 1.102 | 221.8 | 1.009 | .743 | 132.2 |
| 10.00 | 60.00 | 1938 | 1737.6 | 18.893 | 1.2279 | .5667 | 615 | .00043 | 2.156 | 264.4 | 2.218 | 1.266 | 225.0 |
| 20.00 | 30.00 | 1701 | 1605.1 | 18.893 | 1.2369 | .5492 | 564 | .00038 | 2.541 | 280.5 | 3.519 | 1.403 | 249.3 |
| 20.41 | 29.39 | 1694 | 1601.4 | 18.893 | 1.2372 | .5487 | 563 | .00038 | 2.552 | 281.0 | 3.562 | 1.406 | 250.0 |
| 40.00 | 15.00 | 1486 | 1489.0 | 18.893 | 1.2473 | .5304 | 515 | .00034 | 2.919 | 294.1 | 5.693 | 1.512 | 268.8 |
| 40.83 | 14.70 | 1480 | 1485.8 | 18.893 | 1.2477 | .5298 | 513 | .00034 | 2.930 | 294.5 | 5.776 | 1.515 | 269.3 |
| 80.00 | 7.50 | 1292 | 1387.9 | 18.893 | 1.2595 | .5105 | 465 | .00030 | 3.300 | 305.5 | 9.345 | 1.602 | 284.7 |
| 100.00 | 6.00 | 1234 | 1358.3 | 18.893 | 1.2637 | .5041 | 449 | .00029 | 3.424 | 308.7 | 10.979 | 1.627 | 289.2 |
| 200.00 | 3.00 | 1064 | 1274.6 | 18.893 | 1.2777 | .4840 | 396 | .00024 | 3.823 | 317.7 | 18.171 | 1.696 | 301.5 |
| 300.00 | 2.00 | 973 | 1231.2 | 18.893 | 1.2861 | .4728 | 364 | .00022 | 4.066 | 322.2 | 24.429 | 1.731 | 307.7 |
| 500.00 | 1.20 | 867 | 1181.8 | 18.893 | 1.2967 | .4596 | 325 | .00019 | 4.386 | 327.3 | 35.486 | 1.770 | 314.6 |
| 800.00 | .75 | 778 | 1141.1 | 18.893 | 1.3063 | .4485 | 295 | .00017 | 4.696 | 331.3 | 50.034 | 1.801 | 320.2 |
| 1000.00 | .60 | 738 | 1123.3 | 18.893 | 1.3107 | .4437 | 281 | .00016 | 4.849 | 333.1 | 58.894 | 1.815 | 322.6 |
| 1500.00 | .40 | 670 | 1093.3 | 18.893 | 1.3182 | .4357 | 257 | .00015 | 5.139 | 336.0 | 79.187 | 1.838 | 326.6 |
| R = 0.95, PERCENT FUEL = 42.76, O/F = 1.339 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2963 | 2250.6 | 19.291 | 1.2061 | 0.6028 | 818 | 0.00060 | | | | | |
| 1.05 | 571.43 | 2939 | 2235.8 | 19.291 | 1.2064 | .6021 | 814 | .00059 | 0.285 | 402.6 | 2.172 | 0.203 | 35.9 |
| 1.60 | 375.00 | 2733 | 2112.8 | 19.291 | 1.2093 | .5953 | 776 | .00056 | .900 | 221.4 | 1.010 | .618 | 109.5 |
| 1.78 | 337.47 | 2684 | 2083.3 | 19.291 | 1.2100 | .5935 | 767 | .00055 | 1.000 | 220.3 | 1.000 | .681 | 120.6 |
| 2.00 | 300.00 | 2630 | 2051.1 | 19.291 | 1.2109 | .5915 | 757 | .00054 | 1.103 | 221.2 | 1.009 | .743 | 131.7 |
| 10.00 | 60.00 | 1972 | 1671.8 | 19.291 | 1.2256 | .5596 | 626 | .00043 | 2.156 | 263.8 | 2.222 | 1.266 | 224.4 |
| 20.00 | 30.00 | 1732 | 1539.7 | 19.291 | 1.2343 | .5426 | 574 | .00039 | 2.541 | 279.9 | 3.522 | 1.403 | 248.7 |
| 20.41 | 29.39 | 1726 | 1536.0 | 19.291 | 1.2346 | .5421 | 573 | .00038 | 2.552 | 280.4 | 3.572 | 1.407 | 249.4 |
| 40.00 | 15.00 | 1516 | 1423.9 | 19.291 | 1.2444 | .5244 | 525 | .00034 | 2.917 | 293.5 | 5.714 | 1.513 | 268.2 |
| 40.83 | 14.70 | 1509 | 1420.7 | 19.291 | 1.2448 | .5239 | 523 | .00034 | 2.929 | 293.9 | 5.798 | 1.516 | 268.7 |
| 80.00 | 7.50 | 1319 | 1322.8 | 19.291 | 1.2564 | .5048 | 477 | .00030 | 3.297 | 304.9 | 9.390 | 1.603 | 284.1 |
| 100.00 | 6.00 | 1260 | 1293.1 | 19.291 | 1.2604 | .4985 | 463 | .00029 | 3.421 | 308.2 | 11.037 | 1.628 | 288.6 |
| 200.00 | 3.00 | 1089 | 1209.4 | 19.291 | 1.2742 | .4787 | 418 | .00025 | 3.817 | 317.2 | 18.290 | 1.698 | 301.0 |
| 300.00 | 2.00 | 997 | 1165.9 | 19.291 | 1.2826 | .4675 | 392 | .00023 | 4.059 | 321.8 | 24.607 | 1.733 | 307.2 |
| 500.00 | 1.20 | 889 | 1116.3 | 19.291 | 1.2932 | .4543 | 362 | .00021 | 4.376 | 326.9 | 35.778 | 1.772 | 314.2 |
| 800.00 | .75 | 798 | 1075.5 | 19.291 | 1.3029 | .4431 | 334 | .00019 | 4.684 | 331.0 | 50.487 | 1.804 | 319.8 |
| 1000.00 | .60 | 758 | 1057.6 | 19.291 | 1.3073 | .4382 | 322 | .00018 | 4.836 | 332.7 | 59.451 | 1.818 | 322.2 |
| 1500.00 | .40 | 688 | 1027.4 | 19.291 | 1.3150 | .4300 | 299 | .00017 | 5.123 | 335.7 | 79.988 | 1.840 | 326.2 |
| R = 0.975, PERCENT FUEL = 42.13, O/F = 1.374 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2975 | 2217.7 | 19.471 | 1.2056 | 0.5984 | 823 | 0.00060 | | | | | |
| 1.05 | 571.43 | 2950 | 2202.9 | 19.471 | 1.2059 | .5977 | 818 | .00059 | 0.285 | 401.5 | 2.171 | 0.203 | 35.8 |
| 1.60 | 375.00 | 2744 | 2080.6 | 19.471 | 1.2088 | .5909 | 780 | .00056 | .900 | 220.8 | 1.010 | .618 | 109.2 |
| 1.78 | 337.53 | 2695 | 2051.4 | 19.471 | 1.2095 | .5892 | 771 | .00055 | 1.000 | 219.8 | 1.000 | .680 | 120.3 |
| 2.00 | 300.00 | 2640 | 2019.3 | 19.471 | 1.2104 | .5872 | 761 | .00054 | 1.103 | 220.6 | 1.009 | .743 | 131.4 |
| 10.00 | 60.00 | 1981 | 1641.8 | 19.471 | 1.2249 | .5558 | 630 | .00043 | 2.156 | 263.2 | 2.223 | 1.266 | 223.9 |
| 20.00 | 30.00 | 1741 | 1510.3 | 19.471 | 1.2336 | .5390 | 578 | .00039 | 2.541 | 279.3 | 3.525 | 1.403 | 248.1 |
| 20.41 | 29.39 | 1734 | 1506.6 | 19.471 | 1.2338 | .5385 | 577 | .00038 | 2.552 | 279.7 | 3.575 | 1.407 | 248.7 |
| 40.00 | 15.00 | 1524 | 1394.9 | 19.471 | 1.2436 | .5211 | 528 | .00034 | 2.917 | 292.9 | 5.720 | 1.513 | 267.6 |
| 40.83 | 14.70 | 1518 | 1391.7 | 19.471 | 1.2439 | .5205 | 527 | .00034 | 2.928 | 293.2 | 5.804 | 1.516 | 268.1 |
| 80.00 | 7.50 | 1327 | 1294.2 | 19.471 | 1.2554 | .5016 | 481 | .00030 | 3.296 | 304.3 | 9.404 | 1.603 | 283.5 |
| 100.00 | 6.00 | 1268 | 1264.7 | 19.471 | 1.2595 | .4954 | 466 | .00029 | 3.420 | 307.5 | 11.054 | 1.629 | 288.0 |
| 200.00 | 3.00 | 1096 | 1181.2 | 19.471 | 1.2731 | .4757 | 421 | .00025 | 3.816 | 316.5 | 18.325 | 1.699 | 300.3 |
| 300.00 | 2.00 | 1003 | 1137.8 | 19.471 | 1.2815 | .4646 | 395 | .00023 | 4.057 | 321.1 | 24.660 | 1.734 | 306.5 |
| 500.00 | 1.20 | 895 | 1088.3 | 19.471 | 1.2922 | .4514 | 364 | .00021 | 4.374 | 326.2 | 35.865 | 1.773 | 313.5 |
| 800.00 | .75 | 804 | 1047.6 | 19.471 | 1.3019 | .4402 | 337 | .00019 | 4.680 | 330.3 | 50.623 | 1.805 | 319.1 |
| 1000.00 | .60 | 763 | 1029.7 | 19.471 | 1.3063 | .4352 | 324 | .00018 | 4.832 | 332.0 | 59.618 | 1.818 | 321.5 |
| 1500.00 | .40 | 693 | 999.6 | 19.471 | 1.3141 | .4270 | 302 | .00017 | 5.118 | 335.0 | 80.230 | 1.841 | 325.6 |

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CQ-5 back

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(d) 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, $\mathcal{M}$ | Isentropic exponent, $\gamma$ | Specific heat, $c_p$, $\frac{cal}{(g)(°K)}$ | Absolute viscosity, $\mu$, micropoises | Thermal conductivity, k, $\frac{cal}{(sec)(cm)(°K)}$ | Mach number, M | Specific impulse, $I_{vac}$, $\frac{(lb)(sec)}{lb}$ | Area ratio, $\varepsilon$ | Thrust coefficient, $C_F$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 1.00; PERCENT FUEL = 41.51; O/F = 1.409 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2980 | 2185.7 | 19.638 | 1.2054 | 0.5939 | 826 | 0.00060 | | | | | |
| 1.05 | 571.43 | 2956 | 2171.1 | 19.638 | 1.2057 | .5932 | 821 | .00059 | 0.285 | 400.1 | 2.171 | 0.203 | 35.7 |
| 1.60 | 375.00 | 2750 | 2049.5 | 19.638 | 1.2085 | .5866 | 784 | .00056 | .900 | 220.1 | 1.010 | .618 | 108.9 |
| 1.78 | 337.56 | 2700 | 2020.5 | 19.638 | 1.2092 | .5848 | 774 | .00055 | 1.000 | 219.0 | 1.000 | .680 | 119.9 |
| 2.00 | 300.00 | 2646 | 1988.6 | 19.638 | 1.2101 | .5829 | 764 | .00054 | 1.103 | 219.9 | 1.009 | .743 | 131.0 |
| 10.00 | 60.00 | 1986 | 1613.5 | 19.638 | 1.2246 | .5518 | 633 | .00043 | 2.156 | 262.3 | 2.223 | 1.266 | 223.1 |
| 20.00 | 30.00 | 1746 | 1482.8 | 19.638 | 1.2331 | .5352 | 581 | .00038 | 2.540 | 278.4 | 3.527 | 1.403 | 247.3 |
| 20.41 | 29.39 | 1739 | 1479.2 | 19.638 | 1.2334 | .5347 | 579 | .00038 | 2.552 | 278.8 | 3.576 | 1.407 | 247.9 |
| 40.00 | 15.00 | 1528 | 1368.1 | 19.638 | 1.2431 | .5175 | 531 | .00034 | 2.917 | 291.9 | 5.724 | 1.513 | 266.7 |
| 40.83 | 14.70 | 1522 | 1365.0 | 19.638 | 1.2434 | .5169 | 530 | .00034 | 2.928 | 292.3 | 5.808 | 1.516 | 267.2 |
| 80.00 | 7.50 | 1331 | 1268.0 | 19.638 | 1.2549 | .4982 | 482 | .00030 | 3.296 | 303.3 | 9.411 | 1.603 | 282.6 |
| 100.00 | 6.00 | 1271 | 1238.6 | 19.638 | 1.2589 | .4920 | 465 | .00029 | 3.420 | 306.6 | 11.064 | 1.629 | 287.1 |
| 200.00 | 3.00 | 1099 | 1155.6 | 19.638 | 1.2725 | .4725 | 412 | .00025 | 3.815 | 315.6 | 18.345 | 1.699 | 299.4 |
| 300.00 | 2.00 | 1007 | 1112.4 | 19.638 | 1.2809 | .4614 | 381 | .00022 | 4.056 | 320.1 | 24.691 | 1.734 | 305.6 |
| 500.00 | 1.20 | 899 | 1063.2 | 19.638 | 1.2915 | .4483 | 341 | .00020 | 4.372 | 325.2 | 35.916 | 1.773 | 312.5 |
| 800.00 | .75 | 807 | 1022.7 | 19.638 | 1.3012 | .4371 | 308 | .00017 | 4.678 | 329.3 | 50.704 | 1.805 | 318.1 |
| 1000.00 | .60 | 766 | 1004.9 | 19.638 | 1.3057 | .4322 | 294 | .00016 | 4.830 | 331.1 | 59.717 | 1.819 | 320.5 |
| 1500.00 | .40 | 696 | 974.9 | 19.638 | 1.3135 | .4240 | 270 | .00015 | 5.116 | 334.0 | 80.374 | 1.842 | 324.6 |
| R = 1.10; PERCENT FUEL = 39.22; O/F = 1.550 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2962 | 2066.7 | 20.207 | 1.2057 | 0.5764 | 831 | 0.00058 | | | | | |
| 1.05 | 571.43 | 2937 | 2052.6 | 20.207 | 1.2060 | .5757 | 827 | .00058 | 0.285 | 393.2 | 2.171 | 0.203 | 35.1 |
| 1.60 | 375.00 | 2732 | 1935.2 | 20.207 | 1.2088 | .5692 | 789 | .00055 | .900 | 216.3 | 1.010 | .618 | 107.0 |
| 1.78 | 337.52 | 2683 | 1907.2 | 20.207 | 1.2096 | .5676 | 779 | .00054 | 1.000 | 215.2 | 1.000 | .680 | 117.8 |
| 2.00 | 300.00 | 2629 | 1876.4 | 20.207 | 1.2104 | .5657 | 769 | .00053 | 1.103 | 216.1 | 1.009 | .743 | 128.7 |
| 10.00 | 60.00 | 1972 | 1514.3 | 20.207 | 1.2290 | .5354 | 637 | .00042 | 2.156 | 257.7 | 2.223 | 1.266 | 219.3 |
| 20.00 | 30.00 | 1733 | 1388.1 | 20.207 | 1.2336 | .5193 | 584 | .00038 | 2.541 | 273.5 | 3.525 | 1.403 | 243.0 |
| 20.41 | 29.39 | 1727 | 1384.6 | 20.207 | 1.2339 | .5188 | 583 | .00037 | 2.552 | 273.9 | 3.574 | 1.407 | 243.6 |
| 40.00 | 15.00 | 1517 | 1277.5 | 20.207 | 1.2436 | .5021 | 534 | .00033 | 2.917 | 286.8 | 5.720 | 1.513 | 262.1 |
| 40.83 | 14.70 | 1511 | 1274.4 | 20.207 | 1.2439 | .5016 | 532 | .00033 | 2.928 | 287.2 | 5.804 | 1.516 | 262.6 |
| 80.00 | 7.50 | 1321 | 1180.9 | 20.207 | 1.2553 | .4835 | 484 | .00029 | 3.296 | 298.0 | 9.403 | 1.603 | 277.6 |
| 100.00 | 6.00 | 1262 | 1152.5 | 20.207 | 1.2594 | .4775 | 468 | .00028 | 3.421 | 301.2 | 11.054 | 1.629 | 282.0 |
| 200.00 | 3.00 | 1091 | 1072.4 | 20.207 | 1.2730 | .4586 | 414 | .00024 | 3.816 | 310.0 | 18.325 | 1.699 | 294.1 |
| 300.00 | 2.00 | 999 | 1030.8 | 20.207 | 1.2813 | .4480 | 382 | .00022 | 4.057 | 314.5 | 24.661 | 1.734 | 300.2 |
| 500.00 | 1.20 | 892 | 983.3 | 20.207 | 1.2919 | .4353 | 342 | .00019 | 4.374 | 319.5 | 35.870 | 1.773 | 307.0 |
| 800.00 | .75 | 801 | 944.3 | 20.207 | 1.3015 | .4245 | 310 | .00017 | 4.680 | 323.5 | 50.634 | 1.805 | 312.5 |
| 1000.00 | .60 | 760 | 927.2 | 20.207 | 1.3060 | .4197 | 296 | .00016 | 4.832 | 325.2 | 59.633 | 1.818 | 314.9 |
| 1500.00 | .40 | 691 | 898.2 | 20.207 | 1.3137 | .4118 | 272 | .00015 | 5.118 | 328.1 | 80.257 | 1.841 | 318.9 |
| R = 1.20; PERCENT FUEL = 37.16; O/F = 1.691 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2914 | 1960.2 | 20.677 | 1.2071 | 0.5602 | 829 | 0.00056 | | | | | |
| 1.05 | 571.43 | 2890 | 1946.6 | 20.677 | 1.2074 | .5594 | 825 | .00056 | 0.285 | 385.6 | 2.172 | 0.203 | 34.4 |
| 1.60 | 375.00 | 2687 | 1833.7 | 20.677 | 1.2103 | .5531 | 787 | .00053 | .900 | 212.0 | 1.010 | .618 | 104.9 |
| 1.78 | 337.35 | 2638 | 1806.7 | 20.677 | 1.2111 | .5514 | 777 | .00052 | 1.000 | 211.0 | 1.000 | .681 | 115.6 |
| 2.00 | 300.00 | 2585 | 1777.2 | 20.677 | 1.2119 | .5496 | 767 | .00051 | 1.103 | 211.8 | 1.009 | .743 | 126.2 |
| 10.00 | 60.00 | 1936 | 1429.6 | 20.677 | 1.2269 | .5196 | 634 | .00041 | 2.156 | 252.5 | 2.219 | 1.266 | 214.9 |
| 20.00 | 30.00 | 1700 | 1308.6 | 20.677 | 1.2357 | .5039 | 581 | .00036 | 2.541 | 268.0 | 3.517 | 1.403 | 238.1 |
| 20.41 | 29.39 | 1693 | 1305.3 | 20.677 | 1.2359 | .5034 | 580 | .00036 | 2.552 | 268.4 | 3.566 | 1.406 | 238.7 |
| 40.00 | 15.00 | 1486 | 1202.6 | 20.677 | 1.2459 | .4870 | 531 | .00032 | 2.918 | 280.9 | 5.702 | 1.513 | 256.7 |
| 40.83 | 14.70 | 1480 | 1199.7 | 20.677 | 1.2462 | .4865 | 530 | .00032 | 2.929 | 281.3 | 5.786 | 1.515 | 257.2 |
| 80.00 | 7.50 | 1293 | 1110.2 | 20.677 | 1.2577 | .4690 | 483 | .00028 | 3.299 | 291.8 | 9.366 | 1.602 | 272.0 |
| 100.00 | 6.00 | 1234 | 1083.1 | 20.677 | 1.2618 | .4632 | 468 | .00027 | 3.423 | 294.9 | 11.007 | 1.628 | 276.3 |
| 200.00 | 3.00 | 1066 | 1006.6 | 20.677 | 1.2755 | .4450 | 422 | .00024 | 3.821 | 303.5 | 18.231 | 1.697 | 288.1 |
| 300.00 | 2.00 | 976 | 966.8 | 20.677 | 1.2837 | .4348 | 397 | .00022 | 4.063 | 307.9 | 24.522 | 1.732 | 294.0 |
| 500.00 | 1.20 | 870 | 921.5 | 20.677 | 1.2943 | .4227 | 366 | .00020 | 4.381 | 312.7 | 35.644 | 1.771 | 300.6 |
| 800.00 | .75 | 781 | 884.3 | 20.677 | 1.3039 | .4124 | 338 | .00018 | 4.690 | 316.6 | 50.287 | 1.803 | 306.0 |
| 1000.00 | .60 | 741 | 868.0 | 20.677 | 1.3082 | .4079 | 325 | .00017 | 4.842 | 318.3 | 59.209 | 1.816 | 308.3 |
| 1500.00 | .40 | 673 | 840.4 | 20.677 | 1.3159 | .4004 | 302 | .00016 | 5.130 | 321.2 | 79.651 | 1.839 | 312.1 |
| R = 1.50; PERCENT FUEL = 32.12; O/F = 2.114 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2759 | 1698.4 | 21.847 | 1.2121 | 0.5198 | 815 | 0.00052 | | | | | |
| 1.05 | 571.43 | 2736 | 1686.2 | 21.847 | 1.2124 | .5191 | 810 | .00051 | 0.284 | 365.0 | 2.175 | 0.203 | 32.6 |
| 1.60 | 375.00 | 2540 | 1585.2 | 21.847 | 1.2155 | .5130 | 772 | .00048 | .898 | 200.5 | 1.010 | .619 | 99.3 |
| 1.78 | 336.73 | 2492 | 1560.6 | 21.847 | 1.2164 | .5114 | 762 | .00048 | 1.000 | 199.6 | 1.000 | .685 | 109.5 |
| 2.00 | 300.00 | 2441 | 1534.7 | 21.847 | 1.2173 | .5096 | 752 | .00047 | 1.101 | 200.3 | 1.009 | .744 | 119.4 |
| 10.00 | 60.00 | 1817 | 1224.8 | 21.847 | 1.2338 | .4800 | 619 | .00037 | 2.156 | 238.4 | 2.207 | 1.265 | 203.0 |
| 20.00 | 30.00 | 1590 | 1117.5 | 21.847 | 1.2430 | .4654 | 566 | .00033 | 2.542 | 252.8 | 3.488 | 1.401 | 224.8 |
| 20.41 | 29.39 | 1583 | 1114.6 | 21.847 | 1.2433 | .4649 | 565 | .00033 | 2.554 | 253.2 | 3.537 | 1.405 | 225.4 |
| 40.00 | 15.00 | 1385 | 1023.8 | 21.847 | 1.2539 | .4492 | 516 | .00029 | 2.922 | 264.9 | 5.640 | 1.510 | 242.3 |
| 40.83 | 14.70 | 1379 | 1021.3 | 21.847 | 1.2542 | .4487 | 514 | .00029 | 2.934 | 265.2 | 5.722 | 1.513 | 242.7 |
| 80.00 | 7.50 | 1201 | 942.4 | 21.847 | 1.2660 | .4329 | 468 | .00026 | 3.307 | 275.0 | 9.236 | 1.599 | 256.5 |
| 100.00 | 6.00 | 1145 | 918.6 | 21.847 | 1.2703 | .4275 | 455 | .00025 | 3.435 | 277.9 | 10.844 | 1.624 | 260.5 |
| 200.00 | 3.00 | 985 | 851.6 | 21.847 | 1.2840 | .4113 | 408 | .00021 | 3.836 | 285.8 | 17.905 | 1.692 | 271.5 |
| 300.00 | 2.00 | 900 | 816.8 | 21.847 | 1.2922 | .4023 | 382 | .00020 | 4.083 | 289.8 | 24.041 | 1.726 | 277.0 |
| 500.00 | 1.20 | 800 | 777.4 | 21.847 | 1.3025 | .3916 | 352 | .00018 | 4.407 | 294.3 | 34.870 | 1.764 | 283.1 |
| 800.00 | .75 | 717 | 745.0 | 21.847 | 1.3117 | .3828 | 324 | .00016 | 4.722 | 297.9 | 49.102 | 1.795 | 288.0 |
| 1000.00 | .60 | 680 | 730.8 | 21.847 | 1.3159 | .3789 | 312 | .00015 | 4.878 | 299.4 | 57.764 | 1.809 | 290.2 |
| 1500.00 | .40 | 616 | 706.9 | 21.847 | 1.3233 | .3723 | 289 | .00014 | 5.172 | 302.0 | 77.590 | 1.831 | 293.7 |

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TABLE II. - Concluded. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(d) 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, $\mathcal{M}$ | Isentropic exponent, $\gamma$ | Specific heat, $c_p$, $\frac{cal}{(g)(°K)}$ | Absolute viscosity, $\mu$, micropoises | Thermal conductivity, k, $\frac{cal}{(sec)(cm)(°K)}$ | Mach number, M | Specific impulse, $I_{vac}$, $\frac{(lb)(sec)}{lb}$ | Area ratio, $\varepsilon$ | Thrust coefficient, $C_F$ | Specific impulse, $I_s$, $\frac{(lb)(sec)}{lb}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R = 2.00; PERCENT FUEL = 26.19; O/F = 2.818 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2536 | 1391.0 | 23.349 | 1.2200 | 0.4720 | 786 | 0.00045 | | | | | |
| 1.05 | 571.43 | 2513 | 1380.5 | 23.349 | 1.2204 | .4713 | 782 | .00045 | 0.283 | 338.3 | 2.180 | 0.204 | 30.2 |
| 1.60 | 375.00 | 2328 | 1293.7 | 23.349 | 1.2240 | .4651 | 744 | .00043 | .895 | 185.7 | 1.010 | .620 | 92.0 |
| 1.79 | 335.73 | 2281 | 1272.0 | 23.349 | 1.2250 | .4633 | 734 | .00042 | 1.000 | 184.8 | 1.000 | .685 | 101.7 |
| 2.00 | 300.00 | 2235 | 1250.4 | 23.349 | 1.2261 | .4615 | 724 | .00041 | 1.098 | 185.4 | 1.008 | .745 | 110.6 |
| 10.00 | 60.00 | 1646 | 986.3 | 23.349 | 1.2444 | .4334 | 591 | .00032 | 2.155 | 220.1 | 2.188 | 1.264 | 187.7 |
| 20.00 | 30.00 | 1433 | 895.6 | 23.349 | 1.2545 | .4195 | 539 | .00028 | 2.545 | 233.2 | 3.444 | 1.399 | 207.6 |
| 20.41 | 29.39 | 1427 | 893.1 | 23.349 | 1.2548 | .4191 | 537 | .00028 | 2.556 | 233.5 | 3.492 | 1.402 | 208.1 |
| 40.00 | 15.00 | 1242 | 816.8 | 23.349 | 1.2659 | .4052 | 489 | .00025 | 2.929 | 244.1 | 5.546 | 1.506 | 223.5 |
| 40.83 | 14.70 | 1237 | 814.6 | 23.349 | 1.2662 | .4048 | 488 | .00025 | 2.941 | 244.4 | 5.626 | 1.509 | 223.9 |
| 80.00 | 7.50 | 1071 | 748.6 | 23.349 | 1.2786 | .3906 | 442 | .00022 | 3.320 | 253.2 | 9.042 | 1.593 | 236.4 |
| 100.00 | 6.00 | 1020 | 728.8 | 23.349 | 1.2829 | .3860 | 427 | .00021 | 3.449 | 255.8 | 10.600 | 1.617 | 240.0 |
| 200.00 | 3.00 | 873 | 673.1 | 23.349 | 1.2964 | .3723 | 383 | .00018 | 3.861 | 262.9 | 17.426 | 1.684 | 249.9 |
| 300.00 | 2.00 | 795 | 644.3 | 23.349 | 1.3045 | .3646 | 359 | .00017 | 4.114 | 266.4 | 23.338 | 1.718 | 254.9 |
| 500.00 | 1.20 | 704 | 611.7 | 23.349 | 1.3144 | .3558 | 329 | .00015 | 4.447 | 270.4 | 33.746 | 1.755 | 260.4 |
| 800.00 | .75 | 629 | 585.1 | 23.349 | 1.3232 | .3484 | 302 | .00014 | 4.771 | 273.6 | 47.391 | 1.784 | 264.8 |
| 1000.00 | .60 | 595 | 573.5 | 23.349 | 1.3272 | .3452 | 290 | .00013 | 4.931 | 275.0 | 55.682 | 1.797 | 266.7 |
| 1500.00 | .40 | 538 | 553.9 | 23.349 | 1.3341 | .3398 | 268 | .00012 | 5.234 | 277.3 | 74.630 | 1.818 | 269.9 |
| R = 3.00; PERCENT FUEL = 19.13; O/F = 4.227 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 2171 | 1024.7 | 25.337 | 1.2350 | 0.4122 | 728 | 0.00037 | | | | | |
| 1.05 | 571.43 | 2151 | 1016.4 | 25.337 | 1.2355 | .4115 | 724 | .00037 | 0.282 | 300.4 | 2.189 | 0.204 | 26.8 |
| 1.60 | 375.00 | 1984 | 948.2 | 25.337 | 1.2398 | .4056 | 686 | .00035 | .891 | 164.6 | 1.011 | .622 | 81.6 |
| 1.80 | 333.89 | 1940 | 930.3 | 25.337 | 1.2410 | .4038 | 676 | .00034 | 1.000 | 163.7 | 1.000 | .691 | 90.6 |
| 2.00 | 300.00 | 1900 | 914.2 | 25.337 | 1.2423 | .4022 | 667 | .00033 | 1.093 | 164.2 | 1.007 | .747 | 98.1 |
| 10.00 | 60.00 | 1373 | 709.0 | 25.337 | 1.2636 | .3760 | 537 | .00025 | 2.154 | 194.0 | 2.155 | 1.263 | 165.7 |
| 20.00 | 30.00 | 1186 | 639.6 | 25.337 | 1.2745 | .3641 | 487 | .00022 | 2.549 | 205.2 | 3.369 | 1.395 | 183.1 |
| 20.41 | 29.39 | 1181 | 637.7 | 25.337 | 1.2749 | .3638 | 485 | .00022 | 2.561 | 205.5 | 3.415 | 1.398 | 183.5 |
| 40.00 | 15.00 | 1019 | 579.7 | 25.337 | 1.2868 | .3519 | 439 | .00020 | 2.942 | 214.4 | 5.385 | 1.499 | 196.8 |
| 40.83 | 14.70 | 1014 | 578.1 | 25.337 | 1.2872 | .3515 | 438 | .00020 | 2.954 | 214.7 | 5.461 | 1.502 | 197.1 |
| 80.00 | 7.50 | 871 | 528.5 | 25.337 | 1.2997 | .3402 | 394 | .00017 | 3.344 | 222.1 | 8.715 | 1.583 | 207.8 |
| 100.00 | 6.00 | 827 | 513.6 | 25.337 | 1.3040 | .3364 | 380 | .00017 | 3.477 | 224.3 | 10.193 | 1.607 | 210.9 |
| 200.00 | 3.00 | 701 | 472.1 | 25.337 | 1.3174 | .3255 | 339 | .00014 | 3.905 | 230.2 | 16.636 | 1.671 | 219.3 |
| 300.00 | 2.00 | 636 | 450.9 | 25.337 | 1.3253 | .3195 | 315 | .00013 | 4.168 | 233.1 | 22.188 | 1.703 | 223.4 |
| 500.00 | 1.20 | 560 | 427.0 | 25.337 | 1.3348 | .3127 | 287 | .00012 | 4.516 | 236.4 | 31.918 | 1.738 | 228.1 |
| 800.00 | .75 | 497 | 407.5 | 25.337 | 1.3429 | .3072 | 262 | .00011 | 4.856 | 239.1 | 44.621 | 1.766 | 231.7 |
| 1000.00 | .60 | 469 | 399.1 | 25.337 | 1.3468 | .3046 | 251 | .00010 | 5.023 | 240.2 | 52.316 | 1.778 | 233.3 |
| 1500.00 | .40 | 423 | 384.9 | 25.337 | 1.3528 | .3007 | 231 | .00009 | 5.342 | 242.1 | 69.858 | 1.798 | 235.9 |
| R = 4.00; PERCENT FUEL = 15.07; O/F = 5.636 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 1877 | 814.0 | 26.566 | 1.2487 | 0.3755 | 672 | 0.00032 | | | | | |
| 1.05 | 571.43 | 1859 | 807.1 | 26.566 | 1.2493 | .3748 | 668 | .00031 | 0.280 | 272.8 | 2.197 | 0.205 | 24.4 |
| 1.60 | 375.00 | 1708 | 751.0 | 26.566 | 1.2543 | .3689 | 631 | .00029 | .887 | 149.1 | 1.012 | .624 | 74.0 |
| 1.81 | 332.23 | 1667 | 735.7 | 26.566 | 1.2557 | .3673 | 621 | .00029 | 1.000 | 148.3 | 1.000 | .695 | 82.5 |
| 2.00 | 300.00 | 1632 | 723.1 | 26.566 | 1.2570 | .3659 | 613 | .00028 | 1.088 | 148.7 | 1.007 | .749 | 88.9 |
| 10.00 | 60.00 | 1162 | 556.2 | 26.566 | 1.2802 | .3418 | 488 | .00021 | 2.153 | 175.0 | 2.127 | 1.262 | 149.8 |
| 20.00 | 30.00 | 996 | 500.3 | 26.566 | 1.2921 | .3309 | 441 | .00019 | 2.553 | 184.8 | 3.305 | 1.392 | 165.2 |
| 20.41 | 29.39 | 991 | 498.8 | 26.566 | 1.2924 | .3306 | 439 | .00019 | 2.565 | 185.1 | 3.350 | 1.395 | 165.6 |
| 40.00 | 15.00 | 849 | 452.6 | 26.566 | 1.3046 | .3204 | 395 | .00016 | 2.953 | 192.9 | 5.252 | 1.494 | 177.3 |
| 40.83 | 14.70 | 845 | 451.3 | 26.566 | 1.3050 | .3201 | 394 | .00016 | 2.965 | 193.1 | 5.325 | 1.497 | 177.6 |
| 80.00 | 7.50 | 720 | 412.0 | 26.566 | 1.3180 | .3101 | 352 | .00014 | 3.365 | 199.6 | 8.448 | 1.576 | 187.0 |
| 100.00 | 6.00 | 682 | 400.3 | 26.566 | 1.3223 | .3069 | 339 | .00014 | 3.501 | 201.4 | 9.861 | 1.598 | 189.7 |
| 200.00 | 3.00 | 575 | 367.8 | 26.566 | 1.3358 | .2976 | 299 | .00012 | 3.942 | 206.5 | 15.994 | 1.660 | 197.0 |
| 300.00 | 2.00 | 519 | 351.2 | 26.566 | 1.3432 | .2927 | 277 | .00011 | 4.215 | 209.1 | 21.257 | 1.691 | 200.7 |
| 500.00 | 1.20 | 455 | 332.6 | 26.566 | 1.3524 | .2871 | 251 | .00010 | 4.576 | 211.9 | 30.448 | 1.724 | 204.6 |
| 800.00 | .75 | 402 | 317.6 | 26.566 | 1.3592 | .2831 | 228 | .00009 | 4.930 | 214.1 | 42.406 | 1.751 | 207.8 |
| 1000.00 | .60 | 379 | 311.1 | 26.566 | 1.3618 | .2815 | 218 | .00008 | 5.106 | 215.1 | 49.639 | 1.762 | 209.2 |
| 1500.00 | .40 | 340 | 300.2 | 26.566 | 1.3658 | .2793 | 199 | .00007 | 5.440 | 216.7 | 66.112 | 1.781 | 211.4 |
| R = 5.00; PERCENT FUEL = 12.43; O/F = 7.046 | | | | | | | | | | | | | |
| 1.00 | 600.00 | 1641 | 677.0 | 27.398 | 1.2610 | 0.3504 | 621 | 0.00027 | | | | | |
| 1.05 | 571.43 | 1624 | 671.3 | 27.398 | 1.2616 | .3498 | 617 | .00027 | 0.279 | 251.0 | 2.205 | 0.206 | 22.4 |
| 1.60 | 375.00 | 1487 | 623.7 | 27.398 | 1.2670 | .3441 | 582 | .00025 | .883 | 137.0 | 1.013 | .625 | 68.1 |
| 1.81 | 330.77 | 1449 | 610.4 | 27.398 | 1.2687 | .3424 | 572 | .00025 | 1.000 | 136.2 | 1.000 | .699 | 76.2 |
| 2.00 | 300.00 | 1419 | 600.2 | 27.398 | 1.2701 | .3411 | 564 | .00024 | 1.084 | 136.5 | 1.006 | .751 | 81.7 |
| 10.00 | 60.00 | 996 | 460.5 | 27.398 | 1.2948 | .3185 | 446 | .00018 | 2.152 | 160.2 | 2.103 | 1.261 | 137.3 |
| 20.00 | 30.00 | 848 | 414.2 | 27.398 | 1.3071 | .3087 | 400 | .00016 | 2.557 | 168.9 | 3.252 | 1.389 | 151.2 |
| 20.41 | 29.39 | 844 | 412.9 | 27.398 | 1.3075 | .3084 | 399 | .00016 | 2.568 | 169.2 | 3.295 | 1.392 | 151.6 |
| 40.00 | 15.00 | 719 | 374.9 | 27.398 | 1.3203 | .2990 | 357 | .00014 | 2.963 | 176.1 | 5.140 | 1.489 | 162.2 |
| 40.83 | 14.70 | 715 | 373.8 | 27.398 | 1.3207 | .2987 | 355 | .00014 | 2.975 | 176.3 | 5.212 | 1.492 | 162.4 |
| 80.00 | 7.50 | 606 | 341.6 | 27.398 | 1.3340 | .2897 | 316 | .00012 | 3.382 | 182.0 | 8.226 | 1.569 | 170.8 |
| 100.00 | 6.00 | 573 | 332.1 | 27.398 | 1.3384 | .2869 | 303 | .00011 | 3.522 | 183.7 | 9.585 | 1.591 | 173.3 |
| 200.00 | 3.00 | 480 | 305.7 | 27.398 | 1.3514 | .2789 | 266 | .00010 | 3.975 | 188.2 | 15.468 | 1.651 | 179.8 |
| 300.00 | 2.00 | 431 | 292.3 | 27.398 | 1.3584 | .2749 | 245 | .00009 | 4.255 | 190.4 | 20.497 | 1.681 | 183.0 |
| 500.00 | 1.20 | 377 | 277.3 | 27.398 | 1.3652 | .2711 | 221 | .00008 | 4.630 | 192.9 | 29.262 | 1.713 | 186.5 |
| 800.00 | .75 | 332 | 265.3 | 27.398 | 1.3699 | .2686 | 200 | .00007 | 4.997 | 194.8 | 40.653 | 1.739 | 189.3 |
| 1000.00 | .60 | 312 | 260.1 | 27.398 | 1.3717 | .2677 | 190 | .00007 | 5.180 | 195.7 | 47.540 | 1.749 | 190.5 |
| 1500.00 | .40 | 280 | 251.4 | 27.398 | 1.3741 | .2664 | 174 | .00006 | 5.525 | 197.0 | 63.216 | 1.768 | 192.5 |

TABLE III. - THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\epsilon$ | Area-ratio exponent, $n_\epsilon$ | Specific impulse, $I_s$, $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ | Specific heat, $c_p$, $(\partial h/\partial T)_P$, (cal)/(g)(°K) | $\left(\frac{\partial \ln \mathcal{A}}{\partial \ln P}\right)_T$ | $\left(\frac{\partial \ln \mathcal{A}}{\partial \ln T}\right)_P$ |
|---|---|---|---|---|---|---|---|---|---|
| R, 0.40; percent fuel, 63.95; O/F, 0.564 | | | | | | | | | |
| 1.00 | 1349 | 0.0000 | | | | | 0.6541 | 0.00000 | 0.0000 |
| 1.05 | 1334 | .0000 | 2.226 | 0.0000 | 29.1 | 0.0000 | .6524 | .00000 | .0000 |
| 1.60 | 1210 | .0000 | 1.015 | .0000 | 88.3 | .0000 | .6381 | .00000 | .0000 |
| 1.84 | 1171 | .0000 | 1.000 | .0000 | 99.7 | .0000 | .6335 | .00000 | .0000 |
| 2.00 | 1148 | .0000 | 1.004 | .0000 | 105.9 | .0000 | .6306 | .00000 | .0000 |
| 10.00 | 772 | .0000 | 2.030 | .0000 | 176.3 | .0000 | .5855 | .00000 | .0000 |
| 20.00 | 646 | .0000 | 3.093 | .0000 | 193.5 | .0000 | .5720 | .00000 | .0000 |
| 20.41 | 643 | .0000 | 3.133 | .0000 | 193.9 | .0000 | .5718 | .00000 | .0000 |
| 40.00 | 538 | .0000 | 4.823 | .0000 | 206.8 | .0000 | .5617 | .00000 | .0000 |
| 40.83 | 535 | .0000 | 4.888 | .0000 | 207.1 | .0000 | .5614 | .00000 | .0000 |
| 80.00 | 447 | .0000 | 7.629 | .0000 | 217.2 | .0000 | .5547 | .00000 | .0000 |
| 100.00 | 421 | .0000 | 8.863 | .0000 | 220.1 | .0000 | .5530 | .00000 | .0000 |
| 200.00 | 349 | .0000 | 14.191 | .0000 | 227.8 | .0000 | .5479 | .00000 | .0000 |
| 300.00 | 312 | .0000 | 18.744 | .0000 | 231.6 | .0000 | .5454 | .00000 | .0000 |
| 500.00 | 271 | .0000 | 26.680 | .0000 | 235.7 | .0000 | .5429 | .00000 | .0000 |
| 800.00 | 238 | .0000 | 36.978 | .0000 | 239.0 | .0000 | .5377 | .00000 | .0000 |
| 1000.00 | 224 | .0000 | 43.187 | .0000 | 240.4 | .0000 | .5347 | .00000 | .0000 |
| 1500.00 | 200 | .0000 | 57.266 | .0000 | 242.7 | .0000 | .5291 | .00000 | .0000 |
| R, 0.50; percent fuel, 58.67; O/F, 0.705 | | | | | | | | | |
| 1.00 | 1784 | 0.0001 | | | | | 0.6607 | 0.00001 | -.0004 |
| 1.05 | 1766 | .0001 | 2.206 | 0.0000 | 32.1 | 0.0000 | .6590 | .00001 | -.0004 |
| 1.60 | 1617 | .0000 | 1.013 | .0000 | 97.5 | .0000 | .6450 | .00000 | -.0001 |
| 1.82 | 1574 | .0000 | 1.000 | .0000 | 109.2 | .0000 | .6408 | .00000 | -.0001 |
| 2.00 | 1542 | .0000 | 1.006 | .0000 | 117.1 | .0000 | .6375 | .00000 | -.0001 |
| 10.00 | 1075 | .0000 | 2.090 | .0000 | 196.4 | .0000 | .5847 | .00000 | .0000 |
| 20.00 | 911 | .0000 | 3.218 | .0000 | 216.3 | .0000 | .5647 | .00000 | .0000 |
| 20.41 | 906 | .0000 | 3.261 | .0000 | 216.8 | .0000 | .5641 | .00000 | .0000 |
| 40.00 | 768 | .0000 | 5.065 | .0000 | 231.7 | .0000 | .5474 | .00000 | .0000 |
| 40.83 | 764 | .0000 | 5.134 | .0000 | 232.1 | .0000 | .5469 | .00000 | .0000 |
| 80.00 | 644 | .0000 | 8.071 | .0000 | 243.9 | .0000 | .5338 | .00000 | .0000 |
| 100.00 | 608 | .0000 | 9.396 | .0000 | 247.3 | .0000 | .5301 | .00000 | .0000 |
| 200.00 | 508 | .0000 | 15.126 | .0000 | 256.4 | .0000 | .5203 | .00000 | .0000 |
| 300.00 | 456 | .0000 | 20.033 | .0000 | 260.9 | .0000 | .5162 | .00000 | .0000 |
| 500.00 | 398 | .0000 | 28.602 | .0000 | 265.9 | .0000 | .5118 | .00000 | .0000 |
| 800.00 | 351 | .0000 | 39.757 | .0000 | 269.8 | .0000 | .5087 | .00000 | .0000 |
| 1000.00 | 330 | .0000 | 46.508 | .0000 | 271.4 | .0000 | .5073 | .00000 | .0000 |
| 1500.00 | 296 | .0000 | 61.884 | .0000 | 274.2 | .0000 | .5051 | .00000 | .0000 |
| R, 0.60; percent fuel, 54.19; O/F, 0.845 | | | | | | | | | |
| 1.00 | 2169 | 0.0012 | | | | | 0.6765 | 0.00025 | -.0067 |
| 1.05 | 2149 | .0011 | 2.191 | 0.0005 | 34.0 | 0.0005 | .6734 | .00022 | -.0061 |
| 1.60 | 1982 | .0004 | 1.012 | .0001 | 103.6 | .0003 | .6514 | .00009 | -.0026 |
| 1.80 | 1937 | .0003 | 1.000 | .0000 | 115.2 | .0003 | .6461 | .00007 | -.0020 |
| 2.00 | 1897 | .0002 | 1.007 | -.0000 | 124.5 | .0003 | .6417 | .00005 | -.0016 |
| 10.00 | 1361 | -.0001 | 2.140 | -.0001 | 210.1 | .0001 | .5870 | .00000 | .0000 |
| 20.00 | 1169 | -.0001 | 3.331 | -.0001 | 231.9 | .0001 | .5650 | .00000 | .0000 |
| 20.41 | 1164 | -.0001 | 3.376 | -.0001 | 232.5 | .0001 | .5643 | .00000 | .0000 |
| 40.00 | 998 | -.0001 | 5.295 | -.0001 | 249.1 | .0000 | .5439 | .00000 | .0000 |
| 40.83 | 993 | -.0001 | 5.369 | -.0001 | 249.5 | .0000 | .5433 | .00000 | .0000 |
| 80.00 | 847 | -.0001 | 8.519 | -.0001 | 262.8 | .0000 | .5252 | .00000 | .0000 |
| 100.00 | 803 | -.0001 | 9.944 | -.0001 | 266.6 | .0000 | .5198 | .00000 | .0000 |
| 200.00 | 676 | -.0001 | 16.132 | -.0001 | 277.0 | .0000 | .5049 | .00000 | .0000 |
| 300.00 | 611 | -.0001 | 21.449 | -.0001 | 282.1 | .0000 | .4979 | .00000 | .0000 |
| 500.00 | 536 | -.0001 | 30.751 | -.0001 | 287.8 | .0000 | .4902 | .00000 | .0000 |
| 800.00 | 474 | -.0001 | 42.881 | -.0001 | 292.2 | .0000 | .4846 | .00000 | .0000 |
| 1000.00 | 447 | -.0001 | 50.232 | -.0001 | 294.2 | .0000 | .4824 | .00000 | .0000 |
| 1500.00 | 402 | -.0001 | 66.995 | -.0001 | 297.4 | .0000 | .4788 | .00000 | .0000 |
| R, 0.70; percent fuel, 50.34; O/F, 0.986 | | | | | | | | | |
| 1.00 | 2494 | 0.0061 | | | | | 0.7547 | 0.00160 | -.0390 |
| 1.05 | 2474 | .0057 | 2.172 | 0.0018 | 35.3 | 0.0023 | .7474 | .00149 | -.0365 |
| 1.60 | 2305 | .0030 | 1.010 | .0003 | 107.5 | .0017 | .6937 | .00075 | -.0196 |
| 1.78 | 2262 | .0025 | 1.000 | .0000 | 118.6 | .0016 | .6824 | .00062 | -.0164 |
| 2.00 | 2216 | .0020 | 1.009 | -.0003 | 129.3 | .0015 | .6714 | .00050 | -.0135 |
| 10.00 | 1633 | -.0006 | 2.185 | -.0014 | 219.6 | .0006 | .5884 | .00001 | -.0003 |
| 20.00 | 1418 | -.0007 | 3.431 | -.0013 | 243.0 | .0004 | .5662 | .00000 | .0000 |
| 20.41 | 1412 | -.0007 | 3.478 | -.0013 | 243.6 | .0004 | .5656 | .00000 | .0000 |
| 40.00 | 1225 | -.0007 | 5.506 | -.0013 | 261.5 | .0003 | .5447 | .00000 | .0000 |
| 40.83 | 1219 | -.0007 | 5.585 | -.0013 | 262.0 | .0003 | .5441 | .00000 | .0000 |
| 80.00 | 1052 | -.0007 | 8.943 | -.0012 | 276.5 | .0002 | .5236 | .00000 | .0000 |
| 100.00 | 1000 | -.0007 | 10.470 | -.0012 | 280.7 | .0002 | .5172 | .00000 | .0000 |
| 200.00 | 852 | -.0008 | 17.139 | -.0012 | 292.1 | .0002 | .4986 | .00000 | .0000 |
| 300.00 | 773 | -.0008 | 22.897 | -.0012 | 297.8 | .0001 | .4889 | .00000 | .0000 |
| 500.00 | 683 | -.0008 | 33.006 | -.0012 | 304.1 | .0001 | .4781 | .00000 | .0000 |
| 800.00 | 608 | -.0008 | 46.234 | -.0012 | 309.2 | .0001 | .4698 | .00000 | .0000 |
| 1000.00 | 575 | -.0008 | 54.262 | -.0012 | 311.3 | .0001 | .4662 | .00000 | .0000 |
| 1500.00 | 519 | -.0008 | 72.597 | -.0012 | 315.0 | .0001 | .4604 | .00000 | .0000 |

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\varepsilon$ | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ | Specific heat, $c_p$, $(\partial h/\partial T)_P$, (cal)/(g)(°K) | $\left(\frac{\partial \ln \mathcal{A}}{\partial \ln P}\right)_T$ | $\left(\frac{\partial \ln \mathcal{A}}{\partial \ln T}\right)_P$ |
|---|---|---|---|---|---|---|---|---|---|
| R, 0.80; percent fuel, 47.01; O/F, 1.127 | | | | | | | | | |
| 1.00 | 2734 | 0.0148 | | | | | 0.9466 | 0.00557 | -.1262 |
| 1.05 | 2717 | .0143 | 2.151 | 0.0030 | 35.8 | 0.0055 | .9545 | .00531 | -.1210 |
| 1.60 | 2563 | .0100 | 1.008 | .0005 | 109.5 | .0047 | .8356 | .00333 | -.0803 |
| 1.76 | 2528 | .0091 | 1.000 | .0000 | 119.7 | .0045 | .8150 | .00296 | -.0722 |
| 2.00 | 2482 | .0078 | 1.011 | -.0007 | 131.9 | .0042 | .7886 | .00250 | -.0622 |
| 10.00 | 1893 | -.0013 | 2.241 | -.0057 | 225.9 | .0019 | .5974 | .00012 | -.0039 |
| 20.00 | 1661 | -.0020 | 3.544 | -.0058 | 250.5 | .0014 | .5683 | .00002 | -.0007 |
| 20.41 | 1654 | -.0020 | 3.594 | -.0057 | 251.2 | .0014 | .5676 | .00002 | -.0006 |
| 40.00 | 1449 | -.0022 | 5.731 | -.0056 | 270.2 | .0011 | .5461 | .00000 | -.0001 |
| 40.83 | 1443 | -.0022 | 5.815 | -.0056 | 270.8 | .0011 | .5455 | .00000 | -.0001 |
| 80.00 | 1257 | -.0023 | 9.387 | -.0055 | 286.3 | .0008 | .5251 | .00000 | .0000 |
| 100.00 | 1199 | -.0024 | 11.022 | -.0054 | 290.8 | .0008 | .5184 | .00000 | .0000 |
| 200.00 | 1033 | -.0025 | 18.203 | -.0054 | 303.2 | .0006 | .4979 | .00000 | .0000 |
| 300.00 | 943 | -.0025 | 24.443 | -.0053 | 309.5 | .0005 | .4867 | .00000 | .0000 |
| 500.00 | 839 | -.0026 | 35.455 | -.0053 | 316.4 | .0004 | .4735 | .00000 | .0000 |
| 800.00 | 752 | -.0027 | 49.927 | -.0053 | 322.0 | .0004 | .4625 | .00000 | .0000 |
| 1000.00 | 713 | -.0027 | 58.736 | -.0053 | 324.4 | .0004 | .4578 | .00000 | .0000 |
| 1500.00 | 646 | -.0027 | 78.899 | -.0053 | 328.4 | .0003 | .4500 | .00000 | .0000 |
| R, 0.90; percent fuel, 44.09; O/F, 1.268 | | | | | | | | | |
| 1.00 | 2877 | 0.0229 | | | | | 1.2266 | 0.01223 | -.2662 |
| 1.05 | 2862 | .0225 | 2.134 | 0.0025 | 35.9 | 0.0083 | 1.2148 | .01189 | -.2602 |
| 1.60 | 2731 | .0189 | 1.006 | .0004 | 109.8 | .0077 | 1.1072 | .00903 | -.2073 |
| 1.74 | 2704 | .0182 | 1.000 | .0000 | 119.0 | .0075 | 1.0847 | .00848 | -.1967 |
| 2.00 | 2661 | .0168 | 1.013 | -.0008 | 132.5 | .0073 | 1.0470 | .00761 | -.1794 |
| 10.00 | 2135 | .0006 | 2.320 | -.0105 | 229.0 | .0045 | .6645 | .00098 | -.0286 |
| 20.00 | 1900 | -.0033 | 3.704 | -.0126 | 254.8 | .0034 | .5881 | .00023 | -.0074 |
| 20.41 | 1893 | -.0034 | 3.757 | -.0127 | 255.5 | .0034 | .5866 | .00022 | -.0070 |
| 40.00 | 1675 | -.0047 | 6.033 | -.0131 | 275.7 | .0026 | .5510 | .00004 | -.0013 |
| 40.83 | 1668 | -.0047 | 6.122 | -.0131 | 276.3 | .0026 | .5502 | .00003 | -.0012 |
| 80.00 | 1467 | -.0051 | 9.951 | -.0129 | 292.9 | .0020 | .5277 | .00000 | -.0002 |
| 100.00 | 1404 | -.0052 | 11.711 | -.0128 | 297.7 | .0019 | .5209 | .00000 | -.0001 |
| 200.00 | 1221 | -.0055 | 19.495 | -.0127 | 311.1 | .0015 | .5006 | .00000 | .0000 |
| 300.00 | 1122 | -.0056 | 26.305 | -.0126 | 317.8 | .0013 | .4887 | .00000 | .0000 |
| 500.00 | 1006 | -.0058 | 38.394 | -.0126 | 325.4 | .0011 | .4741 | .00000 | .0000 |
| 800.00 | 907 | -.0059 | 54.374 | -.0126 | 331.5 | .0010 | .4616 | .00000 | .0000 |
| 1000.00 | 863 | -.0060 | 64.136 | -.0126 | 334.2 | .0009 | .4559 | .00000 | .0000 |
| 1500.00 | 787 | -.0061 | 86.552 | -.0126 | 338.6 | .0008 | .4461 | .00000 | .0000 |
| R, 0.95; percent fuel, 42.76; O/F, 1.339 | | | | | | | | | |
| 1.00 | 2913 | 0.0254 | | | | | 1.3349 | 0.01520 | -.3270 |
| 1.05 | 2899 | .0250 | 2.130 | 0.0020 | 35.7 | 0.0092 | 1.3256 | .01488 | -.3217 |
| 1.60 | 2774 | .0221 | 1.006 | .0003 | 109.5 | .0086 | 1.2397 | .01215 | -.2750 |
| 1.73 | 2751 | .0215 | 1.000 | .0000 | 118.2 | .0085 | 1.2220 | .01164 | -.2658 |
| 2.00 | 2709 | .0204 | 1.014 | -.0006 | 132.1 | .0083 | 1.1901 | .01076 | -.2498 |
| 10.00 | 2234 | .0051 | 2.364 | -.0100 | 229.1 | .0059 | .7776 | .00254 | -.0716 |
| 20.00 | 2015 | -.0018 | 3.808 | -.0144 | 255.6 | .0048 | .6375 | .00078 | -.0243 |
| 20.41 | 2008 | -.0019 | 3.863 | -.0145 | 256.3 | .0047 | .6345 | .00074 | -.0233 |
| 40.00 | 1791 | -.0056 | 6.237 | -.0165 | 277.1 | .0037 | .5646 | .00015 | -.0054 |
| 40.83 | 1784 | -.0056 | 6.330 | -.0166 | 277.7 | .0037 | .5633 | .00015 | -.0051 |
| 80.00 | 1577 | -.0068 | 10.324 | -.0168 | 294.8 | .0029 | .5315 | .00002 | -.0008 |
| 100.00 | 1512 | -.0070 | 12.164 | -.0168 | 299.8 | .0027 | .5238 | .00001 | -.0004 |
| 200.00 | 1321 | -.0074 | 20.318 | -.0166 | 313.7 | .0022 | .5026 | .00000 | .0000 |
| 300.00 | 1218 | -.0076 | 27.476 | -.0165 | 320.8 | .0019 | .4910 | .00000 | .0000 |
| 500.00 | 1096 | -.0078 | 40.222 | -.0165 | 328.7 | .0016 | .4762 | .00000 | .0000 |
| 800.00 | 992 | -.0080 | 57.122 | -.0165 | 335.1 | .0014 | .4630 | .00000 | .0000 |
| 1000.00 | 945 | -.0081 | 67.468 | -.0165 | 337.9 | .0013 | .4571 | .00000 | .0000 |
| 1500.00 | 864 | -.0083 | 91.270 | -.0165 | 342.5 | .0012 | .4466 | .00000 | .0000 |

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\epsilon$ | Area-ratio exponent, $n_\epsilon$ | Specific impulse, $I_s$, $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ | Specific heat, $c_p$, $(\partial h/\partial T)_P$, (cal)/(g)(°K) | $\left(\frac{\partial \ln \epsilon}{\partial \ln P}\right)_T$ | $\left(\frac{\partial \ln \epsilon}{\partial \ln P}\right)_p$ |
|---|---|---|---|---|---|---|---|---|---|
| R, 1.00; percent fuel, 41.51; O/F, 1.409 | | | | | | | | | |
| 1.00 | 2928 | 0.0262 | | | | | 1.3651 | 0.01648 | -.3522 |
| 1.05 | 2914 | .0259 | 2.128 | 0.0018 | 35.5 | 0.0094 | 1.3572 | .01617 | -.3473 |
| 1.60 | 2792 | .0233 | 1.006 | .0003 | 108.8 | .0090 | 1.2845 | .01359 | -.3050 |
| 1.73 | 2769 | .0227 | 1.000 | .0000 | 117.4 | .0089 | 1.2700 | .01318 | -.2969 |
| 2.00 | 2728 | .0218 | 1.015 | -.0005 | 131.3 | .0087 | 1.2432 | .01229 | -.2824 |
| 10.00 | 2283 | .0098 | 2.388 | -.0078 | 228.1 | .0067 | .9129 | .00460 | -.1267 |
| 20.00 | 2089 | .0039 | 3.887 | -.0115 | 254.9 | .0058 | .7746 | .00244 | -.0735 |
| 20.41 | 2083 | .0038 | 3.945 | -.0116 | 255.6 | .0057 | .7708 | .00239 | -.0721 |
| 40.00 | 1891 | -.0017 | 6.453 | -.0152 | 276.8 | .0049 | .6592 | .00106 | -.0353 |
| 40.83 | 1885 | -.0018 | 6.551 | -.0153 | 277.4 | .0048 | .6562 | .00103 | -.0344 |
| 80.00 | 1691 | -.0060 | 10.799 | -.0179 | 295.2 | .0040 | .5771 | .00036 | -.0132 |
| 100.00 | 1627 | -.0070 | 12.756 | -.0185 | 300.4 | .0037 | .5580 | .00024 | -.0091 |
| 200.00 | 1434 | -.0089 | 21.438 | -.0195 | 314.9 | .0030 | .5153 | .00005 | -.0023 |
| 300.00 | 1326 | -.0095 | 29.067 | -.0197 | 322.3 | .0027 | .4983 | .00002 | -.0009 |
| 500.00 | 1199 | -.0100 | 42.681 | -.0198 | 330.6 | .0023 | .4810 | .00000 | -.0002 |
| 800.00 | 1089 | -.0103 | 60.786 | -.0199 | 337.4 | .0020 | .4668 | .00000 | -.0001 |
| 1000.00 | 1039 | -.0105 | 71.892 | -.0199 | 340.4 | .0019 | .4604 | .00000 | .0000 |
| 1500.00 | 953 | -.0107 | 97.495 | -.0199 | 345.3 | .0017 | .4494 | .00000 | .0000 |
| R, 1.10; percent fuel, 39.22; O/F, 1.550 | | | | | | | | | |
| 1.00 | 2913 | 0.0247 | | | | | 1.2483 | 0.01454 | -.3121 |
| 1.05 | 2898 | .0244 | 2.130 | 0.0020 | 34.9 | 0.0089 | 1.2393 | .01422 | -.3068 |
| 1.60 | 2773 | .0213 | 1.006 | .0003 | 107.0 | .0083 | 1.1574 | .01151 | -.2601 |
| 1.74 | 2749 | .0207 | 1.000 | .0000 | 115.5 | .0082 | 1.1409 | .01101 | -.2511 |
| 2.00 | 2707 | .0197 | 1.014 | -.0006 | 129.0 | .0080 | 1.1117 | .01015 | -.2354 |
| 10.00 | 2236 | .0064 | 2.368 | -.0085 | 223.8 | .0058 | .7848 | .00291 | -.0834 |
| 20.00 | 2030 | .0011 | 3.836 | -.0118 | 249.8 | .0048 | .6769 | .00137 | -.0437 |
| 20.41 | 2023 | .0010 | 3.892 | -.0118 | 250.5 | .0048 | .6741 | .00133 | -.0428 |
| 40.00 | 1823 | -.0030 | 6.334 | -.0142 | 271.0 | .0040 | .5972 | .00055 | -.0200 |
| 40.83 | 1817 | -.0031 | 6.430 | -.0143 | 271.6 | .0039 | .5952 | .00054 | -.0195 |
| 80.00 | 1621 | -.0056 | 10.560 | -.0158 | 288.7 | .0032 | .5421 | .00019 | -.0078 |
| 100.00 | 1557 | -.0062 | 12.464 | -.0161 | 293.7 | .0030 | .5284 | .00013 | -.0055 |
| 200.00 | 1368 | -.0075 | 20.903 | -.0167 | 307.6 | .0024 | .4945 | .00003 | -.0016 |
| 300.00 | 1264 | -.0079 | 28.314 | -.0168 | 314.7 | .0021 | .4794 | .00001 | -.0007 |
| 500.00 | 1140 | -.0083 | 41.518 | -.0169 | 322.7 | .0018 | .4628 | .00000 | -.0002 |
| 800.00 | 1034 | -.0086 | 59.048 | -.0169 | 329.1 | .0016 | .4491 | .00000 | -.0001 |
| 1000.00 | 986 | -.0087 | 69.789 | -.0169 | 332.0 | .0015 | .4431 | .00000 | .0000 |
| 1500.00 | 903 | -.0089 | 94.526 | -.0170 | 336.7 | .0013 | .4327 | .00000 | .0000 |
| R, 1.20; percent fuel, 37.16; O/F, 1.691 | | | | | | | | | |
| 1.00 | 2871 | 0.0222 | | | | | 1.1178 | 0.01176 | -.2575 |
| 1.05 | 2856 | .0219 | 2.133 | 0.0021 | 34.2 | 0.0080 | 1.1093 | .01147 | -.2525 |
| 1.60 | 2726 | .0188 | 1.006 | .0003 | 104.9 | .0075 | 1.0346 | .00906 | -.2100 |
| 1.74 | 2701 | .0182 | 1.000 | .0000 | 113.5 | .0074 | 1.0197 | .00863 | -.2019 |
| 2.00 | 2659 | .0171 | 1.014 | -.0006 | 126.5 | .0072 | .9945 | .00791 | -.1884 |
| 10.00 | 2175 | .0050 | 2.355 | -.0077 | 219.2 | .0050 | .7271 | .00221 | -.0662 |
| 20.00 | 1968 | .0006 | 3.805 | -.0105 | 244.4 | .0042 | .6378 | .00105 | -.0352 |
| 20.41 | 1962 | .0005 | 3.861 | -.0105 | 245.1 | .0042 | .6355 | .00103 | -.0344 |
| 40.00 | 1762 | -.0029 | 6.270 | -.0126 | 265.1 | .0034 | .5686 | .00043 | -.0161 |
| 40.83 | 1756 | -.0029 | 6.364 | -.0126 | 265.6 | .0034 | .5669 | .00041 | -.0157 |
| 80.00 | 1562 | -.0051 | 10.432 | -.0139 | 282.2 | .0028 | .5192 | .00014 | -.0061 |
| 100.00 | 1499 | -.0056 | 12.304 | -.0141 | 287.0 | .0026 | .5067 | .00009 | -.0042 |
| 200.00 | 1314 | -.0066 | 20.590 | -.0146 | 300.5 | .0021 | .4759 | .00002 | -.0012 |
| 300.00 | 1212 | -.0070 | 27.856 | -.0147 | 307.3 | .0018 | .4620 | .00001 | -.0005 |
| 500.00 | 1091 | -.0073 | 40.785 | -.0147 | 315.0 | .0016 | .4465 | .00000 | -.0001 |
| 800.00 | 988 | -.0076 | 57.925 | -.0148 | 321.2 | .0014 | .4338 | .00000 | .0000 |
| 1000.00 | 941 | -.0077 | 68.417 | -.0148 | 323.9 | .0013 | .4281 | .00000 | .0000 |
| 1500.00 | 861 | -.0078 | 92.559 | -.0148 | 328.4 | .0011 | .4183 | .00000 | .0000 |
| R, 1.50; percent fuel, 32.12; O/F, 2.114 | | | | | | | | | |
| 1.00 | 2728 | 0.0173 | | | | | 0.9074 | 0.00731 | -.1719 |
| 1.05 | 2712 | .0170 | 2.138 | 0.0019 | 32.5 | 0.0064 | .9009 | .00710 | -.1682 |
| 1.60 | 2579 | .0142 | 1.007 | .0003 | 99.3 | .0059 | .8450 | .00549 | -.1376 |
| 1.74 | 2551 | .0136 | 1.000 | .0000 | 107.8 | .0058 | .8335 | .00519 | -.1316 |
| 2.00 | 2509 | .0127 | 1.013 | -.0005 | 119.8 | .0056 | .8152 | .00473 | -.1223 |
| 10.00 | 2013 | .0026 | 2.325 | -.0066 | 206.9 | .0038 | .6144 | .00117 | -.0386 |
| 20.00 | 1804 | -.0007 | 3.732 | -.0087 | 230.4 | .0030 | .5472 | .00050 | -.0187 |
| 20.41 | 1798 | -.0008 | 3.786 | -.0087 | 231.0 | .0030 | .5455 | .00049 | -.0182 |
| 40.00 | 1600 | -.0030 | 6.106 | -.0100 | 249.4 | .0024 | .4971 | .00018 | -.0074 |
| 40.83 | 1594 | -.0031 | 6.197 | -.0101 | 249.9 | .0024 | .4959 | .00017 | -.0072 |
| 80.00 | 1405 | -.0043 | 10.088 | -.0107 | 265.1 | .0019 | .4620 | .00005 | -.0023 |
| 100.00 | 1345 | -.0046 | 11.874 | -.0108 | 269.5 | .0018 | .4532 | .00003 | -.0015 |
| 200.00 | 1170 | -.0051 | 19.750 | -.0109 | 281.8 | .0014 | .4310 | .00001 | -.0003 |
| 300.00 | 1075 | -.0053 | 26.630 | -.0109 | 288.0 | .0013 | .4199 | .00000 | -.0001 |
| 500.00 | 963 | -.0055 | 38.831 | -.0109 | 294.9 | .0011 | .4075 | .00000 | .0000 |
| 800.00 | 868 | -.0056 | 54.950 | -.0109 | 300.5 | .0009 | .3969 | .00000 | .0000 |
| 1000.00 | 825 | -.0057 | 64.794 | -.0109 | 302.9 | .0009 | .3928 | .00000 | .0000 |
| 1500.00 | 752 | -.0058 | 87.389 | -.0110 | 306.9 | .0008 | .3840 | .00000 | .0000 |

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\varepsilon$ | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, $I_t$ $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ | Specific heat, $c_p$, $(\partial h/\partial T)_P$, (cal)/(g)(°K) | $\left(\frac{\partial \ln \varepsilon}{\partial \ln P}\right)_T$ | $\left(\frac{\partial \ln \varepsilon}{\partial \ln T}\right)_P$ |
|---|---|---|---|---|---|---|---|---|---|
| R, 2.00; percent fuel, 26.19; O/F, 2.818 | | | | | | | | | |
| 1.00 | 2515 | 0.0122 | | | | | 0.7201 | 0.00397 | -.1032 |
| 1.05 | 2499 | .0119 | 2.147 | 0.0018 | 30.1 | 0.0047 | .7148 | .00383 | -.1004 |
| 1.60 | 2362 | .0094 | 1.008 | .0003 | 92.1 | .0042 | .6684 | .00280 | -.0781 |
| 1.75 | 2332 | .0089 | 1.000 | .0000 | 100.4 | .0041 | .6584 | .00260 | -.0735 |
| 2.00 | 2290 | .0081 | 1.012 | -.0005 | 111.0 | .0040 | .6441 | .00233 | -.0672 |
| 10.00 | 1782 | .0003 | 2.275 | -.0052 | 190.7 | .0023 | .4949 | .00039 | -.0148 |
| 20.00 | 1574 | -.0016 | 3.612 | -.0063 | 211.8 | .0018 | .4530 | .00013 | -.0056 |
| 20.41 | 1568 | -.0016 | 3.663 | -.0063 | 212.4 | .0018 | .4520 | .00013 | -.0054 |
| 40.00 | 1377 | -.0025 | 5.849 | -.0068 | 228.8 | .0014 | .4238 | .00003 | -.0016 |
| 40.83 | 1371 | -.0026 | 5.934 | -.0068 | 229.3 | .0014 | .4230 | .00003 | -.0016 |
| 80.00 | 1195 | -.0030 | 9.579 | -.0069 | 242.6 | .0011 | .4033 | .00001 | -.0004 |
| 100.00 | 1141 | -.0030 | 11.245 | -.0068 | 246.5 | .0010 | .3977 | .00000 | -.0002 |
| 200.00 | 982 | -.0032 | 18.564 | -.0068 | 257.2 | .0008 | .3821 | .00000 | .0000 |
| 300.00 | 898 | -.0033 | 24.925 | -.0068 | 262.5 | .0007 | .3738 | .00000 | .0000 |
| 500.00 | 799 | -.0034 | 36.156 | -.0068 | 268.5 | .0006 | .3639 | .00000 | .0000 |
| 800.00 | 716 | -.0035 | 50.923 | -.0068 | 273.3 | .0005 | .3556 | .00000 | .0000 |
| 1000.00 | 679 | -.0035 | 59.913 | -.0068 | 275.4 | .0005 | .3519 | .00000 | .0000 |
| 1500.00 | 616 | -.0036 | 80.490 | -.0068 | 278.8 | .0004 | .3455 | .00000 | .0000 |
| R, 3.00; percent fuel, 19.13; O/F, 4.227 | | | | | | | | | |
| 1.00 | 2163 | 0.0056 | | | | | 0.5151 | 0.00120 | -.0368 |
| 1.05 | 2146 | .0054 | 2.168 | 0.0014 | 26.8 | 0.0023 | .5112 | .00114 | -.0353 |
| 1.60 | 2004 | .0036 | 1.009 | .0003 | 81.7 | .0019 | .4795 | .00071 | -.0237 |
| 1.78 | 1969 | .0032 | 1.000 | .0000 | 90.0 | .0018 | .4721 | .00063 | -.0213 |
| 2.00 | 1929 | .0027 | 1.009 | -.0003 | 98.3 | .0017 | .4641 | .00054 | -.0187 |
| 10.00 | 1427 | -.0006 | 2.189 | -.0022 | 167.3 | .0008 | .3878 | .00004 | -.0017 |
| 20.00 | 1236 | -.0009 | 3.429 | -.0023 | 185.1 | .0006 | .3700 | .00001 | -.0004 |
| 20.41 | 1231 | -.0009 | 3.476 | -.0023 | 185.5 | .0006 | .3696 | .00001 | -.0004 |
| 40.00 | 1065 | -.0010 | 5.488 | -.0022 | 199.1 | .0004 | .3558 | .00000 | -.0001 |
| 40.83 | 1060 | -.0010 | 5.566 | -.0022 | 199.5 | .0004 | .3554 | .00000 | -.0001 |
| 80.00 | 912 | -.0011 | 8.893 | -.0022 | 210.5 | .0003 | .3434 | .00000 | .0000 |
| 100.00 | 866 | -.0011 | 10.406 | -.0022 | 213.7 | .0003 | .3396 | .00000 | .0000 |
| 200.00 | 737 | -.0011 | 17.008 | -.0021 | 222.3 | .0002 | .3282 | .00000 | .0000 |
| 300.00 | 668 | -.0011 | 22.703 | -.0021 | 226.6 | .0002 | .3221 | .00000 | .0000 |
| 500.00 | 590 | -.0011 | 32.694 | -.0021 | 231.4 | .0002 | .3148 | .00000 | .0000 |
| 800.00 | 524 | -.0012 | 45.747 | -.0021 | 235.2 | .0001 | .3089 | .00000 | .0000 |
| 1000.00 | 495 | -.0012 | 53.660 | -.0021 | 236.8 | .0001 | .3063 | .00000 | .0000 |
| 1500.00 | 446 | -.0012 | 71.702 | -.0021 | 239.6 | .0001 | .3019 | .00000 | .0000 |
| R, 4.00; percent fuel, 15.07; O/F, 5.636 | | | | | | | | | |
| 1.00 | 1875 | 0.0021 | | | | | 0.4158 | 0.00033 | -.0119 |
| 1.05 | 1858 | .0020 | 2.187 | 0.0007 | 24.3 | 0.0009 | .4133 | .00031 | -.0112 |
| 1.60 | 1717 | .0011 | 1.011 | .0001 | 74.1 | .0007 | .3939 | .00016 | -.0064 |
| 1.80 | 1680 | .0009 | 1.000 | .0000 | 82.3 | .0006 | .3893 | .00013 | -.0054 |
| 2.00 | 1645 | .0007 | 1.007 | -.0001 | 89.1 | .0006 | .3853 | .00011 | -.0045 |
| 10.00 | 1179 | -.0002 | 2.137 | -.0006 | 150.4 | .0002 | .3442 | .00000 | -.0002 |
| 20.00 | 1012 | -.0003 | 3.323 | -.0006 | 166.0 | .0002 | .3322 | .00000 | .0000 |
| 20.41 | 1007 | -.0003 | 3.368 | -.0006 | 166.4 | .0002 | .3319 | .00000 | .0000 |
| 40.00 | 864 | -.0003 | 5.282 | -.0005 | 178.2 | .0001 | .3215 | .00000 | .0000 |
| 40.83 | 859 | -.0003 | 5.356 | -.0005 | 178.6 | .0001 | .3211 | .00000 | .0000 |
| 80.00 | 733 | -.0003 | 8.500 | -.0005 | 188.0 | .0001 | .3110 | .00000 | .0000 |
| 100.00 | 695 | -.0003 | 9.924 | -.0005 | 190.8 | .0001 | .3078 | .00000 | .0000 |
| 200.00 | 585 | -.0003 | 16.104 | -.0005 | 198.2 | .0001 | .2983 | .00000 | .0000 |
| 300.00 | 528 | -.0003 | 21.408 | -.0005 | 201.8 | .0001 | .2934 | .00000 | .0000 |
| 500.00 | 463 | -.0003 | 30.675 | -.0005 | 205.9 | .0000 | .2877 | .00000 | .0000 |
| 800.00 | 410 | -.0003 | 42.731 | -.0005 | 209.1 | .0000 | .2834 | .00000 | .0000 |
| 1000.00 | 386 | -.0003 | 50.025 | -.0005 | 210.5 | .0000 | .2818 | .00000 | .0000 |
| 1500.00 | 347 | -.0004 | 66.635 | -.0005 | 212.7 | .0000 | .2794 | .00000 | .0000 |
| R, 5.00; percent fuel, 12.43; O/F, 7.046 | | | | | | | | | |
| 1.00 | 1640 | 0.0007 | | | | | 0.3655 | 0.00009 | -.0035 |
| 1.05 | 1624 | .0006 | 2.200 | 0.0003 | 22.4 | 0.0003 | .3640 | .00008 | -.0033 |
| 1.60 | 1491 | .0003 | 1.013 | .0000 | 68.1 | .0002 | .3523 | .00003 | -.0016 |
| 1.81 | 1453 | .0002 | 1.000 | .0000 | 76.1 | .0002 | .3493 | .00003 | -.0012 |
| 2.00 | 1424 | .0002 | 1.006 | -.0000 | 81.8 | .0002 | .3470 | .00002 | -.0010 |
| 10.00 | 1002 | -.0001 | 2.106 | -.0001 | 137.5 | .0001 | .3191 | .00000 | .0000 |
| 20.00 | 853 | -.0001 | 3.257 | -.0001 | 151.5 | .0000 | .3091 | .00000 | .0000 |
| 20.41 | 849 | -.0001 | 3.301 | -.0001 | 151.9 | .0000 | .3088 | .00000 | .0000 |
| 40.00 | 723 | -.0001 | 5.149 | -.0001 | 162.5 | .0000 | .2993 | .00000 | .0000 |
| 40.83 | 720 | -.0001 | 5.221 | -.0001 | 162.8 | .0000 | .2990 | .00000 | .0000 |
| 80.00 | 610 | -.0001 | 8.241 | -.0001 | 171.2 | .0000 | .2899 | .00000 | .0000 |
| 100.00 | 577 | -.0001 | 9.603 | -.0001 | 173.6 | .0000 | .2871 | .00000 | .0000 |
| 200.00 | 483 | -.0001 | 15.499 | -.0001 | 180.2 | .0000 | .2792 | .00000 | .0000 |
| 300.00 | 434 | -.0001 | 20.540 | -.0001 | 183.4 | .0000 | .2751 | .00000 | .0000 |
| 500.00 | 379 | -.0001 | 29.326 | -.0001 | 186.9 | .0000 | .2712 | .00000 | .0000 |
| 800.00 | 334 | -.0001 | 40.744 | -.0001 | 189.7 | .0000 | .2687 | .00000 | .0000 |
| 1000.00 | 315 | -.0001 | 47.646 | -.0001 | 190.9 | .0000 | .2677 | .00000 | .0000 |
| 1500.00 | 282 | -.0001 | 63.359 | -.0001 | 192.9 | .0000 | .2664 | .00000 | .0000 |

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\varepsilon$ | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ |
|---|---|---|---|---|---|---|
| R, 0.40; percent fuel, 63.95; O/F, 0.564 | | | | | | |
| 1.05 | 1334 | 0.0000 | 2.226 | 0.0000 | 29.1 | 0.0000 |
| 1.60 | 1210 | .0000 | 1.015 | .0000 | 88.3 | .0000 |
| 2.00 | 1148 | .0000 | 1.004 | .0000 | 105.9 | .0000 |
| 10.00 | 772 | .0000 | 2.030 | .0000 | 176.3 | .0000 |
| 20.00 | 646 | .0000 | 3.093 | .0000 | 193.5 | .0000 |
| 20.41 | 643 | .0000 | 3.133 | .0000 | 193.9 | .0000 |
| 40.00 | 538 | .0000 | 4.823 | .0000 | 206.8 | .0000 |
| 40.83 | 535 | .0000 | 4.888 | .0000 | 207.1 | .0000 |
| 80.00 | 447 | .0000 | 7.629 | .0000 | 217.2 | .0000 |
| 100.00 | 421 | .0000 | 8.863 | .0000 | 220.1 | .0000 |
| 200.00 | 349 | .0000 | 14.191 | .0000 | 227.8 | .0000 |
| 300.00 | 312 | .0000 | 18.744 | .0000 | 231.6 | .0000 |
| 500.00 | 271 | .0000 | 26.680 | .0000 | 235.7 | .0000 |
| 800.00 | 238 | .0000 | 36.978 | .0000 | 239.0 | .0000 |
| 1000.00 | 224 | .0000 | 43.187 | .0000 | 240.4 | .0000 |
| 1500.00 | 200 | .0000 | 57.266 | .0000 | 242.7 | .0000 |
| R, 0.50; percent fuel, 58.67; O/F, 0.705 | | | | | | |
| 1.05 | 1766 | 0.0001 | 2.206 | 0.0000 | 52.1 | 0.0001 |
| 1.60 | 1617 | .0001 | 1.013 | .0000 | 97.5 | .0000 |
| 2.00 | 1541 | .0001 | 1.006 | .0000 | 117.1 | .0000 |
| 10.00 | 1074 | .0001 | 2.090 | .0000 | 196.4 | .0000 |
| 20.00 | 911 | .0001 | 3.218 | .0000 | 216.2 | .0000 |
| 20.41 | 906 | .0001 | 3.261 | .0000 | 216.8 | .0000 |
| 40.00 | 768 | .0001 | 5.064 | .0000 | 231.7 | .0000 |
| 40.83 | 764 | .0001 | 5.134 | .0000 | 232.1 | .0000 |
| 80.00 | 644 | .0001 | 8.071 | .0000 | 243.9 | .0000 |
| 100.00 | 608 | .0001 | 9.395 | .0000 | 247.3 | .0000 |
| 200.00 | 508 | .0001 | 15.125 | .0000 | 256.4 | .0000 |
| 300.00 | 456 | .0001 | 20.032 | .0000 | 260.9 | .0000 |
| 500.00 | 398 | .0001 | 28.600 | .0000 | 265.8 | .0000 |
| 800.00 | 351 | .0001 | 39.755 | .0000 | 269.7 | .0000 |
| 1000.00 | 330 | .0001 | 46.505 | .0000 | 271.4 | .0000 |
| 1500.00 | 296 | .0001 | 61.880 | .0000 | 274.2 | .0000 |
| R, 0.60; percent fuel, 54.19; O/F, 0.845 | | | | | | |
| 1.05 | 2149 | 0.0011 | 2.193 | 0.0001 | 34.0 | 0.0005 |
| 1.60 | 1979 | .0011 | 1.012 | .0000 | 103.6 | .0004 |
| 2.00 | 1893 | .0011 | 1.007 | .0000 | 124.4 | .0004 |
| 10.00 | 1357 | .0013 | 2.139 | .0001 | 209.9 | .0005 |
| 20.00 | 1165 | .0013 | 3.328 | .0002 | 231.7 | .0005 |
| 20.41 | 1160 | .0013 | 3.373 | .0002 | 232.2 | .0005 |
| 40.00 | 994 | .0014 | 5.291 | .0003 | 248.8 | .0005 |
| 40.83 | 990 | .0014 | 5.365 | .0003 | 249.2 | .0005 |
| 80.00 | 844 | .0015 | 8.510 | .0003 | 262.5 | .0005 |
| 100.00 | 799 | .0015 | 9.934 | .0003 | 266.3 | .0005 |
| 200.00 | 674 | .0016 | 16.114 | .0004 | 276.6 | .0005 |
| 300.00 | 608 | .0016 | 21.423 | .0004 | 281.8 | .0005 |
| 500.00 | 533 | .0017 | 30.711 | .0005 | 287.4 | .0005 |
| 800.00 | 472 | .0017 | 42.823 | .0005 | 291.9 | .0005 |
| 1000.00 | 445 | .0017 | 50.162 | .0005 | 293.8 | .0006 |
| 1500.00 | 400 | .0017 | 66.899 | .0005 | 297.0 | .0006 |
| R, 0.70; percent fuel, 50.34; O/F, 0.986 | | | | | | |
| 1.05 | 2472 | 0.0054 | 2.183 | 0.0003 | 35.2 | 0.0022 |
| 1.60 | 2286 | .0055 | 1.011 | .0000 | 107.3 | .0021 |
| 2.00 | 2193 | .0056 | 1.008 | .0000 | 129.0 | .0021 |
| 10.00 | 1604 | .0064 | 2.175 | .0006 | 218.6 | .0023 |
| 20.00 | 1391 | .0068 | 3.413 | .0010 | 241.7 | .0024 |
| 20.41 | 1385 | .0068 | 3.460 | .0010 | 242.3 | .0024 |
| 40.00 | 1200 | .0072 | 5.473 | .0013 | 260.0 | .0024 |
| 40.83 | 1195 | .0072 | 5.551 | .0013 | 260.5 | .0024 |
| 80.00 | 1029 | .0076 | 8.882 | .0017 | 274.8 | .0025 |
| 100.00 | 978 | .0078 | 10.396 | .0018 | 278.9 | .0025 |
| 200.00 | 832 | .0082 | 17.002 | .0021 | 290.2 | .0026 |
| 300.00 | 755 | .0084 | 22.701 | .0023 | 295.8 | .0026 |
| 500.00 | 666 | .0087 | 32.704 | .0026 | 302.1 | .0027 |
| 800.00 | 593 | .0089 | 45.786 | .0028 | 307.0 | .0027 |
| 1000.00 | 560 | .0090 | 53.725 | .0028 | 309.2 | .0027 |
| 1500.00 | 505 | .0092 | 71.849 | .0030 | 312.7 | .0028 |

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\varepsilon$ | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ |
|---|---|---|---|---|---|---|
| R, 0.80; percent fuel, 47.01; O/F, 1.127 | | | | | | |
| 1.05 | 2711 | 0.0137 | 2.177 | 0.0004 | 35.8 | 0.0051 |
| 1.60 | 2515 | .0141 | 1.010 | .0001 | 109.1 | .0052 |
| 2.00 | 2416 | .0143 | 1.009 | .0001 | 131.2 | .0053 |
| 10.00 | 1790 | .0163 | 2.200 | .0016 | 222.9 | .0057 |
| 20.00 | 1564 | .0172 | 3.471 | .0024 | 246.8 | .0059 |
| 20.41 | 1557 | .0172 | 3.519 | .0024 | 247.4 | .0059 |
| 40.00 | 1359 | .0183 | 5.599 | .0033 | 265.8 | .0060 |
| 40.83 | 1353 | .0183 | 5.680 | .0033 | 266.3 | .0060 |
| 80.00 | 1174 | .0194 | 9.146 | .0042 | 281.3 | .0062 |
| 100.00 | 1119 | .0198 | 10.728 | .0046 | 285.6 | .0063 |
| 200.00 | 959 | .0210 | 17.662 | .0056 | 297.5 | .0064 |
| 300.00 | 874 | .0217 | 23.671 | .0062 | 303.5 | .0065 |
| 500.00 | 776 | .0226 | 34.253 | .0069 | 310.1 | .0067 |
| 800.00 | 693 | .0233 | 48.133 | .0076 | 315.5 | .0068 |
| 1000.00 | 656 | .0236 | 56.572 | .0078 | 317.7 | .0068 |
| 1500.00 | 594 | .0242 | 75.868 | .0083 | 321.6 | .0069 |
| R, 0.90; percent fuel, 44.09; O/F, 1.268 | | | | | | |
| 1.05 | 2853 | 0.0221 | 2.174 | 0.0007 | 35.8 | 0.0081 |
| 1.60 | 2651 | .0227 | 1.010 | .0001 | 109.2 | .0082 |
| 2.00 | 2549 | .0231 | 1.009 | .0002 | 131.4 | .0083 |
| 10.00 | 1904 | .0262 | 2.214 | .0026 | 223.6 | .0090 |
| 20.00 | 1669 | .0277 | 3.503 | .0038 | 247.7 | .0092 |
| 20.41 | 1662 | .0278 | 3.553 | .0039 | 248.4 | .0093 |
| 40.00 | 1456 | .0295 | 5.672 | .0053 | 267.0 | .0095 |
| 40.83 | 1450 | .0295 | 5.755 | .0053 | 267.6 | .0095 |
| 80.00 | 1264 | .0313 | 9.300 | .0068 | 282.8 | .0098 |
| 100.00 | 1206 | .0320 | 10.923 | .0074 | 287.2 | .0099 |
| 200.00 | 1039 | .0340 | 18.057 | .0091 | 299.4 | .0102 |
| 300.00 | 950 | .0352 | 24.258 | .0101 | 305.5 | .0104 |
| 500.00 | 846 | .0367 | 35.206 | .0114 | 312.3 | .0106 |
| 800.00 | 758 | .0380 | 49.600 | .0126 | 317.8 | .0107 |
| 1000.00 | 719 | .0386 | 58.362 | .0131 | 320.2 | .0108 |
| 1500.00 | 652 | .0396 | 78.422 | .0140 | 324.2 | .0110 |
| R, 0.95; percent fuel, 42.76; O/F, 1.339 | | | | | | |
| 1.05 | 2889 | 0.0247 | 2.173 | 0.0007 | 35.7 | 0.0089 |
| 1.60 | 2686 | .0255 | 1.010 | .0002 | 108.8 | .0091 |
| 2.00 | 2583 | .0259 | 1.009 | .0002 | 130.9 | .0092 |
| 10.00 | 1932 | .0293 | 2.217 | .0029 | 222.9 | .0100 |
| 20.00 | 1696 | .0310 | 3.512 | .0043 | 247.0 | .0103 |
| 20.41 | 1689 | .0311 | 3.561 | .0043 | 247.6 | .0103 |
| 40.00 | 1481 | .0330 | 5.691 | .0059 | 266.3 | .0106 |
| 40.83 | 1475 | .0330 | 5.774 | .0059 | 266.8 | .0106 |
| 80.00 | 1287 | .0351 | 9.341 | .0076 | 282.0 | .0109 |
| 100.00 | 1229 | .0358 | 10.974 | .0082 | 286.4 | .0110 |
| 200.00 | 1060 | .0380 | 18.161 | .0102 | 298.6 | .0114 |
| 300.00 | 970 | .0394 | 24.414 | .0114 | 304.8 | .0115 |
| 500.00 | 864 | .0411 | 35.461 | .0128 | 311.6 | .0118 |
| 800.00 | 775 | .0426 | 49.995 | .0141 | 317.1 | .0120 |
| 1000.00 | 735 | .0433 | 58.846 | .0148 | 319.5 | .0121 |
| 1500.00 | 667 | .0445 | 79.117 | .0158 | 323.5 | .0122 |

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\varepsilon$ | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ |
|---|---|---|---|---|---|---|
| R, 1.00; percent fuel, 41.51; O/F, 1.409 | | | | | | |
| 1.05 | 2904 | 0.0257 | 2.172 | 0.0007 | 35.5 | 0.0092 |
| 1.60 | 2700 | .0265 | 1.010 | .0001 | 108.2 | .0094 |
| 2.00 | 2597 | .0269 | 1.009 | .0002 | 130.1 | .0095 |
| 10.00 | 1945 | .0305 | 2.219 | .0030 | 221.5 | .0103 |
| 20.00 | 1707 | .0323 | 3.516 | .0045 | 245.5 | .0106 |
| 20.41 | 1700 | .0323 | 3.565 | .0045 | 246.1 | .0106 |
| 40.00 | 1492 | .0343 | 5.700 | .0061 | 264.7 | .0110 |
| 40.83 | 1486 | .0343 | 5.783 | .0062 | 265.2 | .0110 |
| 80.00 | 1298 | .0364 | 9.360 | .0079 | 280.4 | .0113 |
| 100.00 | 1239 | .0372 | 10.999 | .0086 | 284.8 | .0114 |
| 200.00 | 1070 | .0395 | 18.211 | .0106 | 297.0 | .0118 |
| 300.00 | 979 | .0410 | 24.489 | .0118 | 303.1 | .0119 |
| 500.00 | 872 | .0427 | 35.585 | .0134 | 309.9 | .0122 |
| 800.00 | 783 | .0443 | 50.188 | .0148 | 315.4 | .0124 |
| 1000.00 | 743 | .0451 | 59.083 | .0154 | 317.8 | .0125 |
| 1500.00 | 674 | .0463 | 79.460 | .0165 | 321.8 | .0127 |
| R, 1.10; percent fuel, 39.22; O/F, 1.550 | | | | | | |
| 1.05 | 2889 | 0.0240 | 2.172 | 0.0007 | 34.9 | 0.0086 |
| 1.60 | 2686 | .0247 | 1.010 | .0001 | 106.3 | .0088 |
| 2.00 | 2583 | .0252 | 1.009 | .0002 | 127.9 | .0089 |
| 10.00 | 1934 | .0285 | 2.218 | .0028 | 217.8 | .0096 |
| 20.00 | 1697 | .0302 | 3.514 | .0042 | 241.3 | .0099 |
| 20.41 | 1691 | .0302 | 3.564 | .0042 | 241.9 | .0099 |
| 40.00 | 1483 | .0321 | 5.697 | .0057 | 260.2 | .0103 |
| 40.83 | 1477 | .0321 | 5.780 | .0058 | 260.7 | .0103 |
| 80.00 | 1290 | .0341 | 9.354 | .0075 | 275.6 | .0106 |
| 100.00 | 1232 | .0348 | 10.992 | .0080 | 280.0 | .0107 |
| 200.00 | 1063 | .0370 | 18.199 | .0099 | 291.9 | .0110 |
| 300.00 | 973 | .0383 | 24.472 | .0111 | 297.9 | .0112 |
| 500.00 | 867 | .0400 | 35.559 | .0125 | 304.6 | .0114 |
| 800.00 | 778 | .0415 | 50.151 | .0138 | 310.0 | .0116 |
| 1000.00 | 738 | .0422 | 59.040 | .0144 | 312.4 | .0117 |
| 1500.00 | 670 | .0434 | 79.401 | .0155 | 316.3 | .0118 |
| R, 1.20; percent fuel, 37.16; O/F, 1.691 | | | | | | |
| 1.05 | 2847 | 0.0214 | 2.173 | 0.0007 | 34.2 | 0.0079 |
| 1.60 | 2646 | .0221 | 1.010 | .0001 | 104.3 | .0079 |
| 2.00 | 2545 | .0225 | 1.009 | .0001 | 125.5 | .0080 |
| 10.00 | 1902 | .0255 | 2.215 | .0025 | 213.6 | .0087 |
| 20.00 | 1668 | .0270 | 3.507 | .0038 | 236.6 | .0089 |
| 20.41 | 1662 | .0270 | 3.557 | .0038 | 237.2 | .0090 |
| 40.00 | 1457 | .0287 | 5.682 | .0051 | 255.1 | .0092 |
| 40.83 | 1451 | .0287 | 5.765 | .0052 | 255.6 | .0092 |
| 80.00 | 1265 | .0305 | 9.322 | .0067 | 270.2 | .0095 |
| 100.00 | 1208 | .0311 | 10.952 | .0072 | 274.4 | .0096 |
| 200.00 | 1042 | .0331 | 18.119 | .0089 | 286.1 | .0099 |
| 300.00 | 953 | .0343 | 24.354 | .0099 | 292.0 | .0100 |
| 500.00 | 849 | .0357 | 35.368 | .0112 | 298.5 | .0102 |
| 800.00 | 761 | .0371 | 49.859 | .0123 | 303.8 | .0104 |
| 1000.00 | 722 | .0377 | 58.683 | .0129 | 306.0 | .0105 |
| 1500.00 | 655 | .0387 | 78.894 | .0138 | 309.8 | .0106 |
| R, 1.50; percent fuel, 32.12; O/F, 2.114 | | | | | | |
| 1.05 | 2705 | 0.0166 | 2.176 | 0.0005 | 32.4 | 0.0062 |
| 1.60 | 2510 | .0171 | 1.010 | .0001 | 98.8 | .0063 |
| 2.00 | 2412 | .0174 | 1.009 | .0001 | 118.9 | .0064 |
| 10.00 | 1792 | .0197 | 2.204 | .0026 | 202.0 | .0069 |
| 20.00 | 1567 | .0209 | 3.481 | .0029 | 223.7 | .0071 |
| 20.41 | 1561 | .0209 | 3.530 | .0029 | 224.3 | .0071 |
| 40.00 | 1364 | .0222 | 5.625 | .0040 | 241.1 | .0073 |
| 40.83 | 1358 | .0222 | 5.706 | .0040 | 241.5 | .0073 |
| 80.00 | 1181 | .0235 | 9.203 | .0051 | 255.1 | .0075 |
| 100.00 | 1126 | .0240 | 10.802 | .0055 | 259.1 | .0076 |
| 200.00 | 968 | .0255 | 17.821 | .0068 | 270.0 | .0078 |
| 300.00 | 884 | .0263 | 23.916 | .0075 | 275.5 | .0079 |
| 500.00 | 785 | .0274 | 34.666 | .0085 | 281.5 | .0081 |
| 800.00 | 703 | .0284 | 48.787 | .0093 | 286.4 | .0082 |
| 1000.00 | 666 | .0288 | 57.379 | .0097 | 288.5 | .0083 |
| 1500.00 | 604 | .0296 | 77.038 | .0103 | 292.0 | .0084 |

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\varepsilon$ | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, I, (lb)(sec)/lb | Specific-impulse exponent, $n_I$ |
|---|---|---|---|---|---|---|
| R, 2.00; percent fuel, 26.19; O/F, 2.818 | | | | | | |
| 1.05 | 2493 | 0.0116 | 2.181 | 0.0004 | 30.1 | 0.0046 |
| 1.60 | 2309 | .0120 | 1.010 | .0001 | 91.7 | .0046 |
| 2.00 | 2216 | .0122 | 1.008 | .0001 | 110.2 | .0047 |
| 10.00 | 1630 | .0138 | 2.186 | .0013 | 187.0 | .0050 |
| 20.00 | 1419 | .0146 | 3.440 | .0020 | 206.9 | .0051 |
| 20.41 | 1413 | .0146 | 3.487 | .0020 | 207.4 | .0052 |
| 40.00 | 1229 | .0155 | 5.535 | .0027 | 222.7 | .0053 |
| 40.83 | 1224 | .0155 | 5.615 | .0027 | 223.1 | .0053 |
| 80.00 | 1059 | .0164 | 9.020 | .0035 | 235.5 | .0054 |
| 100.00 | 1008 | .0167 | 10.572 | .0038 | 239.1 | .0055 |
| 200.00 | 862 | .0177 | 17.371 | .0046 | 249.0 | .0056 |
| 300.00 | 785 | .0182 | 23.257 | .0050 | 253.9 | .0057 |
| 500.00 | 695 | .0189 | 33.615 | .0056 | 259.3 | .0058 |
| 800.00 | 620 | .0195 | 47.191 | .0061 | 263.7 | .0059 |
| 1000.00 | 587 | .0197 | 55.438 | .0063 | 265.6 | .0059 |
| 1500.00 | 531 | .0202 | 74.282 | .0067 | 268.8 | .0060 |
| R, 3.00; percent fuel, 19.13; O/F, 4.227 | | | | | | |
| 1.05 | 2143 | 0.0053 | 2.189 | 0.0001 | 26.8 | 0.0021 |
| 1.60 | 1976 | .0054 | 1.011 | .0000 | 81.5 | .0022 |
| 2.00 | 1892 | .0055 | 1.007 | .0000 | 97.9 | .0022 |
| 10.00 | 1368 | .0062 | 2.154 | .0006 | 165.5 | .0024 |
| 20.00 | 1180 | .0065 | 3.367 | .0008 | 182.8 | .0024 |
| 20.41 | 1175 | .0065 | 3.413 | .0008 | 183.2 | .0024 |
| 40.00 | 1014 | .0069 | 5.381 | .0011 | 196.4 | .0025 |
| 40.83 | 1009 | .0069 | 5.457 | .0011 | 196.8 | .0025 |
| 80.00 | 866 | .0073 | 8.707 | .0014 | 207.4 | .0026 |
| 100.00 | 822 | .0074 | 10.183 | .0015 | 210.5 | .0026 |
| 200.00 | 698 | .0077 | 16.615 | .0018 | 218.9 | .0026 |
| 300.00 | 632 | .0079 | 22.157 | .0020 | 223.0 | .0027 |
| 500.00 | 557 | .0082 | 31.869 | .0022 | 227.6 | .0027 |
| 800.00 | 494 | .0084 | 44.547 | .0024 | 231.3 | .0027 |
| 1000.00 | 467 | .0085 | 52.227 | .0025 | 232.9 | .0027 |
| 1500.00 | 420 | .0086 | 69.732 | .0026 | 235.5 | .0028 |
| R, 4.00; percent fuel, 15.07; O/F, 5.636 | | | | | | |
| 1.05 | 1857 | 0.0020 | 2.198 | 0.0001 | 24.3 | 0.0009 |
| 1.60 | 1706 | .0020 | 1.012 | .0000 | 74.0 | .0009 |
| 2.00 | 1630 | .0021 | 1.007 | .0000 | 88.9 | .0009 |
| 10.00 | 1160 | .0023 | 2.126 | .0002 | 149.7 | .0009 |
| 20.00 | 994 | .0024 | 3.304 | .0003 | 165.1 | .0009 |
| 20.41 | 989 | .0024 | 3.349 | .0003 | 165.5 | .0009 |
| 40.00 | 848 | .0026 | 5.250 | .0004 | 177.2 | .0010 |
| 40.83 | 844 | .0026 | 5.324 | .0004 | 177.5 | .0010 |
| 80.00 | 719 | .0027 | 8.445 | .0005 | 186.9 | .0010 |
| 100.00 | 681 | .0027 | 9.857 | .0005 | 189.6 | .0010 |
| 200.00 | 574 | .0028 | 15.988 | .0006 | 196.9 | .0010 |
| 300.00 | 518 | .0029 | 21.247 | .0007 | 200.5 | .0010 |
| 500.00 | 454 | .0030 | 30.433 | .0007 | 204.5 | .0010 |
| 800.00 | 401 | .0030 | 42.383 | .0008 | 207.7 | .0010 |
| 1000.00 | 378 | .0030 | 49.612 | .0008 | 209.0 | .0010 |
| 1500.00 | 339 | .0031 | 66.074 | .0008 | 211.3 | .0011 |
| R, 5.00; percent fuel, 12.43; O/F, 7.046 | | | | | | |
| 1.05 | 1624 | 0.0006 | 2.205 | 0.0000 | 22.4 | 0.0003 |
| 1.60 | 1487 | .0007 | 1.013 | .0000 | 68.1 | .0003 |
| 2.00 | 1418 | .0007 | 1.006 | .0000 | 81.7 | .0003 |
| 10.00 | 995 | .0007 | 2.103 | .0001 | 137.2 | .0003 |
| 20.00 | 848 | .0008 | 3.252 | .0001 | 151.2 | .0003 |
| 20.41 | 844 | .0008 | 3.295 | .0001 | 151.6 | .0003 |
| 40.00 | 719 | .0008 | 5.140 | .0001 | 162.1 | .0003 |
| 40.83 | 715 | .0008 | 5.211 | .0001 | 162.4 | .0003 |
| 80.00 | 606 | .0009 | 8.225 | .0001 | 170.8 | .0003 |
| 100.00 | 573 | .0009 | 9.584 | .0002 | 173.2 | .0003 |
| 200.00 | 479 | .0009 | 15.466 | .0002 | 179.7 | .0003 |
| 300.00 | 431 | .0009 | 20.494 | .0002 | 182.9 | .0003 |
| 500.00 | 376 | .0009 | 29.258 | .0002 | 186.4 | .0003 |
| 800.00 | 332 | .0009 | 40.647 | .0002 | 189.2 | .0003 |
| 1000.00 | 312 | .0009 | 47.533 | .0002 | 190.4 | .0003 |
| 1500.00 | 280 | .0009 | 63.206 | .0002 | 192.4 | .0003 |

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $p_c/p$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, ε | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, I, (lb)(sec)/lb | Specific-impulse exponent, $n_I$ | Specific heat, $c_p$, $(\partial h/\partial T)_p$, (cal)/(g)(°K) | $\left(\frac{\partial \ln \varepsilon}{\partial \ln p}\right)_T$ | $\left(\frac{\partial \ln \varepsilon}{\partial \ln T}\right)_p$ |
|---|---|---|---|---|---|---|---|---|---|
| R, 0.40; percent fuel, 63.95; O/F, 0.564 | | | | | | | | | |
| 1.00 | 1349 | 0.0000 | | | | | 0.6540 | 0.00000 | 0.0000 |
| 1.05 | 1334 | .0000 | 2.226 | 0.0000 | 29.1 | 0.0000 | .6524 | .00000 | .0000 |
| 1.60 | 1210 | .0000 | 1.015 | .0000 | 88.3 | .0000 | .6381 | .00000 | .0000 |
| 1.84 | 1171 | .0000 | 1.000 | .0000 | 99.7 | .0000 | .6335 | .00000 | .0000 |
| 2.00 | 1148 | .0000 | 1.004 | .0000 | 105.9 | .0000 | .6307 | .00000 | .0000 |
| 10.00 | 772 | .0000 | 2.030 | .0000 | 176.3 | .0000 | .5855 | .00000 | .0000 |
| 20.00 | 646 | .0000 | 3.093 | .0000 | 193.5 | .0000 | .5720 | .00000 | .0000 |
| 20.41 | 643 | .0000 | 3.133 | .0000 | 193.9 | .0000 | .5717 | .00000 | .0000 |
| 40.00 | 538 | .0000 | 4.823 | .0000 | 206.8 | .0000 | .5618 | .00000 | .0000 |
| 40.83 | 535 | .0000 | 4.888 | .0000 | 207.1 | .0000 | .5616 | .00000 | .0000 |
| 80.00 | 447 | .0000 | 7.629 | .0000 | 217.2 | .0000 | .5547 | .00000 | .0000 |
| 100.00 | 421 | .0000 | 8.863 | .0000 | 220.1 | .0000 | .5530 | .00000 | .0000 |
| 200.00 | 349 | .0000 | 14.191 | .0000 | 227.8 | .0000 | .5478 | .00000 | .0000 |
| 300.00 | 312 | .0000 | 18.744 | .0000 | 231.6 | .0000 | .5454 | .00000 | .0000 |
| 500.00 | 271 | .0000 | 26.680 | .0000 | 235.7 | .0000 | .5427 | .00000 | .0000 |
| 800.00 | 238 | .0000 | 36.978 | .0000 | 239.0 | .0000 | .5377 | .00000 | .0000 |
| 1000.00 | 224 | .0000 | 43.187 | .0000 | 240.4 | .0000 | .5344 | .00000 | .0000 |
| 1500.00 | 200 | .0000 | 57.266 | .0000 | 242.7 | .0000 | .5294 | .00000 | .0000 |
| | | | | | | .0000 | .0000 | .00000 | .0000 |
| R, 0.50; percent fuel, 58.67; O/F, 0.705 | | | | | | | | | |
| 1.00 | 1784 | 0.0001 | | | | | 0.6602 | 0.00001 | -.0003 |
| 1.05 | 1766 | .0001 | 2.206 | 0.0000 | 32.1 | 0.0000 | .6585 | .00001 | -.0003 |
| 1.60 | 1617 | .0000 | 1.013 | .0000 | 97.5 | .0000 | .6448 | .00000 | -.0001 |
| 1.82 | 1574 | .0000 | 1.000 | .0000 | 109.2 | .0000 | .6407 | .00000 | -.0001 |
| 2.00 | 1542 | .0000 | 1.006 | .0000 | 117.1 | .0000 | .6375 | .00000 | .0000 |
| 10.00 | 1075 | .0000 | 2.090 | .0000 | 196.4 | .0000 | .5847 | .00000 | .0000 |
| 20.00 | 911 | .0000 | 3.218 | .0000 | 216.3 | .0000 | .5646 | .00000 | .0000 |
| 20.41 | 906 | .0000 | 3.261 | .0000 | 216.8 | .0000 | .5641 | .00000 | .0000 |
| 40.00 | 768 | .0000 | 5.065 | .0000 | 231.7 | .0000 | .5474 | .00000 | .0000 |
| 40.83 | 764 | .0000 | 5.134 | .0000 | 232.1 | .0000 | .5469 | .00000 | .0000 |
| 80.00 | 644 | .0000 | 8.071 | .0000 | 243.9 | .0000 | .5337 | .00000 | .0000 |
| 100.00 | 608 | .0000 | 9.396 | .0000 | 247.3 | .0000 | .5301 | .00000 | .0000 |
| 200.00 | 508 | .0000 | 15.126 | .0000 | 256.4 | .0000 | .5202 | .00000 | .0000 |
| 300.00 | 456 | .0000 | 20.033 | .0000 | 260.9 | .0000 | .5162 | .00000 | .0000 |
| 500.00 | 398 | .0000 | 28.602 | .0000 | 265.9 | .0000 | .5121 | .00000 | .0000 |
| 800.00 | 351 | .0000 | 39.757 | .0000 | 269.8 | .0000 | .5087 | .00000 | .0000 |
| 1000.00 | 330 | .0000 | 46.508 | .0000 | 271.4 | .0000 | .5072 | .00000 | .0000 |
| 1500.00 | 296 | .0000 | 61.884 | .0000 | 274.2 | .0000 | .5054 | .00000 | .0000 |
| R, 0.60; percent fuel, 54.19; O/F, 0.845 | | | | | | | | | |
| 1.00 | 2171 | 0.0009 | | | | | 0.6700 | 0.00018 | -.0047 |
| 1.05 | 2151 | .0008 | 2.191 | 0.0003 | 34.1 | 0.0003 | .6675 | .00016 | -.0043 |
| 1.60 | 1983 | .0003 | 1.012 | .0000 | 103.6 | .0002 | .6486 | .00006 | -.0018 |
| 1.80 | 1938 | .0002 | 1.000 | .0000 | 115.2 | .0002 | .6440 | .00005 | -.0014 |
| 2.00 | 1898 | .0002 | 1.007 | -.0000 | 124.5 | .0002 | .6399 | .00004 | -.0011 |
| 10.00 | 1361 | -.0001 | 2.140 | -.0001 | 210.1 | .0001 | .5870 | .00000 | .0000 |
| 20.00 | 1169 | -.0001 | 3.330 | -.0001 | 231.9 | .0000 | .5650 | .00000 | .0000 |
| 20.41 | 1164 | -.0001 | 3.375 | -.0001 | 232.5 | .0000 | .5643 | .00000 | .0000 |
| 40.00 | 998 | -.0001 | 5.295 | -.0001 | 249.1 | .0000 | .5439 | .00000 | .0000 |
| 40.83 | 993 | -.0001 | 5.369 | -.0001 | 249.5 | .0000 | .5433 | .00000 | .0000 |
| 80.00 | 847 | -.0001 | 8.518 | -.0001 | 262.8 | .0000 | .5252 | .00000 | .0000 |
| 100.00 | 803 | -.0001 | 9.943 | -.0001 | 266.6 | .0000 | .5197 | .00000 | .0000 |
| 200.00 | 676 | -.0001 | 16.131 | -.0001 | 277.0 | .0000 | .5050 | .00000 | .0000 |
| 300.00 | 611 | -.0001 | 21.448 | -.0001 | 282.1 | .0000 | .4979 | .00000 | .0000 |
| 500.00 | 536 | -.0001 | 30.749 | -.0001 | 287.8 | .0000 | .4902 | .00000 | .0000 |
| 800.00 | 474 | -.0001 | 42.879 | -.0001 | 292.3 | .0000 | .4845 | .00000 | .0000 |
| 1000.00 | 447 | -.0001 | 50.228 | -.0001 | 294.2 | .0000 | .4824 | .00000 | .0000 |
| 1500.00 | 402 | -.0001 | 66.991 | -.0001 | 297.4 | .0000 | .4789 | .00000 | .0000 |
| | | | | | | .0000 | .0000 | .00000 | .0000 |
| R, 0.70; percent fuel, 50.34; O/F, 0.988 | | | | | | | | | |
| 1.00 | 2503 | 0.0047 | | | | | 0.7252 | 0.00119 | -.0287 |
| 1.05 | 2483 | .0044 | 2.175 | 0.0015 | 35.3 | 0.0017 | .7195 | .00110 | -.0268 |
| 1.60 | 2309 | .0022 | 1.010 | .0002 | 107.6 | .0013 | .6770 | .00054 | -.0142 |
| 1.78 | 2265 | .0018 | 1.000 | .0000 | 118.9 | .0012 | .6680 | .00045 | -.0118 |
| 2.00 | 2219 | .0014 | 1.009 | -.0002 | 129.4 | .0011 | .6593 | .00036 | -.0097 |
| 10.00 | 1633 | -.0004 | 2.184 | -.0010 | 219.7 | .0004 | .5879 | .00001 | -.0002 |
| 20.00 | 1418 | -.0005 | 3.428 | -.0010 | 243.0 | .0003 | .5661 | .00000 | .0000 |
| 20.41 | 1412 | -.0005 | 3.476 | -.0010 | 243.6 | .0003 | .5655 | .00000 | .0000 |
| 40.00 | 1224 | -.0005 | 5.502 | -.0009 | 261.6 | .0002 | .5447 | .00000 | .0000 |
| 40.83 | 1219 | -.0005 | 5.580 | -.0009 | 262.0 | .0002 | .5441 | .00000 | .0000 |
| 80.00 | 1051 | -.0005 | 8.936 | -.0009 | 276.5 | .0002 | .5236 | .00000 | .0000 |
| 100.00 | 999 | -.0005 | 10.463 | -.0009 | 280.7 | .0002 | .5171 | .00000 | .0000 |
| 200.00 | 851 | -.0006 | 17.127 | -.0009 | 292.1 | .0001 | .4986 | .00000 | .0000 |
| 300.00 | 773 | -.0006 | 22.881 | -.0009 | 297.8 | .0001 | .4888 | .00000 | .0000 |
| 500.00 | 683 | -.0006 | 32.983 | -.0009 | 304.1 | .0001 | .4781 | .00000 | .0000 |
| 800.00 | 608 | -.0006 | 46.201 | -.0008 | 309.2 | .0001 | .4698 | .00000 | .0000 |
| 1000.00 | 575 | -.0006 | 54.224 | -.0008 | 311.4 | .0001 | .4662 | .00000 | .0000 |
| 1500.00 | 518 | -.0006 | 72.546 | -.0008 | 315.0 | .0001 | .4604 | .00000 | .0000 |
| | | | | | | .0000 | .0000 | .00000 | .0000 |

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, ε | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, $I_s$ (lb)(sec)/lb | Specific-impulse exponent, $n_I$ | Specific heat, $c_p$, $(\partial h/\partial T)_P$, (cal)/(g)(°K) | $\left(\frac{\partial \ln \varepsilon}{\partial \ln P}\right)_T$ | $\left(\frac{\partial \ln \varepsilon}{\partial \ln T}\right)_P$ |
|---|---|---|---|---|---|---|---|---|---|
| R, 0.80; percent fuel, 47.01; O/F, 1.127 | | | | | | | | | |
| 1.00 | 2760 | 0.0125 | | | | | 0.8755 | 0.00439 | -.0987 |
| 1.05 | 2741 | .0120 | 2.156 | 0.0027 | 35.9 | 0.0046 | .8653 | .00417 | -.0943 |
| 1.60 | 2580 | .0080 | 1.008 | .0005 | 109.8 | .0038 | .7831 | .00254 | -.0609 |
| 1.76 | 2542 | .0072 | 1.000 | .0000 | 120.3 | .0037 | .7659 | .00223 | -.0543 |
| 2.00 | 2493 | .0061 | 1.011 | -.0006 | 132.2 | .0035 | .7451 | .00188 | -.0465 |
| 10.00 | 1891 | -.0011 | 2.233 | -.0044 | 226.1 | .0015 | .5932 | .00009 | -.0027 |
| 20.00 | 1658 | -.0016 | 3.531 | -.0044 | 250.7 | .0011 | .5673 | .00001 | -.0005 |
| 20.41 | 1652 | -.0016 | 3.581 | -.0044 | 251.4 | .0011 | .5666 | .00001 | -.0004 |
| 40.00 | 1447 | -.0018 | 5.712 | -.0043 | 270.4 | .0008 | .5458 | .00000 | -.0001 |
| 40.83 | 1441 | -.0018 | 5.795 | -.0043 | 270.9 | .0008 | .5452 | .00000 | -.0001 |
| 80.00 | 1255 | -.0018 | 9.356 | -.0042 | 286.5 | .0006 | .5249 | .00000 | .0000 |
| 100.00 | 1197 | -.0019 | 10.986 | -.0041 | 291.0 | .0006 | .5182 | .00000 | .0000 |
| 200.00 | 1031 | -.0019 | 18.144 | -.0041 | 303.4 | .0005 | .4977 | .00000 | .0000 |
| 300.00 | 942 | -.0020 | 24.364 | -.0041 | 309.6 | .0004 | .4865 | .00000 | .0000 |
| 500.00 | 838 | -.0020 | 35.340 | -.0041 | 316.5 | .0004 | .4733 | .00000 | .0000 |
| 800.00 | 751 | -.0021 | 49.765 | -.0041 | 322.1 | .0003 | .4624 | .00000 | .0000 |
| 1000.00 | 712 | -.0021 | 58.545 | -.0041 | 324.5 | .0003 | .4576 | .00000 | .0000 |
| 1500.00 | 645 | -.0022 | 78.642 | -.0041 | 328.5 | .0003 | .4499 | .00000 | .0000 |
| | | | | | | .0000 | .0000 | .00000 | .0000 |
| R, 0.90; percent fuel, 44.09; O/F, 1.268 | | | | | | | | | |
| 1.00 | 2922 | 0.0210 | | | | | 1.1223 | 0.01041 | -.2241 |
| 1.05 | 2905 | .0206 | 2.138 | 0.0026 | 36.1 | 0.0076 | 1.1114 | .01010 | -.2185 |
| 1.60 | 2765 | .0168 | 1.007 | .0005 | 110.4 | .0069 | 1.0129 | .00747 | -.1700 |
| 1.74 | 2736 | .0160 | 1.000 | .0000 | 119.8 | .0068 | .9919 | .00696 | -.1601 |
| 2.00 | 2690 | .0147 | 1.013 | -.0008 | 133.1 | .0065 | .9586 | .00619 | -.1449 |
| 10.00 | 2135 | -.0001 | 2.304 | -.0095 | 229.6 | .0038 | .6391 | .00069 | -.0202 |
| 20.00 | 1896 | -.0030 | 3.674 | -.0109 | 255.4 | .0029 | .5800 | .00015 | -.0050 |
| 20.41 | 1889 | -.0031 | 3.726 | -.0109 | 256.1 | .0028 | .5788 | .00015 | -.0048 |
| 40.00 | 1670 | -.0040 | 5.982 | -.0111 | 276.2 | .0022 | .5490 | .00002 | -.0009 |
| 40.83 | 1663 | -.0040 | 6.071 | -.0111 | 276.7 | .0022 | .5483 | .00002 | -.0008 |
| 80.00 | 1462 | -.0043 | 9.869 | -.0109 | 293.2 | .0017 | .5270 | .00000 | -.0001 |
| 100.00 | 1399 | -.0044 | 11.616 | -.0109 | 298.1 | .0016 | .5203 | .00000 | -.0001 |
| 200.00 | 1217 | -.0046 | 19.337 | -.0107 | 311.4 | .0013 | .5001 | .00000 | .0000 |
| 300.00 | 1118 | -.0047 | 26.094 | -.0107 | 318.1 | .0011 | .4882 | .00000 | .0000 |
| 500.00 | 1003 | -.0049 | 38.086 | -.0107 | 325.6 | .0009 | .4737 | .00000 | .0000 |
| 800.00 | 904 | -.0050 | 53.938 | -.0107 | 331.7 | .0008 | .4611 | .00000 | .0000 |
| 1000.00 | 860 | -.0051 | 63.621 | -.0107 | 334.4 | .0008 | .4555 | .00000 | .0000 |
| 1500.00 | 784 | -.0052 | 85.855 | -.0107 | 338.8 | .0007 | .4458 | .00000 | .0000 |
| | | | | | | .0000 | .0000 | .00000 | .0000 |
| R, 0.95; percent fuel, 42.76; O/F, 1.339 | | | | | | | | | |
| 1.00 | 2963 | 0.0238 | | | | | 1.2294 | 0.01339 | -.2843 |
| 1.05 | 2948 | .0235 | 2.133 | 0.0021 | 35.9 | 0.0085 | 1.2208 | .01309 | -.2793 |
| 1.60 | 2815 | .0204 | 1.006 | .0004 | 110.1 | .0080 | 1.1408 | .01053 | -.2356 |
| 1.74 | 2790 | .0198 | 1.000 | .0000 | 119.1 | .0079 | 1.1240 | .01004 | -.2269 |
| 2.00 | 2746 | .0187 | 1.014 | -.0006 | 132.8 | .0077 | 1.0946 | .00923 | -.2119 |
| 10.00 | 2241 | .0034 | 2.348 | -.0099 | 230.0 | .0053 | .7248 | .00188 | -.0531 |
| 20.00 | 2012 | -.0024 | 3.772 | -.0135 | 256.4 | .0042 | .6138 | .00053 | -.0167 |
| 20.41 | 2005 | -.0025 | 3.826 | -.0135 | 257.1 | .0041 | .6115 | .00051 | -.0161 |
| 40.00 | 1784 | -.0051 | 6.170 | -.0148 | 277.8 | .0032 | .5578 | .00010 | -.0036 |
| 40.83 | 1778 | -.0052 | 6.262 | -.0148 | 278.3 | .0032 | .5567 | .00010 | -.0034 |
| 80.00 | 1570 | -.0060 | 10.212 | -.0149 | 295.4 | .0025 | .5297 | .00001 | -.0005 |
| 100.00 | 1505 | -.0061 | 12.031 | -.0148 | 300.4 | .0023 | .5225 | .00001 | -.0003 |
| 200.00 | 1315 | -.0064 | 20.099 | -.0147 | 314.2 | .0019 | .5019 | .00000 | .0000 |
| 300.00 | 1212 | -.0066 | 27.182 | -.0146 | 321.2 | .0017 | .4903 | .00000 | .0000 |
| 500.00 | 1091 | -.0068 | 39.792 | -.0146 | 329.0 | .0014 | .4755 | .00000 | .0000 |
| 800.00 | 987 | -.0070 | 56.511 | -.0146 | 335.4 | .0012 | .4624 | .00000 | .0000 |
| 1000.00 | 940 | -.0071 | 66.746 | -.0146 | 338.2 | .0012 | .4564 | .00000 | .0000 |
| 1500.00 | 859 | -.0072 | 90.290 | -.0146 | 342.8 | .0010 | .4460 | .00000 | .0000 |
| R, 0.975; percent fuel, 42.13; O/F, 1.374 | | | | | | | | | |
| 1.00 | 2975 | 0.0246 | | | | | 1.2570 | 0.01433 | -.3027 |
| 1.05 | 2960 | .0243 | 2.131 | 0.0019 | 35.8 | 0.0088 | 1.2494 | .01404 | -.2981 |
| 1.60 | 2829 | .0214 | 1.006 | .0003 | 109.8 | .0083 | 1.1792 | .01159 | -.2578 |
| 1.74 | 2804 | .0209 | 1.000 | .0000 | 118.7 | .0082 | 1.1647 | .01113 | -.2499 |
| 2.00 | 2761 | .0199 | 1.014 | -.0006 | 132.5 | .0080 | 1.1390 | .01035 | -.2361 |
| 10.00 | 2280 | .0065 | 2.367 | -.0087 | 229.8 | .0059 | .8037 | .00303 | -.0841 |
| 20.00 | 2064 | -.0003 | 3.825 | -.0131 | 256.4 | .0048 | .6626 | .00110 | -.0338 |
| 20.41 | 2058 | -.0005 | 3.881 | -.0132 | 257.1 | .0048 | .6591 | .00106 | -.0327 |
| 40.00 | 1843 | -.0050 | 6.285 | -.0160 | 278.1 | .0038 | .5737 | .00024 | -.0084 |
| 40.83 | 1836 | -.0051 | 6.379 | -.0160 | 278.7 | .0038 | .5719 | .00023 | -.0080 |
| 80.00 | 1627 | -.0068 | 10.425 | -.0167 | 296.0 | .0030 | .5334 | .00004 | -.0014 |
| 100.00 | 1561 | -.0070 | 12.290 | -.0166 | 301.1 | .0028 | .5251 | .00002 | -.0007 |
| 200.00 | 1367 | -.0075 | 20.564 | -.0165 | 315.2 | .0023 | .5032 | .00000 | -.0001 |
| 300.00 | 1262 | -.0076 | 27.839 | -.0164 | 322.3 | .0020 | .4916 | .00000 | .0000 |
| 500.00 | 1138 | -.0079 | 40.811 | -.0164 | 330.3 | .0017 | .4768 | .00000 | .0000 |
| 800.00 | 1031 | -.0081 | 58.039 | -.0164 | 336.9 | .0015 | .4636 | .00000 | .0000 |
| 1000.00 | 983 | -.0082 | 68.596 | -.0164 | 339.7 | .0014 | .4575 | .00000 | .0000 |
| 1500.00 | 900 | -.0084 | 92.907 | -.0164 | 344.5 | .0012 | .4468 | .00000 | .0000 |

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR

LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\epsilon$ | Area-ratio exponent, $n_\epsilon$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ | Specific heat, $c_p$, $(\partial h/\partial T)_P$, (cal)/(g)(°K) | $\left(\frac{\partial \ln \epsilon}{\partial \ln P}\right)_T$ | $\left(\frac{\partial \ln \epsilon}{\partial \ln T}\right)_P$ |
|---|---|---|---|---|---|---|---|---|---|
| R, 1.00; percent fuel, 41.51; O/F, 1.409 | | | | | | | | | |
| 1.00 | 2980 | 0.0249 | | | | | 1.2619 | 0.01473 | -.3102 |
| 1.05 | 2965 | .0246 | 2.131 | 0.0018 | 35.7 | 0.0089 | 1.2547 | .01444 | -.3057 |
| 1.60 | 2836 | .0218 | 1.006 | .0003 | 109.5 | .0084 | 1.1885 | .01203 | -.2667 |
| 1.74 | 2811 | .0213 | 1.000 | .0000 | 118.3 | .0083 | 1.1750 | .01159 | -.2591 |
| 2.00 | 2768 | .0203 | 1.014 | -.0005 | 132.0 | .0081 | 1.1510 | .01082 | -.2458 |
| 10.00 | 2297 | .0083 | 2.375 | -.0077 | 229.2 | .0061 | .8538 | .00384 | -.1054 |
| 20.00 | 2094 | .0028 | 3.857 | -.0112 | 255.8 | .0052 | .7326 | .00197 | -.0594 |
| 20.41 | 2088 | .0026 | 3.914 | -.0113 | 256.5 | .0052 | .7294 | .00193 | -.0582 |
| 40.00 | 1888 | -.0022 | 6.387 | -.0144 | 277.7 | .0044 | .6340 | .00082 | -.0276 |
| 40.83 | 1882 | -.0024 | 6.484 | -.0145 | 278.3 | .0043 | .6315 | .00080 | -.0268 |
| 80.00 | 1684 | -.0058 | 10.670 | -.0166 | 295.9 | .0036 | .5650 | .00027 | -.0100 |
| 100.00 | 1619 | -.0066 | 12.600 | -.0171 | 301.1 | .0033 | .5490 | .00018 | -.0068 |
| 200.00 | 1425 | -.0081 | 21.162 | -.0178 | 315.5 | .0027 | .5119 | .00004 | -.0017 |
| 300.00 | 1318 | -.0086 | 28.690 | -.0179 | 322.9 | .0024 | .4963 | .00001 | -.0006 |
| 500.00 | 1191 | -.0090 | 42.126 | -.0180 | 331.1 | .0020 | .4798 | .00000 | -.0002 |
| 800.00 | 1082 | -.0093 | 59.993 | -.0180 | 337.9 | .0018 | .4658 | .00000 | .0000 |
| 1000.00 | 1032 | -.0094 | 70.953 | -.0180 | 340.8 | .0017 | .4595 | .00000 | .0000 |
| 1500.00 | 947 | -.0096 | 96.219 | -.0181 | 345.7 | .0015 | .4485 | .00000 | .0000 |
| R, 1.10; percent fuel, 39.22; O/F, 1.550 | | | | | | | | | |
| 1.00 | 2962 | 0.0231 | | | | | 1.1481 | 0.01272 | -.2692 |
| 1.05 | 2946 | .0227 | 2.133 | 0.0021 | 35.1 | 0.0082 | 1.1398 | .01242 | -.2643 |
| 1.60 | 2812 | .0196 | 1.006 | .0004 | 107.6 | .0077 | 1.0656 | .00991 | -.2215 |
| 1.74 | 2786 | .0190 | 1.000 | .0000 | 116.4 | .0076 | 1.0505 | .00945 | -.2132 |
| 2.00 | 2742 | .0179 | 1.014 | -.0006 | 129.7 | .0074 | 1.0246 | .00868 | -.1992 |
| 10.00 | 2245 | .0051 | 2.355 | -.0081 | 224.7 | .0052 | .7419 | .00236 | -.0676 |
| 20.00 | 2031 | .0005 | 3.806 | -.0109 | 250.6 | .0043 | .6513 | .00110 | -.0352 |
| 20.41 | 2024 | .0004 | 3.861 | -.0110 | 251.3 | .0043 | .6490 | .00107 | -.0345 |
| 40.00 | 1819 | -.0029 | 6.274 | -.0129 | 271.7 | .0035 | .5836 | .00044 | -.0161 |
| 40.83 | 1813 | -.0030 | 6.369 | -.0130 | 272.3 | .0035 | .5820 | .00043 | -.0157 |
| 80.00 | 1615 | -.0051 | 10.451 | -.0142 | 289.3 | .0028 | .5356 | .00015 | -.0062 |
| 100.00 | 1551 | -.0056 | 12.333 | -.0144 | 294.3 | .0026 | .5234 | .00010 | -.0044 |
| 200.00 | 1362 | -.0066 | 20.676 | -.0148 | 308.1 | .0021 | .4923 | .00003 | -.0013 |
| 300.00 | 1258 | -.0070 | 28.004 | -.0149 | 315.2 | .0019 | .4779 | .00001 | -.0005 |
| 500.00 | 1134 | -.0073 | 41.063 | -.0150 | 323.1 | .0016 | .4618 | .00000 | -.0002 |
| 800.00 | 1028 | -.0076 | 58.399 | -.0150 | 329.5 | .0014 | .4483 | .00000 | .0000 |
| 1000.00 | 980 | -.0077 | 69.021 | -.0150 | 332.3 | .0013 | .4424 | .00000 | .0000 |
| 1500.00 | 898 | -.0079 | 93.482 | -.0151 | 337.0 | .0012 | .4320 | .00000 | .0000 |
| | | | | | | .0000 | .0000 | .00000 | .0000 |
| R, 1.20; percent fuel, 37.16; O/F, 1.691 | | | | | | | | | |
| 1.00 | 2914 | 0.0205 | | | | | 1.0323 | 0.01016 | -.2198 |
| 1.05 | 2898 | .0201 | 2.136 | 0.0020 | 34.4 | 0.0073 | 1.0248 | .00989 | -.2154 |
| 1.60 | 2761 | .0170 | 1.007 | .0003 | 105.4 | .0068 | .9596 | .00775 | -.1779 |
| 1.74 | 2733 | .0164 | 1.000 | .0000 | 114.2 | .0067 | .9464 | .00735 | -.1706 |
| 2.00 | 2689 | .0154 | 1.013 | -.0006 | 127.1 | .0065 | .9249 | .00673 | -.1591 |
| 10.00 | 2182 | .0041 | 2.343 | -.0072 | 219.9 | .0045 | .6953 | .00183 | -.0548 |
| 20.00 | 1968 | .0002 | 3.779 | -.0096 | 245.1 | .0037 | .6184 | .00086 | -.0289 |
| 20.41 | 1962 | .0001 | 3.834 | -.0096 | 245.8 | .0037 | .6163 | .00084 | -.0283 |
| 40.00 | 1758 | -.0028 | 6.218 | -.0113 | 265.7 | .0030 | .5580 | .00035 | -.0131 |
| 40.83 | 1752 | -.0028 | 6.312 | -.0114 | 266.2 | .0030 | .5564 | .00034 | -.0128 |
| 80.00 | 1556 | -.0046 | 10.337 | -.0124 | 282.7 | .0024 | .5141 | .00011 | -.0049 |
| 100.00 | 1494 | -.0051 | 12.190 | -.0126 | 287.5 | .0022 | .5028 | .00008 | -.0034 |
| 200.00 | 1308 | -.0059 | 20.395 | -.0129 | 300.9 | .0018 | .4742 | .00002 | -.0009 |
| 300.00 | 1206 | -.0062 | 27.591 | -.0130 | 307.7 | .0016 | .4609 | .00001 | -.0004 |
| 500.00 | 1086 | -.0065 | 40.395 | -.0130 | 315.3 | .0014 | .4457 | .00000 | -.0001 |
| 800.00 | 983 | -.0067 | 57.370 | -.0130 | 321.5 | .0012 | .4331 | .00000 | .0000 |
| 1000.00 | 937 | -.0068 | 67.761 | -.0131 | 324.2 | .0011 | .4275 | .00000 | .0000 |
| 1500.00 | 856 | -.0069 | 91.669 | -.0131 | 328.7 | .0010 | .4178 | .00000 | .0000 |
| R, 1.50; percent fuel, 32.12; O/F, 2.114 | | | | | | | | | |
| 1.00 | 2759 | 0.0157 | | | | | 0.8534 | 0.00633 | -.1478 |
| 1.05 | 2743 | .0154 | 2.141 | 0.0018 | 32.6 | 0.0058 | .8478 | .00615 | -.1445 |
| 1.60 | 2603 | .0128 | 1.007 | .0003 | 99.7 | .0053 | .7989 | .00473 | -.1178 |
| 1.75 | 2574 | .0122 | 1.000 | .0000 | 108.3 | .0052 | .7887 | .00446 | -.1125 |
| 2.00 | 2530 | .0114 | 1.013 | -.0005 | 120.2 | .0051 | .7729 | .00407 | -.1046 |
| 10.00 | 2017 | .0021 | 2.315 | -.0060 | 207.4 | .0033 | .5962 | .00098 | -.0324 |
| 20.00 | 1803 | -.0008 | 3.711 | -.0078 | 230.8 | .0027 | .5367 | .00042 | -.0155 |
| 20.41 | 1797 | -.0009 | 3.764 | -.0079 | 231.4 | .0027 | .5352 | .00041 | -.0151 |
| 40.00 | 1596 | -.0028 | 6.066 | -.0090 | 249.8 | .0021 | .4920 | .00014 | -.0061 |
| 40.83 | 1591 | -.0028 | 6.156 | -.0090 | 250.3 | .0021 | .4909 | .00014 | -.0059 |
| 80.00 | 1401 | -.0039 | 10.018 | -.0095 | 265.4 | .0017 | .4598 | .00004 | -.0019 |
| 100.00 | 1341 | -.0041 | 11.790 | -.0096 | 269.8 | .0016 | .4516 | .00002 | -.0012 |
| 200.00 | 1166 | -.0045 | 19.610 | -.0097 | 282.0 | .0013 | .4303 | .00000 | -.0003 |
| 300.00 | 1071 | -.0047 | 26.441 | -.0097 | 289.2 | .0011 | .4194 | .00000 | -.0001 |
| 500.00 | 959 | -.0048 | 38.555 | -.0097 | 295.1 | .0009 | .4071 | .00000 | .0000 |
| 800.00 | 865 | -.0050 | 54.560 | -.0097 | 300.6 | .0008 | .3966 | .00000 | .0000 |
| 1000.00 | 822 | -.0050 | 64.332 | -.0097 | 303.0 | .0008 | .3918 | .00000 | .0000 |
| 1500.00 | 749 | -.0051 | 86.765 | -.0097 | 307.1 | .0007 | .3837 | .00000 | .0000 |

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\varepsilon$ | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, I, (lb)(sec)/lb | Specific-impulse exponent, $n_I$ | Specific heat, $c_p$, $(\partial h/\partial T)_P$, (cal)/(g)(°K) | $\left(\frac{\partial \ln \varepsilon}{\partial \ln P}\right)_T$ | $\left(\frac{\partial \ln \varepsilon}{\partial \ln T}\right)_P$ |
|---|---|---|---|---|---|---|---|---|---|
| R, 2.00; percent fuel, 26.19; O/F, 2.818 | | | | | | | | | |
| 1.00 | 2536 | 0.0110 | | | | | 0.6880 | 0.00344 | -.0889 |
| 1.05 | 2519 | .0107 | 2.150 | 0.0017 | 30.2 | 0.0042 | .6833 | .00332 | -.0865 |
| 1.60 | 2377 | .0084 | 1.008 | .0003 | 92.4 | .0038 | .6421 | .00241 | -.0670 |
| 1.76 | 2345 | .0078 | 1.000 | .0000 | 100.8 | .0037 | .6330 | .00224 | -.0629 |
| 2.00 | 2302 | .0071 | 1.011 | -.0004 | 111.3 | .0035 | .6205 | .00200 | -.0575 |
| 10.00 | 1783 | .0002 | 2.267 | -.0047 | 191.0 | .0021 | .4873 | .00033 | -.0124 |
| 20.00 | 1572 | -.0014 | 3.597 | -.0056 | 212.1 | .0016 | .4495 | .00011 | -.0047 |
| 20.41 | 1566 | -.0015 | 3.648 | -.0056 | 212.6 | .0016 | .4486 | .00011 | -.0045 |
| 40.00 | 1374 | -.0023 | 5.824 | -.0059 | 229.0 | .0012 | .4224 | .00003 | -.0013 |
| 40.83 | 1369 | -.0023 | 5.908 | -.0059 | 229.5 | .0012 | .4217 | .00003 | -.0013 |
| 80.00 | 1193 | -.0026 | 9.537 | -.0060 | 242.8 | .0009 | .4028 | .00001 | -.0003 |
| 100.00 | 1138 | -.0027 | 11.195 | -.0060 | 246.7 | .0009 | .3973 | .00000 | -.0002 |
| 200.00 | 980 | -.0028 | 18.482 | -.0059 | 257.3 | .0007 | .3818 | .00000 | .0000 |
| 300.00 | 896 | -.0029 | 24.816 | -.0059 | 262.7 | .0006 | .3736 | .00000 | .0000 |
| 500.00 | 797 | -.0030 | 35.998 | -.0059 | 268.6 | .0005 | .3637 | .00000 | .0000 |
| 800.00 | 714 | -.0030 | 50.700 | -.0059 | 273.4 | .0004 | .3554 | .00000 | .0000 |
| 1000.00 | 677 | -.0031 | 59.650 | -.0059 | 275.5 | .0004 | .3517 | .00000 | .0000 |
| 1500.00 | 614 | -.0031 | 80.136 | -.0059 | 278.9 | .0004 | .3453 | .00000 | .0000 |
| | | | | | | .0000 | .0000 | .00000 | .0000 |
| R, 3.00; percent fuel, 19.13; O/F, 4.227 | | | | | | | | | |
| 1.00 | 2171 | 0.0049 | | | | | 0.5023 | 0.00102 | -.0315 |
| 1.05 | 2154 | .0047 | 2.170 | 0.0012 | 26.8 | 0.0020 | .4988 | .00097 | -.0301 |
| 1.60 | 2008 | .0031 | 1.010 | .0002 | 81.8 | .0016 | .4704 | .00061 | -.0202 |
| 1.78 | 1972 | .0027 | 1.000 | .0000 | 90.2 | .0016 | .4637 | .00053 | -.0180 |
| 2.00 | 1933 | .0023 | 1.009 | -.0002 | 98.4 | .0015 | .4565 | .00046 | -.0159 |
| 10.00 | 1426 | -.0005 | 2.186 | -.0019 | 167.4 | .0007 | .3868 | .00003 | -.0014 |
| 20.00 | 1235 | -.0008 | 3.424 | -.0019 | 185.1 | .0005 | .3697 | .00001 | -.0003 |
| 20.41 | 1230 | -.0008 | 3.471 | -.0019 | 185.6 | .0005 | .3693 | .00001 | -.0003 |
| 40.00 | 1064 | -.0009 | 5.480 | -.0019 | 199.2 | .0004 | .3557 | .00000 | .0000 |
| 40.83 | 1059 | -.0009 | 5.558 | -.0019 | 199.6 | .0004 | .3553 | .00000 | .0000 |
| 80.00 | 911 | -.0009 | 8.881 | -.0019 | 210.5 | .0003 | .3434 | .00000 | .0000 |
| 100.00 | 866 | -.0009 | 10.392 | -.0019 | 213.7 | .0003 | .3395 | .00000 | .0000 |
| 200.00 | 736 | -.0009 | 16.984 | -.0018 | 222.3 | .0002 | .3282 | .00000 | .0000 |
| 300.00 | 668 | -.0010 | 22.672 | -.0018 | 226.7 | .0002 | .3220 | .00000 | .0000 |
| 500.00 | 589 | -.0010 | 32.650 | -.0018 | 231.4 | .0001 | .3148 | .00000 | .0000 |
| 800.00 | 524 | -.0010 | 45.684 | -.0018 | 235.2 | .0001 | .3089 | .00000 | .0000 |
| 1000.00 | 495 | -.0010 | 53.587 | -.0018 | 236.9 | .0001 | .3063 | .00000 | .0000 |
| 1500.00 | 446 | -.0010 | 71.604 | -.0018 | 239.6 | .0001 | .3019 | .00000 | .0000 |
| | | | | | | .0000 | .0000 | .00000 | .0000 |
| R, 4.00; percent fuel, 15.07; O/F, 5.636 | | | | | | | | | |
| 1.00 | 1877 | 0.0018 | | | | | 0.4111 | 0.00028 | -.0101 |
| 1.05 | 1861 | .0017 | 2.188 | 0.0006 | 24.4 | 0.0008 | .4088 | .00026 | -.0095 |
| 1.60 | 1719 | .0009 | 1.011 | .0001 | 74.1 | .0006 | .3911 | .00014 | -.0054 |
| 1.80 | 1680 | .0007 | 1.000 | .0000 | 82.4 | .0005 | .3868 | .00011 | -.0045 |
| 2.00 | 1646 | .0006 | 1.007 | -.0001 | 89.1 | .0005 | .3831 | .00009 | -.0038 |
| 10.00 | 1179 | -.0002 | 2.136 | -.0005 | 150.4 | .0002 | .3441 | .00000 | -.0001 |
| 20.00 | 1012 | -.0002 | 3.322 | -.0005 | 166.0 | .0001 | .3322 | .00000 | .0000 |
| 20.41 | 1007 | -.0002 | 3.367 | -.0005 | 166.4 | .0001 | .3319 | .00000 | .0000 |
| 40.00 | 863 | -.0003 | 5.280 | -.0005 | 178.2 | .0001 | .3215 | .00000 | .0000 |
| 40.83 | 859 | -.0003 | 5.354 | -.0005 | 178.6 | .0001 | .3211 | .00000 | .0000 |
| 80.00 | 733 | -.0003 | 8.497 | -.0004 | 188.0 | .0001 | .3110 | .00000 | .0000 |
| 100.00 | 694 | -.0003 | 9.920 | -.0004 | 190.8 | .0001 | .3078 | .00000 | .0000 |
| 200.00 | 585 | -.0003 | 16.099 | -.0004 | 198.2 | .0001 | .2983 | .00000 | .0000 |
| 300.00 | 528 | -.0003 | 21.402 | -.0004 | 201.8 | .0000 | .2934 | .00000 | .0000 |
| 500.00 | 463 | -.0003 | 30.665 | -.0004 | 205.9 | .0000 | .2877 | .00000 | .0000 |
| 800.00 | 410 | -.0003 | 42.718 | -.0004 | 209.1 | .0000 | .2834 | .00000 | .0000 |
| 1000.00 | 386 | -.0003 | 50.009 | -.0004 | 210.5 | .0000 | .2818 | .00000 | .0000 |
| 1500.00 | 347 | -.0003 | 66.614 | -.0004 | 212.7 | .0000 | .2794 | .00000 | .0000 |
| | | | | | | .0000 | .0000 | .00000 | .0000 |
| R, 5.00; percent fuel, 12.43; O/F, 7.046 | | | | | | | | | |
| 1.00 | 1641 | 0.0006 | | | | | 0.3639 | 0.00007 | -.0030 |
| 1.05 | 1625 | .0005 | 2.201 | 0.0002 | 22.4 | 0.0003 | .3625 | .00007 | -.0027 |
| 1.60 | 1491 | .0002 | 1.013 | .0000 | 68.1 | .0002 | .3515 | .00003 | -.0013 |
| 1.81 | 1454 | .0002 | 1.000 | .0000 | 76.1 | .0002 | .3487 | .00002 | -.0010 |
| 2.00 | 1424 | .0001 | 1.006 | -.0000 | 81.8 | .0001 | .3465 | .00002 | -.0009 |
| 10.00 | 1001 | -.0001 | 2.106 | -.0001 | 137.5 | .0000 | .3191 | .00000 | .0000 |
| 20.00 | 853 | -.0001 | 3.257 | -.0001 | 151.5 | .0000 | .3091 | .00000 | .0000 |
| 20.41 | 849 | -.0001 | 3.300 | -.0001 | 151.9 | .0000 | .3088 | .00000 | .0000 |
| 40.00 | 723 | -.0001 | 5.149 | -.0001 | 162.5 | .0000 | .2993 | .00000 | .0000 |
| 40.83 | 720 | -.0001 | 5.220 | -.0001 | 162.8 | .0000 | .2990 | .00000 | .0000 |
| 80.00 | 610 | -.0001 | 8.240 | -.0001 | 171.2 | .0000 | .2900 | .00000 | .0000 |
| 100.00 | 577 | -.0001 | 9.603 | -.0001 | 173.6 | .0000 | .2871 | .00000 | .0000 |
| 200.00 | 483 | -.0001 | 15.498 | -.0001 | 180.2 | .0000 | .2792 | .00000 | .0000 |
| 300.00 | 434 | -.0001 | 20.539 | -.0001 | 183.4 | .0000 | .2751 | .00000 | .0000 |
| 500.00 | 379 | -.0001 | 29.324 | -.0001 | 186.9 | .0000 | .2712 | .00000 | .0000 |
| 800.00 | 334 | -.0001 | 40.741 | -.0001 | 189.7 | .0000 | .2687 | .00000 | .0000 |
| 1000.00 | 315 | -.0001 | 47.644 | -.0001 | 190.9 | .0000 | .2677 | .00000 | .0000 |
| 1500.00 | 282 | -.0001 | 63.355 | -.0001 | 192.9 | .0000 | .2664 | .00000 | .0000 |

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\varepsilon$ | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ |
|---|---|---|---|---|---|---|
| R, 0.40; percent fuel, 63.95; O/F, 0.564 | | | | | | |
| 1.05 | 1334 | 0.0000 | 2.226 | 0.0000 | 29.1 | 0.0000 |
| 1.60 | 1210 | .0000 | 1.015 | .0000 | 88.3 | .0000 |
| 2.00 | 1148 | .0000 | 1.004 | .0000 | 105.9 | .0000 |
| 10.00 | 772 | .0000 | 2.030 | .0000 | 176.3 | .0000 |
| 20.00 | 646 | .0000 | 3.093 | .0000 | 193.5 | .0000 |
| 20.41 | 643 | .0000 | 3.133 | .0000 | 193.9 | .0000 |
| 40.00 | 538 | .0000 | 4.823 | .0000 | 206.8 | .0000 |
| 40.83 | 535 | .0000 | 4.888 | .0000 | 207.1 | .0000 |
| 80.00 | 447 | .0000 | 7.629 | .0000 | 217.2 | .0000 |
| 100.00 | 421 | .0000 | 8.863 | .0000 | 220.1 | .0000 |
| 200.00 | 349 | .0000 | 14.191 | .0000 | 227.8 | .0000 |
| 300.00 | 312 | .0000 | 18.744 | .0000 | 231.6 | .0000 |
| 500.00 | 271 | .0000 | 26.680 | .0000 | 235.7 | .0000 |
| 800.00 | 238 | .0000 | 36.978 | .0000 | 239.0 | .0000 |
| 1000.00 | 224 | .0000 | 43.187 | .0000 | 240.4 | .0000 |
| 1500.00 | 200 | .0000 | 57.266 | .0000 | 242.7 | .0000 |
| R, 0.50; percent fuel, 58.67; O/F, 0.705 | | | | | | |
| 1.05 | 1766 | 0.0001 | 2.206 | 0.0000 | 32.1 | 0.0001 |
| 1.60 | 1617 | .0001 | 1.013 | .0000 | 97.5 | .0000 |
| 2.00 | 1541 | .0001 | 1.006 | .0000 | 117.1 | .0000 |
| 10.00 | 1074 | .0001 | 2.090 | .0000 | 196.4 | .0000 |
| 20.00 | 911 | .0001 | 3.218 | .0000 | 216.2 | .0000 |
| 20.41 | 906 | .0001 | 3.261 | .0000 | 216.8 | .0000 |
| 40.00 | 768 | .0001 | 5.065 | .0000 | 231.7 | .0000 |
| 40.83 | 764 | .0001 | 5.134 | .0000 | 232.1 | .0000 |
| 80.00 | 644 | .0001 | 8.071 | .0000 | 243.9 | .0000 |
| 100.00 | 608 | .0001 | 9.395 | .0000 | 247.3 | .0000 |
| 200.00 | 508 | .0001 | 15.126 | .0000 | 256.4 | .0000 |
| 300.00 | 456 | .0001 | 20.032 | .0000 | 260.9 | .0000 |
| 500.00 | 398 | .0001 | 28.601 | .0000 | 265.8 | .0000 |
| 800.00 | 351 | .0001 | 39.755 | .0000 | 269.8 | .0000 |
| 1000.00 | 330 | .0001 | 46.505 | .0000 | 271.4 | .0000 |
| 1500.00 | 296 | .0001 | 61.881 | .0000 | 274.2 | .0000 |
| R, 0.60; percent fuel, 54.19; O/F, 0.845 | | | | | | |
| 1.05 | 2150 | 0.0011 | 2.193 | 0.0001 | 34.1 | 0.0005 |
| 1.60 | 1980 | .0011 | 1.012 | .0000 | 103.6 | .0004 |
| 2.00 | 1895 | .0011 | 1.007 | .0000 | 124.5 | .0004 |
| 10.00 | 1358 | .0013 | 2.139 | .0001 | 210.0 | .0005 |
| 20.00 | 1166 | .0013 | 3.329 | .0002 | 231.8 | .0005 |
| 20.41 | 1161 | .0013 | 3.374 | .0002 | 232.3 | .0005 |
| 40.00 | 995 | .0014 | 5.292 | .0003 | 248.9 | .0005 |
| 40.83 | 991 | .0014 | 5.366 | .0003 | 249.3 | .0005 |
| 80.00 | 845 | .0015 | 8.512 | .0003 | 262.6 | .0005 |
| 100.00 | 800 | .0015 | 9.936 | .0003 | 266.4 | .0005 |
| 200.00 | 674 | .0016 | 16.118 | .0004 | 276.7 | .0005 |
| 300.00 | 609 | .0016 | 21.429 | .0004 | 281.9 | .0005 |
| 500.00 | 534 | .0017 | 30.721 | .0005 | 287.5 | .0005 |
| 800.00 | 473 | .0017 | 42.837 | .0005 | 292.0 | .0005 |
| 1000.00 | 446 | .0017 | 50.179 | .0005 | 293.9 | .0006 |
| 1500.00 | 401 | .0017 | 66.923 | .0005 | 297.1 | .0006 |
| R, 0.70; percent fuel, 50.34; O/F, 0.986 | | | | | | |
| 1.05 | 2481 | 0.0054 | 2.183 | 0.0003 | 35.3 | 0.0022 |
| 1.60 | 2295 | .0055 | 1.011 | .0000 | 107.5 | .0021 |
| 2.00 | 2201 | .0056 | 1.008 | .0000 | 129.2 | .0021 |
| 10.00 | 1611 | .0064 | 2.176 | .0006 | 218.9 | .0023 |
| 20.00 | 1398 | .0068 | 3.415 | .0010 | 242.1 | .0024 |
| 20.41 | 1392 | .0068 | 3.462 | .0010 | 242.7 | .0024 |
| 40.00 | 1206 | .0072 | 5.478 | .0013 | 260.4 | .0024 |
| 40.83 | 1201 | .0072 | 5.556 | .0013 | 260.9 | .0024 |
| 80.00 | 1034 | .0076 | 8.892 | .0017 | 275.3 | .0025 |
| 100.00 | 983 | .0078 | 10.408 | .0018 | 279.4 | .0025 |
| 200.00 | 837 | .0082 | 17.027 | .0021 | 290.7 | .0026 |
| 300.00 | 759 | .0084 | 22.738 | .0023 | 296.4 | .0026 |
| 500.00 | 670 | .0087 | 32.762 | .0026 | 302.6 | .0027 |
| 800.00 | 596 | .0089 | 45.874 | .0028 | 307.6 | .0027 |
| 1000.00 | 564 | .0090 | 53.831 | .0028 | 309.8 | .0027 |
| 1500.00 | 508 | .0092 | 71.999 | .0030 | 313.3 | .0028 |

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\varepsilon$ | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ |
|---|---|---|---|---|---|---|
| R, 0.80; percent fuel, 47.01; O/F, 1.127 | | | | | | |
| 1.05 | 2737 | 0.0137 | 2.176 | 0.0004 | 35.9 | 0.0051 |
| 1.60 | 2539 | .0141 | 1.010 | .0001 | 109.5 | .0052 |
| 2.00 | 2440 | .0143 | 1.009 | .0001 | 131.7 | .0053 |
| 10.00 | 1811 | .0163 | 2.202 | .0016 | 223.8 | .0057 |
| 20.00 | 1582 | .0172 | 3.476 | .0024 | 247.8 | .0059 |
| 20.41 | 1576 | .0172 | 3.525 | .0024 | 248.4 | .0059 |
| 40.00 | 1376 | .0183 | 5.612 | .0033 | 266.9 | .0060 |
| 40.83 | 1370 | .0183 | 5.693 | .0033 | 267.4 | .0060 |
| 80.00 | 1190 | .0194 | 9.173 | .0042 | 282.5 | .0062 |
| 100.00 | 1134 | .0198 | 10.762 | .0046 | 286.9 | .0063 |
| 200.00 | 973 | .0210 | 17.730 | .0056 | 298.9 | .0064 |
| 300.00 | 888 | .0217 | 23.773 | .0062 | 304.9 | .0065 |
| 500.00 | 788 | .0226 | 34.418 | .0069 | 311.6 | .0067 |
| 800.00 | 704 | .0233 | 48.386 | .0076 | 316.9 | .0068 |
| 1000.00 | 667 | .0236 | 56.880 | .0078 | 319.2 | .0068 |
| 1500.00 | 604 | .0242 | 76.307 | .0083 | 323.1 | .0069 |
| R, 0.90; percent fuel, 44.09; O/F, 1.208 | | | | | | |
| 1.05 | 2897 | 0.0221 | 2.173 | 0.0007 | 36.0 | 0.0081 |
| 1.60 | 2693 | .0227 | 1.010 | .0001 | 109.9 | .0082 |
| 2.00 | 2590 | .0231 | 1.009 | .0002 | 132.2 | .0083 |
| 10.00 | 1938 | .0262 | 2.218 | .0026 | 225.0 | .0090 |
| 20.00 | 1701 | .0277 | 3.513 | .0038 | 249.3 | .0092 |
| 20.41 | 1694 | .0278 | 3.562 | .0039 | 250.0 | .0093 |
| 40.00 | 1486 | .0295 | 5.693 | .0053 | 268.8 | .0095 |
| 40.83 | 1480 | .0295 | 5.776 | .0053 | 269.3 | .0095 |
| 80.00 | 1292 | .0313 | 9.345 | .0068 | 284.7 | .0098 |
| 100.00 | 1234 | .0320 | 10.979 | .0074 | 289.2 | .0099 |
| 200.00 | 1064 | .0340 | 18.171 | .0091 | 301.5 | .0102 |
| 300.00 | 973 | .0352 | 24.429 | .0101 | 307.7 | .0104 |
| 500.00 | 867 | .0367 | 35.486 | .0114 | 314.6 | .0106 |
| 800.00 | 778 | .0380 | 50.034 | .0126 | 320.2 | .0107 |
| 1000.00 | 738 | .0386 | 58.894 | .0131 | 322.6 | .0108 |
| 1500.00 | 670 | .0396 | 79.187 | .0140 | 326.6 | .0110 |
| R, 0.95; percent fuel, 42.76; O/F, 1.339 | | | | | | |
| 1.05 | 2939 | 0.0247 | 2.172 | 0.0007 | 35.9 | 0.0089 |
| 1.60 | 2733 | .0255 | 1.010 | .0002 | 109.5 | .0091 |
| 2.00 | 2630 | .0259 | 1.009 | .0002 | 131.7 | .0092 |
| 10.00 | 1972 | .0293 | 2.222 | .0029 | 224.4 | .0100 |
| 20.00 | 1732 | .0310 | 3.522 | .0043 | 248.7 | .0103 |
| 20.41 | 1726 | .0311 | 3.572 | .0043 | 249.4 | .0103 |
| 40.00 | 1516 | .0330 | 5.714 | .0059 | 268.2 | .0106 |
| 40.83 | 1509 | .0330 | 5.798 | .0059 | 268.7 | .0106 |
| 80.00 | 1319 | .0351 | 9.390 | .0076 | 284.1 | .0109 |
| 100.00 | 1260 | .0358 | 11.037 | .0082 | 288.6 | .0110 |
| 200.00 | 1089 | .0380 | 18.290 | .0102 | 301.0 | .0114 |
| 300.00 | 997 | .0394 | 24.607 | .0114 | 307.2 | .0115 |
| 500.00 | 889 | .0411 | 35.778 | .0128 | 314.2 | .0118 |
| 800.00 | 798 | .0426 | 50.487 | .0141 | 319.8 | .0120 |
| 1000.00 | 758 | .0433 | 59.451 | .0148 | 322.2 | .0121 |
| 1500.00 | 688 | .0445 | 79.988 | .0158 | 326.2 | .0122 |

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\varepsilon$ | Area-ratio exponent, $n_\varepsilon$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ |
|---|---|---|---|---|---|---|
| R, 1.00; percent fuel, 41.51; O/F, 1.409 | | | | | | |
| 1.05 | 2956 | 0.0257 | 2.171 | 0.0007 | 35.7 | 0.0092 |
| 1.60 | 2750 | .0265 | 1.010 | .0001 | 108.9 | .0094 |
| 2.00 | 2646 | .0269 | 1.009 | .0002 | 131.0 | .0095 |
| 10.00 | 1986 | .0305 | 2.223 | .0030 | 223.1 | .0103 |
| 20.00 | 1746 | .0323 | 3.527 | .0045 | 247.3 | .0106 |
| 20.41 | 1739 | .0323 | 3.576 | .0045 | 247.9 | .0106 |
| 40.00 | 1528 | .0343 | 5.724 | .0061 | 266.7 | .0110 |
| 40.83 | 1522 | .0343 | 5.808 | .0062 | 267.2 | .0110 |
| 80.00 | 1331 | .0364 | 9.411 | .0079 | 282.6 | .0113 |
| 100.00 | 1271 | .0372 | 11.064 | .0086 | 287.1 | .0114 |
| 200.00 | 1099 | .0395 | 18.345 | .0106 | 299.4 | .0118 |
| 300.00 | 1007 | .0410 | 24.691 | .0118 | 305.6 | .0119 |
| 500.00 | 899 | .0427 | 35.916 | .0134 | 312.5 | .0122 |
| 800.00 | 807 | .0443 | 50.704 | .0148 | 318.1 | .0124 |
| 1000.00 | 766 | .0451 | 59.717 | .0154 | 320.5 | .0125 |
| 1500.00 | 696 | .0463 | 80.374 | .0165 | 324.6 | .0127 |
| R, 1.10; percent fuel, 39.22; O/F, 1.550 | | | | | | |
| 1.05 | 2937 | 0.0240 | 2.171 | 0.0007 | 35.1 | 0.0086 |
| 1.60 | 2732 | .0247 | 1.010 | .0001 | 107.0 | .0088 |
| 2.00 | 2629 | .0252 | 1.009 | .0002 | 128.7 | .0089 |
| 10.00 | 1972 | .0285 | 2.223 | .0028 | 219.3 | .0096 |
| 20.00 | 1733 | .0302 | 3.525 | .0042 | 243.0 | .0099 |
| 20.41 | 1727 | .0302 | 3.574 | .0042 | 243.6 | .0099 |
| 40.00 | 1517 | .0321 | 5.720 | .0057 | 262.1 | .0103 |
| 40.83 | 1511 | .0321 | 5.804 | .0058 | 262.6 | .0103 |
| 80.00 | 1321 | .0341 | 9.403 | .0075 | 277.6 | .0106 |
| 100.00 | 1262 | .0348 | 11.054 | .0080 | 282.0 | .0107 |
| 200.00 | 1091 | .0370 | 18.325 | .0099 | 294.1 | .0110 |
| 300.00 | 999 | .0383 | 24.661 | .0111 | 300.2 | .0112 |
| 500.00 | 892 | .0400 | 35.870 | .0125 | 307.0 | .0114 |
| 800.00 | 801 | .0415 | 50.634 | .0138 | 312.5 | .0116 |
| 1000.00 | 760 | .0422 | 59.633 | .0144 | 314.9 | .0117 |
| 1500.00 | 691 | .0434 | 80.257 | .0155 | 318.9 | .0118 |
| R, 1.20; percent fuel, 37.16; O/F, 1.691 | | | | | | |
| 1.05 | 2890 | 0.0214 | 2.172 | 0.0007 | 34.4 | 0.0079 |
| 1.60 | 2687 | .0221 | 1.010 | .0001 | 104.9 | .0079 |
| 2.00 | 2585 | .0225 | 1.009 | .0001 | 126.2 | .0080 |
| 10.00 | 1936 | .0255 | 2.219 | .0025 | 214.9 | .0087 |
| 20.00 | 1700 | .0270 | 3.517 | .0038 | 238.1 | .0089 |
| 20.41 | 1693 | .0270 | 3.566 | .0038 | 238.7 | .0090 |
| 40.00 | 1486 | .0287 | 5.702 | .0051 | 256.7 | .0092 |
| 40.83 | 1480 | .0287 | 5.786 | .0052 | 257.2 | .0092 |
| 80.00 | 1293 | .0305 | 9.366 | .0067 | 272.0 | .0095 |
| 100.00 | 1234 | .0311 | 11.007 | .0072 | 276.3 | .0096 |
| 200.00 | 1066 | .0331 | 18.231 | .0089 | 288.1 | .0099 |
| 300.00 | 976 | .0343 | 24.522 | .0099 | 294.0 | .0100 |
| 500.00 | 870 | .0357 | 35.644 | .0112 | 300.6 | .0102 |
| 800.00 | 781 | .0371 | 50.287 | .0123 | 306.0 | .0104 |
| 1000.00 | 741 | .0377 | 59.209 | .0129 | 308.3 | .0105 |
| 1500.00 | 673 | .0387 | 79.651 | .0138 | 312.1 | .0106 |
| R, 1.50; percent fuel, 32.12; O/F, 2.114 | | | | | | |
| 1.05 | 2736 | 0.0166 | 2.175 | 0.0005 | 32.6 | 0.0062 |
| 1.60 | 2540 | .0171 | 1.010 | .0001 | 99.3 | .0063 |
| 2.00 | 2441 | .0174 | 1.009 | .0001 | 119.4 | .0064 |
| 10.00 | 1817 | .0197 | 2.207 | .0020 | 203.0 | .0069 |
| 20.00 | 1590 | .0209 | 3.488 | .0029 | 224.8 | .0071 |
| 20.41 | 1583 | .0209 | 3.537 | .0029 | 225.4 | .0071 |
| 40.00 | 1385 | .0222 | 5.640 | .0040 | 242.3 | .0073 |
| 40.83 | 1379 | .0222 | 5.722 | .0040 | 242.7 | .0073 |
| 80.00 | 1201 | .0235 | 9.236 | .0051 | 256.5 | .0075 |
| 100.00 | 1145 | .0240 | 10.844 | .0055 | 260.5 | .0076 |
| 200.00 | 985 | .0255 | 17.905 | .0068 | 271.5 | .0078 |
| 300.00 | 900 | .0263 | 24.041 | .0075 | 277.0 | .0079 |
| 500.00 | 800 | .0274 | 34.870 | .0085 | 283.1 | .0081 |
| 800.00 | 717 | .0284 | 49.102 | .0093 | 288.0 | .0082 |
| 1000.00 | 680 | .0288 | 57.764 | .0097 | 290.2 | .0083 |
| 1500.00 | 616 | .0296 | 77.590 | .0103 | 293.7 | .0084 |

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TABLE III. - Concluded. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

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

| Pressure ratio, $P_c/P$ | Temperature, T, °K | Temperature exponent, $n_T$ | Area ratio, $\varepsilon$ | Area-ratio exponent, $n_\varepsilon$ | Specific impulse I, $\frac{(lb)(sec)}{lb}$ | Specific-impulse exponent, $n_I$ |
|---|---|---|---|---|---|---|
| R, 2.00; percent fuel, 26.19; O/F, 2.818 | | | | | | |
| 1.05 | 2513 | 0.0116 | 2.180 | 0.0004 | 30.2 | 0.0046 |
| 1.60 | 2328 | .0120 | 1.010 | .0001 | 92.0 | .0046 |
| 2.00 | 2235 | .0122 | 1.008 | .0001 | 110.6 | .0047 |
| 10.00 | 1646 | .0138 | 2.188 | .0013 | 187.7 | .0050 |
| 20.00 | 1433 | .0146 | 3.444 | .0020 | 207.6 | .0051 |
| 20.41 | 1427 | .0146 | 3.492 | .0020 | 208.1 | .0052 |
| 40.00 | 1242 | .0155 | 5.546 | .0027 | 223.5 | .0053 |
| 40.83 | 1237 | .0155 | 5.626 | .0027 | 223.9 | .0053 |
| 80.00 | 1071 | .0164 | 9.042 | .0035 | 236.4 | .0054 |
| 100.00 | 1020 | .0167 | 10.600 | .0038 | 240.0 | .0055 |
| 200.00 | 873 | .0177 | 17.426 | .0046 | 249.9 | .0056 |
| 300.00 | 795 | .0182 | 23.338 | .0050 | 254.9 | .0057 |
| 500.00 | 704 | .0189 | 33.746 | .0056 | 260.4 | .0058 |
| 800.00 | 629 | .0195 | 47.391 | .0061 | 264.8 | .0059 |
| 1000.00 | 595 | .0197 | 55.682 | .0063 | 266.7 | .0059 |
| 1500.00 | 538 | .0202 | 74.630 | .0067 | 269.9 | .0060 |
| R, 3.00; percent fuel, 19.13; O/F, 4.227 | | | | | | |
| 1.05 | 2151 | 0.0053 | 2.189 | 0.0001 | 26.8 | 0.0021 |
| 1.60 | 1984 | .0054 | 1.011 | .0000 | 81.6 | .0022 |
| 2.00 | 1900 | .0055 | 1.007 | .0000 | 98.1 | .0022 |
| 10.00 | 1373 | .0062 | 2.155 | .0006 | 165.7 | .0024 |
| 20.00 | 1186 | .0065 | 3.369 | .0008 | 183.1 | .0024 |
| 20.41 | 1181 | .0065 | 3.415 | .0008 | 183.5 | .0024 |
| 40.00 | 1019 | .0069 | 5.385 | .0011 | 196.8 | .0025 |
| 40.83 | 1014 | .0069 | 5.461 | .0011 | 197.1 | .0025 |
| 80.00 | 871 | .0073 | 8.715 | .0014 | 207.8 | .0026 |
| 100.00 | 827 | .0074 | 10.193 | .0015 | 210.9 | .0026 |
| 200.00 | 701 | .0077 | 16.636 | .0018 | 219.3 | .0026 |
| 300.00 | 636 | .0079 | 22.188 | .0020 | 223.4 | .0027 |
| 500.00 | 560 | .0082 | 31.918 | .0022 | 228.1 | .0027 |
| 800.00 | 497 | .0084 | 44.621 | .0024 | 231.7 | .0027 |
| 1000.00 | 469 | .0085 | 52.316 | .0025 | 233.3 | .0027 |
| 1500.00 | 423 | .0086 | 69.858 | .0026 | 235.9 | .0028 |
| R, 4.00; percent fuel, 15.07; O/F, 5.636 | | | | | | |
| 1.05 | 1859 | 0.0020 | 2.197 | 0.0001 | 24.4 | 0.0009 |
| 1.60 | 1708 | .0020 | 1.012 | .0000 | 74.0 | .0009 |
| 2.00 | 1632 | .0021 | 1.007 | .0000 | 88.9 | .0009 |
| 10.00 | 1162 | .0023 | 2.127 | .0002 | 149.8 | .0009 |
| 20.00 | 996 | .0024 | 3.305 | .0003 | 165.2 | .0009 |
| 20.41 | 991 | .0024 | 3.350 | .0003 | 165.6 | .0009 |
| 40.00 | 849 | .0026 | 5.252 | .0004 | 177.3 | .0010 |
| 40.83 | 845 | .0026 | 5.325 | .0004 | 177.6 | .0010 |
| 80.00 | 720 | .0027 | 8.448 | .0005 | 187.0 | .0010 |
| 100.00 | 682 | .0027 | 9.861 | .0005 | 189.7 | .0010 |
| 200.00 | 575 | .0028 | 15.994 | .0006 | 197.0 | .0010 |
| 300.00 | 519 | .0029 | 21.257 | .0007 | 200.7 | .0010 |
| 500.00 | 455 | .0030 | 30.448 | .0007 | 204.6 | .0010 |
| 800.00 | 402 | .0030 | 42.406 | .0008 | 207.8 | .0010 |
| 1000.00 | 379 | .0030 | 49.639 | .0008 | 209.2 | .0010 |
| 1500.00 | 340 | .0031 | 66.112 | .0008 | 211.4 | .0011 |
| R, 5.00; percent fuel, 12.43; O/F, 7.046 | | | | | | |
| 1.05 | 1624 | 0.0006 | 2.205 | 0.0000 | 22.4 | 0.0003 |
| 1.60 | 1487 | .0007 | 1.013 | .0000 | 68.1 | .0003 |
| 2.00 | 1419 | .0007 | 1.006 | .0000 | 81.7 | .0003 |
| 10.00 | 996 | .0007 | 2.103 | .0001 | 137.3 | .0003 |
| 20.00 | 848 | .0008 | 3.252 | .0001 | 151.2 | .0003 |
| 20.41 | 844 | .0008 | 3.295 | .0001 | 151.6 | .0003 |
| 40.00 | 719 | .0008 | 5.140 | .0001 | 162.2 | .0003 |
| 40.83 | 715 | .0008 | 5.212 | .0001 | 162.4 | .0003 |
| 80.00 | 605 | .0009 | 8.226 | .0001 | 170.8 | .0003 |
| 100.00 | 573 | .0009 | 9.585 | .0002 | 173.3 | .0003 |
| 200.00 | 480 | .0009 | 15.468 | .0002 | 179.8 | .0003 |
| 300.00 | 431 | .0009 | 20.497 | .0002 | 183.0 | .0003 |
| 500.00 | 377 | .0009 | 29.262 | .0002 | 186.5 | .0003 |
| 800.00 | 332 | .0009 | 40.653 | .0002 | 189.3 | .0003 |
| 1000.00 | 312 | .0009 | 47.540 | .0002 | 190.5 | .0003 |
| 1500.00 | 280 | .0009 | 63.216 | .0002 | 192.5 | .0003 |

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

[Isentropic expansion from chamber conditions.]

(a) Chamber pressure, 300 pounds per square inch absolute

| Static pressure, P, lb/sq in. abs | Temperature, T, °K | Mole fraction | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2$ | $H_2O$ | $N_2$ | OH | $O_2$ | NO | H | O | N |
| R, 0.40; percent fuel, 83.95; O/F, 0.564 | | | | | | | | | | |
| 600.00 | 1349 | 0.48000 | 0.30000 | 0.25000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 571.43 | 1334 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 375.00 | 1210 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 326.41 | 1171 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 300.00 | 1148 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 60.00 | 772 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 30.00 | 646 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 29.39 | 643 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 15.00 | 538 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 535 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 447 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6.00 | 421 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 349 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 312 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 271 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .75 | 238 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 224 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .40 | 200 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 0.50; percent fuel, 58.67; O/F, 0.705 | | | | | | | | | | |
| 600.00 | 1784 | 0.37498 | 0.37498 | 0.25000 | 0.00000 | 0.00000 | 0.00000 | 0.00003 | 0.00000 | 0.00000 |
| 571.43 | 1766 | .37498 | .37499 | .25000 | .00000 | .00000 | .00000 | .00003 | .00000 | .00000 |
| 375.00 | 1617 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 330.41 | 1574 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 300.00 | 1542 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 60.00 | 1075 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 30.00 | 911 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 29.39 | 906 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 15.00 | 768 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 764 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 644 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6.00 | 608 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 508 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 456 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 398 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .75 | 351 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 330 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .40 | 296 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 0.60; percent fuel, 54.19; O/F, 0.845 | | | | | | | | | | |
| 600.00 | 2171 | 0.29984 | 0.44955 | 0.24991 | 0.00029 | 0.00000 | 0.00000 | 0.00041 | 0.00000 | 0.00000 |
| 571.43 | 2151 | .29985 | .44959 | .24992 | .00026 | .00000 | .00000 | .00037 | .00000 | .00000 |
| 375.00 | 1983 | .29993 | .44985 | .24997 | .00009 | .00000 | .00000 | .00016 | .00000 | .00000 |
| 333.38 | 1938 | .29995 | .44989 | .24998 | .00007 | .00000 | .00000 | .00012 | .00000 | .00000 |
| 300.00 | 1898 | .29996 | .44992 | .24998 | .00005 | .00000 | .00000 | .00009 | .00000 | .00000 |
| 60.00 | 1361 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 30.00 | 1169 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 29.39 | 1164 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 15.00 | 998 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 993 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 847 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6.00 | 803 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 676 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 611 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 536 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .75 | 474 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 447 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .40 | 402 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 0.70; percent fuel, 50.34; O/F, 0.986 | | | | | | | | | | |
| 600.00 | 2503 | 0.22499 | 0.52091 | 0.24938 | 0.00277 | 0.00000 | 0.00007 | 0.00188 | 0.00000 | 0.00000 |
| 571.43 | 2483 | .22497 | .52122 | .24942 | .00255 | .00000 | .00006 | .00176 | .00000 | .00000 |
| 375.00 | 2309 | .22491 | .52320 | .24972 | .00120 | .00000 | .00002 | .00095 | .00000 | .00000 |
| 336.30 | 2265 | .22490 | .52355 | .24977 | .00097 | .00000 | .00002 | .00079 | .00000 | .00000 |
| 300.00 | 2219 | .22491 | .52384 | .24981 | .00077 | .00000 | .00001 | .00066 | .00000 | .00000 |
| 60.00 | 1633 | .22499 | .52498 | .25000 | .00000 | .00000 | .00000 | .00002 | .00000 | .00000 |
| 30.00 | 1418 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 29.39 | 1412 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 15.00 | 1224 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 1219 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 1051 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6.00 | 999 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 851 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 773 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 683 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .75 | 608 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 575 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .40 | 518 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |

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

[Isentropic expansion from chamber conditions.]

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

| Static pressure, P, lb/sq in. abs | Temperature, T, °K | Mole fraction | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2$ | $H_2O$ | $N_2$ | OH | $O_2$ | NO | H | O | N |
| R, 0.80; percent fuel, 47.01; O/F, 1.127 | | | | | | | | | | |
| 300.00 | 2734 | 0.15436 | 0.57682 | 0.24692 | 0.01539 | 0.00020 | 0.00060 | 0.00559 | 0.00013 | 0.00000 |
| 285.71 | 2717 | .15410 | .57795 | .24707 | .01466 | .00018 | .00056 | .00536 | .00012 | .00000 |
| 187.50 | 2563 | .15227 | .58639 | .24820 | .00914 | .00008 | .00029 | .00359 | .00005 | .00000 |
| 170.41 | 2528 | .15195 | .58797 | .24841 | .00810 | .00006 | .00024 | .00324 | .00004 | .00000 |
| 150.00 | 2482 | .15157 | .58987 | .24866 | .00683 | .00004 | .00019 | .00281 | .00003 | .00000 |
| 30.00 | 1893 | .15001 | .59957 | .24994 | .00028 | .00000 | .00000 | .00020 | .00000 | .00000 |
| 15.00 | 1661 | .14999 | .59994 | .24999 | .00004 | .00000 | .00000 | .00004 | .00000 | .00000 |
| 14.70 | 1654 | .14999 | .59994 | .24999 | .00004 | .00000 | .00000 | .00004 | .00000 | .00000 |
| 7.50 | 1449 | .15000 | .59999 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.35 | 1443 | .15000 | .59999 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.75 | 1257 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 1199 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.50 | 1033 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.00 | 943 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 839 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .37 | 752 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .30 | 713 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .20 | 646 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 0.90; percent fuel, 44.09; O/F, 1.268 | | | | | | | | | | |
| 300.00 | 2877 | 0.09462 | 0.61364 | 0.24243 | 0.03742 | 0.00180 | 0.00218 | 0.00723 | 0.00068 | 0.00000 |
| 285.71 | 2862 | .09398 | .61551 | .24268 | .03637 | .00172 | .00209 | .00701 | .00064 | .00000 |
| 187.50 | 2731 | .08877 | .63078 | .24463 | .02763 | .00111 | .00140 | .00529 | .00038 | .00000 |
| 172.33 | 2704 | .08781 | .63362 | .24499 | .02597 | .00100 | .00129 | .00497 | .00034 | .00000 |
| 150.00 | 2661 | .08630 | .63813 | .24556 | .02332 | .00084 | .00110 | .00448 | .00027 | .00000 |
| 30.00 | 2135 | .07611 | .67054 | .24948 | .00303 | .00002 | .00007 | .00074 | .00000 | .00000 |
| 15.00 | 1900 | .07521 | .67401 | .24988 | .00068 | .00000 | .00000 | .00021 | .00000 | .00000 |
| 14.70 | 1893 | .07520 | .67405 | .24989 | .00064 | .00000 | .00000 | .00021 | .00000 | .00000 |
| 7.50 | 1675 | .07502 | .67485 | .24998 | .00010 | .00000 | .00000 | .00004 | .00000 | .00000 |
| 7.35 | 1668 | .07502 | .67486 | .24998 | .00009 | .00000 | .00000 | .00004 | .00000 | .00000 |
| 3.75 | 1467 | .07500 | .67499 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 1404 | .07500 | .67499 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.50 | 1221 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.00 | 1122 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 1006 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .37 | 907 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .30 | 863 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .20 | 787 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 0.95; percent fuel, 42.76; O/F, 1.339 | | | | | | | | | | |
| 300.00 | 2913 | .07104 | .62334 | .23927 | .05031 | .00428 | .00350 | .00705 | .00120 | .00000 |
| 285.71 | 2899 | .07024 | .62544 | .23954 | .04922 | .00416 | .00339 | .00685 | .00115 | .00000 |
| 172.91 | 2751 | .06289 | .64616 | .24218 | .03832 | .00301 | .00237 | .00497 | .00071 | .00000 |
| 187.50 | 2774 | .06353 | .64293 | .24177 | .04004 | .00319 | .00252 | .00525 | .00077 | .00000 |
| 150.00 | 2709 | .06015 | .65171 | .24287 | .03535 | .00270 | .00212 | .00449 | .00061 | .00000 |
| 30.00 | 2234 | .04185 | .69970 | .24858 | .00829 | .00027 | .00029 | .00097 | .00004 | .00000 |
| 15.00 | 2015 | .03870 | .70868 | .24959 | .00259 | .00003 | .00006 | .00035 | .00000 | .00000 |
| 14.70 | 2008 | .03864 | .70884 | .24960 | .00249 | .00003 | .00006 | .00034 | .00000 | .00000 |
| 7.50 | 1791 | .03771 | .71176 | .24992 | .00051 | .00000 | .00000 | .00009 | .00000 | .00000 |
| 7.35 | 1784 | .03770 | .71180 | .24992 | .00049 | .00000 | .00000 | .00009 | .00000 | .00000 |
| 3.75 | 1577 | .03752 | .71240 | .24999 | .00007 | .00000 | .00000 | .00002 | .00000 | .00000 |
| 3.00 | 1512 | .03751 | .71246 | .24999 | .00003 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.50 | 1321 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.00 | 1218 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 1096 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .37 | 992 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .30 | 945 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .20 | 864 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |

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

[Isentropic expansion from chamber conditions.]

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

| Static pressure, P, lb/sq in. abs | Temperature, T, °K | Mole fraction | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2$ | $H_2O$ | $N_2$ | OH | $O_2$ | NO | H | O | N |
| R, 1.00; percent fuel, 41.51; O/F, 1.409 | | | | | | | | | | |
| 300.00 | 2928 | 0.05250 | 0.62756 | 0.23558 | 0.06227 | 0.00882 | 0.00508 | 0.00636 | 0.00181 | 0.00000 |
| 285.71 | 2914 | .05163 | .62973 | .23586 | .06119 | .00871 | .00496 | .00617 | .00175 | .00000 |
| 187.50 | 2792 | .04425 | .64799 | .23820 | .05197 | .00767 | .00398 | .00466 | .00128 | .00000 |
| 173.12 | 2769 | .04288 | .65135 | .23862 | .05026 | .00747 | .00381 | .00440 | .00120 | .00000 |
| 160.00 | 2728 | .04045 | .65730 | .23936 | .04724 | .00712 | .00351 | .00396 | .00106 | .00000 |
| 30.00 | 2283 | .01651 | .71388 | .24608 | .01821 | .00326 | .00111 | .00079 | .00018 | .00000 |
| 15.00 | 2089 | .00912 | .73049 | .24792 | .00968 | .00191 | .00055 | .00027 | .00006 | .00000 |
| 14.70 | 2083 | .00894 | .73090 | .24797 | .00947 | .00187 | .00053 | .00026 | .00005 | .00000 |
| 7.50 | 1891 | .00413 | .74139 | .24910 | .00416 | .00092 | .00022 | .00007 | .00001 | .00000 |
| 7.35 | 1885 | .00402 | .74163 | .24913 | .00404 | .00090 | .00021 | .00006 | .00001 | .00000 |
| 3.75 | 1691 | .00144 | .74708 | .24970 | .00136 | .00035 | .00007 | .00001 | .00000 | .00000 |
| 3.00 | 1627 | .00096 | .74806 | .24980 | .00088 | .00024 | .00004 | .00000 | .00000 | .00000 |
| 1.50 | 1434 | .00022 | .74956 | .24996 | .00019 | .00006 | .00000 | .00000 | .00000 | .00000 |
| 1.00 | 1326 | .00008 | .74984 | .24998 | .00006 | .00002 | .00000 | .00000 | .00000 | .00000 |
| .60 | 1199 | .00002 | .74996 | .25000 | .00001 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .37 | 1089 | .00000 | .74999 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .30 | 1039 | .00000 | .75000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .20 | 953 | .00000 | .75000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 1.10; percent fuel, 39.22; O/F, 1.550 | | | | | | | | | | |
| 300.00 | 2913 | 0.02924 | 0.62393 | 0.22740 | 0.07844 | 0.02527 | 0.00830 | 0.00452 | 0.00291 | 0.00000 |
| 285.71 | 2898 | .02849 | .62596 | .22768 | .07726 | .02530 | .00815 | .00436 | .00282 | .00000 |
| 187.50 | 2773 | .02230 | .64284 | .22994 | .06712 | .02560 | .00695 | .00309 | .00216 | .00000 |
| 172.87 | 2749 | .02117 | .64596 | .23035 | .06518 | .02568 | .00673 | .00288 | .00205 | .00000 |
| 150.00 | 2707 | .01926 | .65129 | .23106 | .06182 | .02583 | .00637 | .00252 | .00185 | .00000 |
| 30.00 | 2236 | .00406 | .69867 | .23728 | .02678 | .02954 | .00296 | .00031 | .00040 | .00000 |
| 15.00 | 2030 | .00142 | .71045 | .23890 | .01525 | .03188 | .00188 | .00007 | .00015 | .00000 |
| 14.70 | 2023 | .00137 | .71072 | .23894 | .01496 | .03195 | .00185 | .00007 | .00014 | .00000 |
| 7.50 | 1823 | .00036 | .71745 | .23995 | .00723 | .03390 | .00106 | .00001 | .00004 | .00000 |
| 7.35 | 1817 | .00035 | .71759 | .23997 | .00705 | .03395 | .00104 | .00001 | .00004 | .00000 |
| 3.75 | 1621 | .00006 | .72093 | .24033 | .00275 | .03520 | .00051 | .00000 | .00000 | .00000 |
| 3.00 | 1557 | .00003 | .72154 | .24065 | .00191 | .03547 | .00039 | .00000 | .00000 | .00000 |
| 1.50 | 1368 | .00000 | .72254 | .24086 | .00051 | .03594 | .00015 | .00000 | .00000 | .00000 |
| 1.00 | 1264 | .00000 | .72275 | .24091 | .00021 | .03605 | .00008 | .00000 | .00000 | .00000 |
| .60 | 1140 | .00000 | .72285 | .24098 | .00006 | .03611 | .00003 | .00000 | .00000 | .00000 |
| .37 | 1034 | .00000 | .72288 | .24096 | .00001 | .03614 | .00001 | .00000 | .00000 | .00000 |
| .30 | 986 | .00000 | .72289 | .24096 | .00000 | .03614 | .00000 | .00000 | .00000 | .00000 |
| .20 | 903 | .00000 | .72289 | .24096 | .00000 | .03614 | .00000 | .00000 | .00000 | .00000 |
| R, 1.20; percent fuel, 37.16; O/F, 1.691 | | | | | | | | | | |
| 300.00 | 2871 | 0.01774 | 0.61255 | 0.21929 | 0.08430 | 0.04886 | 0.01073 | 0.00307 | 0.00346 | 0.00000 |
| 285.71 | 2856 | .01719 | .61437 | .21956 | .08295 | .04909 | .01055 | .00294 | .00336 | .00000 |
| 187.50 | 2726 | .01282 | .62939 | .22176 | .07129 | .05118 | .00903 | .00198 | .00253 | .00000 |
| 172.57 | 2701 | .01204 | .63220 | .22218 | .06901 | .05162 | .00875 | .00182 | .00238 | .00000 |
| 150.00 | 2659 | .01078 | .63682 | .22285 | .06517 | .05238 | .00828 | .00157 | .00215 | .00000 |
| 30.00 | 2175 | .00187 | .67751 | .22894 | .02573 | .06174 | .00367 | .00015 | .00040 | .00000 |
| 15.00 | 1968 | .00060 | .68747 | .23055 | .01382 | .06517 | .00223 | .00003 | .00013 | .00000 |
| 14.70 | 1962 | .00058 | .68769 | .23059 | .01353 | .06526 | .00219 | .00003 | .00013 | .00000 |
| 7.50 | 1762 | .00014 | .69333 | .23159 | .00613 | .06758 | .00119 | .00000 | .00003 | .00000 |
| 7.35 | 1756 | .00013 | .69346 | .23161 | .00597 | .06763 | .00117 | .00000 | .00003 | .00000 |
| 3.75 | 1568 | .00002 | .69619 | .23216 | .00216 | .06892 | .00055 | .00000 | .00000 | .00000 |
| 3.00 | 1499 | .00001 | .69667 | .23227 | .00146 | .06918 | .00041 | .00000 | .00000 | .00000 |
| 1.50 | 1314 | .00000 | .69743 | .23246 | .00036 | .06960 | .00015 | .00000 | .00000 | .00000 |
| 1.00 | 1212 | .00000 | .69758 | .23251 | .00013 | .06969 | .00007 | .00000 | .00000 | .00000 |
| .60 | 1091 | .00000 | .69765 | .23254 | .00003 | .06975 | .00003 | .00000 | .00000 | .00000 |
| .37 | 988 | .00000 | .69767 | .23255 | .00000 | .06976 | .00000 | .00000 | .00000 | .00000 |
| .30 | 941 | .00000 | .69767 | .23256 | .00000 | .06976 | .00000 | .00000 | .00000 | .00000 |
| .20 | 861 | .00000 | .69767 | .23256 | .00000 | .06977 | .00000 | .00000 | .00000 | .00000 |
| R, 1.50; percent fuel, 32.12; O/F, 2.114 | | | | | | | | | | |
| 300.00 | 2728 | 0.00582 | 0.57156 | 0.19856 | 0.07648 | 0.12967 | 0.01364 | 0.00106 | 0.00321 | 0.00000 |
| 285.71 | 2712 | .00560 | .57299 | .19883 | .07490 | .13023 | .01337 | .00101 | .00309 | .00000 |
| 187.50 | 2579 | .00387 | .58473 | .20100 | .06154 | .13499 | .01112 | .00061 | .00215 | .00000 |
| 172.00 | 2551 | .00357 | .58698 | .20142 | .05889 | .13593 | .01068 | .00055 | .00198 | .00000 |
| 150.00 | 2509 | .00312 | .59045 | .20206 | .05477 | .13741 | .01000 | .00045 | .00174 | .00000 |
| 30.00 | 2013 | .00036 | .62014 | .20776 | .01655 | .15131 | .00366 | .00002 | .00020 | .00000 |
| 15.00 | 1804 | .00009 | .62649 | .20912 | .00754 | .15473 | .00198 | .00000 | .00005 | .00000 |
| 14.70 | 1798 | .00008 | .62662 | .20916 | .00734 | .15481 | .00194 | .00000 | .00005 | .00000 |
| 7.50 | 1600 | .00001 | .62975 | .20992 | .00274 | .15664 | .00092 | .00000 | .00000 | .00000 |
| 7.35 | 1594 | .00001 | .62982 | .20993 | .00265 | .15668 | .00090 | .00000 | .00000 | .00000 |
| 3.75 | 1405 | .00000 | .63108 | .21031 | .00076 | .15749 | .00036 | .00000 | .00000 | .00000 |
| 3.00 | 1345 | .00000 | .63127 | .21037 | .00047 | .15763 | .00026 | .00000 | .00000 | .00000 |
| 1.50 | 1170 | .00000 | .63152 | .21048 | .00009 | .15783 | .00008 | .00000 | .00000 | .00000 |
| 1.00 | 1075 | .00000 | .63156 | .21051 | .00003 | .15787 | .00003 | .00000 | .00000 | .00000 |
| .60 | 963 | .00000 | .63158 | .21052 | .00000 | .15789 | .00001 | .00000 | .00000 | .00000 |
| .37 | 868 | .00000 | .63158 | .21052 | .00000 | .15789 | .00000 | .00000 | .00000 | .00000 |
| .30 | 825 | .00000 | .63158 | .21053 | .00000 | .15789 | .00000 | .00000 | .00000 | .00000 |
| .20 | 752 | .00000 | .63158 | .21053 | .00000 | .15789 | .00000 | .00000 | .00000 | .00000 |

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

[Isentropic expansion from chamber conditions.]

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

| Static pressure, P, lb/sq in. abs | Temperature, T, °K | Mole fraction | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2$ | $H_2O$ | $N_2$ | OH | $O_2$ | NO | H | O | N |
| R, 2.00; percent fuel, 26.19; O/F, 2.618 | | | | | | | | | | |
| 300.00 | 2515 | 0.00146 | 0.51070 | 0.17289 | 0.05063 | 0.24976 | 0.01261 | 0.00023 | 0.00171 | 0.00000 |
| 285.71 | 2499 | .00139 | .51176 | .17313 | .04919 | .25041 | .01229 | .00021 | .00162 | .00000 |
| 187.50 | 2362 | .00085 | .52015 | .17508 | .03749 | .25563 | .00970 | .00011 | .00099 | .00000 |
| 171.00 | 2332 | .00076 | .52112 | .17547 | .03513 | .25668 | .00918 | .00009 | .00088 | .00000 |
| 150.00 | 2290 | .00064 | .52408 | .17601 | .03190 | .25812 | .00846 | .00007 | .00074 | .00000 |
| 30.00 | 1782 | .00003 | .54155 | .18041 | .00605 | .26966 | .00226 | .00000 | .00004 | .00000 |
| 15.00 | 1574 | .00000 | .54413 | .18122 | .00206 | .27157 | .00101 | .00000 | .00000 | .00000 |
| 14.70 | 1568 | .00000 | .54418 | .18124 | .00199 | .27160 | .00098 | .00000 | .00000 | .00000 |
| 7.50 | 1377 | .00000 | .54512 | .18161 | .00053 | .27237 | .00038 | .00000 | .00000 | .00000 |
| 7.35 | 1371 | .00000 | .54513 | .18161 | .00051 | .27238 | .00036 | .00000 | .00000 | .00000 |
| 3.75 | 1195 | .00000 | .54539 | .18176 | .00010 | .27264 | .00011 | .00000 | .00000 | .00000 |
| 3.00 | 1141 | .00000 | .54542 | .18178 | .00005 | .27267 | .00007 | .00000 | .00000 | .00000 |
| 1.50 | 982 | .00000 | .54545 | .18181 | .00000 | .27272 | .00002 | .00000 | .00000 | .00000 |
| 1.00 | 898 | .00000 | .54545 | .18182 | .00000 | .27272 | .00000 | .00000 | .00000 | .00000 |
| .60 | 799 | .00000 | .54545 | .18182 | .00000 | .27273 | .00000 | .00000 | .00000 | .00000 |
| .37 | 716 | .00000 | .54545 | .18182 | .00000 | .27273 | .00000 | .00000 | .00000 | .00000 |
| .30 | 679 | .00000 | .54545 | .18182 | .00000 | .27273 | .00000 | .00000 | .00000 | .00000 |
| .20 | 616 | .00000 | .54545 | .18182 | .00000 | .27273 | .00000 | .00000 | .00000 | .00000 |
| R, 3.00; percent fuel, 19.13; O/F, 4.227 | | | | | | | | | | |
| 300.00 | 2163 | 0.00013 | 0.41769 | 0.13859 | 0.01754 | 0.41852 | 0.00722 | 0.00001 | 0.00030 | 0.00000 |
| 285.71 | 2146 | .00012 | .41820 | .13875 | .01673 | .41895 | .00695 | .00001 | .00028 | .00000 |
| 187.50 | 2004 | .00005 | .42197 | .14002 | .01072 | .42223 | .00489 | .00000 | .00012 | .00000 |
| 168.77 | 1969 | .00004 | .42274 | .14029 | .00948 | .42290 | .00444 | .00000 | .00010 | .00000 |
| 150.00 | 1929 | .00003 | .42352 | .14057 | .00822 | .42360 | .00398 | .00000 | .00008 | .00000 |
| 30.00 | 1427 | .00000 | .42822 | .14256 | .00057 | .42809 | .00055 | .00000 | .00000 | .00000 |
| 15.00 | 1236 | .00000 | .42850 | .14277 | .00011 | .42845 | .00017 | .00000 | .00000 | .00000 |
| 14.70 | 1231 | .00000 | .42851 | .14277 | .00011 | .42845 | .00016 | .00000 | .00000 | .00000 |
| 7.50 | 1065 | .00000 | .42856 | .14284 | .00001 | .42855 | .00004 | .00000 | .00000 | .00000 |
| 7.35 | 1060 | .00000 | .42856 | .14284 | .00001 | .42855 | .00004 | .00000 | .00000 | .00000 |
| 3.75 | 912 | .00000 | .42857 | .14285 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 866 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| 1.50 | 737 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| 1.00 | 668 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| .60 | 590 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| .37 | 524 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| .30 | 495 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| .20 | 446 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| R, 4.00; percent fuel, 15.07; O/F, 5.636 | | | | | | | | | | |
| 300.00 | 1875 | 0.00001 | 0.34989 | 0.11579 | 0.00515 | 0.52571 | 0.00341 | 0.00000 | 0.00004 | 0.00000 |
| 285.71 | 1858 | .00000 | .35009 | .11588 | .00481 | .52593 | .00324 | .00000 | .00003 | .00000 |
| 187.50 | 1717 | .00000 | .35144 | .11656 | .00255 | .52742 | .00201 | .00000 | .00001 | .00000 |
| 166.91 | 1680 | .00000 | .35170 | .11671 | .00211 | .52773 | .00175 | .00000 | .00000 | .00000 |
| 150.00 | 1645 | .00000 | .35191 | .11683 | .00175 | .52797 | .00153 | .00000 | .00000 | .00000 |
| 30.00 | 1179 | .00000 | .35291 | .11759 | .00005 | .52934 | .00011 | .00000 | .00000 | .00000 |
| 15.00 | 1012 | .00000 | .35294 | .11763 | .00000 | .52940 | .00002 | .00000 | .00000 | .00000 |
| 14.70 | 1007 | .00000 | .35294 | .11764 | .00000 | .52940 | .00002 | .00000 | .00000 | .00000 |
| 7.50 | 864 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| 7.35 | 859 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| 3.75 | 733 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 695 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| 1.50 | 585 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| 1.00 | 528 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| .60 | 463 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| .37 | 410 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| .30 | 386 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| .20 | 347 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| R, 5.00; percent fuel, 12.43; O/F, 7.046 | | | | | | | | | | |
| 300.00 | 1640 | 0.00000 | 0.29922 | 0.09923 | 0.00136 | 0.59872 | 0.00147 | 0.00000 | 0.00000 | 0.00000 |
| 285.71 | 1624 | .00000 | .29928 | .09928 | .00125 | .59881 | .00138 | .00000 | .00000 | .00000 |
| 187.50 | 1491 | .00000 | .29968 | .09961 | .00055 | .59940 | .00076 | .00000 | .00000 | .00000 |
| 165.69 | 1453 | .00000 | .29976 | .09968 | .00042 | .59952 | .00063 | .00000 | .00000 | .00000 |
| 150.00 | 1424 | .00000 | .29980 | .09972 | .00034 | .59960 | .00054 | .00000 | .00000 | .00000 |
| 30.00 | 1002 | .00000 | .30000 | .09999 | .00000 | .59999 | .00002 | .00000 | .00000 | .00000 |
| 15.00 | 853 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 849 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 723 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 7.35 | 720 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 3.75 | 610 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 577 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 1.50 | 483 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 1.00 | 434 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 379 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| .37 | 334 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| .30 | 315 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| .20 | 282 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |

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

[Isentropic expansion from chamber conditions.]

(b) Chamber pressure, 600 pounds per square inch absolute

| Static pressure, P, lb/sq in. abs | Temperature, T, °K | Mole fraction | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2$ | $H_2O$ | $N_2$ | OH | $O_2$ | NO | H | O | N |
| R, 0.40; percent fuel, 63.95; O/F, 0.564 | | | | | | | | | | |
| 300.00 | 1349 | 0.45000 | 0.30000 | 0.25000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 285.71 | 1334 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 187.50 | 1210 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 163.21 | 1171 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 150.00 | 1148 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 30.00 | 772 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 15.00 | 646 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 643 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 538 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.35 | 535 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.75 | 447 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 421 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.50 | 349 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.00 | 312 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 271 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .37 | 238 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .30 | 224 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .20 | 200 | .45000 | .30000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 0.50; percent fuel, 58.67; O/F, 0.705 | | | | | | | | | | |
| 300.00 | 1784 | 0.37497 | 0.37498 | 0.24999 | 0.00001 | 0.00000 | 0.00000 | 0.00004 | 0.00000 | 0.00000 |
| 285.71 | 1766 | .37498 | .37498 | .24999 | .00001 | .00000 | .00000 | .00004 | .00000 | .00000 |
| 187.50 | 1617 | .37499 | .37499 | .25000 | .00000 | .00000 | .00000 | .00001 | .00000 | .00000 |
| 165.20 | 1574 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 150.00 | 1542 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 30.00 | 1075 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 15.00 | 911 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 906 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 768 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.35 | 764 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.75 | 644 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 608 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.50 | 508 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.00 | 456 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 398 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .37 | 351 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .30 | 330 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .20 | 296 | .37500 | .37500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 0.60; percent fuel, 54.19; O/F, 0.845 | | | | | | | | | | |
| 300.00 | 2169 | 0.29978 | 0.44937 | 0.24987 | 0.00041 | 0.00000 | 0.00000 | 0.00057 | 0.00000 | 0.00000 |
| 285.71 | 2149 | .29979 | .44943 | .24989 | .00037 | .00000 | .00000 | .00052 | .00000 | .00000 |
| 187.50 | 1982 | .29990 | .44979 | .24996 | .00013 | .00000 | .00000 | .00022 | .00000 | .00000 |
| 166.72 | 1937 | .29992 | .44985 | .24997 | .00009 | .00000 | .00000 | .00017 | .00000 | .00000 |
| 150.00 | 1897 | .29994 | .44988 | .24997 | .00007 | .00000 | .00000 | .00013 | .00000 | .00000 |
| 30.00 | 1361 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 15.00 | 1169 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 1164 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 998 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.35 | 993 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.75 | 847 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 803 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.50 | 676 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.00 | 611 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 536 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .37 | 474 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .30 | 447 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .20 | 402 | .30000 | .45000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 0.70; percent fuel, 50.34; O/F, 0.986 | | | | | | | | | | |
| 300.00 | 2494 | 0.22497 | 0.51949 | 0.24916 | 0.00372 | 0.00000 | 0.00009 | 0.00256 | 0.00000 | 0.00000 |
| 285.71 | 2474 | .22495 | .51989 | .24982 | .00344 | .00000 | .00008 | .00240 | .00000 | .00000 |
| 187.50 | 2305 | .22487 | .52252 | .24961 | .00165 | .00000 | .00003 | .00131 | .00000 | .00000 |
| 168.33 | 2262 | .22487 | .52298 | .24968 | .00134 | .00000 | .00002 | .00111 | .00000 | .00000 |
| 150.00 | 2216 | .22487 | .52339 | .24974 | .00107 | .00000 | .00002 | .00091 | .00000 | .00000 |
| 30.00 | 1633 | .22499 | .52495 | .25000 | .00001 | .00000 | .00000 | .00003 | .00000 | .00000 |
| 15.00 | 1418 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 1412 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 1285 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.35 | 1219 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.75 | 1052 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 1000 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.50 | 852 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.00 | 773 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 683 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .37 | 608 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .30 | 575 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .20 | 519 | .22500 | .52500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |

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

[Isentropic expansion from chamber conditions.]

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

| Static pressure, P, lb/sq in. abs | Temperature, T, °K | Mole fraction | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2$ | $H_2O$ | $N_2$ | OH | $O_2$ | NO | H | O | N |
| R, 0.80; percent fuel, 47.01; O/F, 1.127 | | | | | | | | | | |
| 600.00 | 2760 | 0.15349 | 0.58163 | 0.24756 | 0.01228 | 0.00013 | 0.00050 | 0.00433 | 0.00008 | 0.00000 |
| 571.43 | 2741 | .15327 | .58259 | .24769 | .01166 | .00011 | .00046 | .00414 | .00007 | .00000 |
| 375.00 | 2580 | .15175 | .58958 | .24862 | .00704 | .00005 | .00023 | .00271 | .00003 | .00000 |
| 340.01 | 2542 | .15148 | .59088 | .24879 | .00617 | .00004 | .00019 | .00243 | .00002 | .00000 |
| 300.00 | 2493 | .15119 | .59238 | .24899 | .00516 | .00003 | .00015 | .00209 | .00002 | .00000 |
| 60.00 | 1891 | .15000 | .59970 | .24996 | .00020 | .00000 | .00000 | .00014 | .00000 | .00000 |
| 30.00 | 1658 | .15000 | .59996 | .24999 | .00003 | .00000 | .00000 | .00003 | .00000 | .00000 |
| 29.39 | 1652 | .15000 | .59996 | .24999 | .00002 | .00000 | .00000 | .00003 | .00000 | .00000 |
| 15.00 | 1447 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 1441 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 1255 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6.00 | 1197 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 1031 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 942 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 838 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .75 | 751 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 712 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .40 | 645 | .15000 | .60000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 0.90; percent fuel, 44.09; O/F, 1.268 | | | | | | | | | | |
| 600.00 | 2922 | 0.09170 | 0.62276 | 0.24352 | 0.03225 | 0.00136 | 0.00201 | 0.00582 | 0.00049 | 0.00000 |
| 571.43 | 2905 | .09119 | .62449 | .24375 | .03126 | .00129 | .00192 | .00564 | .00046 | .00000 |
| 375.00 | 2765 | .08642 | .63841 | .24554 | .02315 | .00079 | .00125 | .00418 | .00026 | .00000 |
| 343.86 | 2736 | .08553 | .64103 | .24587 | .02160 | .00070 | .00113 | .00391 | .00023 | .00000 |
| 300.00 | 2690 | .08421 | .64497 | .24637 | .01923 | .00058 | .00096 | .00350 | .00018 | .00000 |
| 60.00 | 2135 | .07576 | .67184 | .24963 | .00215 | .00001 | .00005 | .00052 | .00000 | .00000 |
| 30.00 | 1896 | .07514 | .67432 | .24992 | .00046 | .00000 | .00000 | .00015 | .00000 | .00000 |
| 29.39 | 1889 | .07513 | .67436 | .24992 | .00044 | .00000 | .00000 | .00014 | .00000 | .00000 |
| 15.00 | 1670 | .07502 | .67490 | .24999 | .00007 | .00000 | .00000 | .00003 | .00000 | .00000 |
| 14.70 | 1663 | .07501 | .67491 | .24999 | .00006 | .00000 | .00000 | .00003 | .00000 | .00000 |
| 7.50 | 1462 | .07500 | .67499 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 6.00 | 1399 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 1217 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 1118 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 1003 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .75 | 904 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 860 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .40 | 784 | .07500 | .67500 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 0.95; percent fuel, 42.76; O/F, 1.339 | | | | | | | | | | |
| 600.00 | 2963 | 0.06722 | 0.63401 | 0.24046 | 0.04478 | 0.00352 | 0.00339 | 0.00569 | 0.00092 | 0.00000 |
| 571.43 | 2948 | .06645 | .63600 | .24072 | .04374 | .00342 | .00328 | .00552 | .00088 | .00000 |
| 375.00 | 2815 | .06004 | .65247 | .24284 | .03498 | .00254 | .00239 | .00417 | .00057 | .00000 |
| 345.19 | 2790 | .05884 | .65556 | .24323 | .03332 | .00237 | .00223 | .00393 | .00052 | .00000 |
| 300.00 | 2746 | .05685 | .66066 | .24387 | .03055 | .00210 | .00198 | .00354 | .00044 | .00000 |
| 60.00 | 2241 | .04069 | .70303 | .24895 | .00623 | .00016 | .00022 | .00070 | .00002 | .00000 |
| 30.00 | 2012 | .03832 | .70986 | .24971 | .00180 | .00002 | .00004 | .00024 | .00000 | .00000 |
| 29.39 | 2005 | .03828 | .70998 | .24973 | .00173 | .00002 | .00004 | .00023 | .00000 | .00000 |
| 15.00 | 1784 | .03764 | .71201 | .24995 | .00034 | .00000 | .00000 | .00006 | .00000 | .00000 |
| 14.70 | 1778 | .03763 | .71204 | .24995 | .00032 | .00000 | .00000 | .00006 | .00000 | .00000 |
| 7.50 | 1570 | .03752 | .71244 | .24999 | .00004 | .00000 | .00000 | .00001 | .00000 | .00000 |
| 6.00 | 1505 | .03751 | .71247 | .25000 | .00002 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 1315 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 1212 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 1091 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .75 | 987 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 940 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .40 | 859 | .03750 | .71250 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 0.975; percent fuel, 42.15; O/F, 1.374 | | | | | | | | | | |
| 600.00 | 2975 | 0.05696 | 0.63721 | 0.23867 | 0.05096 | 0.00536 | 0.00423 | 0.00543 | 0.00118 | 0.00000 |
| 571.43 | 2960 | .05613 | .63926 | .23894 | .04992 | .00525 | .00411 | .00527 | .00113 | .00000 |
| 375.00 | 2829 | .04920 | .65643 | .24115 | .04110 | .00425 | .00314 | .00396 | .00078 | .00000 |
| 345.55 | 2804 | .04789 | .65964 | .24155 | .03943 | .00406 | .00297 | .00373 | .00072 | .00000 |
| 300.00 | 2761 | .04567 | .66509 | .24224 | .03661 | .00373 | .00268 | .00336 | .00062 | .00000 |
| 60.00 | 2280 | .02531 | .71441 | .24814 | .01023 | .00067 | .00050 | .00068 | .00006 | .00000 |
| 30.00 | 2064 | .02085 | .72550 | .24938 | .00375 | .00013 | .00013 | .00025 | .00000 | .00000 |
| 29.39 | 2058 | .02077 | .72572 | .24941 | .00361 | .00012 | .00013 | .00024 | .00000 | .00000 |
| 15.00 | 1843 | .01918 | .72999 | .24987 | .00086 | .00000 | .00002 | .00007 | .00000 | .00000 |
| 14.70 | 1836 | .01915 | .73006 | .24988 | .00082 | .00000 | .00002 | .00007 | .00000 | .00000 |
| 7.50 | 1627 | .01881 | .73107 | .24998 | .00012 | .00000 | .00000 | .00001 | .00000 | .00000 |
| 6.00 | 1561 | .01878 | .73116 | .24999 | .00006 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 1367 | .01875 | .73124 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 1262 | .01875 | .73125 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 1138 | .01875 | .73125 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .75 | 1031 | .01875 | .73125 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 983 | .01875 | .73125 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .40 | 900 | .01875 | .73125 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |

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

[Isentropic expansion from chamber conditions.]

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

| Static pressure, P, lb/sq in. abs | Temperature, T, °K | Mole fraction | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2$ | $H_2O$ | $N_2$ | OH | $O_2$ | NO | H | O | N |
| R, 1.00; percent fuel, 41.51; O/F, 1.409 | | | | | | | | | | |
| 600.00 | 2980 | 0.04811 | 0.63890 | 0.23674 | 0.05673 | 0.00785 | 0.00513 | 0.00508 | 0.00145 | 0.00000 |
| 571.43 | 2965 | .04726 | .64098 | .23701 | .05568 | .00774 | .00500 | .00492 | .00140 | .00000 |
| 375.00 | 2836 | .04010 | .65839 | .23926 | .04685 | .00676 | .00398 | .00366 | .00101 | .00000 |
| 345.69 | 2811 | .03876 | .66164 | .23967 | .04519 | .00657 | .00379 | .00344 | .00094 | .00000 |
| 300.00 | 2768 | .03644 | .66721 | .24037 | .04234 | .00684 | .00349 | .00308 | .00083 | .00000 |
| 60.00 | 2297 | .01401 | .71953 | .24665 | .01538 | .00272 | .00104 | .00056 | .00012 | .00000 |
| 30.00 | 2094 | .00746 | .73412 | .24829 | .00788 | .00154 | .00050 | .00018 | .00004 | .00000 |
| 29.39 | 2088 | .00730 | .73447 | .24833 | .00770 | .00151 | .00048 | .00017 | .00003 | .00000 |
| 15.00 | 1888 | .00324 | .74326 | .24929 | .00325 | .00072 | .00019 | .00004 | .00000 | .00000 |
| 14.70 | 1882 | .00315 | .74345 | .24931 | .00315 | .00070 | .00019 | .00004 | .00000 | .00000 |
| 7.50 | 1684 | .00109 | .74779 | .24977 | .00102 | .00026 | .00006 | .00000 | .00000 | .00000 |
| 6.00 | 1619 | .00072 | .74855 | .24985 | .00066 | .00018 | .00004 | .00000 | .00000 | .00000 |
| 3.00 | 1425 | .00016 | .74968 | .24997 | .00013 | .00004 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 1318 | .00006 | .74989 | .24999 | .00004 | .00002 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 1191 | .00001 | .74998 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .75 | 1082 | .00000 | .74999 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 1032 | .00000 | .75000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| .40 | 947 | .00000 | .75000 | .25000 | .00000 | .00000 | .00000 | .00000 | .00000 | .00000 |
| R, 1.10; percent fuel, 39.22; O/F, 1.550 | | | | | | | | | | |
| 600.00 | 2962 | 0.02527 | 0.63453 | 0.22826 | 0.07266 | 0.02466 | 0.00873 | 0.00347 | 0.00248 | 0.00000 |
| 571.43 | 2946 | .02457 | .63644 | .22852 | .07151 | .02471 | .00857 | .00334 | .00234 | .00000 |
| 375.00 | 2812 | .01883 | .65224 | .23070 | .06166 | .02519 | .00730 | .00231 | .00177 | .00000 |
| 345.11 | 2786 | .01777 | .65520 | .23110 | .05975 | .02531 | .00706 | .00213 | .00167 | .00000 |
| 300.00 | 2742 | .01606 | .66007 | .23177 | .05653 | .02553 | .00668 | .00186 | .00151 | .00000 |
| 60.00 | 2245 | .00303 | .70257 | .23760 | .02334 | .02993 | .00304 | .00020 | .00030 | .00000 |
| 30.00 | 2031 | .00101 | .71263 | .23909 | .01294 | .03229 | .00190 | .00004 | .00011 | .00000 |
| 29.39 | 2024 | .00097 | .71285 | .23913 | .01268 | .03235 | .00187 | .00004 | .00010 | .00000 |
| 15.00 | 1819 | .00025 | .71846 | .24004 | .00599 | .03418 | .00105 | .00000 | .00003 | .00000 |
| 14.70 | 1813 | .00024 | .71858 | .24007 | .00583 | .03428 | .00103 | .00000 | .00003 | .00000 |
| 7.50 | 1615 | .00004 | .72132 | .24057 | .00223 | .03534 | .00050 | .00000 | .00000 | .00000 |
| 6.00 | 1551 | .00002 | .72181 | .24068 | .00154 | .03557 | .00038 | .00000 | .00000 | .00000 |
| 3.00 | 1362 | .00000 | .72261 | .24087 | .00041 | .03597 | .00014 | .00000 | .00000 | .00000 |
| 2.00 | 1258 | .00000 | .72278 | .24092 | .00016 | .03607 | .00007 | .00000 | .00000 | .00000 |
| 1.20 | 1134 | .00000 | .72286 | .24095 | .00004 | .03612 | .00003 | .00000 | .00000 | .00000 |
| .75 | 1028 | .00000 | .72288 | .24096 | .00001 | .03614 | .00001 | .00000 | .00000 | .00000 |
| .60 | 980 | .00000 | .72289 | .24096 | .00000 | .03614 | .00000 | .00000 | .00000 | .00000 |
| .40 | 898 | .00000 | .72289 | .24096 | .00000 | .03614 | .00000 | .00000 | .00000 | .00000 |
| R, 1.20; percent fuel, 37.16; O/F, 1.691 | | | | | | | | | | |
| 600.00 | 2914 | 0.01485 | 0.62178 | 0.21988 | 0.07789 | 0.04905 | 0.01138 | 0.00329 | 0.00287 | 0.00000 |
| 571.43 | 2898 | .01436 | .62347 | .22014 | .07657 | .04932 | .01118 | .00219 | .00278 | .00000 |
| 375.00 | 2761 | .01049 | .63735 | .22229 | .06522 | .05164 | .00954 | .00144 | .00207 | .00000 |
| 344.53 | 2733 | .00980 | .63998 | .22269 | .06296 | .05210 | .00922 | .00131 | .00194 | .00000 |
| 300.00 | 2689 | .00872 | .64416 | .22334 | .05930 | .05290 | .00872 | .00112 | .00174 | .00000 |
| 60.00 | 2182 | .00138 | .68059 | .22918 | .02228 | .06244 | .00375 | .00009 | .00030 | .00000 |
| 30.00 | 1968 | .00043 | .68917 | .23069 | .01168 | .06567 | .00224 | .00002 | .00009 | .00000 |
| 29.39 | 1962 | .00041 | .68936 | .23073 | .01143 | .06575 | .00220 | .00002 | .00009 | .00000 |
| 15.00 | 1758 | .00010 | .69412 | .23166 | .00507 | .06786 | .00118 | .00000 | .00002 | .00000 |
| 14.70 | 1752 | .00009 | .69422 | .23168 | .00493 | .06790 | .00116 | .00000 | .00002 | .00000 |
| 7.50 | 1556 | .00001 | .69647 | .23219 | .00175 | .06904 | .00053 | .00000 | .00000 | .00000 |
| 6.00 | 1494 | .00000 | .69687 | .23229 | .00118 | .06925 | .00040 | .00000 | .00000 | .00000 |
| 3.00 | 1308 | .00000 | .69748 | .23247 | .00028 | .06962 | .00014 | .00000 | .00000 | .00000 |
| 2.00 | 1206 | .00000 | .69760 | .23252 | .00011 | .06970 | .00007 | .00000 | .00000 | .00000 |
| 1.20 | 1086 | .00000 | .69766 | .23254 | .00003 | .06975 | .00003 | .00000 | .00000 | .00000 |
| .75 | 983 | .00000 | .69767 | .23255 | .00000 | .06976 | .00000 | .00000 | .00000 | .00000 |
| .60 | 937 | .00000 | .69767 | .23256 | .00000 | .06976 | .00000 | .00000 | .00000 | .00000 |
| .40 | 856 | .00000 | .69767 | .23256 | .00000 | .06977 | .00000 | .00000 | .00000 | .00000 |
| R, 1.50; percent fuel, 32.12; O/F, 2.114 | | | | | | | | | | |
| 600.00 | 2759 | 0.00470 | 0.57807 | 0.19880 | 0.06956 | 0.13115 | 0.01436 | 0.00076 | 0.00259 | 0.00000 |
| 571.43 | 2743 | .00451 | .57940 | .19906 | .06805 | .13171 | .01407 | .00071 | .00249 | .00000 |
| 375.00 | 2603 | .00307 | .59017 | .20123 | .05537 | .13641 | .01163 | .00042 | .00171 | .00000 |
| 343.44 | 2574 | .00281 | .59226 | .20165 | .05283 | .13735 | .01114 | .00038 | .00157 | .00000 |
| 300.00 | 2530 | .00245 | .59538 | .20229 | .04901 | .13878 | .01042 | .00031 | .00137 | .00000 |
| 60.00 | 2017 | .00026 | .62188 | .20789 | .01414 | .15198 | .00370 | .00001 | .00015 | .00000 |
| 30.00 | 1803 | .00006 | .62733 | .20920 | .00631 | .15509 | .00198 | .00000 | .00003 | .00000 |
| 29.39 | 1797 | .00006 | .62745 | .20922 | .00615 | .15515 | .00194 | .00000 | .00003 | .00000 |
| 15.00 | 1596 | .00001 | .63008 | .20995 | .00226 | .15679 | .00091 | .00000 | .00000 | .00000 |
| 14.70 | 1591 | .00000 | .63013 | .20997 | .00218 | .15682 | .00089 | .00000 | .00000 | .00000 |
| 7.50 | 1401 | .00000 | .63117 | .21032 | .00062 | .15754 | .00035 | .00000 | .00000 | .00000 |
| 6.00 | 1341 | .00000 | .63133 | .21038 | .00038 | .15768 | .00025 | .00000 | .00000 | .00000 |
| 3.00 | 1166 | .00000 | .63153 | .21049 | .00007 | .15784 | .00007 | .00000 | .00000 | .00000 |
| 2.00 | 1071 | .00000 | .63157 | .21051 | .00002 | .15787 | .00003 | .00000 | .00000 | .00000 |
| 1.20 | 959 | .00000 | .63158 | .21052 | .00000 | .15789 | .00000 | .00000 | .00000 | .00000 |
| .75 | 865 | .00000 | .63158 | .21052 | .00000 | .15789 | .00000 | .00000 | .00000 | .00000 |
| .60 | 822 | .00000 | .63158 | .21053 | .00000 | .15789 | .00000 | .00000 | .00000 | .00000 |
| .40 | 749 | .00000 | .63158 | .21053 | .00000 | .15789 | .00000 | .00000 | .00000 | .00000 |

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

[Isentropic expansion from chamber conditions.]

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

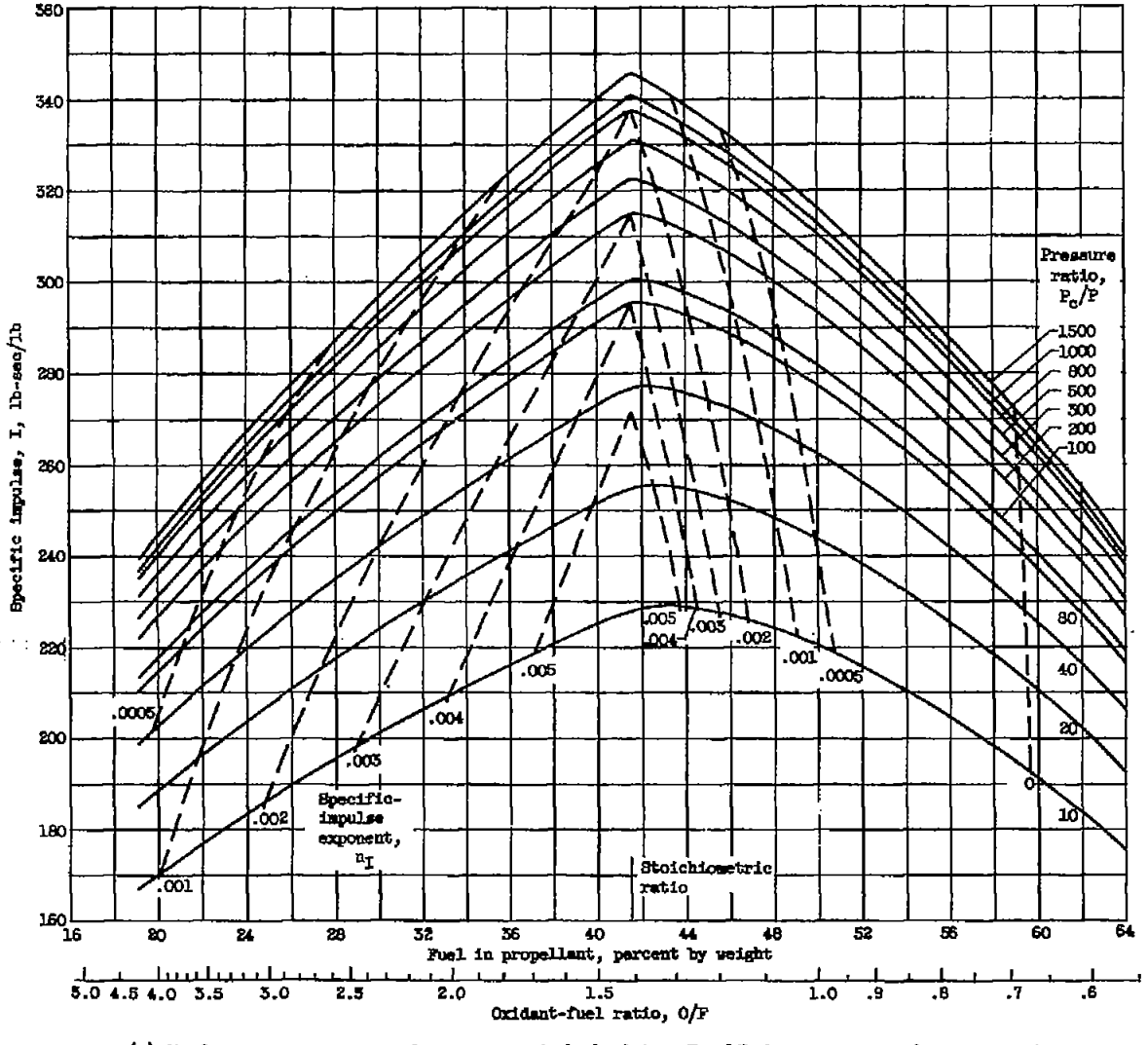
| Static pressure, P, lb/sq in. abs | Temperature, T, °K | Mole fraction | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2$ | $H_2O$ | $N_2$ | OH | $O_2$ | NO | H | O | N |
| R, 2.00; percent fuel, 26.19; O/F, 2.818 | | | | | | | | | | |
| 600.00 | 2536 | 0.00114 | 0.51475 | 0.17297 | 0.04516 | 0.25138 | 0.01310 | 0.00015 | 0.00134 | 0.00000 |
| 571.43 | 2519 | .00108 | .51571 | .17321 | .04383 | .25200 | .01276 | .00014 | .00127 | .00000 |
| 375.00 | 2377 | .00065 | .52330 | .17517 | .03307 | .25696 | .01001 | .00007 | .00076 | .00000 |
| 341.52 | 2345 | .00058 | .52483 | .17557 | .03089 | .25796 | .00944 | .00006 | .00067 | .00000 |
| 300.00 | 2302 | .00048 | .52684 | .17610 | .02798 | .25930 | .00869 | .00005 | .00056 | .00000 |
| 60.00 | 1783 | .00002 | .54217 | .18045 | .00510 | .26997 | .00226 | .00000 | .00003 | .00000 |
| 30.00 | 1572 | .00000 | .54436 | .18124 | .00172 | .27168 | .00100 | .00000 | .00000 | .00000 |
| 29.39 | 1566 | .00000 | .54440 | .18126 | .00165 | .27171 | .00097 | .00000 | .00000 | .00000 |
| 15.00 | 1374 | .00000 | .54518 | .18161 | .00044 | .27240 | .00037 | .00000 | .00000 | .00000 |
| 14.70 | 1369 | .00000 | .54519 | .18162 | .00042 | .27241 | .00036 | .00000 | .00000 | .00000 |
| 7.50 | 1193 | .00000 | .54540 | .18176 | .00008 | .27265 | .00011 | .00000 | .00000 | .00000 |
| 6.00 | 1138 | .00000 | .54543 | .18178 | .00004 | .27268 | .00007 | .00000 | .00000 | .00000 |
| 3.00 | 980 | .00000 | .54545 | .18181 | .00000 | .27272 | .00002 | .00000 | .00000 | .00000 |
| 2.00 | 896 | .00000 | .54545 | .18182 | .00000 | .27272 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 797 | .00000 | .54545 | .18182 | .00000 | .27273 | .00000 | .00000 | .00000 | .00000 |
| .75 | 714 | .00000 | .54545 | .18182 | .00000 | .27273 | .00000 | .00000 | .00000 | .00000 |
| .60 | 677 | .00000 | .54545 | .18182 | .00000 | .27273 | .00000 | .00000 | .00000 | .00000 |
| .40 | 614 | .00000 | .54545 | .18182 | .00000 | .27273 | .00000 | .00000 | .00000 | .00000 |
| R, 3.00; percent fuel, 19.13; O/F, 4.227 | | | | | | | | | | |
| 600.00 | 2171 | 0.00010 | 0.41917 | 0.13861 | 0.01521 | 0.41932 | 0.00736 | 0.00000 | 0.00023 | 0.00000 |
| 571.43 | 2154 | .00009 | .41963 | .13878 | .01449 | .41973 | .00709 | .00000 | .00021 | .00000 |
| 375.00 | 2008 | .00004 | .42291 | .14004 | .00920 | .42275 | .00495 | .00000 | .00009 | .00000 |
| 337.20 | 1972 | .00003 | .42359 | .14031 | .00812 | .42338 | .00449 | .00000 | .00007 | .00000 |
| 300.00 | 1933 | .00002 | .42426 | .14059 | .00703 | .42402 | .00402 | .00000 | .00006 | .00000 |
| 60.00 | 1426 | .00000 | .42828 | .14257 | .00048 | .42813 | .00055 | .00000 | .00000 | .00000 |
| 30.00 | 1235 | .00000 | .42852 | .14277 | .00009 | .42845 | .00017 | .00000 | .00000 | .00000 |
| 29.39 | 1230 | .00000 | .42852 | .14277 | .00009 | .42846 | .00016 | .00000 | .00000 | .00000 |
| 15.00 | 1064 | .00000 | .42856 | .14284 | .00001 | .42855 | .00004 | .00000 | .00000 | .00000 |
| 14.70 | 1059 | .00000 | .42856 | .14284 | .00001 | .42855 | .00004 | .00000 | .00000 | .00000 |
| 7.50 | 911 | .00000 | .42857 | .14285 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| 6.00 | 866 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 736 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 668 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 589 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| .75 | 524 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| .60 | 495 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| .40 | 446 | .00000 | .42857 | .14286 | .00000 | .42857 | .00000 | .00000 | .00000 | .00000 |
| R, 4.00; percent fuel, 15.07; O/F, 5.636 | | | | | | | | | | |
| 600.00 | 1877 | 0.00000 | 0.35035 | 0.11580 | 0.00438 | 0.52600 | 0.00344 | 0.00000 | 0.00003 | 0.00000 |
| 571.43 | 1861 | .00000 | .35052 | .11589 | .00409 | .52620 | .00327 | .00000 | .00002 | .00000 |
| 375.00 | 1719 | .00000 | .35167 | .11657 | .00216 | .52757 | .00202 | .00000 | .00000 | .00000 |
| 333.68 | 1680 | .00000 | .35189 | .11672 | .00178 | .52785 | .00175 | .00000 | .00000 | .00000 |
| 300.00 | 1646 | .00000 | .35207 | .11684 | .00148 | .52808 | .00153 | .00000 | .00000 | .00000 |
| 60.00 | 1179 | .00000 | .35292 | .11759 | .00004 | .52934 | .00011 | .00000 | .00000 | .00000 |
| 30.00 | 1012 | .00000 | .35294 | .11763 | .00000 | .52940 | .00002 | .00000 | .00000 | .00000 |
| 29.39 | 1007 | .00000 | .35294 | .11764 | .00000 | .52940 | .00002 | .00000 | .00000 | .00000 |
| 15.00 | 863 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 859 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 733 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| 6.00 | 694 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 585 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 528 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 463 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| .75 | 410 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| .60 | 386 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| .40 | 347 | .00000 | .35294 | .11765 | .00000 | .52941 | .00000 | .00000 | .00000 | .00000 |
| R, 5.00; percent fuel, 12.43; O/F, 7.046 | | | | | | | | | | |
| 600.00 | 1641 | 0.00000 | 0.29934 | 0.09924 | 0.00115 | 0.59880 | 0.00147 | 0.00000 | 0.00000 | 0.00000 |
| 571.43 | 1625 | .00000 | .29939 | .09928 | .00105 | .59889 | .00138 | .00000 | .00000 | .00000 |
| 375.00 | 1491 | .00000 | .29973 | .09961 | .00046 | .59944 | .00076 | .00000 | .00000 | .00000 |
| 331.33 | 1454 | .00000 | .29979 | .09968 | .00036 | .59954 | .00063 | .00000 | .00000 | .00000 |
| 300.00 | 1424 | .00000 | .29984 | .09972 | .00029 | .59962 | .00054 | .00000 | .00000 | .00000 |
| 60.00 | 1001 | .00000 | .30000 | .09999 | .00000 | .59999 | .00002 | .00000 | .00000 | .00000 |
| 30.00 | 853 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 29.39 | 849 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 15.00 | 723 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 14.70 | 720 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 7.50 | 610 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 6.00 | 577 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 3.00 | 483 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 2.00 | 434 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| 1.20 | 379 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| .75 | 334 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| .60 | 315 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |
| .40 | 282 | .00000 | .30000 | .10000 | .00000 | .60000 | .00000 | .00000 | .00000 | .00000 |

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

| Equivalence ratio, R, 2(O)/H | Fuel, percent by weight | Oxidant-to-fuel weight ratio, O/F | Combustion temperature, $T_c$, °K | Exit temperature, $T_e$, °K | Characteristic velocity, c*, ft/sec | Characteristic-velocity exponent, $n_{c*}$ | Entropy, s, $\frac{cal}{(g)(^{o}K)}$ | Area ratio, ε | Coefficient of thrust, $C_F$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Chamber pressure, 300 pounds per square inch absolute; equilibrium composition | | | | | | | | | | |
| 0.40 | 63.95 | 0.564 | 1349 | 643 | 4509 | 0.0000 | 3.5155 | 3.133 | 1.384 | 193.9 |
| .50 | 58.67 | .705 | 1784 | 906 | 5016 | .0000 | 3.4925 | 3.261 | 1.390 | 216.8 |
| .60 | 54.19 | .845 | 2169 | 1164 | 5358 | .0000 | 3.4355 | 3.376 | 1.396 | 232.5 |
| .70 | 50.34 | .986 | 2494 | 1412 | 5595 | .0003 | 3.3653 | 3.478 | 1.401 | 243.6 |
| .80 | 47.01 | 1.127 | 2734 | 1654 | 5744 | .0023 | 3.2910 | 3.594 | 1.407 | 251.2 |
| .90 | 44.09 | 1.268 | 2877 | 1893 | 5799 | .0057 | 3.2170 | 3.757 | 1.418 | 255.5 |
| .95 | 42.76 | 1.339 | 2913 | 2008 | 5790 | .0070 | 3.1809 | 3.863 | 1.424 | 256.3 |
| 1.00 | 41.51 | 1.409 | 2928 | 2083 | 5759 | .0075 | 3.1454 | 3.945 | 1.428 | 255.6 |
| 1.10 | 39.22 | 1.550 | 2913 | 2023 | 5656 | .0067 | 3.0773 | 3.892 | 1.425 | 250.5 |
| 1.20 | 37.16 | 1.691 | 2871 | 1962 | 5542 | .0058 | 3.0134 | 3.861 | 1.423 | 245.1 |
| 1.50 | 32.12 | 2.114 | 2728 | 1798 | 5238 | .0044 | 2.8478 | 3.786 | 1.419 | 231.0 |
| 2.00 | 26.19 | 2.818 | 2515 | 1568 | 4840 | .0028 | 2.6410 | 3.663 | 1.412 | 212.4 |
| 3.00 | 19.13 | 4.227 | 2163 | 1231 | 4261 | .0008 | 2.3763 | 3.476 | 1.401 | 185.5 |
| 4.00 | 15.07 | 5.636 | 1875 | 1007 | 3837 | .0001 | 2.2111 | 3.368 | 1.395 | 166.4 |
| 5.00 | 12.43 | 7.046 | 1640 | 849 | 3510 | .0000 | 2.0954 | 3.301 | 1.392 | 151.9 |
| Chamber pressure, 300 pounds per square inch absolute; frozen composition | | | | | | | | | | |
| 0.40 | 63.95 | 0.564 | 1349 | 643 | 4509 | 0.0000 | 3.5155 | 3.133 | 1.384 | 193.9 |
| .50 | 58.67 | .705 | 1784 | 906 | 5015 | .0003 | 3.4925 | 3.261 | 1.390 | 216.8 |
| .60 | 54.19 | .845 | 2169 | 1160 | 5351 | .0005 | 3.4355 | 3.373 | 1.396 | 232.2 |
| .70 | 50.34 | .986 | 2494 | 1385 | 5564 | .0023 | 3.3653 | 3.460 | 1.401 | 242.3 |
| .80 | 47.01 | 1.127 | 2734 | 1557 | 5669 | .0056 | 3.2910 | 3.519 | 1.404 | 247.4 |
| .90 | 44.09 | 1.268 | 2877 | 1662 | 5685 | .0086 | 3.2170 | 3.553 | 1.406 | 248.4 |
| .95 | 42.76 | 1.339 | 2913 | 1689 | 5665 | .0096 | 3.1809 | 3.561 | 1.406 | 247.6 |
| 1.00 | 41.51 | 1.409 | 2928 | 1700 | 5631 | .0100 | 3.1454 | 3.565 | 1.406 | 246.1 |
| 1.10 | 39.22 | 1.550 | 2913 | 1691 | 5536 | .0094 | 3.0773 | 3.564 | 1.406 | 241.9 |
| 1.20 | 37.16 | 1.691 | 2871 | 1662 | 5429 | .0085 | 3.0134 | 3.557 | 1.406 | 237.2 |
| 1.50 | 32.12 | 2.114 | 2728 | 1561 | 5138 | .0067 | 2.8478 | 3.530 | 1.404 | 224.3 |
| 2.00 | 26.19 | 2.818 | 2515 | 1413 | 4759 | .0048 | 2.6410 | 3.487 | 1.402 | 207.4 |
| 3.00 | 19.13 | 4.227 | 2163 | 1175 | 4215 | .0024 | 2.3763 | 3.413 | 1.398 | 183.2 |
| 4.00 | 15.07 | 5.636 | 1875 | 989 | 3816 | .0011 | 2.2111 | 3.349 | 1.395 | 165.5 |
| 5.00 | 12.43 | 7.046 | 1640 | 844 | 3502 | .0004 | 2.0954 | 3.295 | 1.392 | 151.6 |

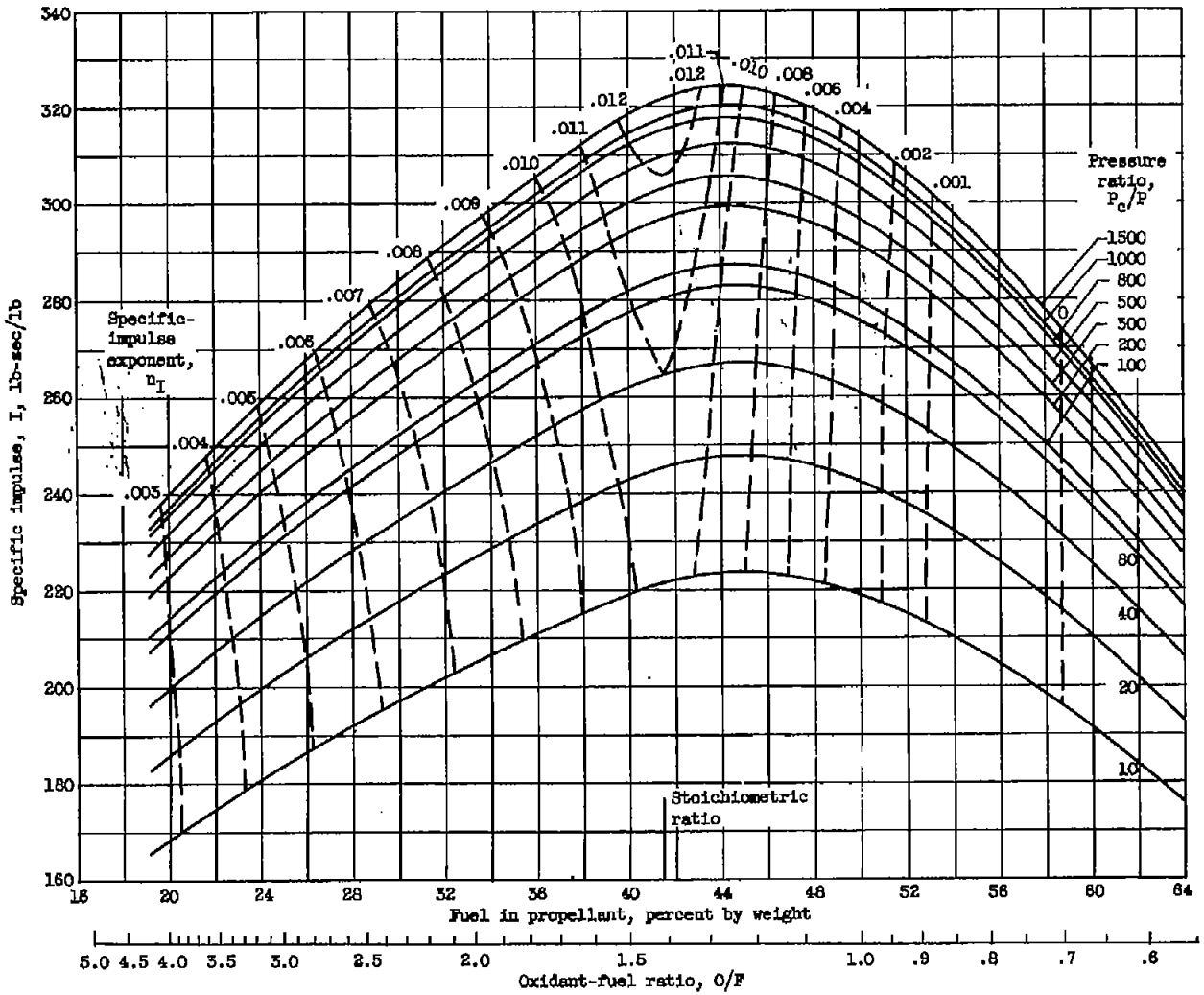
TABLE V. - Concluded. SUMMARY OF COMBUSTION PARAMETERS, CHARACTERISTIC VELOCITY, AND PERFORMANCE FOR EXPANSION TO SEA LEVEL FOR LIQUID AMMONIA WITH LIQUID OXYGEN

| Equivalence ratio, R, 2(O)/H | Fuel, percent by weight | Oxidant-to-fuel weight ratio, O/F | Combustion temperature, $T_c$, °K | Exit temperature, $T_e$, °K | Characteristic velocity, c*, ft/sec | Characteristic-velocity exponent, $n_c$* | Entropy, s, $\frac{cal}{(g)(^{\circ}K)}$ | Area ratio, ε | Coefficient of thrust, $C_F$ | Specific impulse, I, $\frac{(lb)(sec)}{lb}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Chamber pressure, 600 pounds per square inch absolute; equilibrium composition | | | | | | | | | | |
| 0.40 | 63.95 | 0.564 | 1349 | 535 | 4509 | 0.0000 | 3.4121 | 4.888 | 1.478 | 207.1 |
| .50 | 58.67 | .705 | 1784 | 764 | 5016 | .0000 | 3.3976 | 5.134 | 1.489 | 232.1 |
| .60 | 54.19 | .845 | 2171 | 993 | 5358 | .0000 | 3.3478 | 5.369 | 1.498 | 249.5 |
| .70 | 50.34 | .986 | 2503 | 1219 | 5596 | .0002 | 3.2836 | 5.580 | 1.507 | 262.0 |
| .80 | 47.01 | 1.127 | 2760 | 1441 | 5752 | .0017 | 3.2142 | 5.795 | 1.516 | 270.9 |
| .90 | 44.09 | 1.268 | 2922 | 1663 | 5820 | .0049 | 3.1440 | 6.071 | 1.530 | 276.7 |
| .95 | 42.76 | 1.339 | 2963 | 1778 | 5817 | .0063 | 3.1093 | 6.262 | 1.539 | 278.3 |
| .975 | 42.13 | 1.374 | 2975 | 1836 | 5806 | .0068 | 3.0921 | 6.379 | 1.544 | 278.7 |
| 1.00 | 41.51 | 1.409 | 2980 | 1882 | 5788 | .0069 | 3.0751 | 6.484 | 1.547 | 278.3 |
| 1.10 | 39.22 | 1.550 | 2962 | 1813 | 5681 | .0060 | 3.0089 | 6.369 | 1.542 | 272.3 |
| 1.20 | 37.16 | 1.691 | 2914 | 1752 | 5563 | .0052 | 2.9466 | 6.312 | 1.540 | 266.2 |
| 1.50 | 32.12 | 2.114 | 2759 | 1591 | 5253 | .0039 | 2.7847 | 6.156 | 1.533 | 250.3 |
| 2.00 | 26.19 | 2.818 | 2536 | 1369 | 4849 | .0024 | 2.5820 | 5.908 | 1.522 | 229.5 |
| 3.00 | 19.13 | 4.227 | 2171 | 1059 | 4263 | .0007 | 2.3219 | 5.558 | 1.506 | 199.6 |
| 4.00 | 15.07 | 5.636 | 1877 | 859 | 3837 | .0001 | 2.1593 | 5.354 | 1.497 | 178.6 |
| 5.00 | 12.43 | 7.046 | 1641 | 720 | 3510 | .0000 | 2.0451 | 5.220 | 1.492 | 162.8 |
| Chamber pressure, 600 pounds per square inch absolute; frozen composition | | | | | | | | | | |
| 0.40 | 63.95 | 0.564 | 1349 | 535 | 4509 | 0.0000 | 3.4121 | 4.888 | 1.478 | 207.1 |
| .50 | 58.67 | .705 | 1784 | 764 | 5016 | .0003 | 3.3976 | 5.134 | 1.489 | 232.1 |
| .60 | 54.19 | .845 | 2171 | 991 | 5353 | .0005 | 3.3478 | 5.366 | 1.499 | 249.3 |
| .70 | 50.34 | .986 | 2503 | 1201 | 5573 | .0023 | 3.2836 | 5.556 | 1.506 | 260.9 |
| .80 | 47.01 | 1.127 | 2760 | 1370 | 5691 | .0056 | 3.2142 | 5.693 | 1.512 | 267.4 |
| .90 | 44.09 | 1.268 | 2922 | 1480 | 5719 | .0086 | 3.1440 | 5.776 | 1.515 | 269.3 |
| .95 | 42.76 | 1.339 | 2963 | 1509 | 5703 | .0096 | 3.1093 | 5.798 | 1.516 | 268.7 |
| .975 | 42.13 | 1.374 | 2975 | 1518 | 5689 | .0099 | 3.0921 | 5.804 | 1.516 | 268.1 |
| 1.00 | 41.51 | 1.409 | 2980 | 1522 | 5670 | .0100 | 3.0751 | 5.808 | 1.516 | 267.2 |
| 1.10 | 39.22 | 1.550 | 2962 | 1511 | 5572 | .0094 | 3.0089 | 5.804 | 1.516 | 262.6 |
| 1.20 | 37.16 | 1.691 | 2914 | 1480 | 5461 | .0085 | 2.9466 | 5.786 | 1.515 | 257.2 |
| 1.50 | 32.12 | 2.114 | 2759 | 1379 | 5162 | .0067 | 2.7847 | 5.722 | 1.513 | 242.7 |
| 2.00 | 26.19 | 2.818 | 2536 | 1237 | 4775 | .0048 | 2.5820 | 5.626 | 1.509 | 223.9 |
| 3.00 | 19.13 | 4.227 | 2171 | 1014 | 4222 | .0024 | 2.3219 | 5.461 | 1.502 | 197.1 |
| 4.00 | 15.07 | 5.636 | 1877 | 845 | 3819 | .0011 | 2.1593 | 5.325 | 1.497 | 177.6 |
| 5.00 | 12.43 | 7.046 | 1641 | 715 | 3503 | .0004 | 2.0451 | 5.212 | 1.492 | 162.4 |



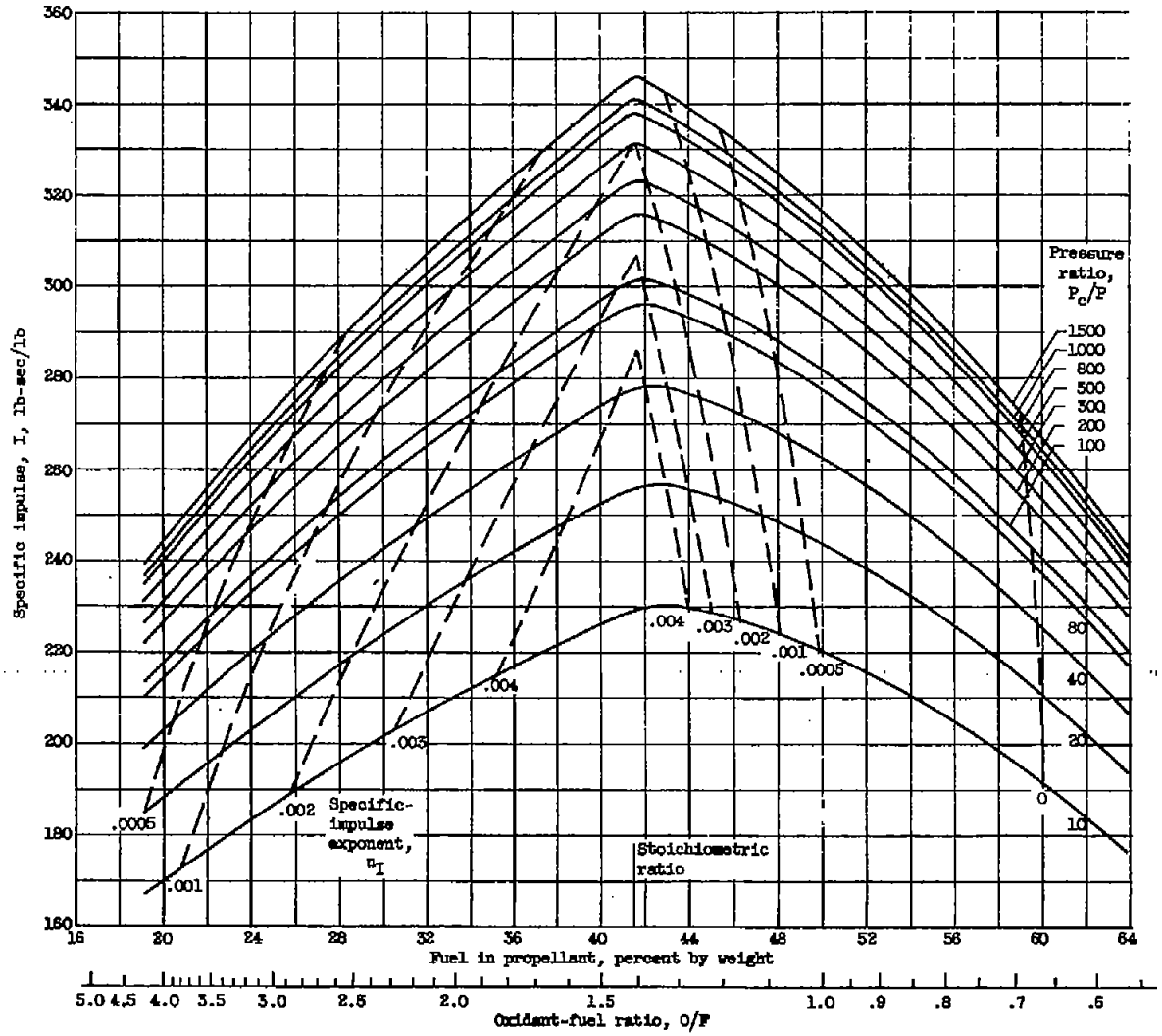

(a) Chamber pressure, 300 pounds per square inch absolute. Equilibrium composition during expansion.

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



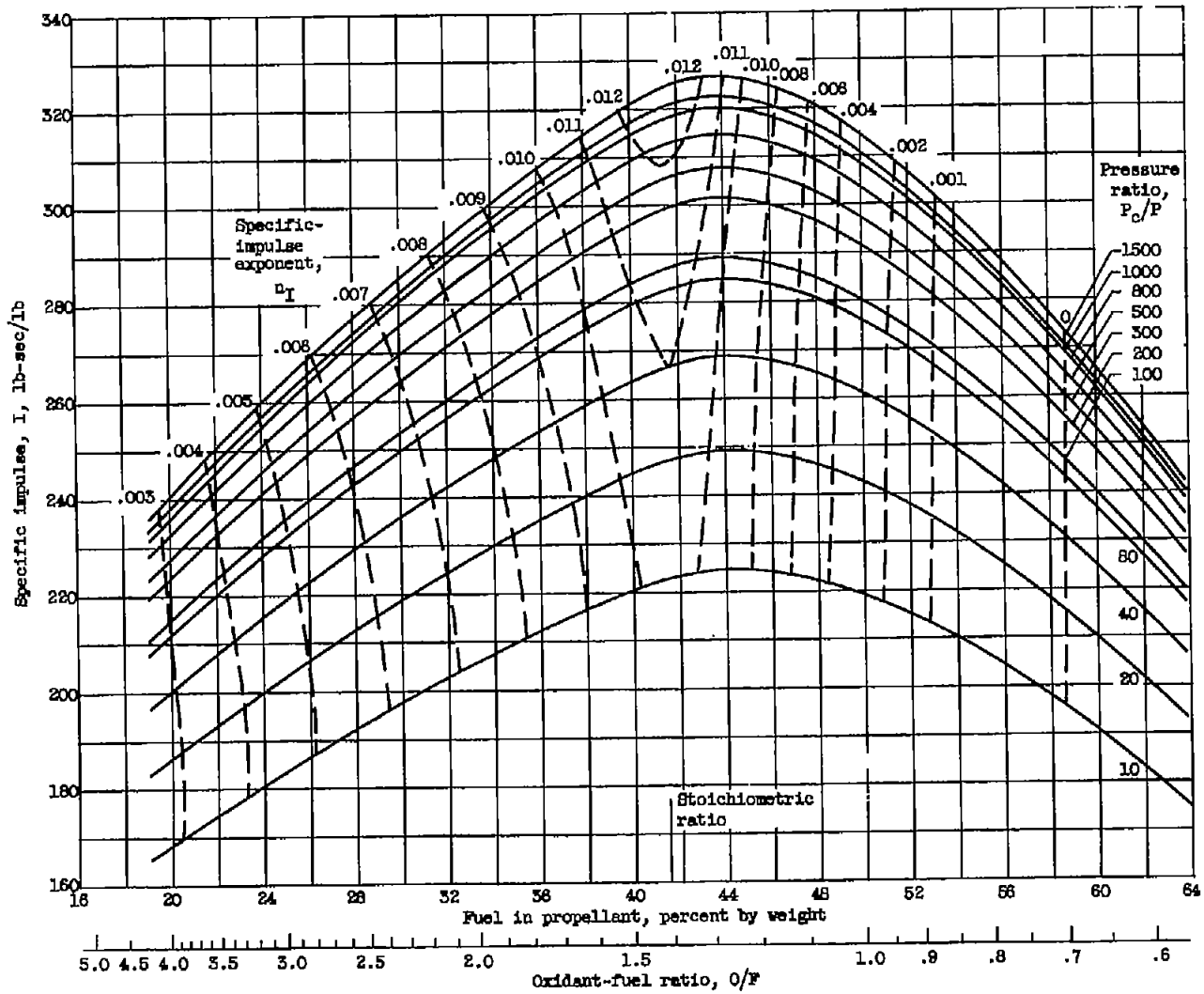

(b) Chamber pressure, 300 pounds per square inch absolute. Frozen composition during expansion.

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




(c) Chamber pressure, 600 pounds per square inch absolute. Equilibrium composition during expansion.

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




(d) Chamber pressure, 600 pounds per square inch absolute. Frozen composition during expansion.

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

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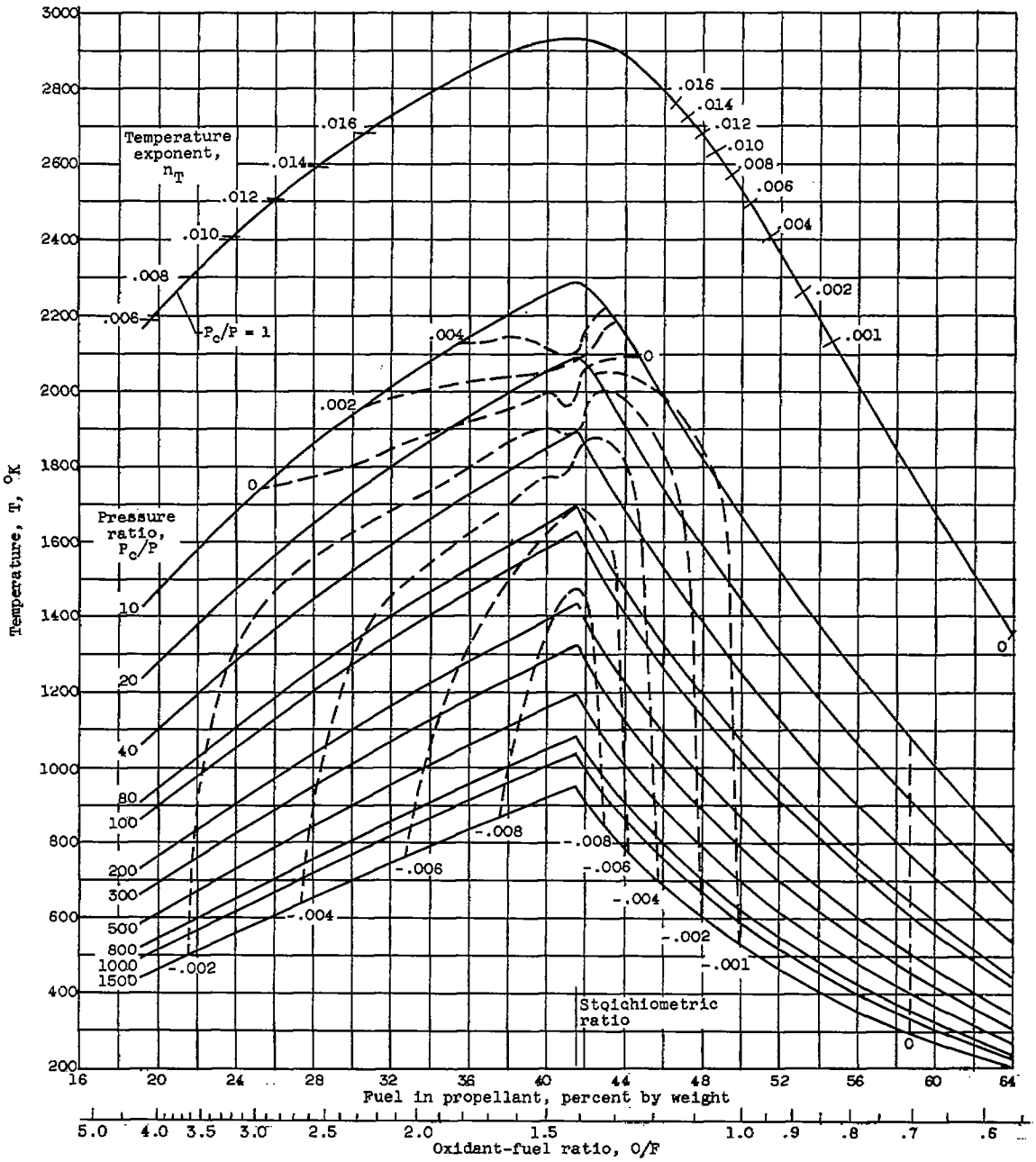
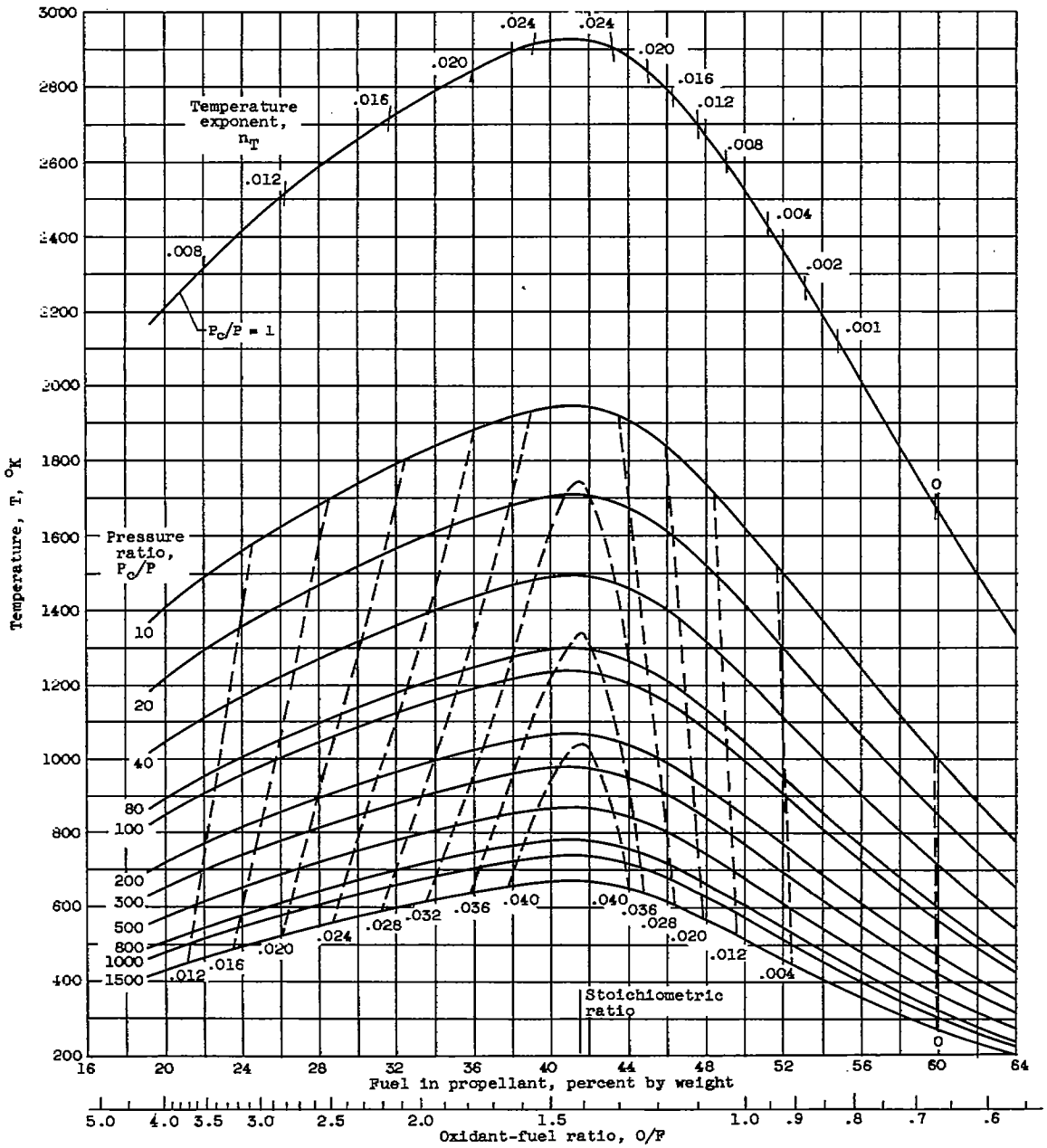



(a) Chamber pressure, 300 pounds per square inch absolute. Equilibrium composition during expansion.

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

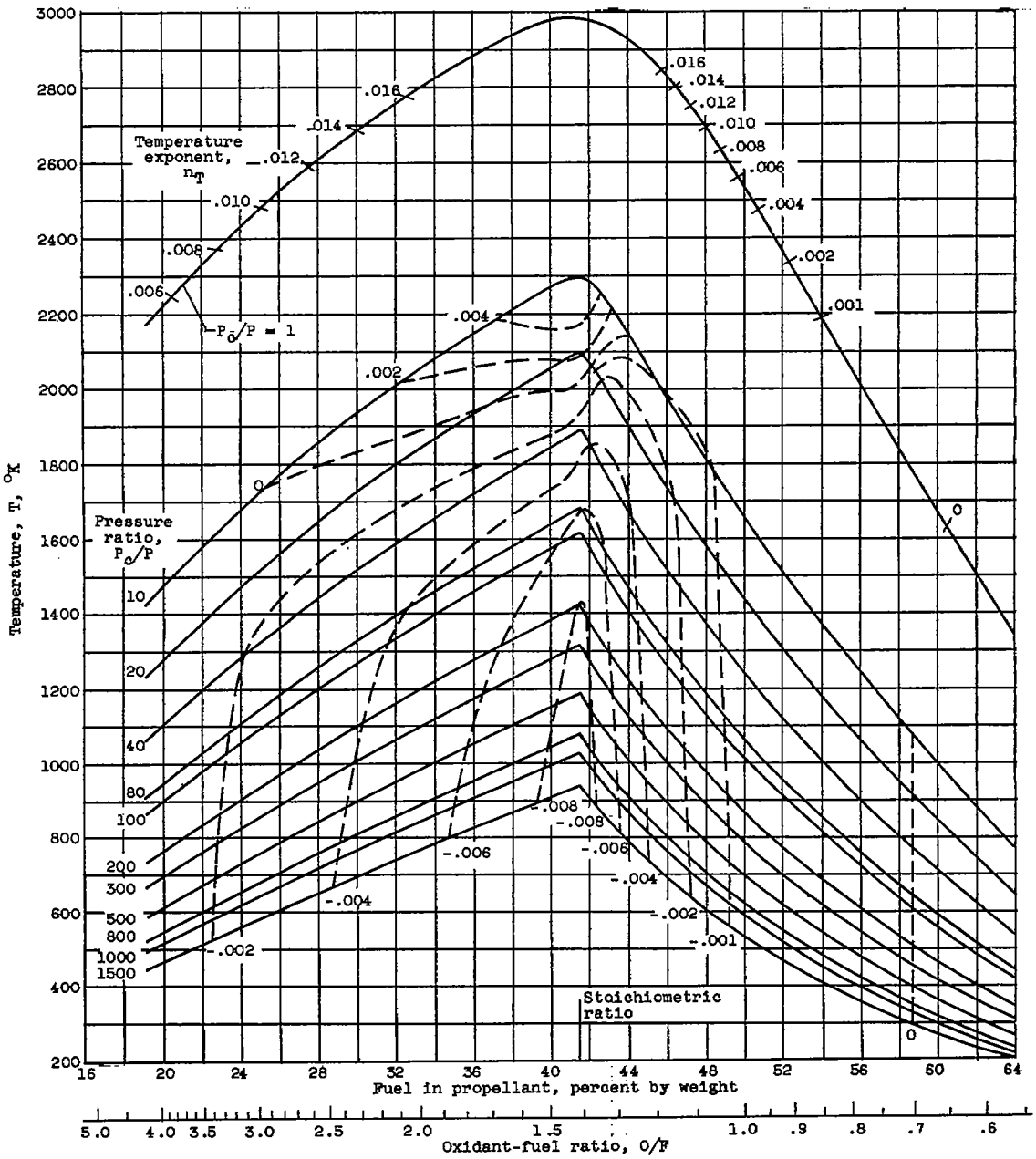
4663




(b) Chamber pressure, 300 pounds per square inch absolute. Frozen composition during expansion.

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

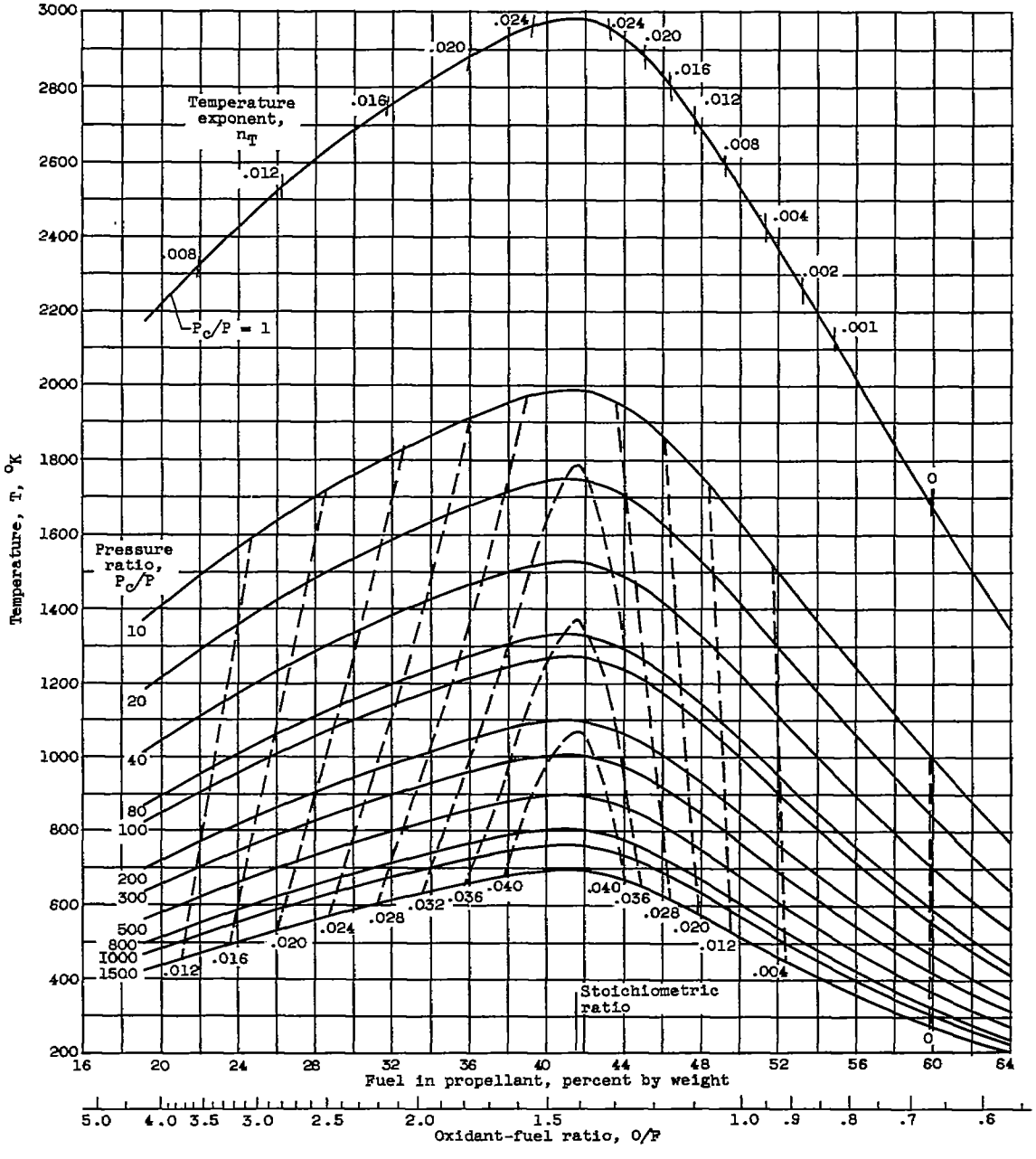
4663




(c) Chamber pressure, 600 pounds per square inch absolute. Equilibrium composition during expansion.

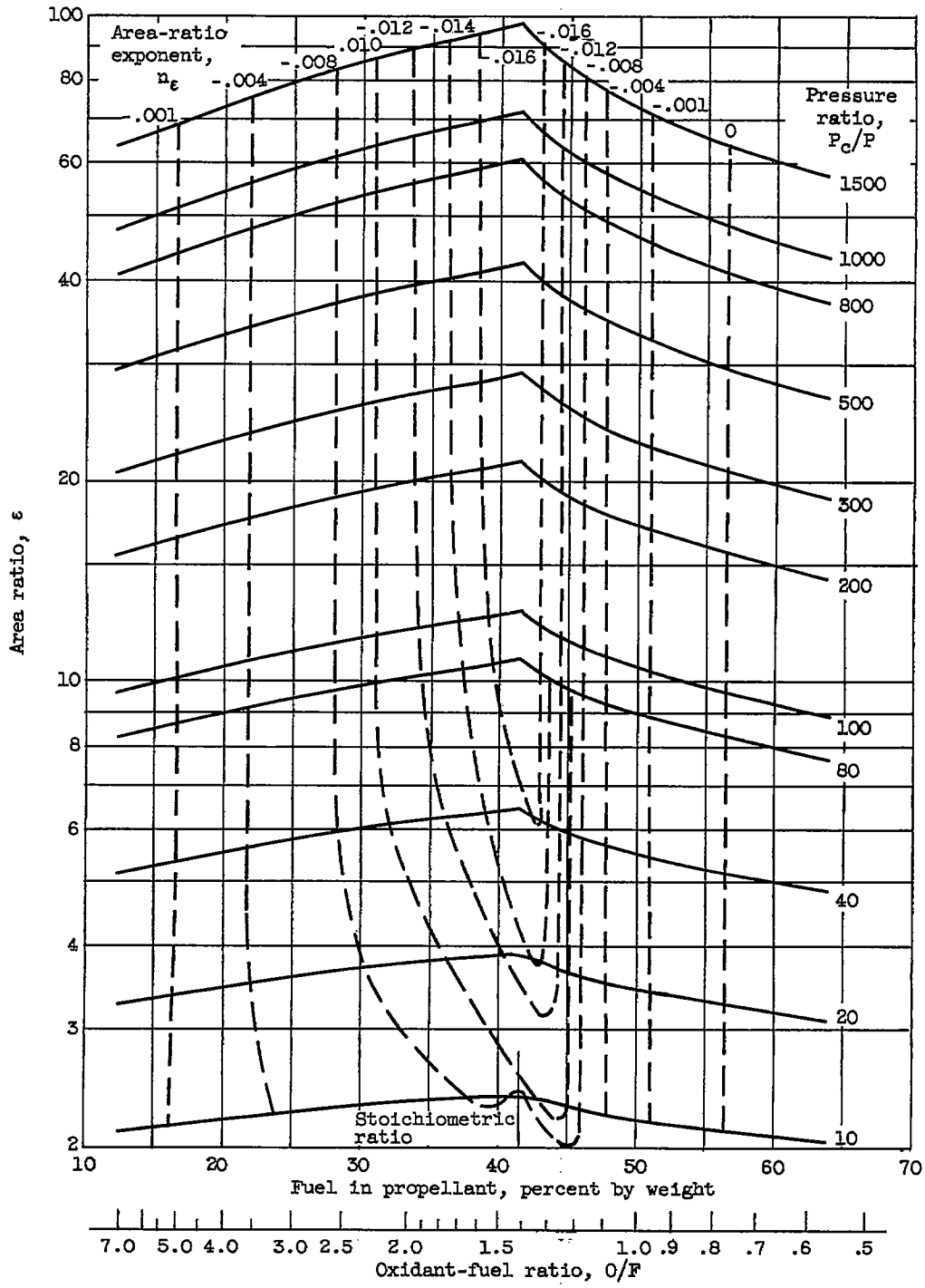
Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.

4663




(d) Chamber pressure, 600 pounds per square inch absolute. Frozen composition during expansion.

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




(a) Chamber pressure, 300 pounds per square inch absolute. Equilibrium composition during expansion.

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

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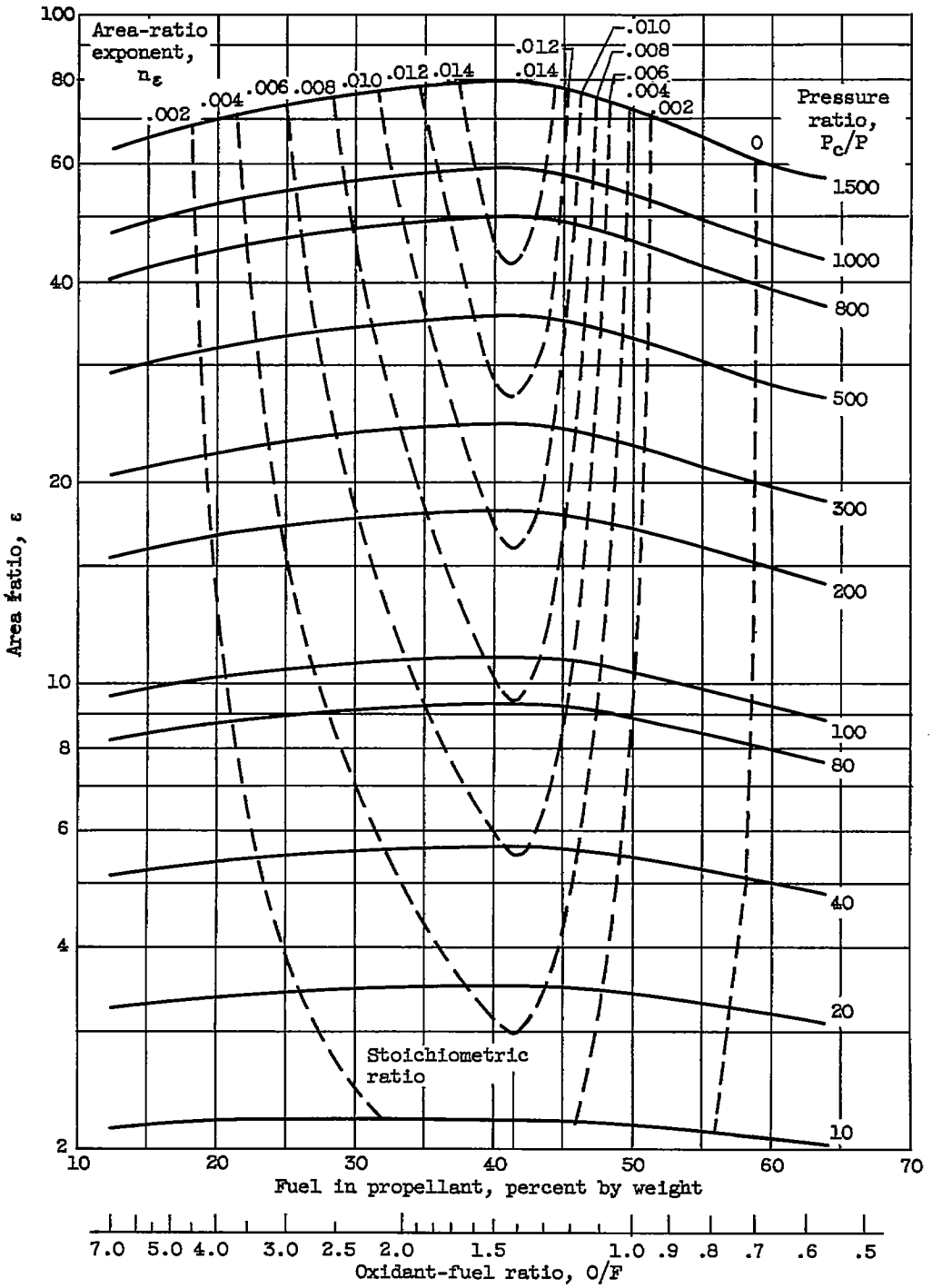
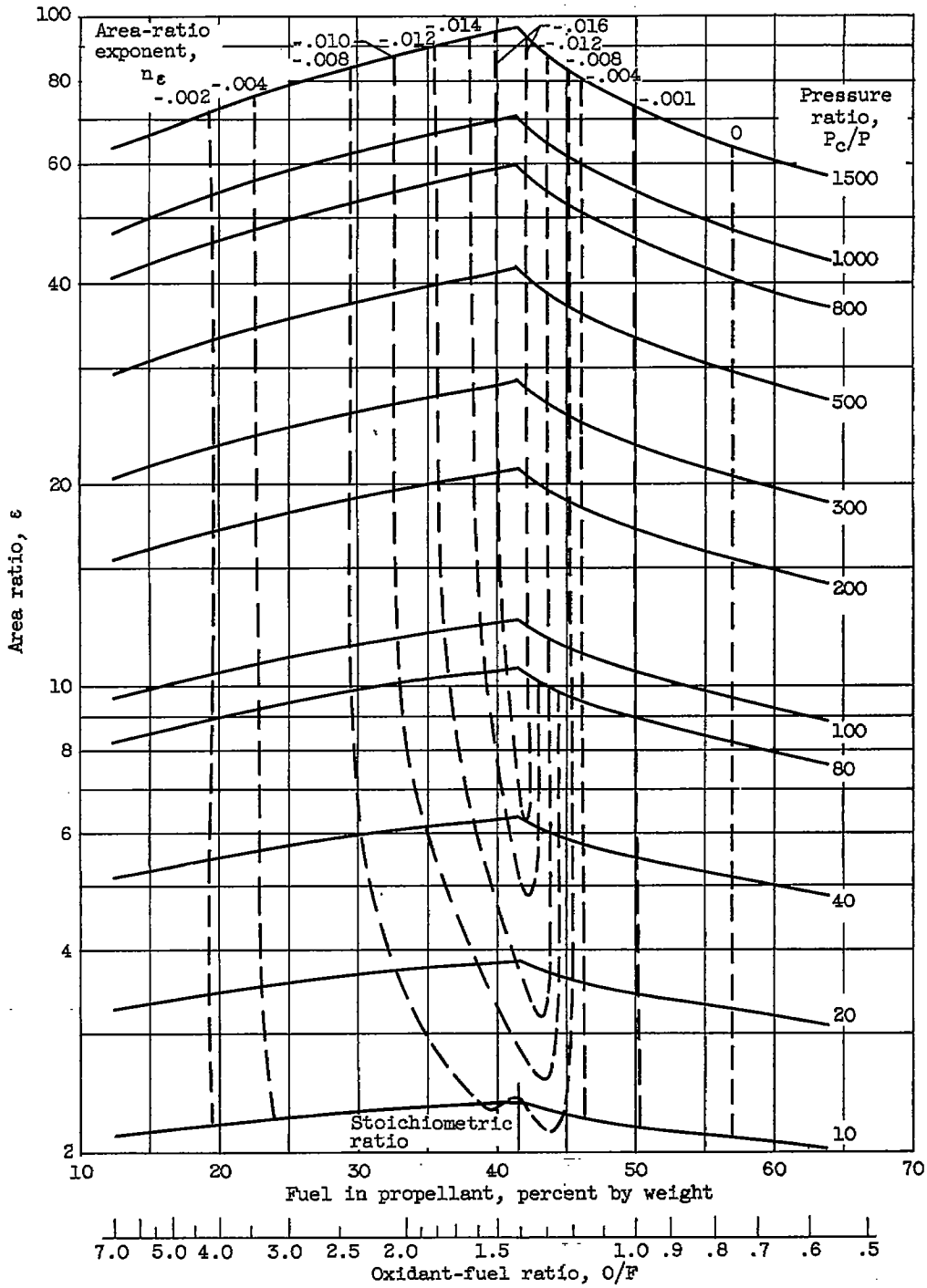
CQ-10




(b) 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 ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.




(c) Chamber pressure, 600 pounds per square inch absolute. Equilibrium composition during expansion.

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

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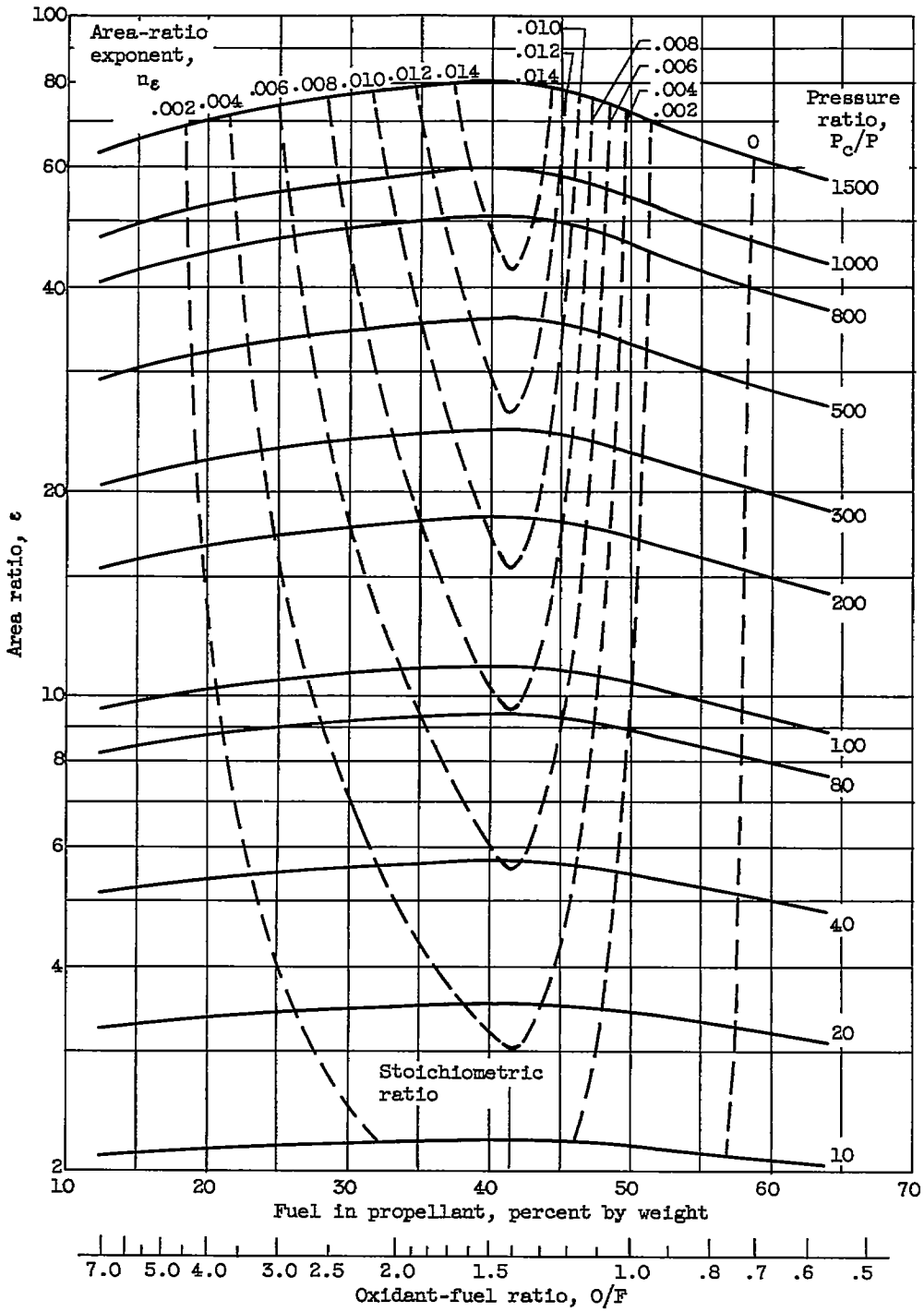
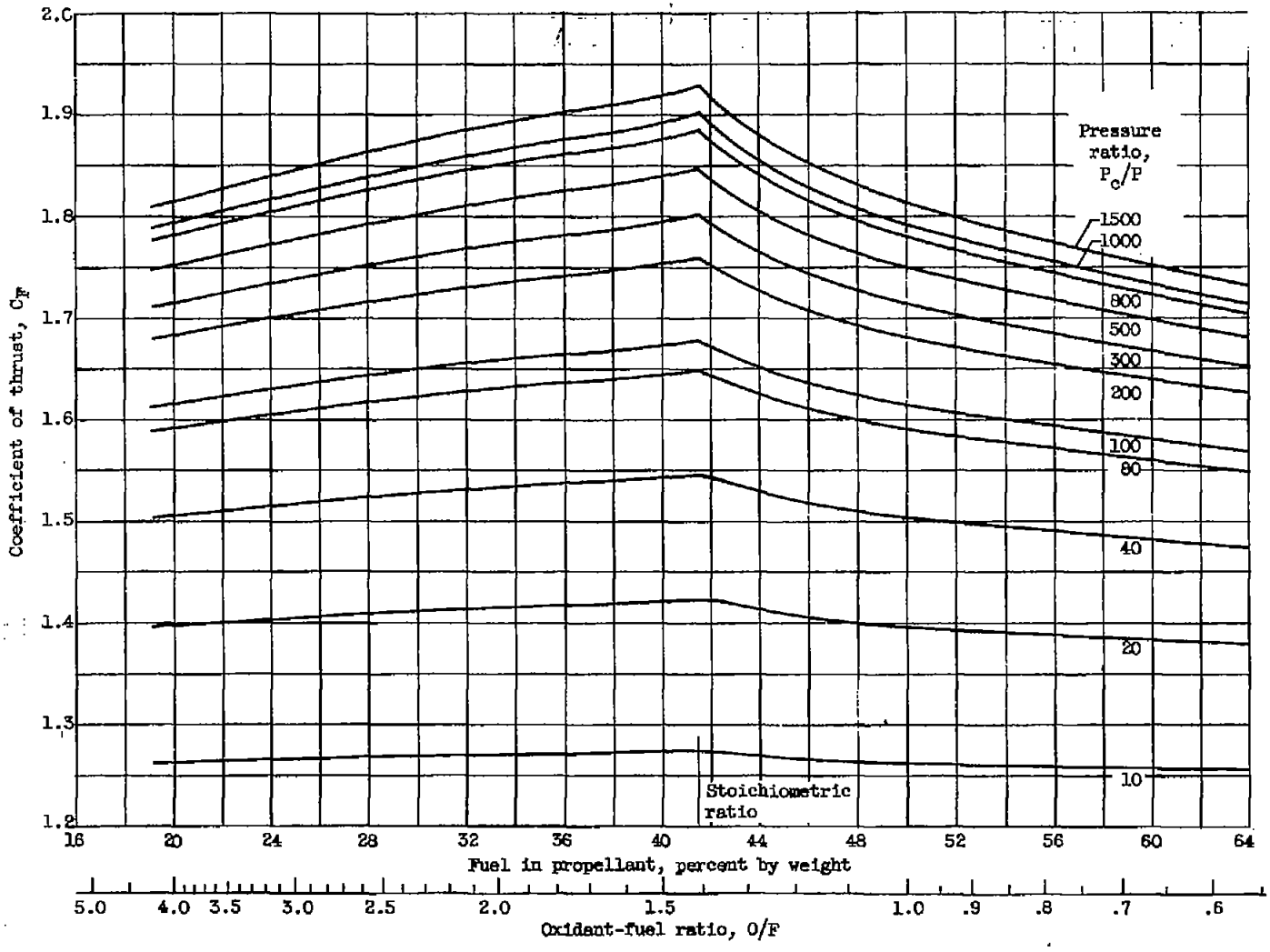
CQ-10 back



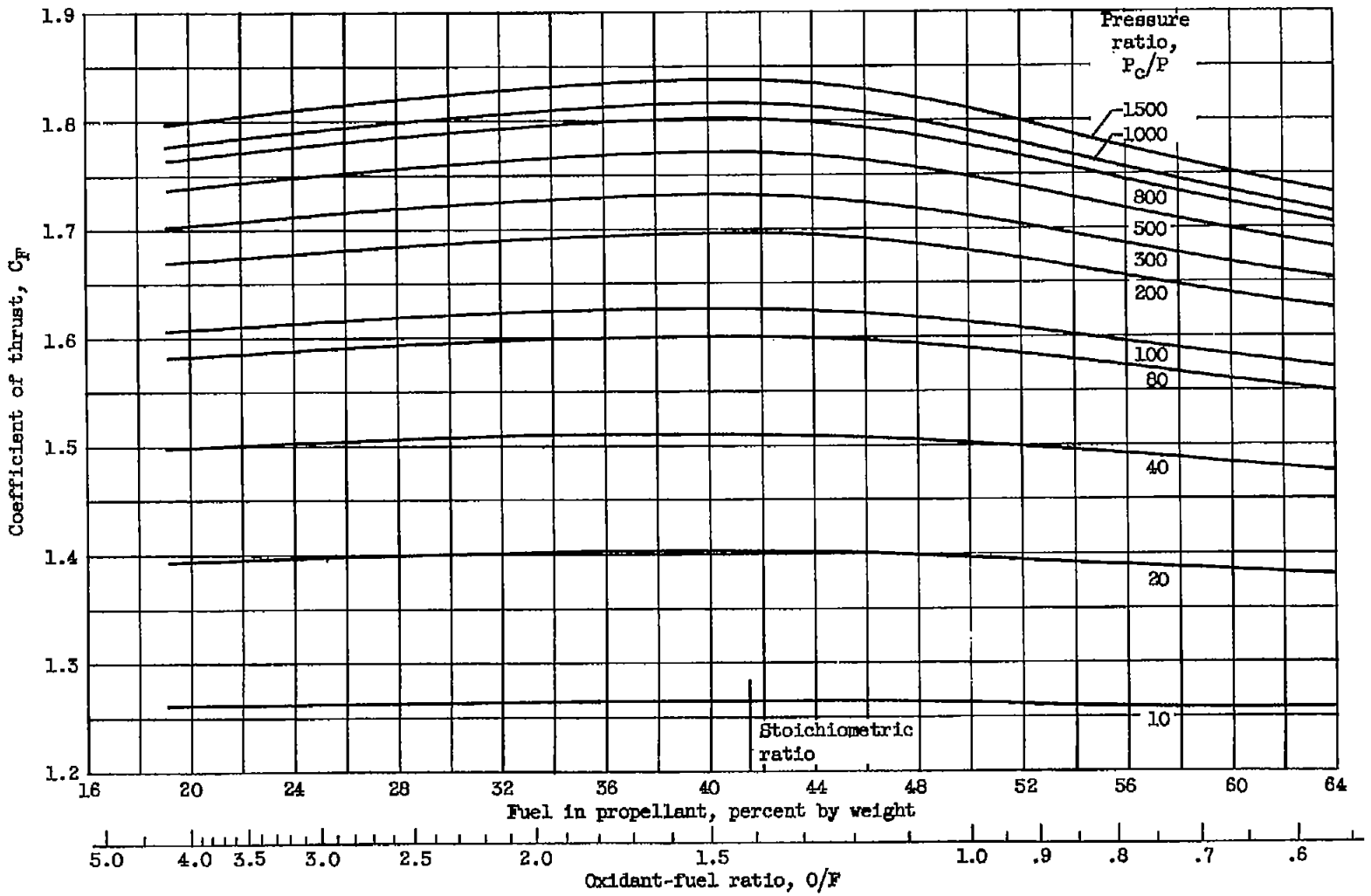

(d) Chamber pressure, 600 pounds per square inch absolute. Frozen composition during expansion.

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



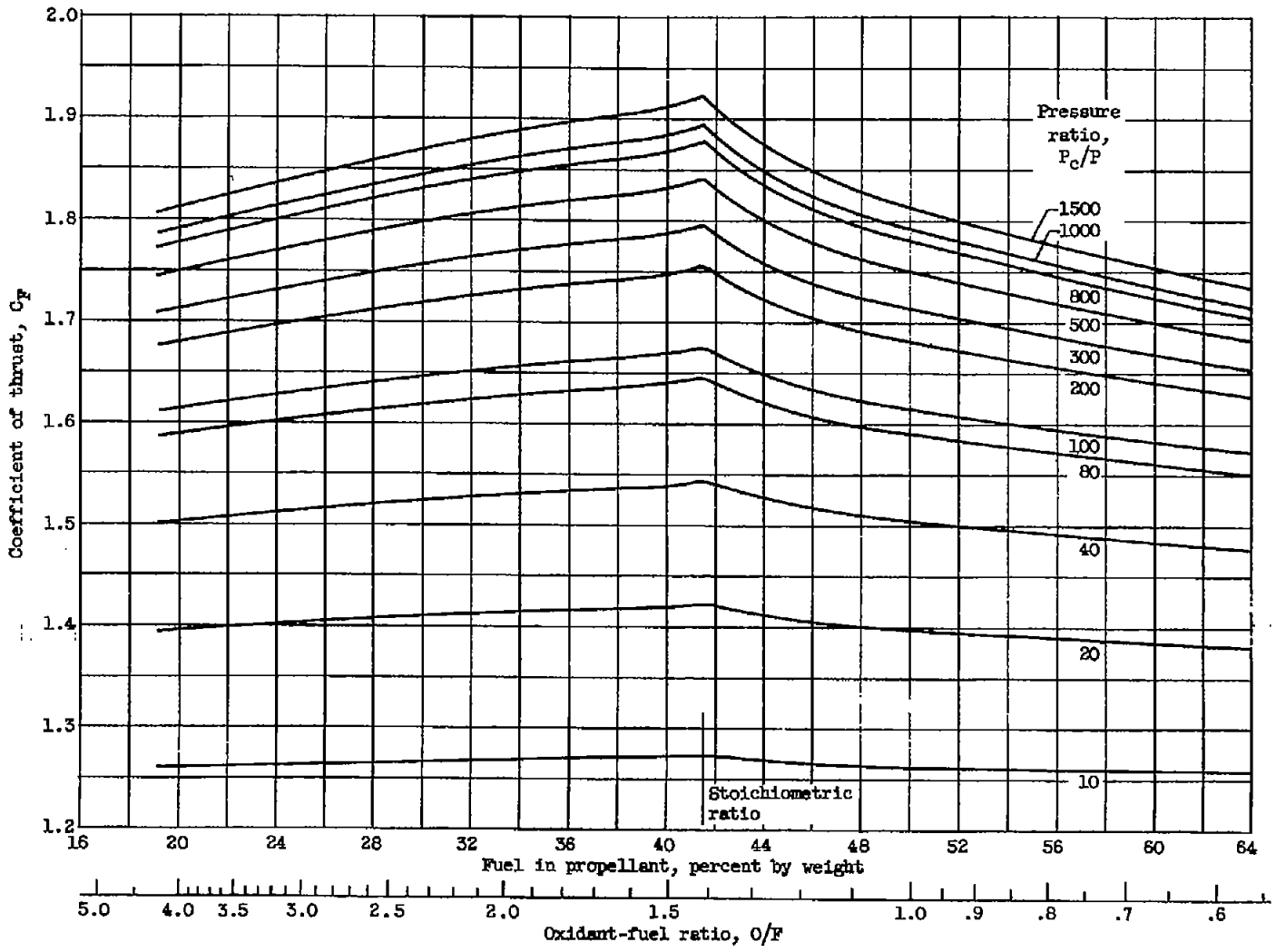

(a) Chamber pressure, 300 pounds per square inch absolute. Equilibrium composition during expansion.

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



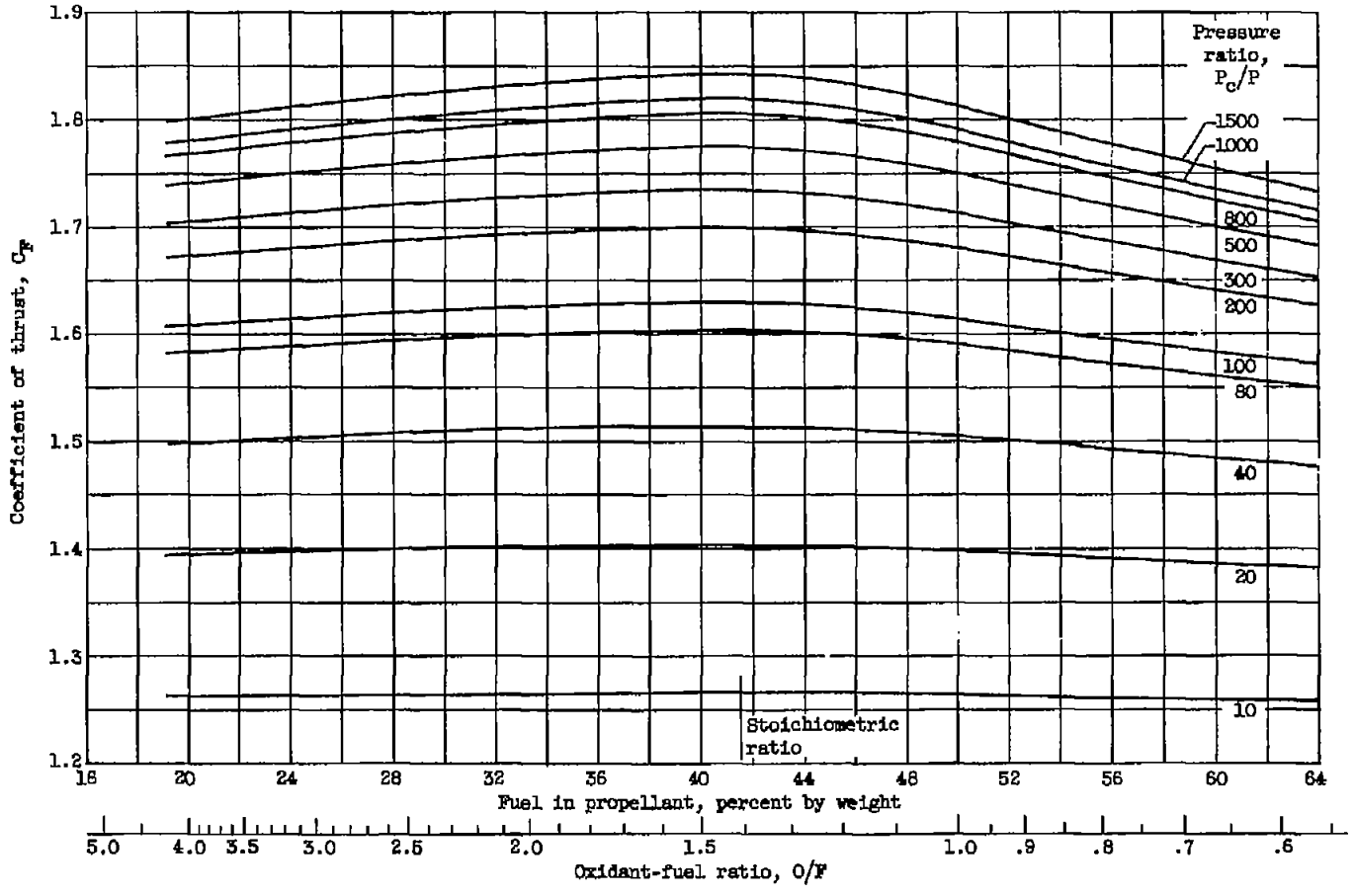

(b) Chamber pressure, 300 pounds per square inch absolute. Frozen composition during expansion.

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




(c) Chamber pressure, 600 pounds per square inch absolute. Equilibrium composition during expansion.

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




(d) Chamber pressure, 600 pounds per square inch absolute. Frozen composition during expansion.

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

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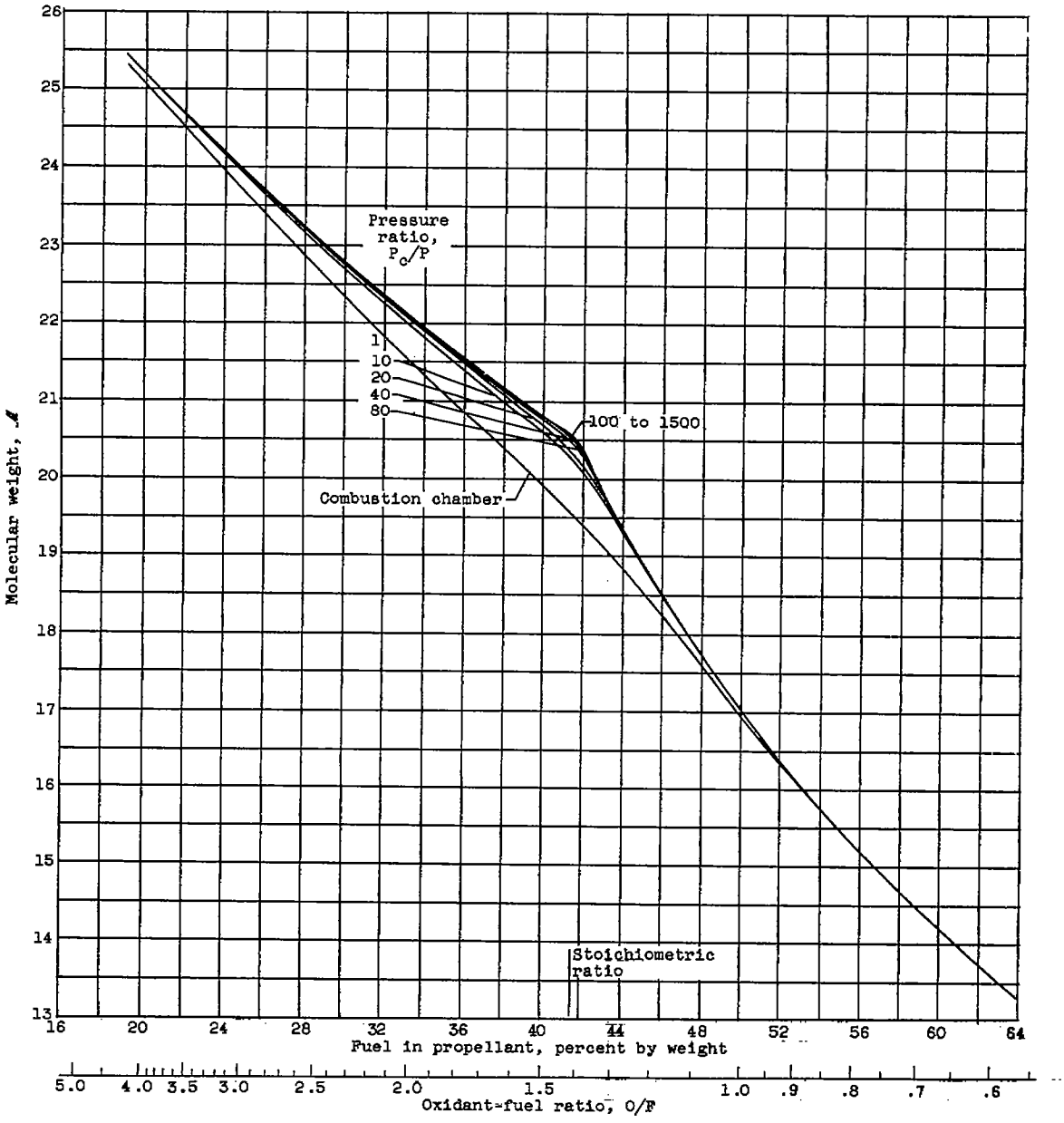
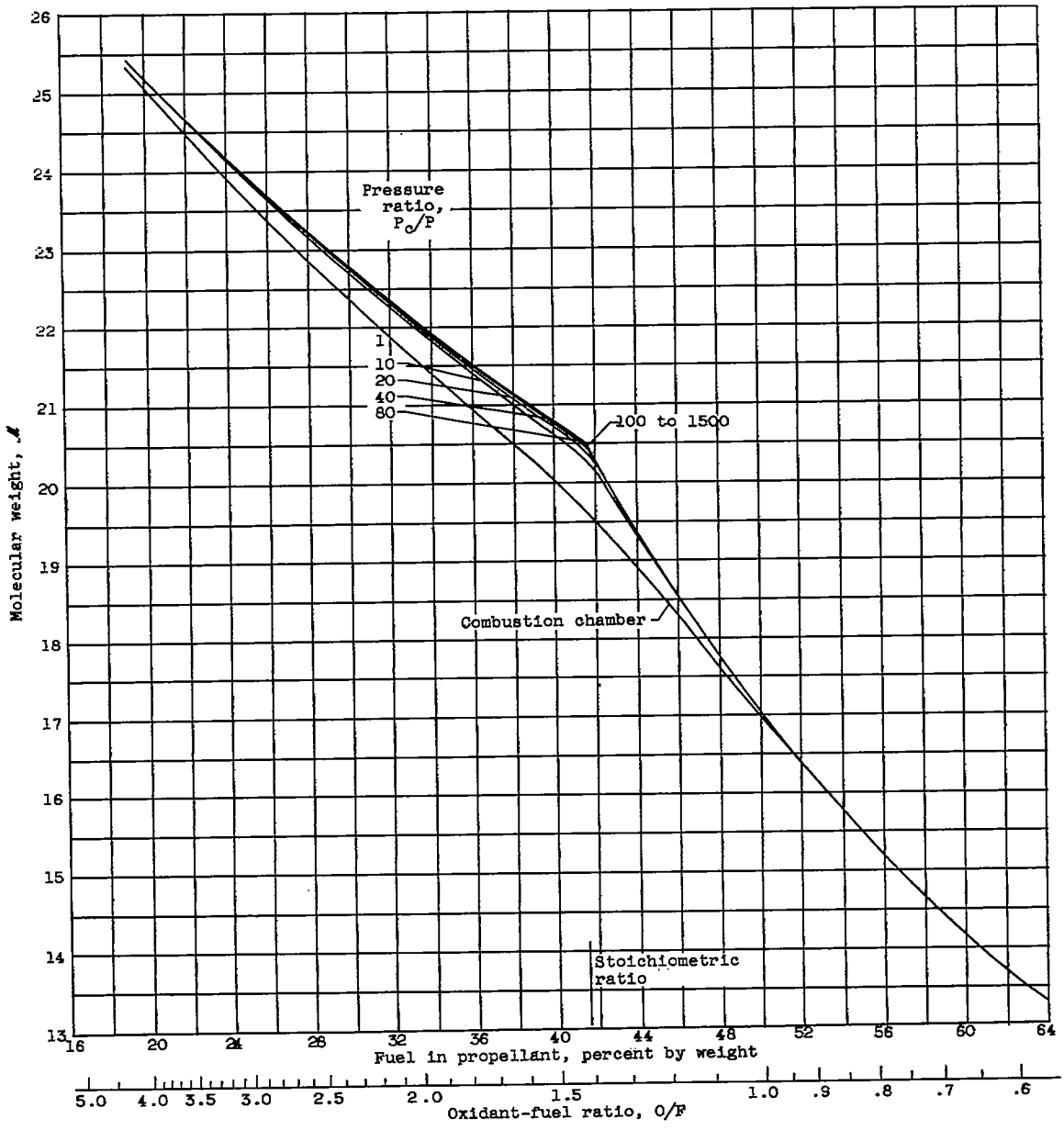


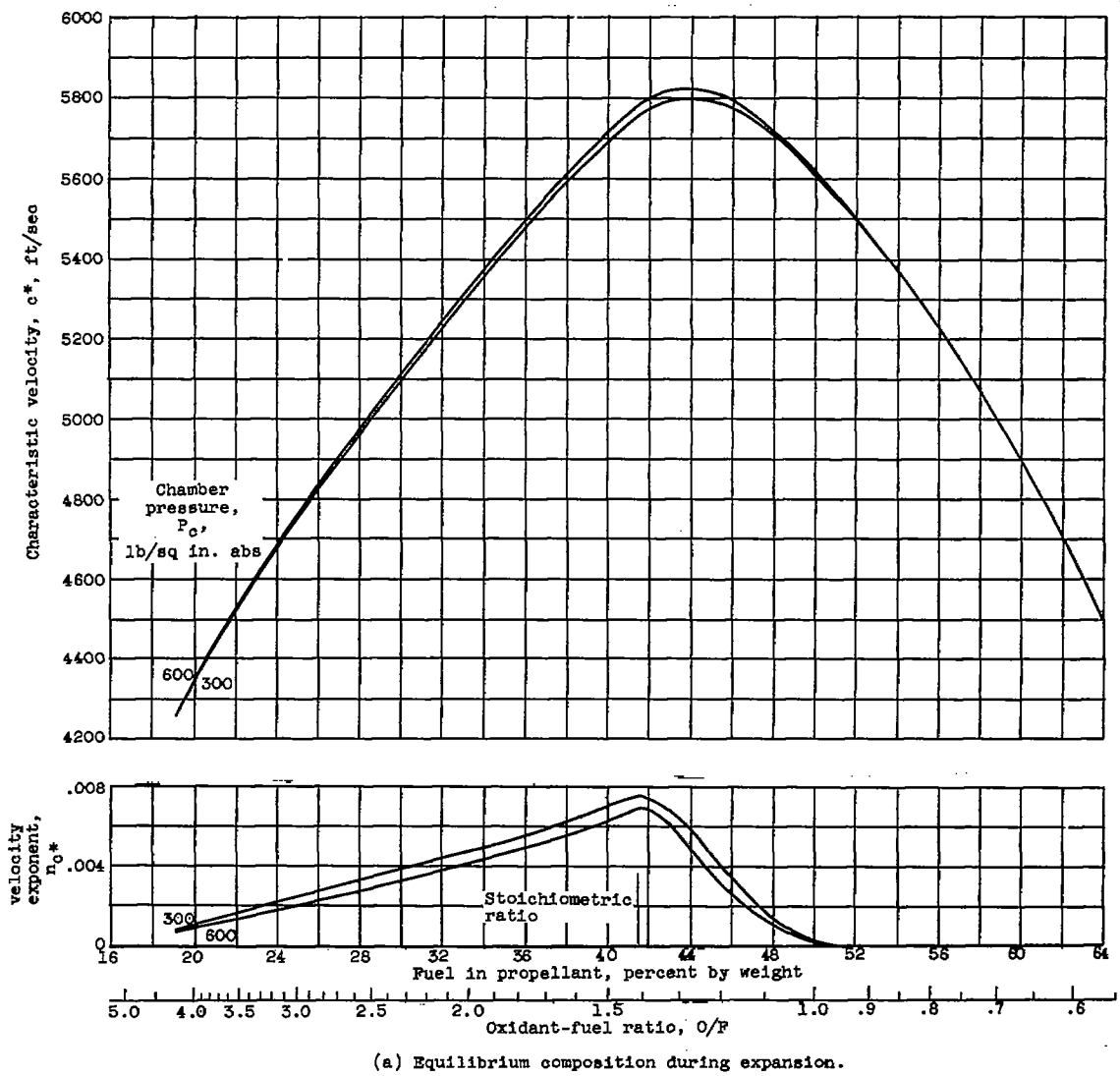

(a) Chamber pressure, 300 pounds per square inch absolute.

Figure 5. - Theoretical molecular weight of liquid ammonia and liquid oxygen assuming equilibrium composition during isentropic expansion to pressure ratio indicated.



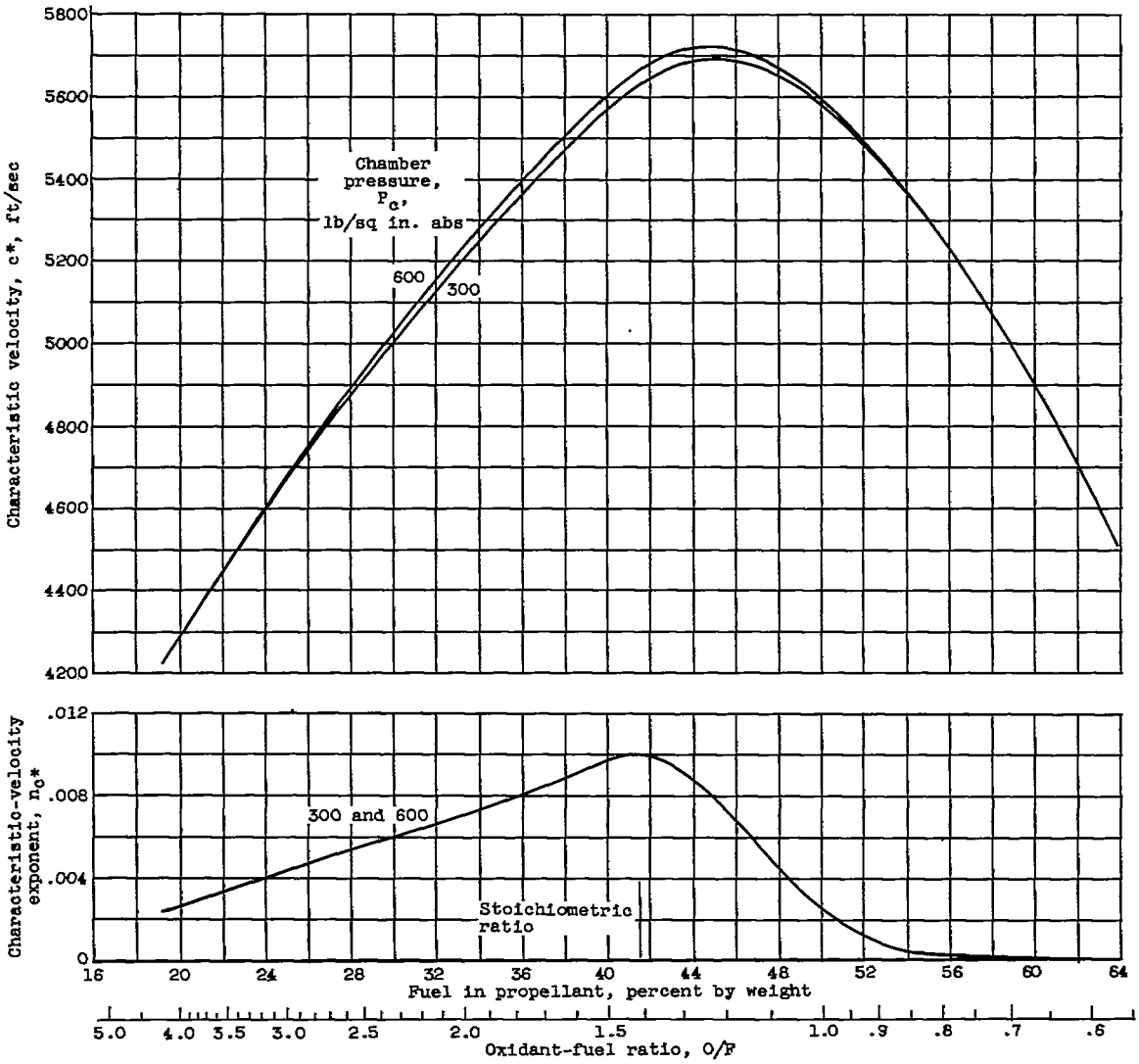

(b) Chamber pressure, 600 pounds per square inch absolute.

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




(a) Equilibrium composition during expansion.

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




(b) Frozen composition during expansion.

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

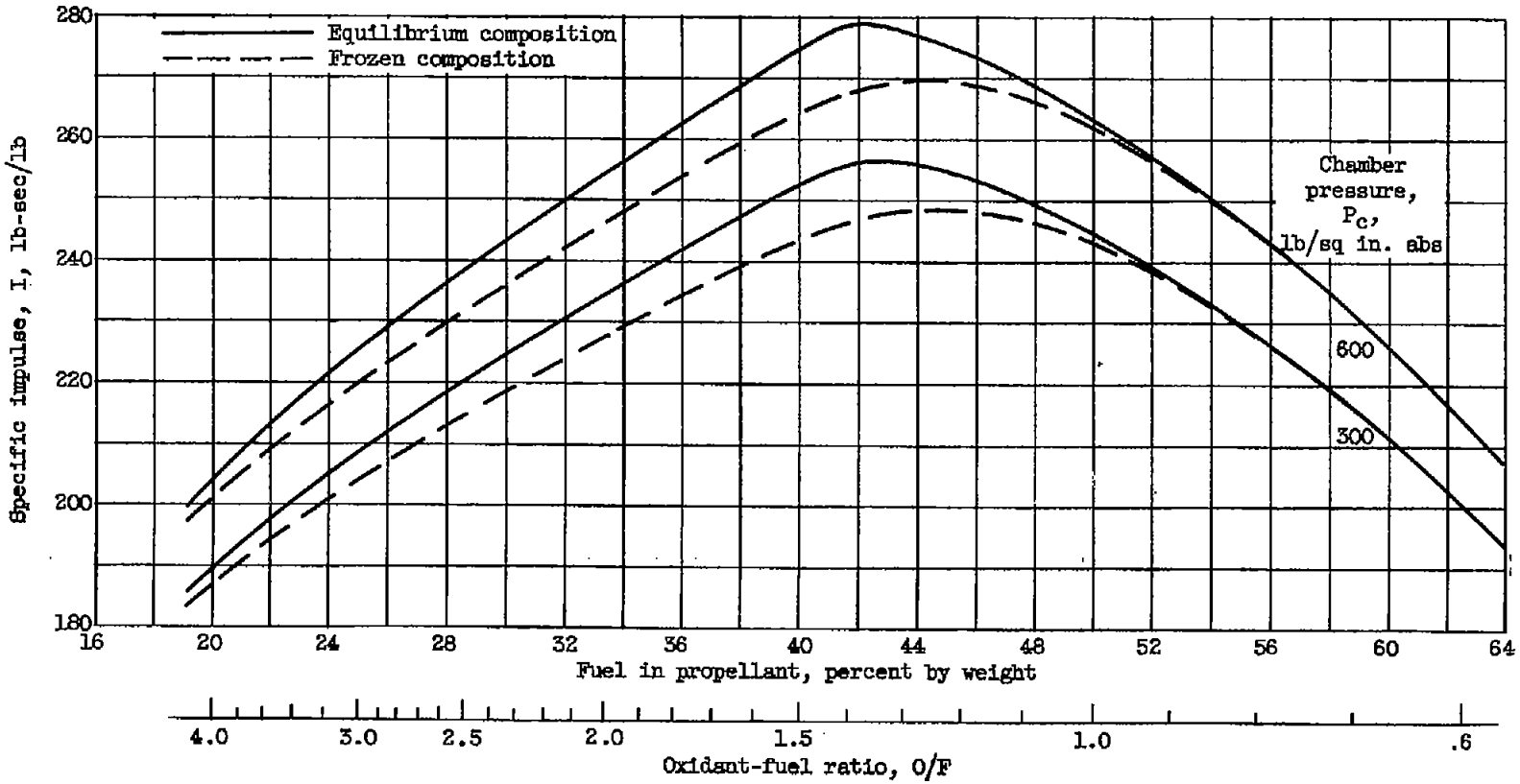



Figure 7. - Theoretical specific impulse for liquid ammonia with liquid oxygen. Isentropic expansion to 1 atmosphere from chamber pressure indicated.