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RESEARCH MEMORANDUM

THEORETICAL ROCKET PERFORMANCE OF JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES ASSUMING EQUILIBRIUM COMPOSITION

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
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SUMMARY

Theoretical rocket performance for equilibrium composition during expansion was calculated for JP-4 fuel with several fluorine-oxygen mixtures for a range of pressure ratios and oxidant-fuel ratios. The parameters included are specific impulse, combustion-chamber temperature, nozzle-exit temperature, molecular weight, characteristic velocity, coefficient of thrust, ratio of nozzle-exit area to throat area, specific heat at constant pressure, isentropic exponent, viscosity, thermal conductivity, and equilibrium gas compositions. A correlation is given for the effect of chamber pressure on several of the parameters.

The maximum value of specific impulse for a chamber pressure of 600 pounds per square inch absolute (40.827 atm) and an exit pressure of 1 atmosphere is 325.7 for 70.37 percent fluorine in the oxidant as compared with 284.9 and 305.1 for 100 percent oxygen and 100 percent fluorine, respectively.

INTRODUCTION

Mixtures of liquid fluorine and liquid oxygen as oxidants with hydrocarbons as fuel have been considered in recent years for possible high-energy rocket propellants. Mixtures of fluorine and oxygen exist that give higher performance with hydrocarbons then either 100 percent oxygen or fluorine because fluorine burns preferentially with hydrogen, and oxygen with carbon.

Theoretical calculations (ref. 1) show that maximum specific impulse can be obtained when the oxidant contains about 70 percent fluorine. Often, however, theoretical performance data are needed for comparison with experimental data obtained for various percentages of fluorine in the oxidant. Calculations were therefore made at the NACA Lewis laboratory during 1955 and 1956 in order to provide performance data for 0 to 100 percent fluorine in the oxidant. Performance data based on frozen composition during expansion are given in reference 2.

SYMBOLS

The following symbols are used in this report:

A	nozzle area, sq in.
a	local velocity of sound (velocity of flow at throat), 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)(°K)
c_p	specific heat at constant pressure, $\left(\frac{\partial h}{\partial T}\right)_P$, cal/(g)(°K)
c*	characteristic velocity, $g_c P_c A_t / w$, ft/sec
F	thrust, lb
g_c	gravitational conversion factor, 32.174 $\left(\frac{\text{lb mass}}{\text{lb force}}\right)\left(\frac{\text{ft}}{\text{sec}^2}\right)$
H_T^o	sum of sensible enthalpy and chemical energy at temperature T, cal/mole
h	sum of sensible enthalpy and chemical energy per unit mass, $\frac{\sum_i x_i (H_T^o)_i}{M(1 - x_k)}$, cal/g
I	specific impulse, (lb force)(sec)/lb mass
k	coefficient of thermal conductivity, cal/(sec)(cm)(°K)
M	molecular weight, $\frac{\sum_i x_i M_i}{1 - x_k}$, g/g-mole or lb/lb-mole
n_{c^*}	characteristic velocity exponent, $\frac{\partial \ln c^*}{\partial \ln P_c}$
n_I	specific-impulse exponent for fixed pressure ratio, $\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{P_c/P}$
n_T	temperature exponent for fixed pressure ratio, $\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{P_c/P}$
n_ϵ	area-ratio exponent for fixed pressure ratio, $\left(\frac{\partial \ln \epsilon}{\partial \ln P_c}\right)_{P_c/P}$

O/F oxidant-fuel weight ratio

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

p partial pressure, lb/sq in.

R universal gas constant (consistent units)

r equivalence ratio, ratio of four times the number of carbon atoms plus the number of hydrogen atoms to two times the number of oxygen atoms plus the number of fluorine atoms, $\frac{4(C) + (H)}{2(O) + (F)}$

S_T^o entropy at a pressure of 1 atmosphere, cal/(mole)(^{o}K)

s entropy per unit mass, $\frac{\sum_i x_i (S_T^o)_i}{M(1 - x_k)} \quad \frac{R\sum_j p_j \ln \frac{p_j}{14.696}}{PM}$ cal/(g)(^{o}K)

T temperature, ^{o}K

w mass-flow rate, lb/sec

x mole fraction

γ isentropic exponent, $\left(\frac{\partial \log P}{\partial \log \rho}\right)_s$

ϵ ratio of nozzle area to throat area

μ absolute viscosity, g/(cm)(sec) or poises

ρ density, lb/cu in.

Subscripts:

c combustion chamber

e nozzle exit

i product of combustion including both gaseous and solid phases

j gaseous product of combustion

k solid product of combustion (graphite)

P constant pressure

P_c/P constant pressure ratio

s constant entropy

t nozzle throat

Superscript:

o thermodynamic standard reference state

CALCULATION OF PERFORMANCE DATA

Performance data were obtained for JP-4 fuel with several fluorine-oxygen mixtures for a range of equivalence ratios and pressure ratios. Equilibrium composition during expansion from a chamber pressure of 600 pounds per square inch absolute was assumed.

The computations were carried out by the method described in reference 3 with modifications to adapt it for use with an IBM card-programmed electronic calculator. 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 and pressure 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 graphite and the following ideal gases: atomic carbon C, carbon monofluoride CF, carbon difluoride CF_2, carbon trifluoride CF_3, carbon tetrafluoride CF_4, difluoroacetylene C_2F_2, methane CH_4, carbon monoxide CO, carbon dioxide CO_2, atomic fluorine F, fluorine F_2, atomic hydrogen H, hydrogen H_2, hydrogen fluoride HF, water H_2O, atomic oxygen O, oxygen O_2, and the hydroxyl radical OH. The combustion products are assumed to be completely expanded within the exit nozzle; that is, ambient pressure equals exit pressure.

The graphite was assumed to be finely divided and in temperature and velocity equilibrium with the gases during the flow process.

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Initial Data

Thermodynamic data. - The thermodynamic data for all combustion products except graphite, methane, the fluorocarbons, and water were taken from reference 3. Data for graphite were taken from reference 4, for carbon monofluoride from reference 5, for the remainder of the fluorocarbons from reference 6, and for water from reference 7. Data for methane were determined by the rigid-rotator - harmonic-oscillator approximation using spectroscopic data from reference 8. The base used in this report for assigning absolute values to enthalpy is the same as in reference 3.

The dissociation energy of fluorine was assumed to be 35.6 kilocalories per mole and the heat of sublimation of graphite at 296.16° K was assumed to be 171.698 kilocalories per mole (ref. 9). The heat of solution of oxygen and fluorine was assumed to be zero.

Physical and thermochemical data. - The properties of the fuel used in these calculations are typical of the JP-4 fuel delivered to the Lewis laboratory over a period of 2 years. The JP-4 fuel was assumed to have a hydrogen-to-carbon weight ratio of 0.163 (atom ratio, 1.942), a lower heat of combustion value of 18,640 Btu per pound, and a specific gravity of 0.769. Additional properties of jet fuels may be found in reference 10. Several properties of the oxidants taken from references 3, 9, 11, and 12 are listed in table I.

Viscosity data. - The viscosity data for the individual combustion products were either taken from the literature when available or estimated. The viscosities of F, H, H_2, and HF are given in reference 13. The viscosities of the remaining substances except H_2O were calculated using similar techniques. The viscosity of H_2O was obtained from a modified Sutherland equation (ref. 14).

Formulas

Interpolation formulas and accuracy of results are discussed in reference 15. The formulas used in computing the various performance parameters are as follows:

Specific impulse, (lb force)(sec)/lb mass

$$I = 294.98 \sqrt{\frac{h_c - h_e}{1000}} \tag{1}$$

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

$$\frac{A_t}{w} = \frac{2781.6\ T_t}{P_t M_t a} \tag{2}$$

Characteristic velocity, ft/sec

$$c^* = g_c P_c \left(\frac{A_t}{w}\right) = 32.174\ P_c \left(\frac{A_t}{w}\right) \tag{3}$$

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Coefficient of thrust

$$C_F = \frac{g_c I}{c^*} = \frac{32.174\ I}{c^*} \tag{4}$$

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

$$\frac{A}{w} = \frac{86.455\ T}{PMI} \tag{5}$$

Ratio of nozzle area to throat area

$$\epsilon = \frac{A/w}{A_t/w} \tag{6}$$

Specific heat at constant pressure, cal/(g)(°K)

$$c_p = \left(\frac{\partial h}{\partial T}\right)_P = \frac{C_p^o}{M(1 - x_k)} \tag{7}$$

where C_p^o is given by equation (37) of reference 3.

Isentropic exponent

$$\gamma = \left(\frac{\partial\ \ln P}{\partial\ \ln \rho}\right)_s \tag{8}$$

Absolute viscosity, poise

$$\mu = \frac{PM}{\sum_j \frac{p_j}{\mu_j/M_j}} \tag{9}$$

Coefficient of thermal conductivity, cal/(sec)(cm)($^{\circ}$K)

$$k = \mu \left(c_p + \frac{5}{4} \frac{R}{M} \right) \tag{10}$$

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THEORETICAL PERFORMANCE DATA

Tables

The calculated values of the various performance parameters for a combustion pressure of 600 pounds per square inch absolute and for a range of oxidant-fuel ratios and exit conditions are given in tables II to V for a range of fluorine-oxygen ratios.

The properties of gases in the combustion chamber and the characteristic velocity are given in table II. Table III presents the values of the performance parameters at assigned temperatures and constant entropy. These values were computed directly and used to interpolate properties at assigned pressure ratios (1 to 8, 1 to 1000, 1 to 1500, or 10 to 1500) given in tables IV and V. Properties at the throat may be found where $\epsilon = 1.000$. The values adjacent to the throat correspond to pressures of 1.2 and 0.8 times the throat pressure. Table VI presents the equilibrium composition in the combustion chamber. Performance data for expansion from chamber pressure to 1 atmosphere are summarized in table VII.

Curves

The performance parameters are plotted in figures 1 to 6.

Curves of specific impulse are presented in figure 1 for assigned pressure ratios as functions of percent by weight of fuel.

Combustion-chamber temperature and exit temperature for assigned pressure ratios are plotted in figure 2 as functions of percent by weight of fuel.

Curves of the ratio of nozzle area to throat area are plotted in figure 3 as functions of percent by weight of fuel for assigned pressure ratios.

Figure 4 gives the curves for coefficient of thrust for assigned pressure ratios as functions of percent by weight of fuel.

Curves of molecular weight in the combustion chamber at assigned pressure ratios as functions of percent by weight of fuel are presented in figure 5.

Figure 6 shows the curves of characteristic velocity as functions of percent by weight of fuel.

Effect of fluorine-oxygen ratio. - The specific-impulse data for expansion from chamber pressure to 1 atmosphere (table VII) are plotted in figure 7 to show the effect of fluorine-oxygen ratio on performance. Specific impulse increases with increasing percentages of fluorine to about 70 percent fluorine in the oxidant. Increasing the amount of fluorine in the oxidant from about 70 to 100 percent results in a decrease in specific impulse.

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Maximum values of specific impulse calculated for a chamber pressure of 600 pounds per square inch absolute (40.827 atm) and an exit pressure of 1 atmosphere are shown in the following table:

Fluorine in oxidant, percent by weight	Maximum specific impulse, $\frac{\text{lb-sec}}{\text{lb}}$
0	284.9
15	292.1
30	299.9
50	311.7
70.37	325.7
100	305.1

The data of the preceding table are plotted in figure 8. The break in the curve is based on similar data shown in figure 1 of reference 1. The curves of characteristic velocity are very similar to those of specific impulse (fig. 6).

Effect of assuming equilibrium or frozen composition during expansion. - The curve of specific impulse assuming frozen composition during expansion (fig. 8, ref. 2) is plotted in figure 8 for comparison with the curve for equilibrium specific impulse. The maximum value of specific impulse for a chamber pressure of 600 pounds per square inch absolute (40.827 atm) and an exit pressure of 1 atmosphere occurs at about 70 percent fluorine fluorine in the oxidant and is 325.7 and 301.1 for equilibrium and frozen composition, respectively.

Effect of solid graphite. - The appearance of solid graphite as a combustion product affected the values of the thermodynamic parameters and resulted in the break in the performance data for 70.37 and 100 percent fluorine in the oxidant. The appearance of graphite occurred at about 22 percent fuel in the propellant for the 70.37-percent fluorine curves and at about 18.5 percent fuel in the propellant for the 100-percent-fluorine curves.

Chamber-pressure effect. - The use of the chamber pressure exponents (n_I, n_T, n_ϵ, and n_{c*}) to obtain performance data for chamber pressures other than 600 pounds per square inch absolute is explained in reference 15.

Effect of finite chamber area. - The use of a combustion chamber of finite cross-sectional area leads to a pressure change across the combustion process. Reference 15 illustrates how the data for low pressure ratios (tables IV and V) may be used to calculate the pressure at the injector face.

SUMMARY OF RESULTS

A theoretical investigation of the performance of JP-4 fuel with fluorine-oxygen mixtures was made for fluorine in oxidant by weight from 0 to 100 percent for various equivalence ratios, pressure ratios from 1 to 1000 (or 1 to 1500), and equilibrium composition during expansion from chamber pressure of 600 pounds per square inch absolute. The maximum values of specific impulse calculated for a chamber pressure of 600 pounds per square inch absolute (40.827 atm) and an exit pressure of 1 atmosphere ranged from 284.9 to 325.7 for 0 to 70.37 percent fluorine in the oxidant and from 325.7 to 305.1 for 70.37 to 100 percent fluorine in the oxidant.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
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TABLE I. - PROPERTIES OF LIQUID OXIDANTS

Property	Oxygen, O_2	Fluorine, F_2
Molecular weight, M	32.00	38.00
Density, g/cc	[a]1.1415	[b]1.54
Freezing point, °C	[c]-218.76	[c]-217.96
Boiling point, °C	[c]-182.97	[c]-187.92
Enthalpy required to convert liquid at boiling point to gas at 25° C, kcal/mole	[d]3.080	[d]3.030
Enthalpy of vaporization, kcal/mole	[c,e]1.630	[c,f]1.51
Enthalpy of fusion, kcal/mole	[c,g]0.106	[c,h]0.372

[a]At -182.0° C; ref. 11.

[b]At -196° C; ref. 12.

[c]Ref. 9.

[d]Ref. 3.

[e]At -182.97° C.

[f]At -187.92° C.

[g]At -218.76° C.

[h]At -217.96° C.

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TABLE II. - THERMODYNAMIC PROPERTIES IN COMBUSTION CHAMBER AND CHARACTERISTIC VELOCITY FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Combustion-chamber pressure, 600 lb/sq in. abs.]

Equivalence ratio, r, $\frac{4(C)+(H)}{2(O)+(F)}$	Fuel, percent by weight	Oxidant to fuel weight ratio, O/F	Temperature, T, °K	Temperature exponent, n_T	Molecular weight, M	Enthalpy, h, cal/g (a)	Entropy, s, $\frac{cal}{(g)(^{o}K)}$	Specific heat, c_p, $\frac{cal}{(g)(^{o}K)}$ (b)	Isentropic exponent, γ (b)	Characteristic velocity exponent, n_{c*} (b)	Characteristic velocity, c*, ft/sec (b)
Percent fluorine in oxidant, 0 (100 percent oxygen)											
1.0	22.71	3.403	3612	0.0426	25.48	2531.6	2.5729	1.845	1.128	0.0127	5622
1.2	26.07	2.836	3628	.0422	24.03	2901.1	2.6815	1.818	1.131	.0125	5795
1.3	27.64	2.618	3612	.0408	23.36	3074.1	2.7297	1.700	1.134	.0119	5859
1.4	29.15	2.431	3576	.0382	22.70	3239.9	2.7740	1.520	1.139	.0110	5904
1.5	30.59	2.269	3518	.0344	22.05	3399.0	2.8146	1.283	1.145	.0092	5924
1.6	31.98	2.127	3436	.0290	21.41	3551.6	2.8515	1.089	1.156	.0069	5918
1.8	34.59	1.891	3205	.0187	20.17	3839.4	2.9142	.798	1.184	.0031	5832
2.0	37.01	1.702	2923	.0099	19.03	4105.8	2.9627	.653	1.215	.0009	5679
3.0	46.85	1.134	1657	.0264	15.49	5188.4	3.0102	.701	1.285	.0114	4674
Percent fluorine in oxidant by weight, 15											
1.2	24.36	3.106	3735	0.0439	23.39	2888.3	2.7033	1.779	1.138	0.0131	5947
1.4	27.31	2.662	3694	.0412	22.25	3206.2	2.7907	1.572	1.144	.0118	6051
1.6	30.04	2.329	3583	.0342	21.15	3500.2	2.8650	1.207	1.157	.0088	6081
1.8	32.57	2.071	3391	.0244	20.08	3773.0	2.9264	.895	1.180	.0049	6022
2.0	34.92	1.864	3142	.0156	19.06	4026.7	2.9753	.718	1.208	.0021	5895
Percent fluorine in oxidant by weight, 30											
1.2	22.56	3.432	3868	0.0454	22.78	2874.8	2.7036	1.693	1.147	0.0136	6117
1.4	25.37	2.942	3836	.0437	21.81	3170.7	2.7867	1.568	1.152	.0127	6215
1.6	27.98	2.574	3745	.0385	20.87	3445.8	2.8580	1.291	1.161	.0103	6253
1.8	30.41	2.288	3586	.0304	19.95	3702.3	2.9180	.992	1.180	.0069	6216
2.0	32.69	2.059	3369	.0219	19.06	3942.1	2.9667	.797	1.203	.0039	6115
Percent fluorine in oxidant by weight, 50											
1.2	20.03	3.992	4120	0.0458	22.10	2855.9	2.6800	1.520	1.158	0.0138	6386
1.4	22.62	3.421	4100	.0451	21.31	3120.2	2.7582	1.447	1.164	.0133	6476
1.6	25.04	2.994	4030	.0420	20.54	3368.1	2.8257	1.277	1.172	.0117	6519
1.8	27.31	2.661	3898	.0361	19.78	3600.8	2.8826	1.045	1.187	.0090	6499
2.0	29.46	2.395	3708	.0294	19.03	3819.9	2.9282	.865	1.206	.0065	6421
Percent fluorine in oxidant by weight, 70.37											
1.0	14.83	5.743	4007	0.0351	22.24	2592.0	2.5230	0.869	1.196	0.0106	6203
1.4	19.60	4.102	4464	.0428	21.20	3064.9	2.6853	1.306	1.171	.0125	6757
1.5	20.71	3.829	4479	.0431	20.95	3175.0	2.7138	1.357	1.169	.0126	6814
1.6	21.79	3.589	4396	.0426	20.97	3282.1	2.7302	1.351	1.167	.0126	6749
2.5	30.33	2.297	3898	.0308	20.41	4128.8	2.8100	1.017	1.172	.0076	6420
Percent fluorine in oxidant, 100 (zero percent oxygen)											
1.0	11.01	8.083	3962	0.0641	27.41	2621.2	2.1971	2.930	1.146	0.0177	5645
1.5	15.65	5.389	4008	.0511	26.63	3060.4	2.3189	1.375	1.157	.0148	5744
2.0	19.84	4.041	4206	.0334	26.42	3456.0	2.4039	1.203	1.121	.0056	5951
2.8	25.73	2.887	4262	.0326	24.72	4013.3	2.5000	1.670	1.105	.0071	6238
3.0	27.07	2.694	4249	.0322	24.41	4140.1	2.5199	1.699	1.105	.0075	6269
3.5	30.22	2.309	4172	.0310	23.76	4437.8	2.5634	1.560	1.112	.0078	6279
4.0	33.10	2.021	4041	.0294	23.26	4710.9	2.5991	1.285	1.126	.0074	6212
5.0	38.22	1.617	3708	.0246	22.53	5194.5	2.6512	.977	1.148	.0056	6009

[a]The base used for enthalpy is given in reference 3.
[b]Parameter includes energy due to change in composition.

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TABLE III. - THEORETICAL PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion or compression from chamber pressure of 600 lb/sq in. abs.]

(a) Percent fluorine in oxidant, 0 (100 percent oxygen)

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(°K)}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r = 1.0; O/F = 3.403; percent fuel = 22.71											
4000	1898.3	2878.7	24.649	-.3198	1.1389	1.7578	997	0.00185	----------	-------	-------
3600	576.23	2520.2	25.513	-.3333	1.1272	1.8470	921	.00179	2.312	0.180	31.4
3200	134.29	2142.8	26.547	-.3397	1.1158	1.8910	843	.00167	1.449	1.053	183.9
2800	22.297	1749.4	27.769	-.3307	1.1057	1.8292	763	.00146	5.146	1.493	260.9
2400	2.497	1352.6	29.139	-.2870	1.0992	1.5619	680	.00122	30.570	1.833	320.3
2000	.211	990.5	30.422	-.1753	1.1055	1.0305	596	.00066	252.02	2.096	366.2
1600	.022	728.9	31.099	-.0376	1.1498	.5328	504	.00031	1718.1	2.267	396.0
900	.001	444.4	31.204	-.0000	1.2171	.3571	339	.00015	33282.	2.439	426.2
r = 1.2; O/F = 2.836; percent fuel = 26.07											
4000	1755.7	3244.6	23.302	-.3133	1.1413	1.7758	981	0.00185	----------	-------	-------
3600	548.54	2874.4	24.095	-.3206	1.1302	1.8191	907	.00174	1.626	0.268	48.3
3200	135.33	2489.9	25.017	-.3139	1.1202	1.7656	831	.00155	1.439	1.050	189.2
2800	25.883	2104.0	26.026	-.2687	1.1150	1.4847	753	.00119	4.545	1.462	263.4
2400	4.562	1764.7	26.866	-.1290	1.1324	.8586	675	.00064	17.934	1.746	314.5
2000	1.102	1534.3	27.150	-.0160	1.1820	.4929	597	.00035	55.823	1.915	344.9
1600	.276	1352.3	27.183	-.0009	1.1995	.4405	514	.00027	167.59	2.038	367.1
1200	.049	1177.6	27.184	-.0000	1.2007	.4373	421	.00022	664.14	2.150	387.3
900	.009	1044.5	27.184	-.0000	1.1924	.4530	348	.00019	2757.3	2.231	401.9
r = 1.3; O/F = 2.618; percent fuel = 27.64											
4000	1787.0	3432.6	22.646	-.3015	1.1438	1.7138	974	0.00177	----------	-------	-------
3600	578.52	3063.0	23.379	-.3006	1.1337	1.6977	901	.00162	2.431	0.171	31.2
3200	153.69	2686.9	24.194	-.2759	1.1264	1.5375	827	.00136	1.335	1.008	183.6
2800	35.125	2329.3	24.985	-.1949	1.1295	1.1272	751	.00092	3.570	1.398	254.6
2400	6.693	2043.0	25.478	-.0654	1.1610	.6547	676	.00050	10.305	1.645	299.5
2000	2.543	1832.7	25.617	-.0097	1.1959	.4840	599	.00035	26.609	1.805	328.7
1600	.676	1648.3	25.637	-.0007	1.2075	.4517	511	.00028	74.711	1.934	352.2
1200	.127	1467.8	25.638	-.0000	1.2050	.4557	418	.00023	281.81	2.053	373.9
900	.022	1327.5	25.638	-.0000	1.1902	.4849	343	.00020	1154.1	2.141	389.8
r = 1.4; O/F = 2.431; percent fuel = 29.15											
3600	642.97	3261.7	22.655	-.2714	1.1391	1.5265	897	0.00147	----------	-------	-------
3200	188.86	2902.1	23.338	-.2265	1.1361	1.2886	824	.00115	1.197	0.934	171.5
2800	52.357	2578.4	23.912	-.1320	1.1482	.8869	751	.00074	2.635	1.307	239.9
2400	15.960	2323.1	24.212	-.0410	1.1806	.5898	678	.00047	6.217	1.539	282.4
2000	5.113	2118.2	24.298	-.0070	1.2066	.4852	601	.00035	14.567	1.703	312.4
1600	1.425	1930.8	24.312	-.0005	1.2154	.4617	517	.00029	38.681	1.839	337.5
1200	.279	1745.5	24.313	-.0000	1.2104	.4702	423	.00024	138.72	1.965	360.6
900	.050	1599.7	24.313	-.0000	1.1917	.5082	345	.00021	551.39	2.059	377.8
r = 1.6; O/F = 2.127; percent fuel = 31.98											
3600	906.91	3687.1	21.218	-.2007	1.1554	1.1842	893	0.00116	----------	-------	-------
3200	328.53	3367.2	21.653	-.1407	1.1613	.9387	823	.00087	1.001	0.689	126.7
2800	118.890	3089.4	21.956	-.0707	1.1804	.7005	753	.00061	1.508	1.090	200.6
2400	44.037	2856.5	22.104	-.0232	1.2062	.5547	680	.00045	2.827	1.337	245.9
2000	15.689	2652.2	22.151	-.0043	1.2248	.4936	603	.00037	5.823	1.521	279.8
1800	8.837	2555.1	22.157	-.0014	1.2294	.4822	562	.00033	8.804	1.601	294.5
1600	4.710	2459.3	22.159	-.0003	1.2312	.4780	517	.00030	14.022	1.676	308.3
1400	2.310	2363.6	22.160	-.0001	1.2297	.4801	474	.00028	23.985	1.748	321.5
1200	1.005	2266.7	22.160	-.0000	1.2236	.4907	426	.00026	45.468	1.818	334.4
1000	.362	2166.4	22.160	-.0000	1.2104	.5159	374	.00024	101.28	1.887	347.2
r = 1.8; O/F = 1.891; percent fuel = 34.59											
3600	1413.2	4128.5	19.890	-.1437	1.1748	0.9704	891	0.00098	----------	-------	-------
3200	593.22	3835.8	20.170	-.0941	1.1847	.7954	824	.00076	4.333	0.097	17.7
2800	245.81	3576.7	20.357	-.0468	1.2033	.6452	754	.00058	1.059	.834	151.8
2400	100.02	3349.2	20.449	-.0160	1.2249	.5488	682	.00046	1.626	1.139	206.5
2000	37.910	3142.3	20.479	-.0031	1.2407	.5036	605	.00038	2.993	1.359	246.3
1600	12.164	2944.6	20.485	-.0002	1.2466	.4906	521	.00032	6.585	1.539	279.0
1200	2.808	2746.9	20.485	-.0000	1.2388	.5032	428	.00027	19.363	1.701	308.3
900	.594	2590.2	20.492	-.0069	1.2131	.5617	350	.00024	64.211	1.819	329.7
r = 3.0; O/F = 1.134; percent fuel = 46.85											
1800	883.10	5274.2	15.429	-.0384	1.2932	0.6508	567	0.00046	----------	-------	-------
1600	506.25	5152.9	15.527	-.0735	1.2787	.7384	526	.00047	1.309	0.382	55.5
1400	247.22	5016.7	15.752	-.1491	1.2385	1.0099	484	.00056	1.050	.641	122.2
1200	82.492	4840.6	16.278	-.2808	1.1771	1.8389	443	.00088	1.834	1.197	174.0
1000	12.191	4593.8	17.350	-.4051	1.1270	3.5681	407	.00151	7.421	1.566	227.5
900	2.931	4442.5	18.143	-.4369	1.1099	4.4190	389	.00177	23.717	1.754	254.8

TABLE III. - Continued. THEORETICAL PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion or compression from chamber pressure of 600 lb/sq in. abs.]

(b) Percent fluorine in oxidant by weight, 15

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(°K)}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r = 1.2; O/F = 3.106; percent fuel = 24.38											
4000	1244.8	3130.6	22.881	-.3175	1.1458	1.7430	1061	0.00197	----------	--------	-------
3600	399.74	2762.5	23.670	-.3245	1.1341	1.7886	978	.00185	1.021	0.566	104.6
3200	101.77	2380.0	24.588	-.3180	1.1236	1.7460	893	.00166	1.707	1.138	210.3
2800	20.101	1995.2	25.596	-.2748	1.1179	1.4867	807	.00128	5.479	1.508	278.8
2400	3.640	1655.8	26.450	-.1346	1.1361	.8598	720	.00069	21.36	1.772	327.5
2000	.927	1430.4	26.738	-.0157	1.1939	.4740	634	.00036	63.56	1.927	356.2
1600	.260	1255.6	26.768	-.0009	1.2137	.4284	543	.00028	178.0	2.039	376.9
r = 1.4; O/F = 2.682; percent fuel = 27.31											
4000	1332.5	3483.3	21.744	-.2918	1.1512	1.6123	1044	0.00180	----------	--------	-------
3600	460.08	3120.0	22.414	-.2814	1.1421	1.5432	965	.00160	1.112	0.460	86.6
3200	136.38	2759.5	23.121	-.2390	1.1383	1.3124	884	.00125	1.420	1.048	197.1
2800	37.934	2433.9	23.727	-.1421	1.1506	.9013	802	.00081	3.310	1.378	259.2
2400	11.795	2181.0	24.047	-.0435	1.1878	.5775	721	.00049	7.813	1.588	298.7
2000	3.949	1982.6	24.138	-.0072	1.2183	.4669	637	.00036	17.74	1.735	326.3
1600	1.168	1802.8	24.152	-.0005	1.2289	.4422	545	.00030	44.75	1.858	349.4
1200	.248	1625.7	24.153	-.0000	1.2249	.4481	444	.00024	148.8	1.972	370.8
r = 1.6; O/F = 2.329; percent fuel = 30.04											
3600	626.49	3514.8	21.189	-.2149	1.1574	1.2165	956	0.00128	----------	--------	-------
3200	226.55	3193.3	21.596	-.1532	1.1631	.9594	879	.00094	1.098	0.665	163.4
2800	82.316	2915.9	21.927	-.0774	1.1841	.6997	802	.00066	1.888	1.193	225.6
2400	31.093	2687.4	22.090	-.0254	1.2139	.5409	722	.00047	3.606	1.407	265.9
2000	11.429	2489.9	22.141	-.0047	1.2359	.4752	638	.00037	7.316	1.569	296.5
1600	3.618	2304.7	22.150	-.0003	1.2441	.4575	547	.00031	16.99	1.706	322.5
1200	.829	2121.0	22.150	-.0000	1.2384	.4661	446	.00026	51.78	1.833	346.4
900	.177	1976.8	22.150	-.0002	1.2184	.5007	362	.00022	173.1	1.926	364.1
r = 1.8; O/F = 2.071; percent fuel = 32.57											
3600	943.29	3930.2	19.905	-.1574	1.1765	0.9944	951	0.00106	----------	--------	-------
3200	395.11	3637.8	20.214	-.1044	1.1868	.8054	877	.00081	1.022	0.581	108.7
2800	164.45	3380.1	20.423	-.0525	1.2073	.6408	802	.00061	1.250	.988	184.9
2400	67.989	3157.3	20.527	-.0180	1.2324	.5348	723	.00047	2.059	1.237	231.4
2000	26.520	2957.4	20.552	-.0035	1.2513	.4849	639	.00039	3.816	1.423	266.4
1600	8.872	2767.6	20.568	-.0003	1.2593	.4695	548	.00032	8.216	1.580	295.8
1200	2.183	2579.3	20.568	-.0000	1.2542	.4768	448	.00027	22.99	1.722	322.3
900	.505	2432.2	20.573	-.0052	1.2330	.5177	364	.00023	70.27	1.885	341.6
r = 2.0; O/F = 1.884; percent fuel = 34.92											
3200	672.25	4064.3	19.037	-.0779	1.2059	0.7377	876	0.00076	----------	--------	-------
2800	302.58	3815.4	19.184	-.0394	1.2251	.6180	801	.00060	1.007	0.740	135.6
2400	132.44	3593.5	19.258	-.0137	1.2476	.5363	722	.00048	1.372	1.060	194.1
2000	53.994	3390.3	19.292	-.0026	1.2652	.4946	639	.00040	2.311	1.284	235.3
1600	18.910	3196.4	19.286	-.0002	1.2740	.4793	548	.00033	4.621	1.467	268.8
1200	4.961	3004.8	19.287	-.0002	1.2712	.4832	449	.00027	11.91	1.627	298.2
900	1.199	2852.9	19.341	-.0590	1.2196	.6592	366	.00029	34.39	1.744	319.6

TABLE III. - Continued. THEORETICAL PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion or compression from chamber pressure of 600 lb/sq in. abs.]

(c) Percent fluorine in oxidant by weight, 30

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(^{\circ}K)}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r = 1.2; O/F = 3.432; percent fuel = 22.56											
4000	844.58	2992.8	22.536	-.3164	1.1806	1.6747	1158	0.00207	----------	-------	--------
3600	280.47	2630.1	23.310	-.3227	1.1387	1.7175	1065	.00194	1.030	0.768	145.9
3200	74.441	2253.5	24.208	-.3164	1.1278	1.6846	969	.00173	2.084	1.283	232.5
2800	15.420	1874.1	25.197	-.2748	1.1217	1.4582	871	.00135	6.663	1.552	295.1
2400	2.931	1539.0	26.043	-.1354	1.1417	.8419	774	.00073	25.16	1.793	340.9
2000	.799	1321.4	26.321	-.0144	1.2088	.4513	678	.00037	70.55	1.934	367.7
1600	.234	1154.7	26.348	-.0008	1.2308	.4028	578	.00029	183.4	2.035	386.9
r = 1.4; O/F = 2.942; percent fuel = 25.37											
4000	902.90	3317.4	21.543	-.2946	1.1555	1.5763	1136	0.00192	----------	-------	--------
3600	318.86	2958.6	22.215	-.2855	1.1460	1.5204	1046	.00171	1.005	0.703	135.8
3200	96.594	2601.5	22.930	-.2456	1.1416	1.3093	955	.00135	1.743	1.152	222.5
2800	27.382	2278.2	23.553	-.1479	1.1546	.8972	864	.00087	4.184	1.443	278.7
2400	8.801	2030.6	23.881	-.0441	1.1974	.5581	773	.00051	9.737	1.631	315.0
2000	3.101	1840.1	23.972	-.0071	1.2326	.4463	680	.00037	21.24	1.762	340.3
1600	.978	1668.5	23.985	-.0005	1.2453	.4210	579	.00030	50.67	1.872	361.5
1200	.227	1500.5	23.986	-.0000	1.2434	.4232	469	.00025	155.0	1.974	381.2
r = 1.6; O/F = 2.574; percent fuel = 27.98											
4000	1077.2	3663.2	20.539	-.2537	1.1649	1.3704	1118	0.00167	----------	-------	--------
3600	422.23	3323.5	21.056	-.2237	1.1607	1.2205	1033	.00138	1.047	0.531	103.1
3200	154.22	3004.4	21.555	-.1615	1.1665	.9614	947	.00102	1.311	1.008	196.0
2800	56.873	2730.6	21.904	-.0819	1.1897	.6895	861	.00069	2.405	1.283	249.5
2400	22.071	2508.3	22.076	-.0268	1.2237	.5234	773	.00049	4.603	1.470	285.6
2000	8.439	2318.4	22.130	-.0050	1.2494	.4549	680	.00039	9.125	1.612	313.2
1600	2.818	2141.7	22.139	-.0004	1.2601	.4352	580	.00032	20.38	1.733	336.9
1200	.699	1967.8	22.140	-.0000	1.2575	.4382	470	.00026	57.70	1.845	358.6
900	.166	1833.7	22.140	-.0002	1.2434	.4588	379	.00022	174.0	1.927	374.5
r = 1.8; O/F = 2.288; percent fuel = 30.41											
3600	618.64	3713.3	19.939	-.1669	1.1797	0.9993	1025	0.00115	----------	-------	--------
3200	260.86	3423.2	20.270	-.1123	1.1905	.8043	942	.00087	1.043	0.807	165.8
2800	109.79	3170.2	20.497	-.0574	1.2129	.6313	859	.00065	1.552	1.114	215.2
2400	46.322	2963.4	20.612	-.0199	1.2415	.5184	771	.00049	2.644	1.321	255.5
2000	18.659	2761.0	20.650	-.0038	1.2642	.4644	679	.00040	4.870	1.481	286.2
1600	6.537	2580.0	20.657	-.0003	1.2750	.4462	579	.00033	10.18	1.618	312.5
1200	1.787	2402.0	20.657	-.0000	1.2743	.4470	471	.00027	26.84	1.741	336.4
900	.444	2265.8	20.661	-.0043	1.2609	.4697	381	.00022	74.54	1.830	353.5
r = 2.0; O/F = 2.069; percent fuel = 32.69											
3600	935.15	4103.9	18.916	-.1291	1.1976	0.8791	1018	0.00103	----------	-------	--------
3200	431.27	3829.3	19.157	-.0860	1.2093	.7370	939	.00081	1.067	0.581	99.1
2800	195.51	3584.3	19.322	-.0445	1.2301	.6096	856	.00063	1.146	0.928	176.4
2400	86.917	3368.2	19.407	-.0157	1.2561	.5203	769	.00050	1.738	1.176	223.5
2000	36.406	3172.6	19.435	-.0030	1.2775	.4738	678	.00041	2.981	1.361	258.8
1600	13.277	2967.7	19.440	-.0008	1.2896	.4554	579	.00034	5.871	1.516	288.2
1200	3.719	2806.8	19.440	-.0001	1.2926	.4517	472	.00027	14.41	1.654	314.3
1000	1.652	2715.8	19.444	-.0046	1.2856	.4651	413	.00024	26.01	1.719	326.7
900	.999	2687.3	19.484	-.0508	1.2461	.5820	382	.00027	37.89	1.752	333.1

TABLE III. - Continued. THEORETICAL PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion or compression from chamber pressure of 600 lb/sq in. abs.]

(d) Percent fluorine in oxidant by weight, 50

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(°K)}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r = 1.2; O/F = 3.892; percent fuel = 20.05											
4400	1108.3	3093.2	21.670	-.2974	1.1652	1.6035	1419	0.00230	----------	--------	--------
4000	451.54	2752.6	22.298	-.3021	1.1552	1.5255	1318	.00216	1.095	0.478	94.8
3600	187.55	2402.1	23.022	-.3036	1.1450	1.5389	1211	.00199	1.305	1.001	198.7
3200	48.190	2042.6	23.853	-.2960	1.1352	1.4974	1098	.00176	2.917	1.340	266.0
2800	10.389	1682.5	24.763	-.2571	1.1297	1.3105	981	.00138	8.902	1.610	319.5
2400	2.236	1366.7	25.533	-.1214	1.1556	.7625	865	.00074	30.62	1.814	360.0
2000	.698	1167.6	25.760	-.0100	1.2374	.4111	753	.00038	75.84	1.931	383.3
1600	.230	1013.6	25.777	-.0005	1.2608	.3730	635	.00030	176.5	2.017	400.4
r = 1.4; O/F = 3.421; percent fuel = 22.62											
4400	1130.7	3373.7	20.889	-.2830	1.1704	1.4507	1386	0.00218	----------	--------	--------
4000	478.36	3035.0	21.461	-.2828	1.1614	1.4419	1288	.00201	1.166	0.428	86.1
3600	177.21	2691.1	22.101	-.2726	1.1531	1.3850	1184	.00177	1.226	.960	193.2
3200	57.194	2360.9	22.780	-.2349	1.1497	1.2047	1077	.00142	2.447	1.286	258.7
2800	17.485	2044.7	23.369	-.1389	1.1663	.8265	969	.00090	5.773	1.520	305.9
2400	6.150	1814.8	23.665	-.0382	1.2187	.5099	862	.00053	12.61	1.675	337.0
2000	2.367	1630.8	23.742	-.0060	1.2585	.4129	752	.00039	25.55	1.784	359.0
1600	.821	1479.9	23.753	-.0004	1.2745	.3887	635	.00031	55.94	1.877	377.8
1200	.219	1386.1	23.754	-.0000	1.2800	.3884	509	.00025	150.5	1.963	395.1
r = 1.6; O/F = 2.994; percent fuel = 25.04											
4400	1256.6	3672.6	20.093	-.2566	1.1782	1.3320	1357	0.00197	----------	--------	--------
4000	565.31	3343.6	20.581	-.2457	1.1717	1.2698	1263	.00176	1.914	0.288	46.8
3600	230.22	3019.5	21.092	-.2160	1.1690	1.1308	1165	.00145	1.090	.859	174.1
3200	88.627	2717.3	21.564	-.1553	1.1771	.8926	1064	.00107	1.801	1.174	238.0
2800	34.706	2460.0	21.899	-.0784	1.2044	.6414	963	.00073	3.355	1.387	281.1
2400	14.319	2281.9	22.053	-.0259	1.2430	.4885	859	.00052	6.241	1.538	311.6
2000	5.844	2074.7	22.116	-.0049	1.2733	.4231	750	.00040	11.81	1.656	335.5
1600	2.117	1911.1	22.124	-.0003	1.2888	.4011	634	.00033	24.56	1.757	356.1
1200	.594	1752.4	22.126	-.0000	1.2956	.3937	509	.00026	62.30	1.851	374.9
r = 1.8; O/F = 2.661; percent fuel = 27.31											
4000	730.43	3679.1	19.678	-.1988	1.1871	1.0765	1243	0.00180	----------	--------	--------
3600	332.36	3360.0	20.058	-.1626	1.1897	.9327	1150	.00122	1.000	0.686	138.6
3200	146.14	3105.5	20.396	-.1117	1.2018	.7589	1055	.00093	1.329	1.028	207.6
2800	64.022	2865.6	20.617	-.0592	1.2258	.6000	957	.00069	2.154	1.252	252.9
2400	28.145	2660.7	20.738	-.0212	1.2584	.4894	854	.00058	3.691	1.416	286.1
2000	11.939	2480.0	20.779	-.0041	1.2869	.4329	747	.00041	6.630	1.546	312.3
1600	4.492	2312.3	20.786	-.0003	1.3038	.4105	632	.00034	13.14	1.658	334.8
1200	1.331	2150.5	20.786	-.0000	1.3147	.3994	509	.00026	31.36	1.759	355.2
900	.404	2031.5	20.790	-.0051	1.3174	.4014	408	.00021	74.64	1.829	369.5
r = 2.0; O/F = 2.395; percent fuel = 29.46											
4000	1002.5	4087.6	18.811	-.1603	1.2040	0.9421	1229	0.00132	----------	--------	--------
3600	493.83	3745.7	19.101	-.1299	1.2079	.8338	1139	.00110	1.235	0.403	80.3
3200	234.31	3463.9	19.352	-.0907	1.2190	.7094	1047	.00088	1.073	.867	171.0
2800	108.88	3248.9	19.531	-.0493	1.2407	.5874	950	.00068	1.535	1.117	222.9
2400	49.836	3042.9	19.637	-.0179	1.2711	.4941	849	.00053	2.453	1.303	260.0
2000	21.790	2859.0	19.660	-.0035	1.2991	.4424	743	.00042	4.197	1.449	289.1
1600	8.468	2667.7	19.666	-.0002	1.3165	.4186	630	.00034	7.956	1.573	313.9
1200	2.638	2523.6	19.667	-.0002	1.3360	.4020	509	.00027	17.90	1.683	336.8
1000	1.291	2443.6	19.676	-.0092	1.3343	.4119	443	.00024	29.81	1.734	346.1
900	.587	2370.1	20.025	-.3155	1.1370	1.7596	412	.00078	56.05	1.780	355.2

TABLE III. - Continued. THEORETICAL PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion or compression from chamber pressure of 600 lb/sq in. abs.]

(e) Percent fluorine in oxidant by weight, 70.37

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, ξ, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(^oK)}$	Coefficient of viscosity, μ, micropoises	Coefficient of thermal conductivity, k, cal/(sec)(cm)(°K)	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r = 1.0; O/F = 5.743; percent fuel = 14.83											
4400	1179.7	2848.0	21.838	-.2021	1.1996	0.9105	1590	0.00163	--------	--------	--------
4000	592.07	2587.2	22.248	-.1893	1.1961	.8684	1474	.00144	4.015	0.106	20.3
3600	274.15	2328.7	22.683	-.1785	1.1903	.8418	1351	.00129	1.029	.785	151.4
3200	114.500	2071.5	23.142	-.1585	1.1858	.7944	1224	.00110	1.527	1.104	212.8
3000	71.518	1946.8	23.365	-.1362	1.1892	.7322	1160	.00097	2.039	1.229	236.9
2800	44.430	1829.9	23.563	-.1128	1.2000	.6573	1095	.00084	2.794	1.336	257.5
2600	26.212	1710.6	23.823	-.2283	1.1729	1.0050	1025	.00114	4.045	1.436	276.9
2400	11.395	1539.6	24.487	-.4313	1.1331	2.3226	936	.00227	7.648	1.570	302.6
2200	3.537	1326.1	25.523	-.5057	1.1160	3.3806	840	.00287	19.755	1.721	331.9
2000	.819	1093.1	26.815	-.5244	1.1046	3.6467	746	.00279	67.815	1.873	361.1
1800	.141	852.2	28.321	-.5068	1.0961	3.3413	658	.00226	312.080	2.018	389.1
1600	.018	616.6	29.954	-.4332	1.0922	2.4256	578	.00145	1880.5	2.150	414.6
1400	.002	417.1	31.378	-.2416	1.1067	1.1511	507	.00062	11620.	2.256	435.0
900	.000	198.6	32.013	-.0000	1.2463	.3142	357	.00014	138020	2.367	456.3
r = 1.4; O/F = 4.102; percent fuel = 19.60											
4800	1126.6	3341.1	20.775	-.2856	1.1757	1.3763	1653	0.00247	--------	--------	--------
4400	528.97	3012.7	21.284	-.2683	1.1697	1.2888	1559	.00219	1.432	0.321	67.4
4000	230.67	2691.3	21.804	-.2357	1.1674	1.1434	1459	.00183	1.090	.858	180.3
3600	95.692	2390.1	22.292	-.1812	1.1737	.9283	1350	.00140	1.720	1.154	242.3
3200	40.662	2132.7	22.660	-.0929	1.2058	.6357	1233	.00092	3.012	1.356	284.8
3000	27.800	2029.5	22.761	-.0460	1.2396	.5011	1172	.00071	3.901	1.429	300.2
2800	19.653	1941.7	22.806	-.0162	1.2744	.4195	1110	.00059	4.936	1.489	312.6
2600	14.036	1862.6	22.883	-.0065	1.2934	.3896	1047	.00052	6.198	1.540	323.4
2400	9.557	1779.2	22.876	-.0905	1.2273	.5804	980	.00068	8.106	1.593	334.5
2200	4.791	1642.8	23.266	-.2538	1.1564	1.1737	897	.00115	13.858	1.675	351.8
2000	1.987	1486.8	23.801	-.1992	1.1607	.9633	811	.00087	28.184	1.764	370.6
1800	.919	1365.0	24.131	-.0671	1.2176	.5357	735	.00047	52.145	1.831	384.6
1600	.506	1281.6	24.215	-.0078	1.2884	.3729	668	.00032	81.850	1.876	393.9
1400	.285	1210.8	24.223	-.0004	1.3119	.3454	600	.00027	124.91	1.913	401.7
1200	.150	1142.7	24.223	-.0000	1.3235	.3356	531	.00023	199.24	1.947	409.0
r = 1.5; O/F = 3.829; percent fuel = 20.71											
4800	1101.8	3445.0	20.544	-.2878	1.1734	1.4230	1636	0.00253	--------	--------	--------
4400	512.05	3108.4	21.053	-.2721	1.1675	1.3349	1544	.00224	1.313	0.359	76.1
4000	220.29	2778.3	21.576	-.2403	1.1646	1.1868	1446	.00188	1.110	.877	185.8
3600	89.635	2467.3	22.070	-.1866	1.1690	.9722	1340	.00145	1.796	1.172	248.1
3200	36.424	2194.0	22.464	-.1130	1.1889	.7209	1227	.00102	3.279	1.380	292.2
3000	23.768	2077.3	22.600	-.0742	1.2088	.6012	1168	.00083	4.426	1.459	309.1
2800	15.923	1975.3	22.687	-.0402	1.2378	.4985	1107	.00067	5.876	1.526	323.1
2600	10.864	1885.0	22.741	-.0311	1.2551	.4611	1043	.00060	7.693	1.582	335.0
2400	7.140	1793.5	22.814	-.0440	1.2437	.4907	976	.00058	10.409	1.637	346.7
2200	4.570	1704.3	22.884	-.0238	1.2662	.4354	907	.00049	14.405	1.689	357.7
2000	2.943	1624.1	22.915	-.0071	1.2956	.3860	839	.00041	19.775	1.735	367.4
1800	1.874	1549.7	22.923	-.0013	1.3138	.3640	771	.00036	27.298	1.776	376.1
1600	1.152	1478.1	22.925	-.0001	1.3248	.3537	701	.00032	38.626	1.814	384.3
1200	.366	1339.9	22.926	-.0006	1.3455	.3381	556	.00025	87.599	1.887	399.6
r = 1.6; O/F = 3.589; percent fuel = 21.79											
4400	604.93	3285.5	20.965	-.2703	1.1670	1.3538	1497	0.00220	--------	--------	--------
4000	260.94	2955.0	21.479	-.2343	1.1654	1.1806	1396	.00181	1.046	0.804	168.7
3600	99.836	2621.5	21.948	-.1776	1.1521	1.0671	1329	.00157	1.695	1.143	239.7
3200	38.634	2331.5	22.323	-.1087	1.1827	.7427	1242	.00106	3.191	1.371	287.6
2800	16.680	2108.0	22.544	-.0448	1.2321	.5178	1126	.00071	5.761	1.524	319.6
2400	7.650	1929.8	22.636	-.0135	1.2745	.4201	997	.00053	9.998	1.635	343.0
2000	3.375	1772.1	22.663	-.0025	1.3013	.3807	862	.00042	17.841	1.728	362.5
1600	1.318	1624.1	22.668	-.0002	1.3206	.3612	780	.00034	34.879	1.811	379.8
1200	.414	1483.0	22.669	-.0007	1.3412	.3451	569	.00026	79.838	1.886	395.7
900	.124	1373.8	22.773	-.0759	1.2423	.5296	450	.00029	192.75	1.943	407.5
r = 2.5; O/F = 2.297; percent fuel = 30.33											
4000	737.24	4208.2	20.326	-.1657	1.1677	1.0699	1563	0.00186	--------	--------	--------
3600	326.65	3908.2	20.651	-.1342	1.1816	.8848	1459	.00147	1.001	0.694	138.6
3200	142.10	3637.8	20.935	-.0972	1.1936	.7432	1335	.00115	1.353	1.036	206.7
2800	60.257	3394.9	21.150	-.0565	1.2102	.6181	1204	.00089	2.260	1.267	252.7
2400	24.973	3180.5	21.273	-.0222	1.2346	.5171	1066	.00068	4.089	1.440	287.3
2000	9.863	2990.1	21.318	-.0047	1.2598	.4568	923	.00053	7.856	1.578	314.8
1600	3.446	2814.2	21.327	-.0005	1.2789	.4277	772	.00042	16.734	1.695	338.2
1200	.952	2647.4	21.331	-.0020	1.2970	.4087	612	.00032	42.778	1.799	359.0
900	.240	2514.9	21.494	-.1082	1.2030	.7018	485	.00040	121.00	1.878	374.7

TABLE III. - Concluded. THEORETICAL PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion or compression from chamber pressure of 600 lb/sq in. abs]

(f) Percent fluorine in oxidant, 100 (zero percent oxygen)

Temperature, T, $^{\circ}K$	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(^{\circ}K)}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r = 1.0; O/F = 8.083; percent fuel = 11.01											
4000	667.83	2652.2	27.300	-0.4336	1.1478	2.8700	1112	0.00329	-------	-----	-----
3600	191.08	2314.8	28.641	-.4747	1.1322	3.5019	984	.00353	1.191	0.931	163.3
3200	38.944	1951.1	30.352	-.5089	1.1172	4.0707	861	.00358	3.314	1.376	241.5
2800	4.978	1561.9	32.546	-.5337	1.1030	4.4031	744	.00333	16.828	1.730	303.6
2400	.330	1150.0	35.369	-.5410	1.0896	4.2218	634	.00272	169.76	2.039	357.8
r = 1.5; O/F = 5.389; percent fuel = 15.65											
4400	1384.1	3325.4	26.007	-0.2292	1.1679	1.1023	1246	0.00149	-------	-----	-----
4000	588.28	3054.5	26.647	-.2857	1.1562	1.3832	1139	.00168	3.275	0.127	22.6
3600	199.28	2753.4	27.567	-.3562	1.1397	1.8716	1022	.00200	1.165	.915	163.4
3400	103.33	2589.6	28.159	-.3848	1.1316	2.1169	962	.00212	1.677	1.134	202.4
3200	48.924	2417.6	28.843	-.4058	1.1240	2.3050	901	.00216	2.786	1.325	236.5
2800	7.932	2052.9	30.479	-.3529	1.0879	3.0138	786	.00243	11.366	1.658	296.1
2400	.527	1607.5	32.330	-.4055	1.0845	3.0752	740	.00233	115.02	1.992	355.6
2200	.110	1390.4	33.499	-.4053	1.0857	2.5735	695	.00184	453.39	2.135	381.2
r = 2.0; O/F = 4.041; percent fuel = 19.84											
4400	970.85	3612.2	26.264	-0.1341	1.1155	1.3451	1229	0.00177	-------	-----	-----
4000	364.23	3502.4	26.583	-.1179	1.1322	1.0463	1222	.00139	1.002	0.625	115.6
3600	142.62	3037.5	26.900	-.1140	1.1521	.8579	1163	.00111	1.379	1.032	190.8
3200	49.681	2775.5	27.358	-.1910	1.1320	1.1697	1075	.00136	2.713	1.315	243.3
2800	9.375	2420.0	28.321	-.3149	1.1001	2.1262	1009	.00223	9.850	1.623	300.2
2400	.881	2000.6	29.846	-.3452	1.0948	2.0980	924	.00202	71.894	1.924	355.9
2000	.068	1634.7	31.452	-.1936	1.1141	.9891	785	.00084	658.56	2.152	398.1
r = 2.8; O/F = 2.887; percent fuel = 25.73											
4400	892.71	4152.0	24.584	-0.1717	1.1029	1.7445	1832	0.00338	-------	-----	-----
4000	276.77	3757.8	25.005	-.1802	1.1097	1.4949	1965	.00313	1.037	0.769	149.1
3600	83.794	3400.2	25.461	-.1568	1.1221	1.1543	2006	.00251	1.955	1.191	231.0
3200	27.080	3102.4	25.850	-.0983	1.1483	.7888	1906	.00169	4.345	1.452	281.5
3000	16.130	2979.3	25.994	-.0788	1.1637	.6800	1805	.00140	6.382	1.547	300.0
2800	9.480	2861.8	26.149	-.1021	1.1593	.7298	1685	.00139	9.548	1.633	316.5
2400	2.241	2581.3	26.757	-.1596	1.1333	.9382	1437	.00148	30.344	1.821	353.0
2200	1.000	2444.2	27.069	-.1019	1.1484	.7233	1313	.00107	58.873	1.906	369.5
2000	.482	2331.9	27.245	-.0394	1.1779	.5285	1194	.00074	106.56	1.973	382.5
r = 3.0; O/F = 2.694; percent fuel = 27.07											
4400	930.95	4295.2	24.253	-0.1762	1.1026	1.7742	1988	0.00373	-------	-----	-----
4000	284.94	3891.4	24.687	-.1922	1.1088	1.5507	2150	.00355	1.029	0.755	147.1
3600	82.906	3517.5	25.184	-.1814	1.1177	1.2603	2207	.00300	1.972	1.195	232.7
3200	24.019	3188.2	25.666	-.1350	1.1319	.9403	2120	.00220	4:802	1.477	287.8
2800	7.505	2919.6	26.004	-.0612	1.1610	.6397	1915	.00141	11.721	1.673	325.9
2400	2.537	2705.1	26.188	-.0568	1.1731	.5897	1643	.00112	27.218	1.814	353.4
2000	.722	2496.4	26.403	-.0192	1.1961	.4797	1359	.00078	73.825	1.941	378.2
1600	.200	2323.1	26.438	-.0006	1.2231	.4125	1092	.00055	202.29	2.041	397.6
r = 3.5; O/F = 2.309; percent fuel = 30.22											
4400	1136.2	4667.8	23.531	-0.1742	1.1066	1.6970	2327	0.00419	-------	-----	-----
4000	368.22	4271.6	23.945	-.1867	1.1164	1.4333	2477	.00381	1.003	0.616	120.3
3600	118.58	3917.5	24.400	-.1647	1.1306	1.1139	2443	.00297	1.554	1.090	212.8
3200	39.451	3615.2	24.810	-.1172	1.1481	.8400	2247	.00211	3.248	1.371	267.5
3000	23.015	3481.8	24.978	-.0925	1.1567	.7408	2120	.00178	4.810	1.478	288.4
2600	7.822	3242.7	25.226	-.0484	1.1739	.5975	1849	.00129	10.862	1.652	322.5
2400	4.518	3134.8	25.305	-.0302	1.1834	.5442	1710	.00110	16.572	1.725	336.7
2000	1.440	2937.8	25.382	-.0072	1.2030	.4715	1432	.00082	40.271	1.851	361.3
1600	.400	2757.9	25.398	-.0006	1.2194	.4355	1152	.00061	109.50	1.959	382.3
r = 4.0; O/F = 2.021; percent fuel = 33.10											
4400	1514.7	5047.2	22.937	-0.1618	1.1143	1.5299	2569	0.00421	-------	-----	-----
4000	540.22	4674.9	23.302	-.1652	1.1278	1.2577	2639	.00360	1.525	0.290	56.0
3600	194.12	4345.9	23.688	-.1435	1.1420	1.0090	2513	.00280	1.180	.923	178.2
3200	69.302	4054.4	24.044	-.1097	1.1533	.8294	2276	.00212	2.159	1.238	239.0
2800	23.916	3792.3	24.335	-.0703	1.1640	.6901	2009	.00159	4.572	1.464	282.7
2400	7.911	3558.5	24.522	-.0317	1.1798	.5738	1732	.00117	10.497	1.640	316.7
2000	2.464	3351.2	24.601	-.0077	1.1985	.4964	1453	.00087	25.774	1.782	344.0
1600	.668	3162.0	24.618	-.0007	1.2146	.4576	1171	.00065	71.199	1.901	367.1
r = 5.0; O/F = 1.617; percent fuel = 38.22											
4000	1179.3	5425.3	22.309	-0.1325	1.1414	1.0848	2778	0.00332	-------	-----	-----
3600	464.89	5112.4	22.607	-.1174	1.1499	.9417	2576	.00271	1.126	0.452	84.5
3200	174.19	4821.1	22.889	-.0923	1.1558	.8235	2323	.00216	1.236	.965	180.3
2800	61.261	4550.5	23.122	-.0593	1.1636	.7092	2050	.00167	2.319	1.267	236.7
2400	20.260	4304.3	23.272	-.0265	1.1768	.6056	1772	.00126	5.079	1.490	278.3
2000	6.192	4082.3	23.335	-.0065	1.1929	.5344	1491	.00096	12.357	1.666	311.1
1600	1.622	3877.6	23.349	-.0006	1.2074	.4961	1206	.00073	34.657	1.812	338.5
1200	.320	3685.1	23.350	-.0001	1.2236	.4658	917	.00052	123.18	1.940	362.4

TABLE IV. - THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 8 FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion from chamber pressure of 600 lb/sq in. abs.]

(a) Percent fluorine in oxidant, 0 (100 percent oxygen)

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Temperature exponent, n_T, $\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{P_c/P}$	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, cal/(g)(°K)	Area ratio, ε	Area-ratio exponent, n_ε, $\left(\frac{\partial \ln \varepsilon}{\partial \ln P_c}\right)_{P_c/P}$	Thrust coefficient, C_F	Specific-impulse exponent, n_I, $\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{P_c/P}$	Specific impulse, I, lb-sec/lb
r = 1.0; O/F = 3.403; percent fuel = 22.71													
1.000	600.00	3612	0.0426	2531.6	25.48	-.333	1.128	1.845	--------	--------	--------	--------	--------
1.020	588.24	3606	.0425	2526.0	25.50	-.334	1.127	1.846	3.242	0.0013	0.126	0.0141	22.0
1.040	576.92	3600	.0424	2520.5	25.51	-.333	1.127	1.847	2.345	.0013	.177	.0141	31.0
1.200	500.00	3557	.0418	2480.7	25.62	-.335	1.126	1.855	1.240	.0009	.381	.0140	66.5
1.437	417.60	3504	.0410	2431.5	25.74	-.336	1.124	1.863	1.037	.0004	.534	.0138	93.3
[a]1.724	348.00	3452	.0402	2382.7	25.87	-.336	1.123	1.871	1.000	.0000	.651	.0136	113.8
2.155	278.40	3390	.0393	2324.3	26.03	-.339	1.121	1.879	1.034	-.0006	.769	.0135	134.3
4.000	150.00	3228	.0367	2169.4	26.47	-.339	1.117	1.890	1.359	-.0021	1.016	.0129	177.5
8.000	75.00	3061	.0339	2007.3	26.95	-.340	1.112	1.886	2.105	-.0039	1.222	.0124	213.6
r = 1.2; O/F = 2.836; percent fuel = 26.07													
1.000	600.00	3628	0.0422	2901.1	24.03	-.320	1.131	1.818	--------	--------	--------	--------	--------
1.020	588.24	3622	.0421	2895.2	24.05	-.321	1.131	1.818	3.245	0.0016	0.126	0.0140	22.7
1.040	576.92	3616	.0420	2889.4	24.06	-.320	1.131	1.819	2.347	.0015	.177	.0140	32.0
1.200	500.00	3571	.0413	2847.0	24.16	-.321	1.129	1.820	1.241	.0009	.381	.0139	68.6
1.439	417.07	3516	.0404	2794.3	24.28	-.321	1.128	1.819	1.037	.0006	.535	.0137	96.4
[a]1.726	347.56	3461	.0395	2742.4	24.40	-.321	1.126	1.817	1.000	-.0001	.653	.0135	117.5
2.158	278.05	3397	.0384	2680.2	24.55	-.320	1.125	1.810	1.034	-.0007	.770	.0133	138.6
4.000	150.00	3227	.0354	2516.2	24.95	-.316	1.121	1.775	1.357	-.0024	1.016	.0127	183.0
8.000	75.00	3051	.0314	2344.5	25.39	-.305	1.117	1.696	2.096	-.0046	1.222	.0121	220.1
r = 1.3; O/F = 2.618; percent fuel = 27.64													
1.000	600.00	3612	0.0408	3074.1	23.36	-.302	1.134	1.700	--------	--------	--------	--------	--------
1.020	588.24	3605	.0407	3068.1	23.37	-.301	1.134	1.699	3.249	0.0018	0.126	0.0136	23.0
1.040	576.92	3599	.0406	3062.1	23.38	-.300	1.134	1.698	2.350	.0017	.178	.0136	32.3
1.200	500.00	3553	.0397	3018.7	23.47	-.300	1.133	1.688	1.242	.0012	.381	.0135	69.8
1.441	416.51	3495	.0386	2964.3	23.59	-.298	1.131	1.674	1.037	.0005	.537	.0133	97.7
[a]1.729	347.09	3439	.0375	2911.2	23.70	-.296	1.130	1.656	1.000	-.0000	.654	.0131	119.1
2.161	277.68	3371	.0362	2847.7	23.84	-.291	1.129	1.630	1.033	-.0007	.771	.0128	140.4
4.000	150.00	3193	.0324	2680.5	24.21	-.276	1.126	1.532	1.353	-.0031	1.016	.0122	185.1
8.000	75.00	3003	.0269	2505.7	24.60	-.244	1.125	1.359	2.085	-.0063	1.221	.0114	222.4
r = 1.4; O/F = 2.431; percent fuel = 29.15													
1.000	600.00	3576	0.0382	3239.9	22.70	-.271	1.139	1.520	--------	--------	--------	--------	--------
1.020	588.24	3569	.0381	3233.7	22.71	-.270	1.139	1.518	3.254	0.0020	0.127	0.0129	23.2
1.040	576.92	3563	.0380	3227.7	22.72	-.271	1.138	1.515	2.353	.0019	.178	.0129	32.7
1.200	500.00	3514	.0370	3183.5	22.80	-.268	1.138	1.497	1.243	.0015	.382	.0127	70.1
1.444	415.57	3453	.0356	3127.4	22.91	-.264	1.137	1.468	1.036	.0008	.539	.0125	98.9
[a]1.733	346.31	3393	.0343	3073.4	23.01	-.258	1.136	1.433	1.000	-.0000	.656	.0122	120.4
2.166	277.05	3321	.0326	3008.9	23.13	-.248	1.136	1.383	1.033	-.0009	.773	.0119	141.8
4.000	150.00	3128	.0274	2840.2	23.45	-.212	1.137	1.216	1.348	-.0043	1.016	.0111	186.5
8.000	75.00	2913	.0200	2664.0	23.77	-.161	1.143	.999	2.064	-.0088	1.220	.0100	223.9
r = 1.6; O/F = 2.127; percent fuel = 31.98													
1.000	600.00	3436	0.0290	3551.6	21.41	-.180	1.156	1.089	--------	--------	--------	--------	--------
1.020	588.24	3428	.0288	3545.3	21.42	-.179	1.156	1.084	3.275	0.0033	0.127	0.0102	23.4
1.040	576.92	3420	.0286	3539.2	21.42	-.179	1.156	1.079	2.368	.0033	.179	.0102	32.9
1.200	500.00	3364	.0271	3494.2	21.49	-.169	1.157	1.044	1.249	.0024	.384	.0099	70.7
1.457	411.91	3288	.0252	3434.7	21.57	-.157	1.159	.996	1.035	.0012	.548	.0096	100.9
[a]1.748	343.87	3217	.0233	3380.1	21.64	-.144	1.161	.950	1.000	.0001	.664	.0092	122.2
2.185	274.61	3130	.0210	3315.2	21.72	-.128	1.164	.894	1.032	-.0015	.780	.0088	143.4
4.000	150.00	2898	.0135	3149.3	21.90	-.086	1.175	.750	1.327	-.0058	1.017	.0075	187.1
8.000	75.00	2615	.0051	2976.7	22.04	-.045	1.192	.622	1.994	-.0106	1.216	.0061	223.7
r = 1.8; O/F = 1.891; percent fuel = 34.59													
1.000	600.00	3205	0.0187	3839.4	20.17	-.095	1.184	0.798	--------	--------	--------	--------	--------
1.020	588.24	3196	.0185	3833.1	20.17	-.093	1.185	.794	3.307	0.0036	0.129	0.0067	23.3
1.040	576.92	3187	.0183	3827.0	20.18	-.093	1.185	.790	2.390	.0035	.181	.0067	32.8
1.200	500.00	3122	.0167	3782.6	20.21	-.083	1.188	.763	1.258	.0025	.388	.0063	70.3
1.475	406.86	3028	.0144	3720.4	20.26	-.072	1.192	.726	1.033	.0011	.561	.0059	101.8
[a]1.770	339.05	2946	.0124	3667.0	20.30	-.062	1.196	.695	1.000	-.0000	.676	.0055	122.5
2.212	271.24	2845	.0098	3603.8	20.34	-.052	1.201	.660	1.031	-.0013	.790	.0051	143.2
4.000	150.00	2578	.0042	3447.3	20.42	-.028	1.215	.588	1.304	-.0044	1.019	.0040	184.7
8.000	75.00	2277	-.0004	3283.8	20.46	-.010	1.231	.530	1.931	-.0062	1.213	.0029	219.9
r = 3.0; O/F = 1.134; percent fuel = 46.85													
1.000	600.00	1657	0.0264	5188.4	15.49	-.060	1.285	0.701	--------	--------	--------	--------	--------
1.020	588.24	1650	.0267	5184.2	15.50	-.061	1.285	.705	3.381	-.0053	0.132	0.0064	19.1
1.040	576.92	1644	.0271	5180.1	15.50	-.063	1.284	.709	2.442	-.0049	.185	.0064	26.9
1.200	500.00	1596	.0295	5150.4	15.53	-.075	1.278	.741	1.276	-.0036	.396	.0068	57.5
1.504	399.00	1526	.0334	5105.4	15.59	-.096	1.267	.807	1.031	-.0016	.585	.0074	85.0
[a]1.805	332.50	1475	.0365	5070.6	15.65	-.115	1.257	.874	1.000	-.0001	.697	.0079	101.2
2.256	266.00	1418	.0397	5029.7	15.72	-.141	1.243	.973	1.030	.0017	.809	.0085	117.5
4.000	150.00	1296	.0475	4932.4	15.97	-.210	1.210	1.341	1.294	.0045	1.027	.0095	149.2
8.000	75.00	1187	.0478	4826.7	16.33	-.290	1.173	1.923	1.950	.0047	1.221	.0108	177.4

[a]At throat.

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TABLE IV. - Concluded. THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 8 FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion from chamber pressure of 600 lb/sq in. abs.]

(b) Percent fluorine in oxidant by weight, 70.37

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Temperature exponent, n_T, $\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, ξ, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Area ratio, ϵ	Area-ratio exponent, n_ϵ, $\left(\frac{\partial \ln \epsilon}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Thrust coefficient, C_F	Specific-impulse exponent, n_I, $\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Specific impulse, I, $\frac{\text{lb-sec}}{\text{lb}}$
r = 1.0; O/F = 5.743; percent fuel = 14.83													
1.000	600.00	4007	0.0351	2592.0	22.24	-.189	1.196	0.869	------	------	------	------	------
1.020	588.24	3996	.0349	2584.9	22.25	-.189	1.196	.868	3.310	0.0024	0.129	0.0130	24.8
1.040	576.92	3986	.0348	2578.0	22.26	-.190	1.196	.867	2.392	.0025	.181	.0130	34.9
1.200	500.00	3908	.0337	2527.6	22.35	-.187	1.195	.862	1.258	.0017	.388	.0128	74.8
1.472	407.61	3800	.0323	2457.8	22.46	-.184	1.193	.855	1.034	.0008	.560	.0125	108.0
[a]1.766	339.67	3706	.0310	2397.4	22.56	-.182	1.192	.849	1.000	.0001	.675	.0122	130.1
2.208	271.73	3596	.0295	2325.9	22.69	-.179	1.190	.842	1.031	-.0009	.789	.0119	152.2
4.000	150.00	3319	.0249	2147.3	23.01	-.167	1.186	.816	1.315	-.0038	1.020	.0111	196.7
8.000	75.00	3020	.0185	1959.0	23.34	-.138	1.189	.739	1.978	-.0082	1.217	.0101	234.7
r = 1.4; O/F = 4.102; percent fuel = 19.60													
1.000	600.00	4464	0.0428	3064.9	21.20	-.272	1.171	1.306	------	------	------	------	------
1.020	588.24	4454	.0426	3056.6	21.21	-.271	1.170	1.304	3.285	0.0029	0.128	0.0155	26.8
1.040	576.92	4444	.0424	3048.5	21.23	-.270	1.170	1.301	2.375	.0027	.180	.0155	37.7
1.200	500.00	4372	.0412	2989.6	21.32	-.267	1.169	1.281	1.251	.0021	.385	.0152	80.9
1.460	411.02	4275	.0394	2910.9	21.45	-.261	1.168	1.250	1.035	.0011	.551	.0149	115.8
[a]1.752	342.50	4187	.0377	2839.6	21.56	-.252	1.168	1.219	1.000	-.0000	.667	.0146	140.0
2.190	274.01	4080	.0357	2754.9	21.70	-.244	1.167	1.178	1.032	-.0013	.782	.0142	164.2
4.000	150.00	3803	.0293	2539.2	22.05	-.212	1.168	1.047	1.328	-.0052	1.018	.0131	213.9
8.000	75.00	3490	.0203	2313.3	22.41	-.159	1.178	.850	2.005	-.0111	1.218	.0118	255.7
r = 1.5; O/F = 3.829; percent fuel = 20.71													
1.000	600.00	4479	0.0431	3175.0	20.95	-.276	1.169	1.357	------	------	------	------	------
1.020	588.24	4469	.0429	3166.6	20.96	-.275	1.168	1.354	3.283	0.0027	0.128	0.0156	27.0
1.040	576.92	4460	.0427	3158.4	20.98	-.276	1.168	1.352	2.374	.0029	.180	.0155	38.0
1.200	500.00	4388	.0415	3098.5	21.07	-.271	1.167	1.331	1.251	.0019	.385	.0153	81.6
1.459	411.36	4293	.0398	3018.9	21.19	-.265	1.166	1.302	1.035	.0009	.550	.0150	116.6
[a]1.750	342.80	4205	.0381	2946.4	21.31	-.258	1.165	1.271	1.000	-.0002	.666	.0147	141.0
2.188	274.24	4101	.0361	2860.3	21.44	-.251	1.165	1.230	1.032	-.0012	.781	.0143	165.5
4.000	150.00	3827	.0300	2640.5	21.80	-.219	1.165	1.101	1.329	-.0051	1.018	.0132	215.7
8.000	75.00	3522	.0219	2410.3	22.16	-.173	1.171	.984	2.012	-.0102	1.218	.0119	258.0
r = 1.6; O/F = 3.589; percent fuel = 21.79													
1.000	600.00	4396	0.0426	3282.1	20.97	-.270	1.167	1.351	------	------	------	------	------
1.020	588.24	4386	.0426	3273.8	20.98	-.270	1.168	1.344	3.282	0.0027	0.128	0.0152	26.8
1.040	576.92	4377	.0425	3265.8	21.00	-.269	1.168	1.338	2.373	.0027	.180	.0151	37.7
1.200	500.00	4307	.0417	3207.1	21.09	-.263	1.170	1.297	1.251	.0021	.385	.0149	80.8
1.459	411.39	4213	.0401	3129.0	21.21	-.256	1.170	1.251	1.035	.0012	.550	.0145	115.4
[a]1.750	342.81	4127	.0381	3057.9	21.32	-.248	1.169	1.218	1.000	-.0000	.666	.0142	139.6
2.188	274.26	4023	.0354	2973.4	21.45	-.236	1.166	1.187	1.032	-.0018	.781	.0138	163.9
4.000	150.00	3764	.0276	2757.7	21.77	-.204	1.156	1.123	1.335	-.0064	1.018	.0124	213.6
8.000	75.00	3483	.0206	2530.0	22.07	-.158	1.158	.978	2.034	-.0111	1.220	.0109	255.8
r = 2.5; O/F = 2.297; percent fuel = 30.33													
1.000	600.00	3898	0.0308	4128.8	20.41	-.159	1.172	1.017	------	------	------	------	------
1.020	588.24	3889	.0307	4121.3	20.42	-.158	1.172	1.012	3.294	0.0024	0.128	0.0100	25.6
1.040	576.92	3879	.0305	4114.0	20.43	-.158	1.172	1.008	2.381	.0023	.180	.0100	35.9
1.200	500.00	3809	.0294	4060.6	20.49	-.151	1.175	.974	1.254	.0016	.386	.0098	77.1
1.467	408.97	3710	.0276	3987.4	20.56	-.144	1.178	.930	1.034	.0010	.556	.0095	110.9
[a]1.761	340.81	3621	.0258	3922.9	20.63	-.137	1.181	.893	1.000	.0001	.671	.0093	133.8
2.201	272.65	3512	.0236	3846.5	20.72	-.127	1.184	.851	1.031	-.0011	.786	.0089	156.7
4.000	150.00	3226	.0174	3654.3	20.92	-.100	1.193	.751	1.315	-.0046	1.018	.0080	203.2
8.000	75.00	2901	.0095	3453.6	21.10	-.066	1.205	.648	1.966	-.0094	1.215	.0069	242.4

[a]At throat.

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TABLE V. - THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion from chamber pressure of 600 lb/sq in. abs.]

(a) Percent fluorine in oxidant, 0 (100 percent oxygen)

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Temperature exponent, n_T, $\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{P_c/P}$	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, cal/(g)(°K)	Area ratio, ε	Area-ratio exponent, n_ε, $\left(\frac{\partial \ln \varepsilon}{\partial \ln P_c}\right)_{P_c/P}$	Thrust coefficient, C_F	Specific-impulse exponent, n_I, $\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{P_c/P}$	Specific impulse, I, lb-sec/lb
r = 1.0; O/F = 3.403; percent fuel = 22.71													
10	60.00	3010	0.0330	1957.5	27.10	-.339	1.111	1.880	2.46	-.0043	1.279	0.0122	223.5
15	40.00	2921	.0314	1869.8	27.38	-.336	1.109	1.864	3.30	-.0054	1.373	.0119	240.0
20	30.00	2861	.0303	1809.7	27.57	-.334	1.107	1.849	4.10	-.0061	1.434	.0117	250.6
30	20.00	2778	.0287	1727.7	27.84	-.329	1.105	1.821	5.60	-.0071	1.514	.0114	264.5
40	15.00	2722	.0276	1671.4	28.03	-.326	1.104	1.796	7.03	-.0078	1.566	.0112	273.6
60	10.00	2645	.0259	1594.6	28.29	-.320	1.102	1.755	9.72	-.0089	1.634	.0109	285.5
80	7.50	2592	.0247	1541.9	28.47	-.315	1.101	1.722	12.28	-.0096	1.679	.0107	293.5
100	6.00	2552	.0238	1501.9	28.61	-.310	1.101	1.693	14.74	-.0101	1.713	.0106	299.3
150	4.00	2480	.0221	1431.4	28.86	-.301	1.100	1.636	20.62	-.0112	1.771	.0103	309.4
200	3.00	2431	.0209	1382.9	29.03	-.292	1.099	1.592	26.21	-.0121	1.809	.0101	316.1
300	2.00	2363	.0190	1316.6	29.27	-.279	1.099	1.581	36.86	-.0133	1.861	.0098	325.1
400	1.50	2316	.0173	1271.1	29.43	-.269	1.098	1.465	47.01	-.0142	1.895	.0096	331.2
600	1.00	2250	.0150	1208.8	29.66	-.253	1.098	1.381	66.38	-.0157	1.942	.0093	339.3
800	.75	2203	.0133	1166.0	29.81	-.239	1.099	1.320	84.87	-.0167	1.973	.0091	344.7
1000	.60	2168	.0120	1133.6	29.93	-.230	1.099	1.270	102.75	-.0176	1.996	.0090	348.8
1500	.40	2103	.0095	1076.3	30.13	-.209	1.101	1.178	145.56	-.0193	2.037	.0087	355.8
r = 1.2; O/F = 2.836; percent fuel = 26.07													
10	60.00	2996	0.0301	2291.8	25.53	-.300	1.116	1.661	2.45	-.0053	1.278	0.0119	230.5
15	40.00	2900	.0279	2199.2	25.77	-.288	1.115	1.585	3.28	-.0067	1.372	.0115	247.1
20	30.00	2834	.0264	2135.8	25.94	-.275	1.115	1.521	4.06	-.0079	1.433	.0113	258.1
30	20.00	2742	.0237	2049.6	26.17	-.251	1.115	1.400	5.54	-.0099	1.511	.0109	272.2
40	15.00	2677	.0213	1990.6	26.33	-.230	1.117	1.298	6.94	-.0116	1.563	.0106	281.5
60	10.00	2586	.0175	1910.4	26.53	-.197	1.120	1.148	9.56	-.0143	1.630	.0102	293.6
80	7.50	2520	.0143	1855.5	26.67	-.172	1.124	1.040	12.03	-.0164	1.675	.0098	301.6
100	6.00	2467	.0114	1814.2	26.76	-.153	1.127	.957	14.39	-.0182	1.707	.0096	307.5
150	4.00	2367	.0064	1741.6	26.91	-.116	1.137	.816	19.93	-.0218	1.763	.0090	317.6
200	3.00	2291	.0040	1692.2	26.99	-.089	1.147	.728	25.12	-.0250	1.801	.0086	324.3
300	2.00	2177	-.0019	1625.6	27.08	-.055	1.162	.618	34.74	-.0298	1.850	.0079	333.2
400	1.50	2093	-.0081	1580.5	27.12	-.034	1.172	.551	43.70	-.0333	1.882	.0075	339.0
600	1.00	1971	-.0180	1520.2	27.16	-.013	1.184	.482	60.29	-.0372	1.924	.0068	346.6
800	.75	1884	-.0223	1479.6	27.17	-.007	1.189	.458	75.72	-.0383	1.953	.0063	351.7
1000	.60	1818	-.0241	1449.4	27.18	-.003	1.193	.447	90.36	-.0391	1.973	.0060	355.4
1500	.40	1702	-.0242	1397.3	27.18	-.001	1.197	.439	124.62	-.0391	2.008	.0054	361.7
r = 1.3; O/F = 2.618; percent fuel = 27.64													
10	60.00	2943	0.0251	2452.3	24.72	-.231	1.126	1.295	2.43	-.0078	1.277	0.0111	232.6
15	40.00	2835	.0216	2358.5	24.92	-.205	1.128	1.169	3.25	-.0095	1.370	.0106	249.5
20	30.00	2757	.0194	2294.5	25.06	-.179	1.132	1.070	4.01	-.0116	1.430	.0102	260.5
30	20.00	2646	.0156	2207.9	25.23	-.139	1.140	.924	5.44	-.0151	1.508	.0096	274.5
40	15.00	2564	.0117	2149.0	25.33	-.112	1.147	.824	6.78	-.0178	1.558	.0092	283.7
60	10.00	2443	.0037	2069.5	25.45	-.077	1.157	.694	9.25	-.0220	1.624	.0085	295.7
80	7.50	2353	-.0019	2015.7	25.51	-.056	1.165	.624	11.55	-.0246	1.666	.0080	303.5
100	6.00	2288	-.0050	1975.4	25.54	-.043	1.172	.584	13.71	-.0266	1.698	.0076	309.2
150	4.00	2148	-.0098	1905.6	25.59	-.024	1.184	.526	18.75	-.0295	1.751	.0068	318.9
200	3.00	2054	-.0124	1858.7	25.61	-.014	1.192	.497	23.42	-.0312	1.786	.0063	325.2
300	2.00	1923	-.0157	1796.2	25.63	-.006	1.200	.470	32.05	-.0327	1.831	.0057	333.5
400	1.50	1833	-.0173	1754.3	25.63	-.003	1.203	.459	40.07	-.0329	1.861	.0052	338.9
600	1.00	1711	-.0177	1698.6	25.64	-.001	1.206	.452	54.96	-.0331	1.900	.0047	346.0
800	.75	1629	-.0170	1661.4	25.64	-.001	1.207	.451	68.83	-.0329	1.925	.0044	350.6
1000	.60	1568	-.0168	1633.8	25.64	-.001	1.208	.451	82.00	-.0327	1.944	.0041	354.0
1500	.40	1462	-.0172	1586.2	25.64	-.000	1.208	.449	112.86	-.0324	1.976	.0037	359.8
r = 1.4; O/F = 2.431; percent fuel = 29.15													
10	60.00	2843	0.0172	2610.4	23.86	-.143	1.146	0.929	2.40	-.0105	1.275	0.0097	234.0
15	40.00	2713	.0126	2516.9	24.00	-.109	1.155	.809	3.18	-.0138	1.367	.0089	250.8
20	30.00	2618	.0091	2453.5	24.08	-.085	1.162	.731	3.91	-.0164	1.426	.0084	261.6
30	20.00	2479	.0027	2368.4	24.17	-.055	1.174	.635	5.26	-.0199	1.501	.0076	275.4
40	15.00	2378	-.0023	2311.0	24.22	-.038	1.182	.580	6.51	-.0224	1.549	.0071	284.3
60	10.00	2234	-.0070	2234.3	24.26	-.022	1.193	.531	8.80	-.0247	1.612	.0063	295.8
80	7.50	2133	-.0091	2182.9	24.28	-.014	1.199	.507	10.91	-.0259	1.653	.0058	303.3
100	6.00	2055	-.0101	2144.7	24.29	-.009	1.204	.493	12.91	-.0267	1.682	.0054	308.7
150	4.00	1918	-.0118	2078.9	24.30	-.004	1.210	.475	17.54	-.0273	1.732	.0048	317.8
200	3.00	1824	-.0127	2034.9	24.31	-.002	1.212	.467	21.84	-.0274	1.765	.0044	323.8
300	2.00	1699	-.0130	1976.5	24.31	-.001	1.215	.462	29.79	-.0274	1.807	.0039	331.6
400	1.50	1615	-.0126	1937.6	24.31	-.001	1.215	.462	37.18	-.0270	1.835	.0036	336.6
600	1.00	1503	-.0128	1885.9	24.31	-.000	1.216	.460	50.90	-.0269	1.871	.0032	343.2
800	.75	1428	-.0129	1851.5	24.31	-.000	1.215	.461	63.69	-.0266	1.894	.0030	347.6
1000	.60	1373	-.0129	1825.9	24.31	-.000	1.215	.462	75.83	-.0264	1.912	.0028	350.8
1500	.40	1278	-.0127	1782.0	24.31	-.000	1.213	.465	104.30	-.0261	1.941	.0026	356.2

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TABLE V. - Continued. THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion from chamber pressure of 600 lb/sq in. abs.]

(b) Percent fluorine in oxidant by weight, 15

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Temperature exponent, n_T, $\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Area ratio, ε	Area ratio exponent, $n_ε$, $\left(\frac{\partial \ln ε}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Thrust coefficient, C_F	Specific impulse exponent, n_I, $\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Specific impulse, I, $\frac{\text{lb-sec}}{\text{lb}}$
r = 1.2; O/F = 3.106; percent fuel = 24.36													
1.000	600.00	3735	0.0439	2888.3	23.39	-.323	1.138	1.779					
1.040	576.92	3721	.0437	2875.9	23.42	-.323	1.138	1.780	2.352	0.0017	0.178	0.0147	32.9
1.442	416.14	3613	.0420	2774.7	23.64	-.324	1.134	1.788	1.037	.0006	.538	.0144	99.4
1.730	346.79	3555	.0410	2719.9	23.77	-.325	1.133	1.790	1.000	.0000	.655	.0142	121.0
2.163	277.43	3486	.0399	2654.5	23.92	-.325	1.131	1.790	1.033	-.0007	.772	.0140	142.6
10.000	60.00	3063	.0316	2247.2	24.93	-.311	1.120	1.691	2.433	-.0055	1.278	.0125	236.2
20.000	30.00	2894	.0277	2084.1	25.36	-.292	1.118	1.577	4.035	-.0080	1.431	.0119	264.5
20.414	29.39	2889	.0276	2079.5	25.37	-.291	1.118	1.573	4.098	-.0081	1.435	.0118	265.3
40.000	15.00	2733	.0231	1932.5	25.76	-.255	1.118	1.390	6.882	-.0114	1.560	.0112	288.4
40.827	14.70	2728	.0229	1928.2	25.78	-.253	1.118	1.383	6.993	-.0115	1.564	.0112	289.0
60.000	10.00	2641	.0194	1848.9	25.99	-.223	1.120	1.243	9.483	-.0140	1.627	.0108	300.7
100.000	6.00	2522	.0138	1748.6	26.24	-.180	1.126	1.048	14.280	-.0178	1.704	.0102	314.9
300.000	2.00	2236	.0014	1551.7	26.63	-.074	1.162	.663	34.550	-.0301	1.845	.0086	341.0
600.000	1.00	2024	-.0167	1441.7	26.73	-.020	1.191	.488	59.890	-.0399	1.919	.0074	354.8
1000.000	.60	1862	-.0345	1367.9	26.76	-.000	1.208	.412	89.480	-.0440	1.968	.0065	363.7
r = 1.4; O/F = 2.662; percent fuel = 27.31													
1.000	600.00	3694	0.0412	3206.2	22.25	-.286	1.144	1.572					
1.040	576.92	3680	.0409	3193.3	22.27	-.285	1.144	1.568	2.357	0.0020	0.178	0.0140	33.5
1.446	415.00	3564	.0385	3087.3	22.46	-.279	1.141	1.530	1.036	.0007	.541	.0135	101.7
1.735	345.83	3502	.0371	3030.5	22.59	-.275	1.140	1.503	1.000	.0000	.657	.0133	123.6
2.169	276.67	3427	.0354	2962.7	22.72	-.269	1.139	1.466	1.033	-.0009	.774	.0130	145.6
10.000	60.00	2945	.0215	2544.7	23.53	-.180	1.143	1.054	2.397	-.0096	1.276	.0108	239.9
20.000	30.00	2724	.0132	2379.7	23.81	-.120	1.157	.827	3.921	-.0154	1.426	.0097	268.2
20.414	29.39	2717	.0130	2375.1	23.82	-.118	1.158	.820	3.980	-.0156	1.430	.0096	268.9
40.000	15.00	2486	.0023	2229.6	24.00	-.060	1.180	.632	6.533	-.0228	1.550	.0083	291.5
40.827	14.70	2479	.0018	2225.4	24.01	-.059	1.180	.627	6.634	-.0230	1.553	.0083	292.1
60.000	10.00	2340	-.0057	2148.7	24.07	-.035	1.193	.551	8.837	-.0266	1.613	.0075	303.3
100.000	6.00	2151	-.0115	2054.1	24.12	-.016	1.208	.494	12.950	-.0297	1.683	.0065	316.6
300.000	2.00	1768	-.0163	1877.2	24.15	-.001	1.227	.445	29.680	-.0320	1.808	.0047	340.1
600.000	1.00	1554	-.0164	1782.6	24.15	-.001	1.229	.443	50.430	-.0315	1.871	.0038	352.0
1000.000	.60	1413	-.0140	1720.3	24.15	-.001	1.228	.447	74.790	-.0308	1.912	.0033	359.6
r = 1.6; O/F = 2.329; percent fuel = 30.04													
1.000	600.00	3583	0.0342	3500.2	21.15	-.213	1.157	1.207					
1.040	576.92	3567	.0337	3487.1	21.17	-.212	1.157	1.198	2.368	0.0029	0.179	0.0120	33.8
1.456	412.19	3434	.0299	3377.0	21.33	-.194	1.158	1.118	1.035	.0011	.548	.0113	103.5
1.747	343.49	3362	.0280	3319.4	21.42	-.183	1.159	1.071	1.000	.0000	.664	.0109	125.4
2.183	274.79	3275	.0257	3250.9	21.52	-.168	1.161	1.012	1.032	-.0015	.779	.0105	147.3
10.000	60.00	2671	.0062	2837.7	22.00	-.058	1.194	.638	2.313	-.0134	1.270	.0073	240.1
20.000	30.00	2385	-.0022	2679.7	22.09	-.024	1.215	.537	3.696	-.0181	1.414	.0058	267.2
20.414	29.39	2377	-.0024	2675.3	22.09	-.024	1.215	.535	3.749	-.0182	1.417	.0058	267.9
40.000	15.00	2105	-.0071	2539.9	22.13	-.008	1.231	.486	6.020	-.0205	1.529	.0046	289.1
40.827	14.70	2097	-.0072	2536.1	22.13	-.008	1.231	.485	6.109	-.0205	1.532	.0045	289.6
60.000	10.00	1950	-.0083	2466.2	22.14	-.004	1.238	.471	8.056	-.0211	1.587	.0040	300.0
100.000	6.00	1766	-.0094	2381.1	22.15	-.001	1.242	.460	11.690	-.0211	1.651	.0033	312.1
300.000	2.00	1424	-.0095	2224.4	22.15	-.000	1.244	.457	26.480	-.0204	1.763	.0024	333.2
600.000	1.00	1244	-.0092	2141.6	22.15	-.000	1.240	.463	44.840	-.0199	1.819	.0019	343.8
1000.000	.60	1128	-.0089	2087.3	22.15	-.000	1.235	.472	66.440	-.0194	1.855	.0017	350.6
r = 1.8; O/F = 2.071; percent fuel = 32.57													
1.000	600.00	3391	0.0244	3773.0	20.08	-.131	1.180	0.895					
1.040	576.92	3373	.0240	3759.9	20.09	-.129	1.181	.886	2.387	0.0036	0.181	0.0088	33.8
1.472	407.71	3214	.0200	3647.1	20.20	-.106	1.186	.812	1.033	.0013	.559	.0080	104.7
1.766	339.76	3131	.0178	3590.3	20.26	-.095	1.190	.774	1.000	.0000	.674	.0076	126.1
2.207	271.81	3029	.0151	3522.9	20.32	-.081	1.195	.730	1.031	-.0016	.788	.0071	147.5
10.000	60.00	2345	-.0008	3128.6	20.54	-.015	1.235	.525	2.227	-.0104	1.265	.0040	236.8
20.000	30.00	2050	-.0038	2981.5	20.56	-.005	1.249	.489	3.510	-.0118	1.402	.0030	262.4
20.414	29.39	2041	-.0038	2977.5	20.56	-.004	1.250	.488	3.559	-.0118	1.406	.0030	263.1
40.000	15.00	1782	-.0051	2853.3	20.57	-.001	1.257	.473	5.660	-.0120	1.511	.0023	282.9
40.827	14.70	1775	-.0051	2849.8	20.57	-.001	1.257	.472	5.748	-.0120	1.514	.0023	283.4
60.000	10.00	1640	-.0051	2786.3	20.57	-.000	1.259	.470	7.542	-.0118	1.566	.0020	293.0
100.000	6.00	1476	-.0053	2709.5	20.57	-.000	1.260	.468	10.900	-.0115	1.625	.0016	304.2
300.000	2.00	1179	-.0049	2569.2	20.57	-.000	1.253	.478	24.540	-.0110	1.729	.0012	323.6
600.000	1.00	1027	-.0041	2495.6	20.57	-.002	1.245	.494	41.490	-.0102	1.781	.0009	333.4
1000.000	.60	930	-.0034	2447.4	20.57	-.004	1.236	.511	61.480	-.0096	1.815	.0008	339.6
r = 2.0; O/F = 1.864; percent fuel = 34.92													
1.000	600.00	3142	0.0156	4026.7	19.06	-.078	1.208	0.718					
1.040	576.92	3123	.0151	4013.9	19.07	-.070	1.209	.712	2.407	0.0034	0.182	0.0057	33.4
1.488	403.13	2943	.0110	3900.8	19.14	-.052	1.217	.656	1.032	.0011	.571	.0049	104.6
1.786	335.94	2852	.0091	3846.0	19.17	-.044	1.222	.631	1.000	.0000	.684	.0046	125.4
2.233	268.75	2741	.0070	3781.4	19.20	-.036	1.228	.604	1.030	-.0012	.797	.0041	146.1
10.000	60.00	2044	-.0016	3412.3	19.28	-.003	1.264	.498	2.164	-.0067	1.262	.0020	231.2
20.000	30.00	1766	-.0025	3276.4	19.29	-.001	1.272	.483	3.383	-.0059	1.395	.0014	255.5
20.414	29.39	1759	-.0026	3272.7	19.29	-.001	1.272	.482	3.429	-.0059	1.398	.0014	256.1
40.000	15.00	1522	-.0041	3159.2	19.29	-.000	1.275	.475	5.422	-.0052	1.500	.0011	274.7
40.827	14.70	1515	-.0042	3156.0	19.29	-.000	1.275	.475	5.500	-.0052	1.502	.0011	275.2
60.000	10.00	1395	-.0060	3098.3	19.29	-.000	1.276	.471	7.204	-.0045	1.551	.0009	284.2
100.000	6.00	1250	-.0045	3028.8	19.29	-.000	1.274	.476	10.380	-.0048	1.608	.0008	294.7
300.000	2.00	992	.0075	2902.6	19.29	-.030	1.246	.565	23.270	.0007	1.707	.0005	312.7
600.000	1.00	874	.0120	2836.4	19.39	-.072	1.208	.703	39.680	.0061	1.756	.0006	321.8
1000.000	.60	828	.0057	2792.2	19.66	-.117	1.166	.858	60.620	.0077	1.789	.0011	327.7

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TABLE V. - Continued. THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion from chamber pressure of 600 lb/sq in. abs.]

(c) Percent fluorine in oxidant by weight, 30

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Temperature exponent, n_T, $\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Area ratio, ε	Area ratio exponent, n_ε, $\left(\frac{\partial \ln \varepsilon}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Thrust coefficient, C_F	Specific impulse exponent, n_I, $\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r = 1.2; O/F = 3.432; percent fuel = 22.56													
1.000	600.00	3868	0.0454	2874.8	22.78	-.319	1.147	1.693					
1.040	576.92	3853	.0452	2861.6	22.81	-.319	1.146	1.694	2.358	0.0017	0.178	0.0155	33.9
1.446	415.00	3734	.0434	2753.3	23.04	-.321	1.143	1.708	1.036	.0006	.541	.0151	102.8
1.735	345.84	3671	.0424	2695.2	23.16	-.322	1.141	1.713	1.000	.0000	.656	.0149	125.0
2.169	276.67	3595	.0412	2625.9	23.32	-.323	1.139	1.718	1.033	-.0007	.774	.0146	147.2
10.000	60.00	3141	.0329	2197.5	24.35	-.314	1.126	1.666	2.416	-.0058	1.277	.0131	242.9
20.000	30.00	2962	.0287	2026.5	24.79	-.301	1.122	1.584	3.999	-.0082	1.429	.0124	271.7
20.414	29.39	2957	.0286	2021.6	24.81	-.300	1.122	1.580	4.061	-.0083	1.433	.0124	272.5
40.000	15.00	2793	.0248	1868.0	25.21	-.273	1.122	1.444	6.808	-.0111	1.557	.0117	296.0
40.827	14.70	2789	.0246	1863.5	25.23	-.272	1.122	1.437	6.918	-.0113	1.560	.0117	296.7
60.000	10.00	2698	.0209	1780.6	25.45	-.244	1.122	1.308	9.376	-.0138	1.623	.0113	308.6
100.000	6.00	2578	.0154	1676.0	25.72	-.202	1.127	1.117	14.110	-.0176	1.699	.0107	323.0
300.000	2.00	2294	.0034	1470.7	26.17	-.093	1.161	.705	34.210	-.0300	1.838	.0092	349.5
600.000	1.00	2075	-.0136	1355.9	26.30	-.029	1.198	.501	59.220	-.0418	1.912	.0080	363.5
1000.000	.60	1903	-.0357	1279.2	26.34	-.001	1.220	.404	88.170	-.0487	1.960	.0070	378.6
r = 1.4; O/F = 2.942; percent fuel = 25.37													
1.000	600.00	3836	0.0437	3170.7	21.81	-.292	1.152	1.568					
1.040	576.92	3820	.0435	3157.0	21.84	-.292	1.151	1.566	2.361	0.0028	0.179	0.0147	34.5
1.449	414.12	3695	.0411	3044.2	22.05	-.289	1.148	1.545	1.036	.0007	.543	.0144	104.9
1.739	345.10	3628	.0398	2984.2	22.17	-.287	1.147	1.529	1.000	.0000	.659	.0142	127.4
2.173	276.08	3549	.0381	2912.6	22.31	-.283	1.145	1.504	1.033	-.0009	.776	.0139	149.8
10.000	60.00	3050	.0251	2473.3	23.19	-.213	1.143	1.164	2.390	-.0090	1.275	.0118	246.3
20.000	30.00	2830	.0164	2299.9	23.52	-.156	1.153	.928	3.913	-.0145	1.425	.0107	275.3
20.414	29.39	2823	.0161	2295.0	23.53	-.154	1.153	.921	3.972	-.0147	1.429	.0107	276.0
40.000	15.00	2595	.0074	2141.7	23.76	-.088	1.176	.700	6.536	-.0223	1.549	.0094	299.2
40.827	14.70	2588	.0070	2137.3	23.77	-.086	1.177	.694	6.636	-.0226	1.552	.0094	299.9
60.000	10.00	2448	-.0018	2056.4	23.86	-.053	1.192	.588	8.849	-.0275	1.612	.0086	311.4
100.000	6.00	2253	-.0116	1956.5	23.93	-.026	1.218	.500	12.960	-.0324	1.683	.0075	325.0
300.000	2.00	1840	-.0196	1770.4	23.98	-.002	1.240	.428	29.510	-.0369	1.807	.0054	349.1
600.000	1.00	1607	-.0196	1671.5	23.99	-.001	1.245	.421	49.820	-.0367	1.870	.0044	361.2
1000.000	.60	1453	-.0179	1606.8	23.99	-.001	1.246	.424	73.500	-.0360	1.910	.0038	368.9
r = 1.6; O/F = 2.574; percent fuel = 27.98													
1.000	600.00	3745	0.0385	3445.8	20.87	-.239	1.161	1.291					
1.040	576.92	3729	.0382	3431.9	20.90	-.237	1.161	1.264	2.370	0.0032	0.179	0.0131	34.8
1.456	411.99	3590	.0349	3315.2	21.08	-.228	1.161	1.215	1.035	.0011	.548	.0127	106.6
1.748	343.33	3516	.0330	3254.3	21.17	-.213	1.161	1.173	1.000	.0000	.664	.0124	129.1
2.184	274.66	3427	.0556	3181.8	21.29	-.200	1.161	1.117	1.032	-.0014	.780	.0120	151.6
10.000	60.00	2822	.0103	2744.3	21.89	-.086	1.188	.703	2.321	-.0137	1.271	.0089	247.1
20.000	30.00	2531	.0005	2576.4	22.04	-.041	1.213	.567	3.715	-.0200	1.415	.0073	275.0
20.414	29.39	2522	.0002	2571.8	22.04	-.040	1.213	.564	3.768	-.0202	1.419	.0073	275.8
40.000	15.00	2236	-.0079	2427.7	22.11	-.015	1.235	.487	6.046	-.0244	1.531	.0058	297.4
40.827	14.70	2227	-.0081	2423.6	22.11	-.015	1.236	.485	6.135	-.0245	1.534	.0058	298.2
60.000	10.00	2068	-.0102	2349.4	22.13	-.007	1.246	.462	8.077	-.0257	1.589	.0051	308.9
100.000	6.00	1868	-.0121	2259.2	22.14	-.002	1.255	.444	11.680	-.0263	1.653	.0043	321.3
300.000	2.00	1491	-.0127	2094.2	22.14	-.000	1.261	.434	26.200	-.0258	1.764	.0030	342.9
600.000	1.00	1292	-.0127	2007.8	22.14	-.000	1.260	.435	44.020	-.0252	1.820	.0024	353.7
1000.000	.60	1163	-.0123	1951.6	22.14	-.000	1.256	.440	64.810	-.0248	1.855	.0021	360.6
r = 1.8; O/F = 2.288; percent fuel = 30.41													
1.000	600.00	3586	0.0304	3702.3	19.95	-.165	1.180	0.992					
1.040	576.92	3567	.0299	3688.4	19.97	-.163	1.180	.984	2.385	0.0036	0.180	0.0108	34.9
1.469	408.30	3407	.0254	3568.9	20.11	-.142	1.183	.905	1.034	.0013	.558	.0100	107.8
1.763	340.25	3322	.0232	3508.3	20.18	-.130	1.186	.864	1.000	.0000	.672	.0096	129.9
2.204	272.20	3220	.0205	3436.6	20.26	-.115	1.190	.814	1.031	-.0017	.787	.0091	152.1
10.000	60.00	2519	.0013	3014.7	20.59	-.029	1.233	.546	2.238	-.0131	1.266	.0056	244.6
20.000	30.00	2204	-.0046	2857.0	20.64	-.010	1.254	.486	3.525	-.0161	1.404	.0043	271.2
20.414	29.39	2195	-.0047	2852.7	20.64	-.010	1.254	.485	3.573	-.0161	1.407	.0043	271.9
40.000	15.00	1911	-.0070	2719.9	20.65	-.002	1.268	.458	5.664	-.0171	1.513	.0033	292.4
40.827	14.70	1902	-.0071	2716.2	20.65	-.002	1.268	.457	5.745	-.0171	1.516	.0033	293.9
60.000	10.00	1753	-.0077	2648.5	20.66	-.001	1.272	.450	7.525	-.0171	1.567	.0028	302.8
100.000	6.00	1571	-.0076	2566.9	20.66	-.000	1.275	.446	10.830	-.0169	1.627	.0024	314.3
300.000	2.00	1238	-.0078	2419.2	20.66	-.000	1.275	.446	24.090	-.0161	1.730	.0016	334.1
600.000	1.00	1067	-.0071	2342.4	20.66	-.001	1.270	.454	40.330	-.0155	1.780	.0013	344.0
1000.000	.60	958	-.0064	2292.8	20.66	-.003	1.265	.463	59.270	-.0148	1.813	.0012	350.2
r = 2.0; O/F = 2.059; percent fuel = 32.69													
1.000	600.00	3369	0.0219	3942.1	19.06	-.105	1.203	0.797					
1.040	576.92	3349	.0214	3928.4	19.08	-.103	1.204	.769	2.403	0.0038	0.182	0.0080	34.6
1.485	404.16	3167	.0171	3807.9	19.17	-.082	1.211	.726	1.032	.0013	.569	.0071	108.1
1.781	336.80	3074	.0149	3749.0	19.22	-.072	1.215	.694	1.000	.0000	.682	.0067	129.6
2.227	269.44	2961	.0121	3679.5	19.27	-.060	1.221	.658	1.030	-.0016	.795	.0062	151.2
10.000	60.00	2225	-.0019	3260.5	19.42	-.009	1.266	.495	2.171	-.0093	1.262	.0035	239.9
20.000	30.00	1917	-.0039	3133.9	19.44	-.002	1.281	.468	3.384	-.0101	1.395	.0024	265.2
20.414	29.39	1909	-.0040	3129.9	19.44	-.002	1.281	.467	3.430	-.0102	1.399	.0024	265.8
40.000	15.00	1644	-.0043	3007.9	19.44	-.000	1.289	.457	5.398	-.0100	1.500	.0018	285.1
40.827	14.70	1637	-.0042	3004.5	19.44	-.000	1.289	.457	5.474	-.0100	1.503	.0018	285.6
60.000	10.00	1501	-.0062	2942.8	19.44	-.000	1.292	.449	7.146	-.0093	1.551	.0015	294.9
100.000	6.00	1337	-.0077	2868.7	19.44	-.000	1.295	.444	10.240	-.0087	1.608	.0013	305.6
300.000	2.00	1043	.0015	2735.8	19.44	-.016	1.279	.489	22.600	-.0055	1.705	.0009	324.0
600.000	1.00	900	.0090	2667.3	19.48	-.050	1.246	.589	37.860	.0006	1.752	.0008	333.1
1000.000	.60	835	.0074	2622.4	19.68	-.087	1.206	.695	56.940	.0036	1.783	.0010	338.9

TABLE V. - Continued. THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion from chamber pressure of 600 lb/sq in. abs.]

(d) Percent fluorine in oxidant by weight, 50

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Temperature exponent, n_T, $\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Area ratio, ε	Area ratio exponent, $n_ε$, $\left(\frac{\partial \ln ε}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Thrust coefficient, C_F	Specific impulse exponent, n_I, $\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r = 1.2; O/F = 3.892; percent fuel = 20.03													
1.000	600.00	4120	0.0458	2855.9	22.10	-.301	1.158	1.520					
1.040	576.92	4103	.0456	2841.4	22.13	-.301	1.158	1.521	2.366	0.0018	0.179	0.0157	35.5
1.452	413.29	3964	.0437	2721.2	22.36	-.303	1.154	1.527	1.036	.0006	.545	.0154	108.3
1.742	344.41	3891	.0427	2657.8	22.49	-.303	1.152	1.530	1.000	.0000	.662	.0151	131.3
2.178	275.53	3804	.0415	2582.1	22.64	-.304	1.150	1.532	1.033	-.0008	.778	.0149	154.3
10.000	60.00	3285	.0334	2119.4	23.67	-.299	1.137	1.513	2.388	-.0059	1.275	.0133	253.1
20.000	30.00	3083	.0291	1936.0	24.12	-.291	1.132	1.468	3.936	-.0083	1.425	.0126	282.9
20.414	29.39	3077	.0290	1930.8	24.13	-.291	1.132	1.466	3.996	-.0084	1.429	.0126	283.7
40.000	15.00	2895	.0248	1766.8	24.55	-.274	1.129	1.381	6.676	-.0111	1.551	.0119	307.8
40.827	14.70	2890	.0247	1762.0	24.56	-.273	1.129	1.377	6.783	-.0112	1.554	.0119	308.5
60.000	10.00	2790	.0223	1674.0	24.79	-.255	1.130	1.299	9.174	-.0132	1.616	.0115	320.7
100.000	6.00	2662	.0164	1563.0	25.07	-.215	1.132	1.131	13.790	-.0171	1.690	.0110	335.4
300.000	2.00	2367	.0019	1346.0	25.57	-.108	1.163	.721	33.370	-.0296	1.826	.0096	362.5
600.000	1.00	2134	-.0111	1224.9	25.73	-.036	1.214	.496	57.540	-.0439	1.898	.0083	376.7
1000.000	.60	1943	-.0373	1144.6	25.77	-.002	1.246	.384	85.110	-.0533	1.944	.0073	385.9
r = 1.4; O/F = 3.421; percent fuel = 22.62													
1.000	600.00	4100	0.0451	3120.2	21.31	-.283	1.164	1.447					
1.040	576.92	4082	.0449	3105.3	21.34	-.283	1.163	1.446	2.370	0.0020	0.179	0.0155	36.1
1.455	412.43	3936	.0427	2980.6	21.56	-.282	1.160	1.438	1.035	.0007	.548	.0150	110.2
1.746	343.69	3860	.0415	2915.3	21.68	-.281	1.158	1.431	1.000	.0000	.664	.0148	133.5
2.182	274.95	3770	.0400	2837.5	21.82	-.279	1.156	1.419	1.032	-.0009	.779	.0145	156.8
10.000	60.00	3216	.0284	2364.3	22.75	-.237	1.150	1.216	2.367	-.0081	1.274	.0126	256.5
20.000	30.00	2984	.0203	2178.2	23.12	-.187	1.155	1.009	3.873	-.0134	1.423	.0116	286.3
20.414	29.39	2978	.0200	2172.9	23.13	-.185	1.155	1.002	3.931	-.0136	1.426	.0115	287.1
40.000	15.00	2746	.0109	2008.6	23.43	-.122	1.173	.774	6.474	-.0207	1.545	.0104	311.0
40.827	14.70	2738	.0106	2003.8	23.44	-.120	1.174	.767	6.574	-.0210	1.549	.0104	311.7
60.000	10.00	2595	.0044	1917.0	23.56	-.080	1.193	.641	8.772	-.0268	1.608	.0096	323.6
100.000	6.00	2390	-.0105	1809.8	23.67	-.037	1.220	.506	12.840	-.0346	1.678	.0088	337.7
300.000	2.00	1932	-.0232	1611.1	23.75	-.004	1.263	.405	28.930	-.0423	1.800	.0061	362.4
600.000	1.00	1669	-.0250	1506.8	23.75	-.000	1.273	.390	48.330	-.0428	1.862	.0050	374.7
1000.000	.60	1495	-.0235	1439.3	23.75	-.001	1.276	.389	70.690	-.0422	1.900	.0043	382.4
r = 1.6; O/F = 2.994; percent fuel = 25.04													
1.000	600.00	4030	0.0420	3368.1	20.54	-.247	1.172	1.277					
1.040	576.92	4011	.0417	3352.8	20.57	-.246	1.172	1.273	2.376	0.0027	0.180	0.0144	36.4
1.461	410.80	3854	.0387	3224.4	20.77	-.238	1.170	1.230	1.035	.0010	.552	.0139	111.8
1.753	342.33	3773	.0370	3158.0	20.87	-.232	1.169	1.202	1.000	.0000	.667	.0136	135.2
2.191	273.86	3675	.0350	3079.2	21.00	-.224	1.169	1.164	1.032	-.0012	.782	.0133	158.5
10.000	60.00	3036	.0165	2605.6	21.72	-.123	1.186	.784	2.316	-.0131	1.271	.0104	257.6
20.000	30.00	2735	.0043	2423.4	21.94	-.068	1.210	.610	3.712	-.0206	1.415	.0089	286.7
20.414	29.39	2726	.0040	2418.4	21.94	-.067	1.211	.606	3.765	-.0208	1.419	.0088	287.5
40.000	15.00	2421	-.0068	2262.0	22.06	-.028	1.241	.494	6.039	-.0277	1.531	.0073	310.2
40.827	14.70	2412	-.0071	2257.5	22.06	-.027	1.242	.492	6.127	-.0278	1.534	.0072	310.9
60.000	10.00	2237	-.0118	2177.0	22.09	-.015	1.257	.454	8.051	-.0304	1.589	.0064	321.9
100.000	6.00	2011	-.0149	2079.5	22.11	-.005	1.273	.424	11.590	-.0323	1.653	.0054	334.8
300.000	2.00	1580	-.0171	1903.0	22.12	-.000	1.289	.401	25.600	-.0327	1.762	.0037	357.0
600.000	1.00	1351	-.0161	1811.9	22.12	-.001	1.293	.398	42.480	-.0321	1.816	.0030	368.0
1000.000	.60	1203	-.0175	1753.4	22.12	-.000	1.296	.394	61.870	-.0319	1.850	.0026	374.8
r = 1.8; O/F = 2.661; percent fuel = 27.31													
1.000	600.00	3898	0.0361	3600.8	19.78	-.192	1.187	1.045					
1.040	576.92	3877	.0356	3585.5	19.80	-.190	1.187	1.038	2.389	0.0034	0.181	0.0126	36.5
1.471	407.84	3702	.0318	3454.1	19.96	-.174	1.188	.974	1.033	.0012	.559	.0119	113.0
1.765	339.86	3611	.0297	3387.9	20.05	-.164	1.190	.937	1.000	.0000	.674	.0115	136.1
2.207	271.89	3501	.0270	3309.5	20.15	-.151	1.192	.891	1.031	-.0016	.788	.0110	159.2
10.000	60.00	2768	.0056	2848.2	20.63	-.056	1.228	.589	2.244	-.0148	1.267	.0076	255.9
20.000	30.00	2431	-.0034	2675.1	20.73	-.023	1.256	.496	3.537	-.0201	1.405	.0061	283.8
20.414	29.39	2421	-.0037	2670.3	20.73	-.023	1.257	.494	3.585	-.0202	1.409	.0060	284.5
40.000	15.00	2103	-.0092	2524.8	20.77	-.007	1.280	.443	5.664	-.0232	1.515	.0047	306.0
40.827	14.70	2094	-.0093	2520.6	20.77	-.007	1.281	.442	5.745	-.0232	1.518	.0047	306.6
60.000	10.00	1922	-.0109	2446.7	20.78	-.003	1.291	.426	7.497	-.0239	1.569	.0040	316.9
100.000	6.00	1711	-.0119	2358.1	20.79	-.001	1.300	.414	10.720	-.0240	1.628	.0034	328.8
300.000	2.00	1322	-.0126	2199.6	20.79	-.757	1.312	.401	23.400	-.0233	1.729	.0023	349.2
600.000	1.00	1120	-.0120	2118.8	20.79	-.001	1.316	.399	38.550	-.0229	1.778	.0018	359.1
1000.000	.60	990	-.0113	2067.3	20.78	-.003	1.317	.400	55.820	-.0222	1.808	.0016	365.3
r = 2.0; O/F = 2.395; percent fuel = 29.46													
1.000	600.00	3708	0.0294	3819.9	19.03	-.139	1.206	0.865					
1.040	576.92	3686	.0289	3804.7	19.04	-.137	1.207	.859	2.403	0.0037	0.182	0.0103	36.3
1.483	404.57	3491	.0246	3672.3	19.17	-.120	1.210	.801	1.032	.0013	.568	.0096	113.3
1.780	337.14	3393	.0223	3607.4	19.24	-.110	1.213	.770	1.000	.0000	.681	.0092	136.0
2.225	269.71	3274	.0194	3530.7	19.31	-.098	1.216	.733	1.030	-.0017	.795	.0087	158.6
10.000	60.00	2494	.0002	3088.9	19.61	-.024	1.264	.513	2.184	-.0132	1.264	.0053	252.2
20.000	30.00	2150	-.0055	2926.1	19.65	-.007	1.289	.458	3.399	-.0162	1.397	.0040	278.9
20.414	29.39	2140	-.0056	2921.7	19.65	-.007	1.290	.457	3.445	-.0162	1.401	.0040	279.6
40.000	15.00	1834	-.0078	2786.7	19.66	-.001	1.308	.430	5.389	-.0171	1.502	.0030	299.8
40.827	14.70	1825	-.0079	2782.9	19.66	-.001	1.308	.429	5.464	-.0171	1.505	.0030	300.4
60.000	10.00	1665	-.0081	2715.1	19.67	-.000	1.316	.421	7.099	-.0170	1.554	.0026	310.1
100.000	6.00	1471	-.0090	2634.2	19.67	-.000	1.325	.411	10.090	-.0165	1.609	.0021	321.2
300.000	2.00	1119	-.0645	2491.2	19.67	-.000	1.347	.329	21.740	-.0119	1.704	.0014	340.0
600.000	1.00	952	.0531	2419.3	19.73	-.064	1.301	.635	35.940	-.0018	1.749	.0013	349.1
1000.000	.60	902	.0372	2372.0	20.01	-.301	1.148	1.691	55.000	.0165	1.778	.0016	354.9

TABLE V. - Continued. THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion from chamber pressure of 600 lb/sq in. abs.]

(e) Percent fluorine in oxidant by weight, 70.37

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Temperature exponent, n_T, $\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, ξ, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, cal/(g)(°K)	Area ratio, ϵ	Area-ratio exponent, n_ϵ, $\left(\frac{\partial \ln \epsilon}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Thrust coefficient, C_F	Specific-impulse exponent, n_I, $\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{\frac{P_c}{P}}$	Specific impulse, I, lb-sec/lb
r = 1.0; O/F = 5.743; percent fuel = 14.83													
10	60.00	2926	0.0151	1902.7	23.44	-.121	1.194	0.687	2.89	-.0105	1.270	0.0097	244.9
15	40.00	2756	.0167	1805.3	23.61	-.128	1.197	.692	3.00	-.0099	1.357	.0091	261.6
20	30.00	2645	.0271	1740.1	23.74	-.192	1.188	.876	3.67	-.0033	1.412	.0088	272.2
30	20.00	2524	.0387	1653.0	24.02	-.297	1.155	1.380	4.95	.0031	1.483	.0089	285.8
40	15.00	2456	.0423	1594.1	24.25	-.370	1.141	1.852	6.17	.0055	1.526	.0091	294.7
60	10.00	2375	.0437	1514.4	24.60	-.444	1.130	2.485	8.48	.0070	1.588	.0094	306.2
80	7.50	2322	.0434	1460.1	24.85	-.474	1.125	2.788	10.68	.0067	1.628	.0096	313.8
100	6.00	2284	.0430	1419.2	25.05	-.490	1.122	2.975	12.80	.0062	1.657	.0098	319.8
150	4.00	2219	.0422	1347.3	25.41	-.504	1.117	3.254	17.85	.0047	1.707	.0099	329.1
200	3.00	2175	.0416	1298.1	25.67	-.511	1.114	3.401	22.65	.0037	1.740	.0100	335.8
300	2.00	2117	.0403	1231.2	26.03	-.520	1.111	3.546	31.80	.0023	1.785	.0101	344.1
400	1.50	2078	.0394	1185.4	26.28	-.523	1.108	3.608	40.53	.0011	1.815	.0102	349.8
600	1.00	2025	.0382	1122.9	26.64	-.524	1.106	3.646	57.20	-.0002	1.854	.0102	357.8
800	.75	1989	.0373	1080.0	26.89	-.524	1.104	3.647	73.15	-.0013	1.881	.0102	362.7
1000	.60	1962	.0365	1047.6	27.09	-.524	1.103	3.641	88.60	-.0020	1.901	.0102	366.6
1500	.40	1914	.0351	990.3	27.44	-.522	1.100	3.599	125.7	-.0034	1.936	.0101	373.3
r = 1.4; O/F = 4.102; percent fuel = 19.60													
10	60.00	3387	0.0163	2245.4	22.51	-.137	1.185	0.774	2.32	-.0135	1.271	0.0113	267.0
15	40.00	3192	.0083	2128.1	22.67	-.090	1.207	.629	3.05	-.0196	1.359	.0103	285.5
20	30.00	3042	.0003	2049.6	22.74	-.055	1.232	.525	3.70	-.0251	1.415	.0095	297.2
30	20.00	2810	-.0111	1946.0	22.81	-.017	1.273	.423	4.88	-.0331	1.486	.0083	312.0
40	15.00	2639	-.0172	1877.7	22.82	-.003	1.293	.385	5.92	-.0363	1.530	.0074	321.4
60	10.00	2419	.0071	1788.7	22.86	-.078	1.237	.549	7.84	-.0190	1.587	.0065	333.2
80	7.50	2315	.0226	1729.7	22.99	-.154	1.195	.788	9.73	-.0089	1.623	.0063	340.9
100	6.00	2254	.0272	1685.7	23.12	-.210	1.173	.992	11.59	-.0044	1.649	.0064	346.4
150	4.00	2158	.0250	1609.3	23.38	-.260	1.150	1.195	16.01	-.0027	1.695	.0065	355.9
200	3.00	2093	.0217	1557.5	23.56	-.248	1.148	1.148	20.20	-.0049	1.724	.0065	362.2
300	2.00	2001	.0182	1487.9	23.80	-.200	1.160	.967	28.04	-.0101	1.764	.0065	370.4
400	1.50	1933	.0139	1440.7	23.94	-.151	1.176	.806	35.36	-.0161	1.790	.0064	375.9
600	1.00	1825	-.0021	1377.7	24.11	-.080	1.209	.578	48.80	-.0278	1.824	.0061	383.2
800	.75	1736	-.0141	1335.5	24.18	-.042	1.243	.464	60.95	-.0369	1.847	.0058	387.9
1000	.60	1660	-.0227	1304.4	24.20	-.020	1.270	.405	72.13	-.0433	1.864	.0055	391.4
1500	.40	1517	-.0347	1251.5	24.22	-.002	1.302	.352	97.34	-.0499	1.891	.0049	397.2
r = 1.5; O/F = 3.829; percent fuel = 20.71													
10	60.00	3424	0.0188	2340.9	22.26	-.155	1.175	0.862	2.33	-.0121	1.272	0.0115	269.4
15	40.00	3243	.0127	2220.7	22.43	-.121	1.186	.747	3.07	-.0161	1.361	.0106	288.2
20	30.00	3110	.0076	2139.9	22.53	-.095	1.197	.666	3.76	-.0197	1.417	.0100	300.1
30	20.00	2916	-.0004	2032.4	22.64	-.058	1.221	.552	5.00	-.0255	1.489	.0090	315.3
40	15.00	2769	-.0065	1960.8	22.70	-.038	1.242	.489	6.13	-.0295	1.535	.0083	325.0
60	10.00	2558	-.0081	1866.3	22.75	-.034	1.253	.466	8.16	-.0303	1.593	.0074	337.4
80	7.50	2422	-.0058	1803.9	22.80	-.044	1.245	.488	10.04	-.0279	1.631	.0068	345.4
100	6.00	2322	-.0073	1757.8	22.85	-.038	1.250	.475	11.82	-.0293	1.658	.0064	351.2
150	4.00	2140	-.0144	1679.2	22.90	-.018	1.275	.419	15.86	-.0343	1.703	.0058	360.8
200	3.00	2009	-.0189	1627.4	22.91	-.008	1.294	.388	19.50	-.0373	1.733	.0053	367.0
300	2.00	1828	-.0219	1560.0	22.92	-.002	1.312	.366	26.06	-.0392	1.770	.0046	374.9
400	1.50	1706	-.0228	1515.9	22.92	-.000	1.320	.358	31.99	-.0396	1.794	.0042	379.9
600	1.00	1545	-.0232	1458.8	22.92	-.000	1.328	.351	42.73	-.0396	1.825	.0037	386.4
800	.75	1439	-.0235	1421.6	22.92	-.000	1.333	.347	52.48	-.0395	1.844	.0034	390.6
1000	.60	1361	-.0238	1394.6	22.92	-.000	1.337	.344	61.55	-.0394	1.858	.0031	393.6
1500	.40	1227	-.0240	1349.1	22.93	-.001	1.344	.339	82.25	-.0395	1.882	.0027	398.6
r = 1.6; O/F = 3.589; percent fuel = 21.79													
10	60.00	3391	0.0183	2461.1	22.16	-.142	1.164	0.900	2.36	-.0126	1.274	0.0105	267.3
15	40.00	3215	.0124	2341.4	22.31	-.111	1.181	.755	3.11	-.0158	1.364	.0097	286.1
20	30.00	3085	.0087	2260.8	22.40	-.088	1.197	.666	3.81	-.0188	1.421	.0092	298.1
30	20.00	2891	.0015	2153.6	22.51	-.057	1.221	.558	5.07	-.0238	1.494	.0083	313.4
40	15.00	2746	-.0045	2088.1	22.56	-.039	1.238	.499	6.21	-.0269	1.541	.0076	323.1
60	10.00	2538	-.0105	1987.8	22.61	-.021	1.261	.443	8.27	-.0309	1.600	.0068	335.6
80	7.50	2390	-.0133	1925.6	22.64	-.013	1.275	.419	10.13	-.0329	1.638	.0061	343.6
100	6.00	2277	-.0156	1879.9	22.65	-.009	1.284	.403	11.86	-.0338	1.665	.0057	349.3
150	4.00	2080	-.0177	1802.5	22.66	-.004	1.297	.386	15.81	-.0351	1.711	.0050	358.8
200	3.00	1946	-.0183	1751.7	22.66	-.002	1.304	.377	19.40	-.0355	1.740	.0045	364.9
300	2.00	1769	-.0191	1685.7	22.67	-.001	1.313	.368	25.89	-.0356	1.777	.0039	372.7
400	1.50	1651	-.0194	1642.6	22.67	-.000	1.319	.363	31.79	-.0358	1.801	.0036	377.7
600	1.00	1496	-.0198	1586.7	22.67	-.000	1.326	.357	42.49	-.0356	1.831	.0031	384.1
800	.75	1393	-.0201	1550.3	22.67	-.000	1.330	.353	52.20	-.0356	1.851	.0029	388.2
1000	.60	1318	-.0202	1523.8	22.67	-.000	1.336	.349	61.25	-.0357	1.865	.0027	391.1
1500	.40	1189	-.0203	1479.3	22.67	-.001	1.341	.347	81.89	-.0352	1.888	.0023	396.1
r = 2.5; O/F = 2.297; percent fuel = 30.33													
10	60.00	2798	0.0068	3393.8	21.15	-.057	1.210	0.617	2.27	-.0107	1.267	0.0065	252.9
15	40.00	2612	.0025	3290.9	21.22	-.039	1.221	.567	2.96	-.0134	1.353	.0058	270.0
20	30.00	2482	-.0005	3222.3	21.26	-.028	1.229	.535	3.60	-.0154	1.408	.0053	280.8
30	20.00	2302	-.0042	3131.8	21.29	-.016	1.241	.499	4.77	-.0173	1.476	.0046	294.5
40	15.00	2176	-.0060	3071.7	21.31	-.010	1.249	.479	5.84	-.0185	1.520	.0042	303.3
60	10.00	2006	-.0079	2992.6	21.32	-.005	1.259	.457	7.78	-.0195	1.576	.0037	314.4
80	7.50	1890	-.0089	2940.4	21.32	-.003	1.265	.446	9.55	-.0196	1.612	.0033	321.6
100	6.00	1803	-.0094	2902.0	21.32	-.002	1.270	.439	11.21	-.0198	1.637	.0031	326.7
150	4.00	1653	-.0097	2836.8	21.33	-.001	1.277	.430	15.02	-.0199	1.680	.0027	335.3
200	3.00	1552	-.0097	2793.9	21.33	-.001	1.280	.426	18.51	-.0197	1.708	.0024	340.8
300	2.00	1419	-.0100	2737.8	21.33	-.001	1.286	.418	24.86	-.0195	1.744	.0021	347.9
400	1.50	1330	-.0099	2700.9	21.33	-.001	1.291	.414	30.67	-.0196	1.767	.0020	352.5
600	1.00	1213	-.0096	2652.9	21.33	-.002	1.296	.409	41.27	-.0192	1.796	.0017	358.4
800	.75	1136	-.0088	2621.4	21.33	-.004	1.296	.410	50.96	-.0184	1.815	.0016	362.2
1000	.60	1079	-.0079	2598.4	21.34	-.009	1.293	.415	60.04	-.0174	1.829	.0015	364.9
1500	.40	988	-.0053	2559.5	21.37	-.028	1.272	.455	81.26	-.0131	1.852	.0014	369.5

TABLE V. - Continued. THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion from chamber pressure of 600 lb/sq in. abs.]

(f) Percent fluorine in oxidant, 100 (zero percent oxygen)

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r = 1.0; O/F = 8.083; percent fuel = 11.01										
1.000	600.00	3962	2621.2	27.41	-0.438	1.146	2.930	------	------	------
1.040	576.92	3948	2610.0	27.46	-.438	1.146	2.952	2.357	0.178	31.3
1.445	415.26	3837	2518.0	27.81	-.451	1.141	3.129	1.036	.540	94.8
1.734	346.06	3778	2468.5	28.00	-.457	1.139	3.222	1.000	.657	115.3
2.167	276.84	3709	2409.5	28.24	-.464	1.136	3.331	1.033	.774	135.7
10.000	60.00	3299	2043.7	29.89	-.501	1.121	3.943	2.43	1.278	224.2
20.000	30.00	3143	1897.2	30.63	-.513	1.115	4.137	4.03	1.431	251.0
20.414	29.392	3139	1893.0	30.65	-.514	1.115	4.142	4.09	1.435	251.7
40.000	15.00	3001	1760.7	31.37	-.523	1.110	4.279	6.89	1.560	273.6
40.827	14.696	2997	1756.8	31.40	-.523	1.110	4.282	7.00	1.563	274.3
60.000	10.00	2924	1685.2	31.81	-.528	1.107	4.339	9.52	1.627	285.4
100.000	6.00	2832	1594.1	32.35	-.532	1.104	4.391	14.43	1.704	299.0
300.000	2.00	2652	1412.3	33.51	-.540	1.098	4.415	36.08	1.848	324.3
600.000	1.00	2550	1306.6	34.23	-.544	1.094	4.374	65.12	1.928	338.2
1000.000	.60	2479	1232.6	34.76	-.543	1.092	4.316	101.09	1.981	347.6
1500.000	.40	2425	1176.1	35.17	-.540	1.090	4.255	143.69	2.021	354.6
r = 1.5; O/F = 5.389; percent fuel = 15.65										
1.000	600.00	4008	3060.4	26.63	-0.284	1.157	1.375	------	------	------
1.040	576.92	3992	3048.7	26.66	-.287	1.156	1.391	2.363	0.178	31.9
1.449	414.02	3859	2952.1	26.93	-.311	1.151	1.538	1.036	.544	97.1
1.739	345.02	3790	2900.8	27.09	-.323	1.148	1.622	1.000	.660	117.8
2.174	276.02	3710	2839.7	27.28	-.337	1.145	1.726	1.033	.776	138.6
10.000	60.00	3252	2463.1	28.66	-.402	1.126	2.264	2.41	1.277	228.0
20.000	30.00	3082	2312.6	29.29	-.418	1.121	2.339	3.99	1.429	255.1
20.414	29.392	3077	2308.3	29.31	-.418	1.121	2.341	4.06	1.433	255.8
40.000	15.00	2926	2172.8	29.94	-.396	1.108	2.585	6.81	1.557	277.9
40.827	14.696	2907	2168.4	30.09	-.391	1.107	2.598	6.86	1.561	278.6
60.000	10.00	2842	2095.7	30.31	-.367	1.095	2.860	9.40	1.623	289.7
100.000	6.00	2754	2002.5	30.66	-.354	1.085	3.109	14.34	1.699	303.4
300.000	2.00	2585	1814.7	31.39	-.385	1.085	3.228	36.35	1.844	329.2
600.000	1.00	2487	1704.3	31.87	-.398	1.084	3.187	66.00	1.924	343.5
1000.000	.60	2417	1626.6	32.24	-.404	1.084	3.103	102.81	1.978	353.2
1500.000	.40	2363	1567.2	32.53	-.408	1.085	3.009	146.40	2.019	360.5
r = 2.0; O/F = 4.041; percent fuel = 19.84										
1.000	600.00	4206	3456.0	26.42	-0.129	1.121	1.203	------	------	------
1.040	576.92	4190	3443.6	26.43	-.128	1.122	1.191	2.347	0.177	32.8
1.443	415.81	4055	3342.3	26.54	-.121	1.129	1.087	1.036	.538	99.5
1.732	346.50	3979	3287.5	26.60	-.117	1.133	1.031	1.000	.655	121.1
2.164	277.20	3885	3222.0	26.67	-.114	1.139	.970	1.033	.771	142.7
10.000	60.00	3262	2819.8	27.26	-.172	1.139	1.065	2.38	1.272	235.3
20.000	30.00	3057	2661.5	27.63	-.240	1.118	1.499	3.93	1.421	262.9
20.414	29.392	3052	2657.0	27.64	-.242	1.117	1.513	3.99	1.425	263.7
40.000	15.00	2895	2514.3	28.03	-.291	1.105	1.917	6.74	1.547	286.2
40.827	14.696	2891	2510.1	28.05	-.293	1.104	1.927	6.86	1.551	286.9
60.000	10.00	2813	2432.7	28.28	-.312	1.101	2.101	9.35	1.613	298.4
100.000	6.00	2716	2334.0	28.60	-.330	1.097	2.244	14.21	1.689	312.4
300.000	2.00	2529	2136.3	29.31	-.349	1.094	2.275	35.71	1.832	338.9
600.000	1.00	2420	2020.9	29.76	-.347	1.095	2.134	64.52	1.910	353.4
1000.000	.60	2341	1940.2	30.10	-.338	1.095	1.972	100.09	1.963	363.2
1500.000	.40	2279	1878.6	30.37	-.326	1.097	1.817	142.03	2.003	370.5
r = 2.8; O/F = 2.887; percent fuel = 25.73										
1.000	600.00	4262	4013.3	24.72	-0.178	1.105	1.670	------	------	------
1.040	576.92	4249	3999.9	24.74	-.177	1.105	1.662	2.332	0.176	34.2
1.430	419.69	4140	3892.9	24.85	-.180	1.107	1.594	1.038	.528	102.3
1.716	349.75	4079	3833.1	24.92	-.180	1.108	1.552	1.000	.646	125.2
2.144	279.80	4004	3761.3	25.00	-.181	1.110	1.498	1.034	.764	148.1
10.000	60.00	3486	3308.0	25.58	-.143	1.128	1.045	2.45	1.278	247.7
20.000	30.00	3238	3127.8	25.82	-.104	1.145	.818	4.05	1.432	277.6
20.414	29.392	3231	3122.7	25.83	-.103	1.146	.812	4.09	1.436	278.4
40.000	15.00	2972	2962.7	26.01	-.080	1.164	.678	6.74	1.560	302.4
40.827	14.696	2964	2958.1	26.02	-.081	1.164	.678	6.84	1.563	303.0
60.000	10.00	2819	2873.3	26.13	-.098	1.160	.719	9.16	1.625	315.0
100.000	6.00	2655	2767.4	26.32	-.143	1.144	.875	13.66	1.698	329.3
300.000	2.00	2372	2561.1	26.81	-.154	1.134	.916	33.31	1.834	355.5
600.000	1.00	2200	2444.2	27.07	-.102	1.148	.723	58.86	1.906	369.5
1000.000	.60	2063	2364.5	27.21	-.056	1.168	.581	89.26	1.954	378.8
1500.000	.40	1945	2305.2	27.27	-.028	1.186	.496	123.76	1.989	385.5

TABLE V. Concluded. THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Equilibrium composition during isentropic expansion from chamber pressure of 600 lb/sq in. abs.]

(f) Concluded. - Percent fluorine in oxidant, 100 (zero percent oxygen)

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Isentropic exponent, γ, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r = 3.0; O/F = 2.694; percent fuel = 27.07										
1.000	600.00	4249	4140.1	24.41	-0.184	1.105	1.699	-------	-----	-----
1.040	576.92	4236	4126.5	24.42	-.185	1.105	1.692	2.332	0.176	34.3
1.429	419.78	4129	4018.6	24.54	-.188	1.107	1.631	1.038	.528	102.8
1.715	349.81	4068	3958.1	24.61	-.190	1.108	1.594	1.000	.646	125.8
2.144	279.86	3994	3885.6	24.69	-.186	1.109	1.547	1.034	.764	148.8
10.000	60.00	3496	3427.2	25.32	-.173	1.120	1.179	2.46	1.278	249.0
20.000	30.00	3273	3244.0	25.58	-.146	1.129	.999	4.07	1.433	279.2
20.414	29.392	3266	3238.8	25.59	-.145	1.129	.993	4.13	1.437	280.0
40.000	15.00	3043	3074.8	25.82	-.107	1.141	.816	6.87	1.563	304.5
40.827	14.696	3036	3070.0	25.83	-.106	1.141	.811	6.98	1.566	305.1
60.000	10.00	2903	2982.2	25.94	-.079	1.152	.709	9.39	1.629	317.4
100.000	6.00	2717	2872.5	26.05	-.048	1.170	.592	13.94	1.705	332.1
300.000	2.00	2522	2662.5	26.24	-.057	1.175	.589	32.86	1.840	358.6
600.000	1.00	2104	2546.6	26.37	-.035	1.185	.526	57.05	1.911	372.4
1000.000	.60	1940	2468.9	26.42	-.011	1.202	.462	85.47	1.957	381.3
1500.000	.40	1811	2411.7	26.43	-.005	1.212	.434	117.58	1.990	387.8
r = 3.5; O/F = 2.309; percent fuel = 30.22										
1.000	600.00	4172	4437.8	23.76	-0.186	1.112	1.560	-------	-----	-----
1.040	576.92	4158	4424.1	23.77	-.185	1.112	1.550	2.338	0.177	34.5
1.434	418.34	4045	4314.2	23.90	-.188	1.115	1.468	1.037	.531	103.7
1.721	348.60	3981	4253.5	23.97	-.188	1.117	1.418	1.000	.649	126.6
2.151	278.89	3902	4180.7	24.06	-.185	1.119	1.356	1.034	.766	149.6
10.000	60.00	3354	3725.6	24.66	-.136	1.141	.936	2.42	1.276	248.9
20.000	30.00	3099	3546.2	24.90	-.104	1.153	.787	3.96	1.427	278.5
20.414	29.392	3091	3541.2	24.90	-.103	1.153	.783	4.02	1.431	279.3
40.000	15.00	2841	3382.6	25.09	-.074	1.163	.677	6.62	1.553	303.0
40.827	14.696	2833	3378.0	25.10	-.073	1.164	.674	6.72	1.556	303.7
60.000	10.00	2690	3293.9	25.18	-.058	1.170	.625	9.00	1.617	315.5
100.000	6.00	2503	3189.5	25.27	-.040	1.178	.570	13.31	1.689	329.6
300.000	2.00	2112	2990.7	25.37	-.012	1.198	.487	31.18	1.818	354.8
600.000	1.00	1880	2882.5	25.39	-.004	1.208	.458	53.50	1.885	367.9
1000.000	.60	1720	2810.6	25.40	-.001	1.215	.444	79.73	1.928	376.3
1500.000	.40	1600	2757.9	25.40	-.001	1.219	.435	109.50	1.959	382.3
r = 4.0; O/F = 2.021; percent fuel = 33.10										
1.000	600.00	4041	4710.9	23.26	-0.167	1.126	1.285	-------	-----	-----
1.040	576.92	4026	4697.4	23.28	-.166	1.127	1.275	2.349	0.178	34.3
1.443	415.75	3898	4586.9	23.40	-.162	1.132	1.190	1.036	.538	103.9
1.732	346.46	3827	4527.2	23.47	-.158	1.134	1.144	1.000	.655	126.4
2.165	277.17	3739	4455.8	23.55	-.152	1.137	1.090	1.033	.772	149.0
10.000	60.00	3145	4016.6	24.09	-.104	1.155	.808	2.38	1.273	245.8
20.000	30.00	2884	3845.0	24.28	-.078	1.162	.717	3.88	1.422	274.5
20.414	29.392	2876	3840.1	24.29	-.078	1.162	.715	3.93	1.426	275.3
40.000	15.00	2629	3689.1	24.43	-.053	1.170	.637	6.47	1.544	298.2
40.827	14.696	2622	3684.7	24.43	-.053	1.170	.635	6.57	1.548	298.8
60.000	10.00	2483	3604.9	24.49	-.038	1.176	.596	8.78	1.607	310.2
100.000	6.00	2303	3505.9	24.55	-.024	1.184	.551	12.97	1.677	323.8
300.000	2.00	1932	3318.1	24.61	-.006	1.201	.488	30.30	1.803	348.1
600.000	1.00	1717	3216.0	24.62	-.001	1.210	.466	51.96	1.868	360.7
1000.000	.60	1570	3148.3	24.62	-.001	1.216	.455	77.44	1.910	368.7
1500.000	.40	1460	3098.7	24.62	------	1.220	.448	106.36	1.940	374.5
r = 5.0; O/F = 1.617; percent fuel = 38.22										
1.000	600.00	3708	5194.5	22.53	-0.122	1.148	0.977	-------	-----	-----
1.040	576.92	3691	5181.7	22.54	-.121	1.148	.971	2.363	0.179	33.4
1.452	413.24	3551	5075.4	22.64	-.114	1.151	.927	1.035	.545	101.8
1.742	344.37	3475	5019.3	22.70	-.110	1.152	.904	1.000	.661	123.5
2.178	275.49	3384	4952.4	22.76	-.106	1.153	.877	1.032	.777	145.1
10.000	60.00	2792	4545.5	23.13	-.059	1.164	.707	2.35	1.272	237.6
20.000	30.00	2539	4387.1	23.23	-.037	1.172	.639	3.82	1.419	265.1
20.414	29.392	2532	4382.7	23.23	-.036	1.172	.637	3.87	1.423	265.8
40.000	15.00	2295	4244.1	23.30	-.020	1.181	.583	6.34	1.540	287.6
40.827	14.696	2288	4240.1	23.30	-.020	1.181	.582	6.44	1.543	288.2
60.000	10.00	2157	4167.1	23.32	-.012	1.187	.558	8.59	1.601	299.0
100.000	6.00	1990	4076.9	23.34	-.006	1.193	.553	12.66	1.670	311.8
300.000	2.00	1658	3906.6	23.35	-.001	1.205	.501	29.46	1.792	334.8
600.000	1.00	1471	3814.4	23.35	------	1.097	.443	50.50	1.855	346.5
1000.000	.60	1344	3753.2	23.35	------	1.217	.477	75.26	1.896	354.1
1500.000	.40	1250	3708.5	23.35	-------	1.221	.470	103.36	1.925	359.6

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TABLE VI. - EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Isentropic expansion or compression from combustion-chamber pressure of 600 lb/sq in. abs.]

(a) Percent fluorine in oxidant, 0 (100 percent oxygen)

Mole fraction[a] at temperature T										
r = 1.0; O/F = 3.403; percent fuel = 22.71										
T, °K	4000	[b]3612	3600	3200	2800	2400	2000	1600	900	
CO	0.23473	0.21540	0.21467	0.18574	0.14517	0.09229	0.03652	0.00482	----------	
CO_2	.16604	.19895	.20015	.24590	.30633	.38148	.45811	.50082	0.50734	
H	.02986	.02369	.02349	.01701	.01069	.00505	.00120	.00005	----------	
H_2	.04573	.04043	.04025	.03374	.02609	.01723	.00790	.00151	----------	
H_2O	.27686	.30785	.30892	.34566	.38672	.43007	.46877	.48919	.49265	
O	.04324	.03303	.03270	.02223	.01259	.00499	.00088	.00002	----------	
O_2	.10025	.09621	.09603	.08726	.07187	.04842	.02055	.00303	----------	
OH	.10329	.08444	.08380	.06246	.04055	.02046	.00607	.00056	----------	
r = 1.2; O/F = 2.836; percent fuel = 26.07										
T, °K	4000	[b]3628	3600	3200	2800	2400	2000	1600	1200	900
CO	0.29586	0.28284	0.28163	0.26076	0.23308	0.20684	0.19393	0.17833	0.14424	0.09103
CO_2	.13902	.16572	.16805	.20614	.25264	.29456	.31277	.32898	.36310	.41631
H	.03879	.03125	.03067	.02235	.01406	.00636	.00141	.00011	----------	----------
H_2	.07136	.06578	.06534	.05869	.05235	.04993	.05688	.07284	.10698	.16019
H_2O	.28698	.31844	.32097	.35902	.39859	.42933	.43399	.41973	.38568	.33246
O	.03105	.02262	.02198	.01317	.00557	.00094	.00008	----------	----------	----------
O_2	.04783	.04189	.04132	.03088	.01634	.00315	.00007	----------	----------	----------
OH	.08912	.07146	.07004	.04900	.02739	.00888	.00092	.00002	----------	----------
r = 1.3; O/F = 2.618; percent fuel = 27.64										
T, °K	4000	[b]3612	3600	3200	2800	2400	2000	1600	1200	900
CO	0.32446	0.31453	0.31416	0.29939	0.28220	0.26944	0.25858	0.23870	0.19676	0.13234
CO_2	.12367	.14764	.14847	.17937	.21222	.23474	.24835	.26862	.31059	.37501
H	.04264	.03378	.03350	.02399	.01432	.00574	.00116	.00008	----------	----------
H_2	.08777	.08240	.08223	.07682	.07374	.07736	.08865	.10909	.15109	.21551
H_2O	.28633	.31891	.31995	.35615	.38953	.40691	.40280	.38349	.34157	.27714
O	.02475	.01675	.01651	.00879	.00285	.00030	.00001	----------	----------	----------
O_2	.03091	.02480	.02458	.01562	.00579	.00062	.00001	----------	----------	----------
OH	.07947	.06119	.06060	.03987	.01936	.00490	.00045	.00001	----------	----------
r = 1.4; O/F = 2.431; percent fuel = 29.15										
T, °K	3600	[b]3576	3200	2800	2400	2000	1600	1200	900	
CO	0.34489	0.34444	0.33630	0.32751	0.31995	0.30849	0.28626	0.24044	0.17069	
CO_2	.12785	.12914	.15070	.17146	.18527	.19855	.22106	.26690	.33665	
H	.03558	.03488	.02465	.01371	.00501	.00096	.00007	----------	----------	
H_2	.10270	.10247	.09966	.10074	.10824	.12157	.14436	.19023	.25998	
H_2O	.31341	.31534	.34559	.37047	.37843	.37018	.34824	.30243	.23268	
O	.01165	.01124	.00535	.00133	.00011	----------	----------	----------	----------	
O_2	.01360	.01324	.00711	.00188	.00015	----------	----------	----------	----------	
OH	.05038	.04923	.03064	.01290	.00284	.00025	.00001	----------	----------	
r = 1.6; O/F = 2.127; percent fuel = 31.98										
T, °K	3600	[b]3436	3200	2800	2400	2000	1600	1200		
CO	0.39683	0.39669	0.39624	0.39430	0.38899	0.37740	0.35488	0.30879		
CO_2	.08894	.09344	.09949	.10838	.11709	.12975	.15246	.19856		
H	.03660	.03118	.02344	.01160	.00382	.00068	.00004	----------		
H_2	.15384	.15462	.15681	.16359	.17355	.18735	.21034	.25647		
H_2O	.28388	.29328	.30468	.31587	.31540	.30473	.28228	.23619		
O	.00499	.00343	.00172	.00031	.00002	----------	----------	----------		
O_2	.00353	.00248	.00128	.00083	.00001	----------	----------	----------		
OH	.03139	.02488	.01633	.00573	.00113	.00009	----------	----------		
r = 1.8; O/F = 1.891; percent fuel = 34.59										
T, °K	3600	[b]3205	3200	2800	2400	2000	1600	1200	900	
CH_4	----------	----------	----------	----------	----------	----------	----------	----------	0.00016	
CO	0.43331	0.43518	0.43519	0.43472	0.43042	0.42044	0.40078	0.35968	.29689	
CO_2	.05929	.06430	.06436	.06945	.07604	.08676	.10656	.14766	.21046	
H	.03447	.02080	.02064	.00952	.00296	.00050	.00003	----------	----------	
H_2	.21259	.21932	.21942	.22779	.23713	.24907	.26912	.31024	.37262	
H_2O	.23949	.25101	.25111	.25566	.25293	.24317	.22351	.18241	.11987	
O	.00196	.00057	.00056	.00009	.00001	----------	----------	----------	----------	
O_2	.00084	.00025	.00025	.00004	----------	----------	----------	----------	----------	
OH	.01805	.00857	.00847	.00273	.00051	.00004	----------	----------	----------	
r = 3.0; O/F = 1.134; percent fuel = 46.85										
T, °K	2000	[b]1657	1600	1200	900					
GRAPHITE	----------	0.00130	0.00213	0.03684	0.14454					
CH_4	0.00838	.01146	.01219	.01828	.01304					
CO	.50682	.50434	.50303	.45006	.27290					
CO_2	.00062	.00187	.00236	.02072	.09009					
H	.00011	.00001	.00001	----------	----------					
H_2	.48128	.47514	.47333	.44478	.41695					
H_2O	.00279	.00588	.00695	.02932	.06247					

[a]Mole fractions were computed for all 19 substances considered in this report but are omitted if less than 5×10^{-6}.
[b]Combustion temperature.

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TABLE VI. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Isentropic expansion or compression from combustion chamber pressure of 600 lb/sq in. abs.]

(b) Percent fluorine in oxidant by weight, 15

	Mole fraction[a] at temperature T								
	r = 1.2; O/F = 3.106; percent fuel = 24.36								
T, °K	4000	[b]3735	3600	3200	2800	2400	2000	1600	
CO	0.28715	0.27899	0.27378	0.25329	0.22509	0.19752	0.18528	0.17223	
CO_2	.11183	.12887	.13896	.17545	.22122	.26369	.28095	.29453	
F	.00278	.00196	.00161	.00079	.00029	.00006	.00000	.00000	
H	.04218	.03600	.03284	.02345	.01440	.00637	.00138	.00010	
H_2	.05983	.05643	.05457	.04859	.04266	.03991	.04548	.05886	
HF	.13386	.13772	.13975	.14605	.15257	.15790	.15967	.15986	
H_2O	.19942	.21795	.22804	.26046	.29453	.32165	.32630	.31440	
O	.03630	.02924	.02566	.01535	.00650	.00111	.00002	.00000	
O_2	.04633	.04321	.04102	.03152	.01729	.00347	.00007	.00000	
OH	.08032	.06962	.06378	.04505	.02544	.00833	.00084	.00002	
	r = 1.4; O/F = 2.662; percent fuel = 27.31								
T, °K	4000	[b]3694	3600	3200	2800	2400	2000	1600	1200
CO	0.33771	0.33350	0.33184	0.32315	0.31404	0.30709	0.29737	0.27827	0.23871
CO_2	.08737	.10148	.10635	.12885	.14983	.16303	.17452	.19390	.23348
F	.00199	.00127	.00108	.00047	.00013	.00002	.00000	.00000	.00000
H	.05043	.04157	.03877	.02669	.01477	.00535	.00100	.00007	.00000
H_2	.09155	.08849	.08755	.08437	.08473	.09118	.10283	.12251	.16211
HF	.12279	.12643	.12756	.13222	.13604	.13799	.13853	.13861	.13861
H_2O	.20272	.22411	.23102	.26033	.28397	.29226	.28551	.26665	.22709
O	.02253	.01603	.01408	.00659	.00167	.00014	.00000	.00000	.00000
O_2	.01910	.01553	.01421	.00780	.00216	.00017	.00000	.00000	.00000
OH	.06380	.05159	.04755	.02952	.01267	.00278	.00024	.00000	.00000
	r = 1.6; O/F = 2.329; percent fuel = 30.04								
T, °K	3600	[b]3583	3200	2800	2400	2000	1600	1200	900
CH_4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001
CO	.38082	.38089	.38058	.37932	.37518	.36542	.34612	.30671	.24775
CO_2	.07353	.07399	.08383	.09220	.09983	.11069	.13018	.16960	.22855
F	.00068	.00066	.00026	.00006	.00001	.00000	.00000	.00000	.00000
H	.04113	.04049	.02638	.01304	.00426	.00075	.00005	.00000	.00000
H_2	.13416	.13422	.13689	.14329	.15253	.16471	.18452	.22397	.28291
HF	.11602	.11617	.11903	.12105	.12200	.12229	.12234	.12235	.12235
H_2O	.21326	.21422	.23331	.24468	.24504	.23605	.21679	.17738	.11843
O	.00623	.00601	.00219	.00039	.00003	.00000	.00000	.00000	.00000
O_2	.00379	.00367	.00143	.00026	.00002	.00000	.00000	.00000	.00000
OH	.03039	.02975	.01612	.00570	.00111	.00009	.00000	.00000	.00000
	r = 1.8; O/F = 2.071; percent fuel = 32.57								
T, °K	3600	[b]3391	3200	2800	2400	2000	1600	1200	900
CH_4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00011
CO	.41631	.41784	.41888	.41934	.41626	.40809	.39166	.35739	.30615
CO_2	.04780	.05029	.05844	.05685	.06237	.07133	.08790	.12218	.17342
F	.00042	.00025	.00015	.00003	.00000	.00000	.00000	.00000	.00000
H	.03986	.03136	.02396	.01105	.00341	.00057	.00003	.00000	.00000
H_2	.18980	.19331	.19698	.20548	.21431	.22470	.24156	.27586	.32680
HF	.10554	.10663	.10747	.10869	.10928	.10946	.10949	.10950	.10952
H_2O	.17940	.18608	.19082	.19570	.19386	.18580	.16935	.13507	.08400
O	.00246	.00138	.00071	.00011	.00001	.00000	.00000	.00000	.00000
O_2	.00089	.00051	.00027	.00004	.00000	.00000	.00000	.00000	.00000
OH	.01751	.01235	.00832	.00269	.00050	.00004	.00000	.00000	.00000
	r = 2.0; O/F = 1.864; percent fuel = 34.92								
T, °K	3200	[b]3142	2800	2400	2000	1600	1200	1000	900
CH_4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00015	0.00140
CO	.44345	.44375	.44443	.44238	.43633	.42373	.39655	.37175	.35433
CO_2	.03252	.03287	.03521	.03910	.04577	.05847	.08566	.11045	.12782
F	.00009	.00007	.00002	.00000	.00000	.00000	.00000	.00000	.00000
H	.02093	.01895	.00924	.00275	.00045	.00003	.00000	.00000	.00000
H_2	.25567	.25696	.26418	.27162	.27962	.29258	.31977	.34419	.35840
HF	.09772	.09787	.09854	.09894	.09907	.09909	.09909	.09912	.09937
H_2O	.14507	.14561	.14702	.14496	.13875	.12611	.09893	.07433	.05867
O	.00025	.00019	.00003	.00000	.00000	.00000	.00000	.00000	.00000
O_2	.00005	.00004	.00001	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00426	.00360	.00132	.00024	.00002	.00000	.00000	.00000	.00000

[a]Mole fractions were computed for all 19 substances considered in this report but were omitted if less than 5×10^{-6}.
[b]Combustion temperature.

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TABLE VI. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Isentropic expansion or compression from combustion chamber pressure of 600 lb/sq in. abs.]

(c) Percent fluorine in oxidant by weight, 30

Mole fraction[a] at temperature T										
r = 1.2; O/F = 3.432; percent fuel = 22.56										
T, °K	4000	[b]3868	3600	3200	2800	2400	2000	1600		
CO	0.27826	0.27490	0.26599	0.24609	0.21749	0.18873	0.17742	0.16738		
CO_2	.08577	.09303	.11053	.14494	.18952	.23194	.24774	.25828		
F	.00778	.00657	.00444	.00214	.00077	.00015	.00001	.00000		
H	.04443	.04100	.03398	.02369	.01410	.00603	.00126	.00009		
H_2	.04505	.04381	.04101	.03627	.03138	.02883	.03299	.04333		
HF	.26777	.27194	.28056	.29386	.30732	.31828	.32182	.32216		
H_2O	.11885	.12550	.14031	.16532	.19209	.21388	.21796	.20881		
O	.04234	.03829	.02994	.01784	.00752	.00126	.00003	.00000		
O_2	.04278	.04197	.03919	.03116	.01772	.00365	.00007	.00000		
OH	.06697	.06300	.05404	.03870	.02208	.00726	.00071	.00001		
r = 1.4; O/F = 2.942; percent fuel = 25.37										
T, °K	4000	[b]3836	3600	3200	2800	2400	2000	1600	1200	
CO	0.32447	0.32271	0.31921	0.31067	0.30134	0.29515	0.28741	0.27196	0.23990	
CO_2	.06680	.07342	.08427	.10580	.12641	.13859	.14796	.16367	.19574	
F	.00549	.00434	.00295	.00127	.00036	.00005	.00000	.00000	.00000	
H	.05461	.04927	.04150	.02820	.01543	.00550	.00101	.00007	.00000	
H_2	.07276	.07145	.06954	.06671	.06671	.07809	.08177	.09780	.12990	
HF	.24837	.25268	.25883	.26894	.27719	.28137	.28248	.28264	.28265	
H_2O	.12820	.13727	.15113	.17580	.19656	.20438	.19915	.18386	.15180	
O	.02645	.02242	.01673	.00795	.00204	.00016	.00000	.00000	.00000	
O_2	.01785	.01648	.01391	.00803	.00231	.00018	.00000	.00000	.00000	
OH	.05498	.04994	.04193	.02664	.01163	.00253	.00021	.00000	.00000	
r = 1.6; O/F = 2.574; percent fuel = 27.98										
T, °K	4000	[b]3745	3600	3200	2800	2400	2000	1600	1200	900
CO	0.36409	0.36485	0.36511	0.36536	0.36489	0.36206	0.35440	0.33890	0.30751	0.26214
CO_2	.04732	.05330	.05686	.06640	.07388	.08014	.08888	.10457	.13597	.18133
F	.00377	.00247	.00186	.00070	.00017	.00002	.00000	.00000	.00000	.00000
H	.06171	.05159	.04567	.02922	.01439	.00465	.00080	.00005	.00000	.00000
H_2	.11084	.11109	.11150	.11431	.12046	.12886	.13912	.15516	.18659	.23194
HF	.22979	.23492	.23770	.24442	.24893	.25102	.25166	.25176	.25177	.25177
H_2O	.12329	.13581	.14296	.16077	.17133	.17220	.16506	.14956	.11816	.07281
O	.01400	.00969	.00745	.00266	.00047	.00003	.00000	.00000	.00000	.00000
O_2	.00596	.00453	.00366	.00143	.00026	.00002	.00000	.00000	.00000	.00000
OH	.03922	.03175	.02722	.01473	.00523	.00101	.00008	.00000	.00000	.00000
r = 1.8; O/F = 2.288; percent fuel = 30.41										
T, °K	3600	[b]3586	3200	2800	2400	2000	1600	1200	900	
CH_4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00009	
CO	.39917	.39931	.40250	.40396	.40226	.39624	.38369	.35771	.32050	
CO_2	.03496	.03511	.03885	.04233	.04653	.05338	.06607	.09206	.12926	
F	.00116	.00113	.00040	.00009	.00001	.00000	.00000	.00000	.00000	
H	.04574	.04507	.02753	.01267	.00388	.00064	.00004	.00000	.00000	
H_2	.16390	.16415	.17171	.18045	.18865	.19716	.21018	.23680	.27315	
HF	.21792	.21810	.22232	.22513	.22647	.22689	.22697	.22697	.22701	
H_2O	.11817	.11860	.12824	.13283	.13175	.12565	.11305	.08706	.04999	
O	.00286	.00276	.00083	.00013	.00001	.00000	.00000	.00000	.00000	
O_2	.00079	.00076	.00024	.00004	.00000	.00000	.00000	.00000	.00000	
OH	.01533	.01502	.00737	.00239	.00044	.00003	.00000	.00000	.00000	
r = 2.0, O/F = 2.059, percent fuel = 32.69										
T, °K	3600	[b]3369	3200	2800	2400	2000	1600	1200	1000	900
CH_4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00011	0.00112
CO	.42268	.43512	.43660	.42858	.42788	.42393	.41521	.39642	.37976	.36833
CO_2	.01999	.02100	.02172	.02359	.02627	.03088	.03971	.05851	.07516	.08650
F	.00075	.00041	.00024	.00005	.00001	.00000	.00000	.00000	.00000	.00000
H	.04301	.03210	.02474	.01091	.00323	.00052	.00003	.00000	.00000	.00000
H_2	.21901	.22495	.22923	.23829	.24526	.25145	.26058	.27938	.29576	.30451
HF	.20030	.20220	.20337	.20531	.20626	.20656	.20661	.20662	.20666	.20708
H_2O	.08530	.08855	.09030	.09214	.09090	.08665	.07786	.05906	.04255	.03845
O	.00102	.00050	.00087	.00004	.00000	.00000	.00000	.00000	.00000	.00000
O_2	.00015	.00003	.00004	.00001	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00779	.00510	.00349	.00108	.00019	.00002	.00000	.00000	.00000	.00000

[a]Mole fractions were computed for all 19 substances considered in this report but were omitted if less than 5×10^{-6}.
[b]Combustion temperature.

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TABLE VI. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Isentropic expansion or compression from combustion chamber pressure of 600 lb/sq in. abs.]

(d) Percent fluorine in oxidant by weight, 50

Mole fraction[a] at temperature T										
r = 1.2; O/F = 3.992; percent fuel = 20.03										
T, °K	4400	[b]4120	4000	3600	3200	2800	2400	2000	1600	
CO	0.27184	0.26919	0.26737	0.25721	0.23833	0.20898	0.17872	0.16962	0.16505	
CO_2	.03897	.04779	.05245	.07299	.10379	.14620	.18750	.19985	.20468	
F	.04118	.03110	.02708	.01550	.00729	.00252	.00046	.00002	.00000	
H	.05022	.04266	.03944	.02899	.01926	.01080	.00432	.00086	.00006	
H_2	.02128	.01966	.01898	.01676	.01456	.01241	.01129	.01325	.01801	
HF	.41483	.43396	.44215	.46897	.49466	.51860	.53686	.54206	.54245	
H_2O	.02671	.03012	.03187	.03916	.04906	.06099	.07162	.07386	.06975	
O	.06234	.05424	.05041	.03640	.02172	.00895	.00141	.00002	.00000	
O_2	.03005	.03186	.03241	.03254	.02806	.01695	.00348	.00005	.00000	
OH	.04260	.03942	.03784	.03148	.02327	.01358	.00444	.00041	.00001	
r = 1.4; O/F = 3.421; percent fuel = 22.62										
T, °K	4400	[b]4100	4000	3600	3200	2800	2400	2000	1600	1200
CO	0.30926	0.30910	0.30870	0.30487	0.29704	0.28800	0.28332	0.27897	0.26992	0.25160
CO_2	.02900	.03600	.03881	.05301	.07184	.09042	.09989	.10547	.11470	.13304
F	.02795	.01970	.01724	.00911	.00380	.00103	.00013	.00001	.00000	.00000
H	.06950	.05907	.05553	.04122	.02719	.01439	.00496	.00088	.00005	.00000
H_2	.04158	.04028	.03985	.03813	.03672	.03705	.04088	.04700	.05655	.07491
HF	.39744	.41429	.41979	.44095	.46010	.47486	.48179	.48346	.48370	.48372
H_2O	.03413	.04043	.04288	.05458	.06871	.08172	.08701	.08407	.07506	.05673
O	.03998	.03301	.03049	.01983	.00953	.00839	.00017	.00000	.00000	.00000
O_2	.01261	.01270	.01257	.01086	.00684	.00203	.00014	.00000	.00000	.00000
OH	.03857	.03544	.03414	.02743	.01824	.00812	.00171	.00013	.00000	.00000
r = 1.6; O/F = 2.994; percent fuel = 25.04										
T, °K	4400	[b]4030	4000	3600	3200	2800	2400	2000	1600	1200
CO	0.34125	0.34426	0.34447	0.34671	0.34817	0.34916	0.34845	0.34435	0.33550	0.31842
CO_2	.01895	.02403	.02449	.03140	.03840	.04342	.04707	.05211	.06112	.07821
F	.01935	.01170	.01117	.00537	.00194	.00044	.00005	.00000	.00000	.00000
H	.08567	.06978	.06846	.05016	.03166	.01531	.00483	.00080	.00005	.00000
H_2	.07022	.07122	.07133	.07335	.07715	.08330	.09019	.09699	.10637	.12348
HF	.37701	.39356	.39483	.41071	.42344	.43154	.43518	.43626	.43644	.43645
H_2O	.03413	.04264	.04340	.05469	.06584	.07277	.07356	.06944	.06053	.04344
O	.02130	.01515	.01464	.00795	.00281	.00048	.00003	.00000	.00000	.00000
O_2	.00398	.00347	.00341	.00227	.00092	.00016	.00001	.00000	.00000	.00000
OH	.02815	.02420	.02380	.01739	.00969	.00342	.00064	.00005	.00000	.00000
r = 1.8; O/F = 2.681; percent fuel = 27.31										
T, °K	4000	[b]3898	3600	3200	2800	2400	2000	1600	1200	900
CH_4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010
CO	.37267	.37403	.37784	.38232	.38527	.38582	.38358	.37807	.36699	.35323
CO_2	.01214	.01274	.01442	.01634	.01790	.01972	.02276	.02841	.03949	.05324
F	.00727	.00603	.00321	.00106	.00023	.00003	.00000	.00000	.00000	.00000
H	.07584	.07028	.05376	.03216	.01465	.00440	.00070	.00004	.00000	.00000
H_2	.11350	.11541	.12165	.13128	.14062	.14761	.15264	.15865	.16976	.18323
HF	.36912	.37227	.38046	.38887	.39412	.39664	.39745	.39759	.39759	.39767
H_2O	.03165	.03336	.03821	.04341	.04588	.04555	.04285	.03724	.02616	.01253
O	.00518	.00436	.00232	.00066	.00010	.00001	.00000	.00000	.00000	.00000
O_2	.00055	.00048	.00028	.00008	.00001	.00000	.00000	.00000	.00000	.00000
OH	.01208	.01105	.00785	.00381	.00122	.00022	.00002	.00000	.00000	.00000
r = 2.0; O/F = 2.395; percent fuel = 29.46										
T, °K	4000	[b]3708	3600	3200	2800	2400	2000	1600	1200	900
GRAPHITE	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01676
CH_4	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00001	.00059
CO	.39358	.39783	.39938	.40426	.40770	.40924	.40906	.40748	.40399	.36916
CO_2	.00311	.00340	.00350	.00384	.00418	.00468	.00555	.00724	.01074	.02871
F	.00485	.00263	.00204	.00065	.00014	.00002	.00000	.00000	.00000	.00000
H	.07732	.05941	.05289	.03037	.01332	.00389	.00061	.00003	.00000	.00000
H_2	.16192	.17137	.17492	.18761	.19771	.20373	.20655	.20858	.21209	.21179
HF	.34436	.35057	.35257	.35860	.36245	.36436	.36498	.36509	.36510	.36552
H_2O	.01094	.01221	.01262	.01378	.01425	.01406	.01326	.01158	.00808	.00748
O	.00091	.00048	.00036	.00009	.00001	.00000	.00000	.00000	.00000	.00000
O_2	.00002	.00001	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00299	.00809	.00177	.00080	.00025	.00004	.00000	.00000	.00000	.00000

[a]Mole fractions were computed for all 18 substances considered in this report but were omitted if less than 5×10^{-6}.

[b]Combustion temperature.

TABLE VI. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED TEMPERATURES

FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Isentropic expansion or compression from combustion chamber pressure of 600 lb/sq in. abs.]

(e) Percent fluorine in oxidant by weight, 70.37

Mole fraction[a] at temperature T											
r = 1; O/F = 5.743; percent fuel = 14.83											
T, °K	4400	[b]4007	4000	3600	3200	2800	2400	2000	1600	900	
CF_4	----	----	----	----	0.00001	0.00018	0.00836	0.03269	0.06574	0.08743	
CO	0.20805	0.20066	0.20047	0.18636	.16467	.14054	.11887	.08143	.03216	----	
CO_2	.02381	.03547	.03574	.05447	.08103	.10945	.13275	.17058	.22012	.25246	
F	.25416	.25010	.25007	.25013	.25325	.25668	.23400	.16218	.06429	----	
F_2	.00007	.00006	.00006	.00005	.00004	.00004	.00003	.00001	----	----	
H	.00801	.00339	.00333	.00108	.00021	.00002	----	----	----	----	
H_2	.00058	.00018	.00018	.00004	----	----	----	----	----	----	
HF	.43456	.45135	.45163	.46531	.47665	.48580	.50491	.55292	.61765	.66011	
H_2O	.00058	.00027	.00027	.00009	.00002	----	----	----	----	----	
O	.04677	.03517	.03494	.02155	.00969	.00233	.00030	.00004	----	----	
O_2	.01800	.02039	.02042	.01984	.01414	.00491	.00077	.00015	.00002	----	
OH	.00542	.00294	.00290	.00115	.00029	.00003	----	----	----	----	
r = 1.40; O/F = 4.102; percent fuel = 19.60											
T, °K	4800	[b]4464	4400	4000	3600	3200	2800	2400	2000	1600	1200
C(GAS)	0.00001	----	----	----	----	----	----	----	----	----	----
CF	.00001	----	----	----	----	----	----	----	----	----	----
CF_4	----	----	----	----	----	----	----	0.00055	0.01068	0.01521	0.01530
CO	.28924	0.29436	0.29530	0.30053	0.30343	0.30274	0.30108	.30030	.29221	.28860	.28853
CO_2	.00225	.00312	.00334	.00542	.00937	.01523	.01894	.02014	.03108	.03597	.03607
F	.14374	.12346	.11956	.09565	.07488	.06179	.05801	.05559	.01744	.00034	----
F_2	.00001	.00001	.00001	----	----	----	----	----	----	----	----
H	.06281	.04781	.04492	.02737	.01241	.00313	.00030	.00001	----	----	----
H_2	.01175	.00871	.00813	.00467	.00187	.00035	.00002	----	----	----	----
HF	.47487	.50784	.51421	.55362	.58894	.61299	.62112	.62338	.64860	.65988	.66011
H_2O	.00081	.00081	.00081	.00072	.00047	.00013	.00001	----	----	----	----
O	.01084	.01043	.01031	.00907	.00652	.00279	.00043	.00002	----	----	----
O_2	.00029	.00037	.00039	.00054	.00063	.00042	.00007	----	----	----	----
OH	.00336	.00308	.00301	.00241	.00147	.00044	.00003	----	----	----	----
r = 1.50; O/F = 3.829; percent fuel = 20.71											
T, °K	4800	[b]4479	4400	4000	3600	3200	2800	2400	2000	1600	1200
C(GAS)	0.00121	0.00099	0.00093	0.00060	0.00026	0.00006	----	----	----	----	----
GRAPHITE	----	----	----	----	----	----	----	----	----	----	0.00005
CF	.00128	.00117	.00114	.00090	.00055	.00023	0.00005	----	----	----	----
CF_2	.00005	.00005	.00005	.00004	.00003	.00002	.00001	0.00001	----	----	----
CF_3	.00001	.00001	.00001	.00001	----	----	.00001	.00002	----	----	----
CF_4	----	----	----	----	----	.00001	.00004	.00139	0.00311	0.00328	.00328
C_2F_2	.00028	.00042	.00046	.00077	.00115	.00145	.00156	.00092	.00008	----	----
CO	.30145	.30754	.30907	.31680	.32406	.32985	.33313	.33499	.33647	.33661	.33651
CO_2	.00002	.00001	.00001	----	----	----	----	----	----	----	.00005
F	.12128	.10077	.09556	.06922	.04433	.02421	.01243	.00577	.00052	.00001	----
F_2	.00001	.00001	----	----	----	----	----	----	----	----	----
H	.07694	.06245	.05877	.04020	.02282	.00920	.00179	.00013	.00001	----	----
H_2	.01725	.01423	.01346	.00962	.00591	.00268	.00052	.00003	.00001	----	----
HF	.48004	.51231	.52049	.56184	.60085	.63229	.65044	.65673	.65979	.66010	.66011
H_2O	.00001	----	----	----	----	----	----	----	----	----	----
O	.00011	.00003	.00002	----	----	----	----	----	----	----	----
OH	.00004	.00001	.00001	----	----	----	----	----	----	----	----
r = 1.60; O/F = 3.589; percent fuel = 21.79											
T, °K	4400	[b]4396	4000	3600	3200	2800	2400	2000	1600	1200	900
C(GAS)	0.00411	0.00409	0.00255	0.00078	0.00010	0.00001	----	----	----	----	----
GRAPHITE	----	----	----	.01261	.02198	.02433	0.02463	0.02467	0.02468	0.02473	.02915
CF	.00420	.00419	.00285	.00106	.00019	.00001	----	----	----	----	----
CF_2	.00015	.00015	.00010	.00004	.00001	----	----	----	----	----	----
CF_3	.00002	.00002	.00001	----	----	----	----	----	----	----	----
C_2F_2	.00746	.00748	.00923	.00484	.00105	.00010	----	----	----	----	----
CO	.30364	.30371	.31108	.31387	.31621	.31857	.31977	.32014	.32020	.32010	.31135
CO_2	----	----	----	----	----	----	----	----	----	.00005	.00439
F	.06782	.06758	.04358	.02554	.01084	.00246	.00026	.00001	----	----	----
H	.07002	.06986	.05343	.03458	.01855	.00823	.00253	.00040	.00002	----	----
H_2	.02258	.02255	.02013	.01530	.01180	.01184	.01354	.01449	.01468	.01469	.01460
HF	.51997	.52035	.55703	.59136	.61927	.63446	.63926	.64028	.64042	.64042	.64042
H_2O	----	----	----	----	----	----	----	----	----	----	.00009
r = 2.50; O/F = 2.297; percent fuel = 30.33											
T, °K	4000	[b]3898	3600	3200	2800	2400	2000	1600	1200	900	
C(GAS)	0.00098	0.00069	0.00021	0.00002	----	----	----	----	----	----	
GRAPHITE	.14771	.14949	.15304	.15560	0.15706	0.15785	0.15813	0.15819	0.15831	0.16450	
CF	.00066	.00047	.00015	.00002	----	----	----	----	----	----	
CF_2	.00001	.00001	----	----	----	----	----	----	----	----	
C_2F_2	.00163	.00114	.00035	.00005	----	----	----	----	----	----	
CH_4	.00002	.00002	.00001	.00001	.00001	.00001	.00001	.00001	.00003	.00013	
CO	.22351	.22398	.22566	.22807	.23001	.23114	.23155	.23162	.23144	.22037	
CO_2	----	----	----	----	----	----	----	----	.00007	.00493	
F	.00790	.00660	.00352	.00116	.00025	.00003	----	----	----	----	
H	.06950	.06463	.04966	.02986	.01379	.00424	.00070	.00004	----	----	
H_2	.11289	.11438	.12044	.13033	.13909	.14447	.14649	.14685	.14679	.14520	
HF	.43518	.43859	.44695	.45486	.45977	.46226	.46312	.46327	.46330	.46340	
H_2O	----	----	----	----	----	----	----	.00001	.00007	.00147	

[a]Mole fractions were computed for all 19 substances considered in this report but are omitted if less than 5×10^{-6}.

[b]Combustion temperature.

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TABLE VI. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Isentropic expansion or compression from combustion chamber pressure of 600 lb/sq in. abs.]

(f) Percent fluorine in oxidant, 100 (zero percent oxygen)

Mole fraction[a] at temperature T										
r = 1.0; O/F = 8.083; percent fuel = 11.01										
T, °K	4000	[b]3962	3600	3200	2800	2400				
C(gas)	0.00017	0.00015	0.00007	0.00002	0.00001	--------				
CF	.00477	.00453	.00277	.00138	.00054	0.00014				
CF_2	.00441	.00430	.00321	.00202	.00103	.00037				
CF_3	.01120	.01100	.00876	.00598	.00336	.00141				
CF_4	.06245	.06446	.08645	.11726	.15639	.20600				
C_2F_2	.06610	.06582	.06225	.05629	.04760	.03543				
F	.43286	.42994	.39799	.35239	.29285	.21522				
F_2	.00019	.00018	.00008	.00003	.00001	--------				
H	.00157	.00148	.00087	.00043	.00019	.00006				
H_2	.00004	.00004	.00002	.00001	--------	--------				
HF	.41625	.41810	.43753	.46419	.49802	.54136				
r = 1.5; O/F = 5.389; percent fuel = 15.65										
T, °K	4400	[b]4008	4000	3600	3400	3200	2800	2400	2200	
C(gas)	0.00123	0.00049	0.00049	0.00017	0.00009	0.00005	0.00001	--------	--------	
Graphite	--------	--------	--------	--------	--------	--------	.00521	0.11790	0.14872	
CF	.01166	.00732	.00725	.00401	.00283	.00190	.00070	.00012	.00003	
CF_2	.00396	.00351	.00349	.00276	.00230	.00183	.00095	.00027	.00010	
CF_3	.00429	.00462	.00463	.00447	.00410	.00356	.00220	.00089	.00043	
CF_4	.00671	.01327	.01347	.02623	.03517	.04580	.07236	.11270	.13145	
C_2F_2	.13180	.13462	.13464	.13565	.13553	.13504	.12918	.04386	.01942	
F	.27491	.25679	.25629	.22681	.20717	.18410	.12952	.10360	.07919	
F_2	.00010	.00006	.00006	.00003	.00002	.00001	--------	--------	--------	
H	.00808	.00421	.00416	.00200	.00135	.00089	.00035	.00008	.00003	
H_2	.00069	.00028	.00028	.00010	.00006	.00003	.00001	--------	--------	
HF	.55657	.57484	.57524	.59778	.61138	.62678	.65952	.62059	.62062	
r = 2.0; O/F = 4.041; percent fuel = 19.84										
T, °K	4400	[b]4206	4000	3600	3200	2800	2400	2000		
C(gas)	0.00582	0.00377	0.00216	0.00051	0.00007	0.00001	--------	--------		
Graphite	.03344	.05516	.07258	.09162	.10934	.16354	0.22331	0.24928		
CF	.01472	.01170	.00880	.00431	.00163	.00044	.00006	--------		
CF_2	.00133	.00124	.00116	.00107	.00092	.00052	.00014	.00001		
CF_3	.00039	.00039	.00042	.00062	.00105	.00105	.00046	.00008		
CF_4	.00016	.00022	.00034	.00132	.00789	.03016	.05911	.08095		
C_2F_2	.15232	.14101	.13232	.12378	.11257	.07035	.02305	.00249		
F	.10112	.10382	.10546	.10360	.09465	.08061	.05452	.01600		
F_2	.00001	.00001	.00001	--------	--------	--------	--------	--------		
H	.03515	.02577	.01729	.00618	.00163	.00039	.00008	.00001		
H_2	.00945	.00577	.00317	.00076	.00013	.00002	--------	--------		
HF	.64609	.65115	.65630	.66622	.67013	.65291	.63925	.65118		
r = 2.8; O/F = 2.887; percent fuel = 25.73										
T, °K	4400	[b]4262	4000	3600	3200	3000	2800	2400	2200	2000
C(gas)	0.00501	0.00392	0.00224	0.00067	0.00010	0.00003	0.00001	--------	--------	--------
Graphite	.23513	.24806	.26916	.29213	.30380	.30584	.30714	0.31727	0.32194	0.32398
CF	.00774	.00645	.00429	.00192	.00067	.00035	.00017	.00002	--------	--------
CF_2	.00043	.00037	.00027	.00016	.00011	.00010	.00009	.00003	.00001	--------
CF_3	.00008	.00006	.00005	.00003	.00004	.00005	.00009	.00008	.00004	.00001
CF_4	.00002	.00002	.00002	.00002	.00008	.00026	.00117	.00869	.01253	.01452
C_2F_2	.04898	.04176	.03031	.01853	.01335	.01287	.01253	.00520	.00178	.00038
F	.05320	.05296	.05140	.04616	.03903	.03533	.03079	.01522	.00711	.00222
H	.05117	.04509	.03348	.01710	.00538	.00230	.00084	.00011	.00004	.00001
H_2	.02326	.01859	.01147	.00438	.00098	.00034	.00010	.00001	--------	--------
HF	.57498	.58271	.59734	.61890	.63646	.64253	.64708	.65337	.65655	.65888

[a]Mole fractions were computed for all 19 substances considered in this report but are omitted if less than 5×10^{-6}.

[b]Combustion temperature.

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TABLE VI. - Concluded. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED TEMPERATURES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Isentropic expansion or compression from combustion chamber pressure of 600 lb/sq in. abs.]

(f) Concluded. Percent fluorine in oxidant, 100 (zero percent oxygen)

Mole fraction[a] at temperature T										
r = 3.0; O/F = 2.694; percent fuel = 27.07										
T, °K	4400	[b]4249	4000	3600	3200	2800	2400	2000	1600	
C(gas)	0.00464	0.00356	0.00210	0.00066	0.00011	0.00001	-------	-------	-------	
Graphite	.26112	.27409	.29237	.31388	.32668	.33259	0.33425	0.33635	0.33661	
CF	.00650	.00522	.00340	.00136	.00038	.00007	.00001	-------	-------	
CF_2	.00033	.00026	.00018	.00008	.00003	.00001	.00001	-------	-------	
CF_3	.00005	.00004	.00003	.00001	.00001	-------	.00001	-------	-------	
CF_4	.00001	.00001	.00001	.00001	.00001	.00002	.00075	.00294	.00327	
C_2F_2	.03731	.03008	.02023	.00943	.00385	.00182	.00142	.00014	-------	
F	.04469	.04365	.04072	.03260	.02188	.01295	.00739	.00108	.00002	
H	.05507	.04901	.03896	.02338	.01041	.00243	.00019	.00001	-------	
H_2	.02909	.02373	.01651	.00837	.00336	.00068	.00004	-------	-------	
HF	.56118	.57034	.58550	.61022	.63329	.64942	.65593	.65946	.66009	
r = 3.5; O/F = 2.309; percent fuel = 30.22										
T, °K	4400	[b]4172	4000	3600	3200	3000	2600	2400	2000	1600
C(gas)	0.00357	0.00231	0.00154	0.00044	0.00007	0.00002	-------	-------	-------	-------
Graphite	.30584	.31993	.32852	.34203	.34872	.35063	0.35305	0.35377	0.35447	0.35461
CF	.00416	.00271	.00182	.00053	.00009	.00003	-------	-------	-------	-------
CF_2	.00017	.00011	.00007	.00002	-------	-------	-------	-------	-------	-------
CF_3	.00002	.00001	.00001	-------	-------	-------	-------	-------	-------	-------
C_2F_2	.01980	.01223	.00793	.00214	.00034	.00011	.00001	-------	-------	-------
F	.02856	.02517	.02185	.01272	.00497	.00260	.00047	.00015	.00001	-------
H	.06231	.05545	.05015	.03767	.02506	.01891	.00835	.00465	.00086	.00005
H_2	.04838	.04127	.03727	.03238	.03304	.03483	.03920	.04097	.04288	.04330
HF	.52718	.54081	.55083	.57206	.58771	.59288	.59893	.60045	.60178	.60204
r = 4.0; O/F = 2.021; percent fuel = 33.10										
T, °K	4400	[b]4041	4000	3600	3200	2800	2400	2000	1600	
C(gas)	0.00257	0.00114	0.00102	0.00026	0.00004	-------	-------	-------	-------	
Graphite	.33369	.34819	.34941	.35807	.36279	0.36577	0.36757	0.36832	0.36847	
CF	.00270	.00116	.00104	.00026	.00004	-------	-------	-------	-------	
CF_2	.00010	.00004	.00003	.00001	-------	-------	-------	-------	-------	
CF_3	.00001	-------	-------	-------	-------	-------	-------	-------	-------	
C_2F_2	.01157	.00442	.00390	.00090	.00013	.00001	-------	-------	-------	
CH_4	.00002	.00001	.00001	-------	-------	-------	-------	-------	-------	
F	.01852	.01310	.01245	.00635	.00232	.00056	.00007	-------	-------	
H	.06476	.05526	.05409	.04144	.02733	.01410	.00491	.00091	.00006	
H_2	.07258	.06600	.06564	.06576	.07054	.07674	.08149	.08363	.08409	
HF	.49349	.51067	.51240	.52696	.53681	.54281	.54596	.54714	.54738	
r = 5.0; O/F = 1.617; percent fuel = 38.22										
T, °K	4000	[b]3708	3600	3200	2800	2400	2000	1600	1200	
C(gas)	0.00045	0.00016	0.00011	0.00001	-------	-------	-------	-------	-------	
Graphite	.37652	.38045	.38160	.38501	0.38749	0.38903	0.38968	0.38981	0.38982	
CF	.00043	.00016	.00010	.00002	-------	-------	-------	-------	-------	
CF_2	.00001	-------	-------	-------	-------	-------	-------	-------	-------	
C_2F_2	.00156	.00053	.00034	.00005	-------	-------	-------	-------	-------	
CH_4	.00005	.00003	.00003	.00002	.00001	.00001	.00001	.00001	.00001	
F	.00521	.00310	.00248	.00089	.00021	.00003	-------	-------	-------	
H	.04909	.04012	.03659	.02334	.01171	.00401	.00075	.00005	-------	
H_2	.12317	.12595	.12743	.13394	.14027	.14460	.14646	.14686	.14688	
HF	.44350	.44949	.45133	.45673	.46030	.46232	.46311	.46327	.46329	

[a]Mole fractions were computed for all 19 substances considered in this report but are omitted if less than 5×10^{-6}.

[b]Combustion temperature.

TABLE VII. - THEORETICAL PERFORMANCE FOR EXPANSION TO 1 ATMOSPHERE

FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Combustion-chamber pressure, 600 lb/sq in. abs. Equilibrium composition during isentropic expansion.]

Equivalence ratio, $\frac{4(C)+(H)}{2(O)+(F)}$	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	Coefficient of thrust, C_F	Area ratio, ε	Specific impulse, I, $\frac{\text{lb-sec}}{\text{lb}}$
Percent fluorine in oxidant, 0 (100 percent oxygen)								
1.0	22.71	3.403	3612	2718	5622	1.569	7.14	274.2
1.2	26.07	2.836	3628	2673	5795	1.566	7.05	282.1
1.3	27.64	2.618	3612	2558	5859	1.561	6.88	284.4
1.4	29.15	2.431	3576	2371	5904	1.553	6.61	284.9
1.5	30.59	2.269	3518	2167	5924	1.541	6.32	283.8
1.6	31.98	2.127	3436	1978	5918	1.530	6.09	281.5
1.8	34.59	1.891	3205	1661	5832	1.513	5.76	274.3
2.0	37.01	1.702	2923	1409	5679	1.503	5.55	265.4
3.0	46.85	1.134	1657	1015	4674	1.537	6.42	223.3
Percent fluorine in oxidant by weight, 15								
1.20	24.36	3.106	3735	2728	5947	1.564	6.993	289.0
1.40	27.31	2.662	3694	2479	6051	1.553	6.634	292.1
1.60	30.04	2.329	3583	2097	6081	1.532	6.109	289.6
1.80	32.57	2.071	3391	1775	6022	1.514	5.742	283.4
2.00	34.92	1.864	3142	1515	5895	1.502	5.500	275.2
Percent fluorine in oxidant by weight, 30								
1.20	22.56	3.432	3868	2789	6117	1.560	6.918	296.7
1.40	25.37	2.942	3836	2588	6215	1.552	6.636	299.9
1.60	27.98	2.574	3745	2227	6253	1.534	6.135	298.2
1.80	30.41	2.288	3586	1902	6216	1.516	5.745	292.9
2.00	32.69	2.059	3369	1637	6115	1.503	5.474	285.6
Percent fluorine in oxidant by weight, 50								
1.20	20.03	3.992	4120	2890	6386	1.554	6.783	308.5
1.40	22.62	3.421	4100	2738	6476	1.549	6.574	311.7
1.60	25.04	2.994	4030	2412	6519	1.534	6.127	310.9
1.80	27.31	2.661	3898	2094	6499	1.518	5.745	306.6
2.00	29.46	2.395	3708	1825	6421	1.505	5.464	300.4
Percent fluorine in oxidant by weight, 70.37								
1.0	14.83	5.743	4007	2452	6203	1.532	6.26	295.3
1.4	19.60	4.102	4464	2627	6757	1.533	6.01	322.0
1.5	20.71	3.829	4479	2758	6814	1.538	6.22	325.7
1.6	21.79	3.589	4396	2736	6749	1.544	6.30	323.8
2.5	30.33	2.297	3898	2168	6420	1.523	5.92	303.9
Percent fluorine in oxidant, 100 (zero percent oxygen)								
1.0	11.01	8.083	3962	2997	5645	1.563	7.002	274.3
1.5	15.65	5.389	4008	2907	5744	1.561	6.857	278.6
2.0	19.84	4.041	4206	2891	5951	1.551	6.856	286.9
2.8	25.73	2.887	4262	2964	6238	1.563	6.844	303.0
3.0	27.07	2.694	4249	3036	6269	1.566	6.979	305.1
3.5	30.22	2.309	4172	2833	6279	1.556	6.724	303.7
4.0	33.10	2.021	4041	2622	6212	1.548	6.566	298.8
5.0	38.22	1.617	3708	2288	6009	1.543	6.441	288.2

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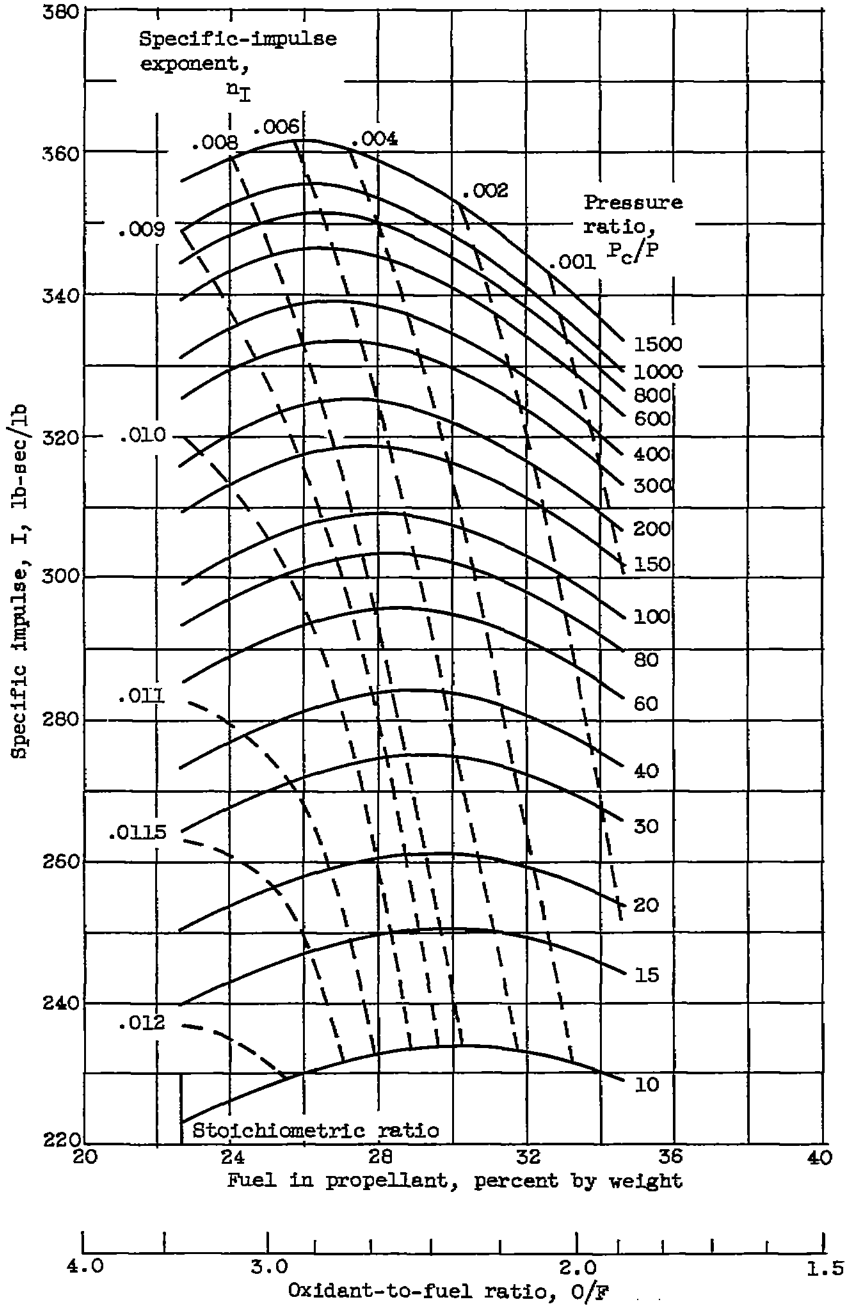
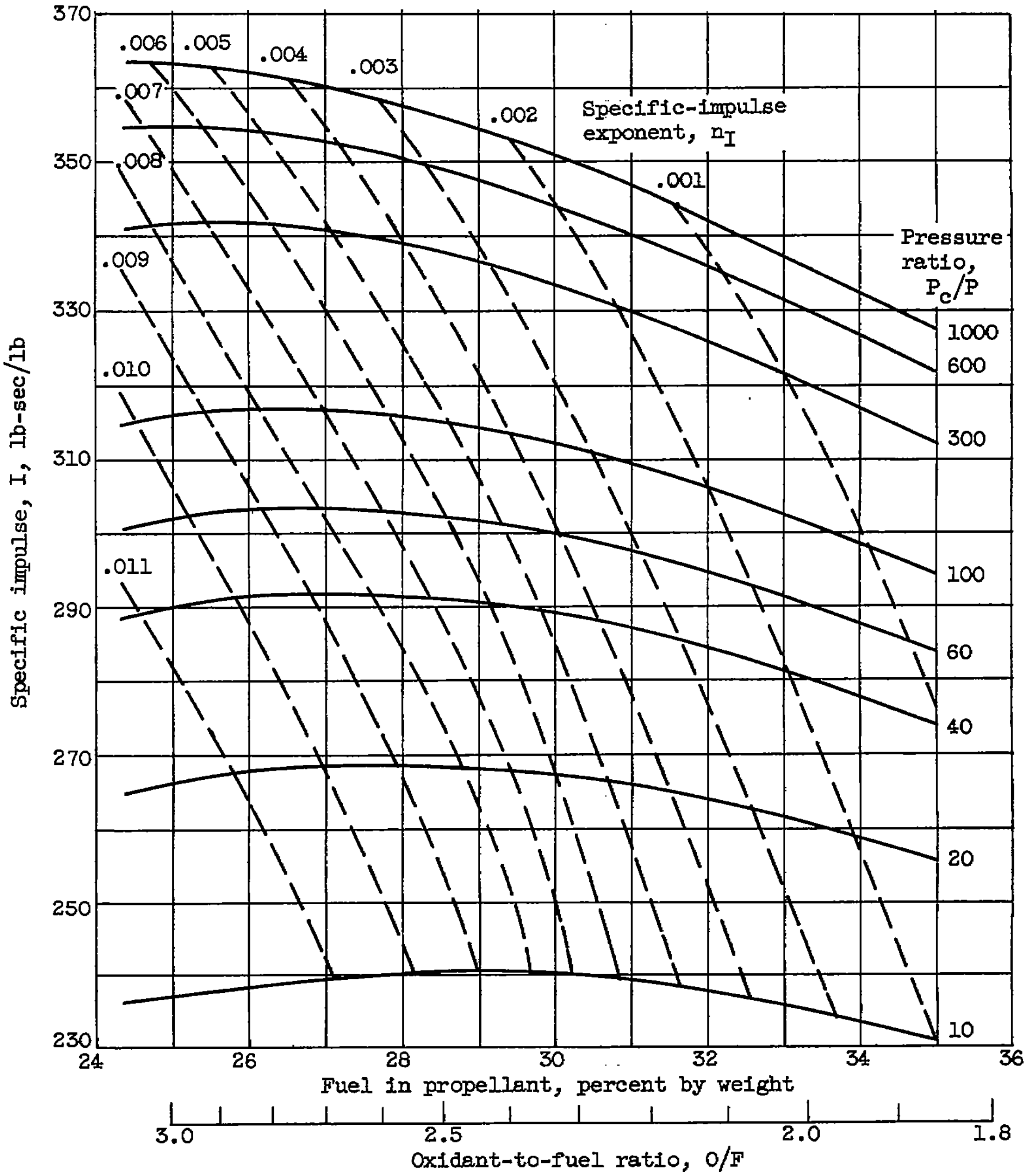


(a) Percent fluorine in oxidant, 0 (100 percent oxygen). Exponent n_I for use in equation $I = I_{600}(P_c/600)^{n_I}$.

Figure 1. - Theoretical specific impulse of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



(b) Percent fluorine in oxidant by weight, 15. Exponent n_I for use in equation $I = I_{600}(P_c/600)^{n_I}$.

Figure 1. - Continued. Theoretical specific impulse of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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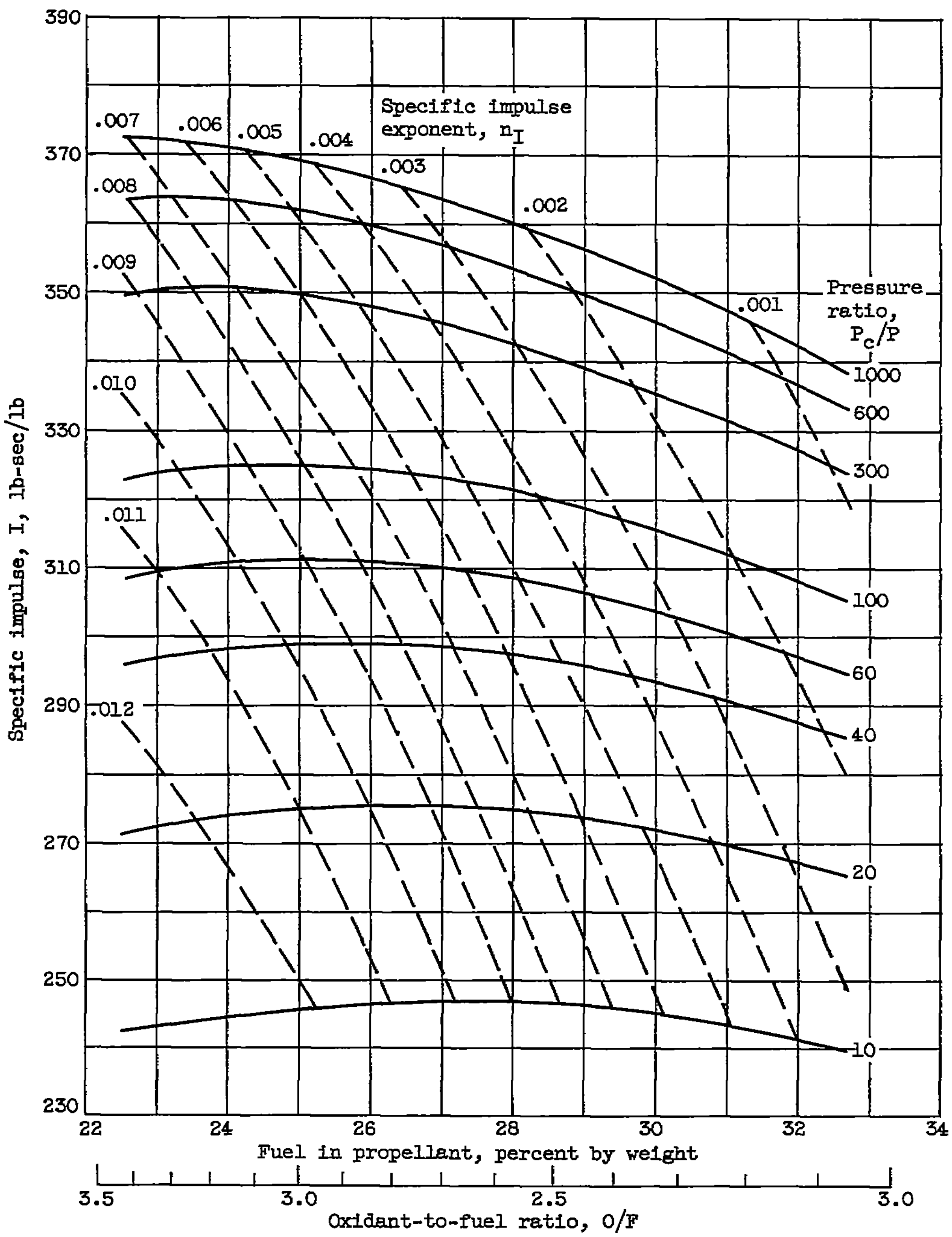
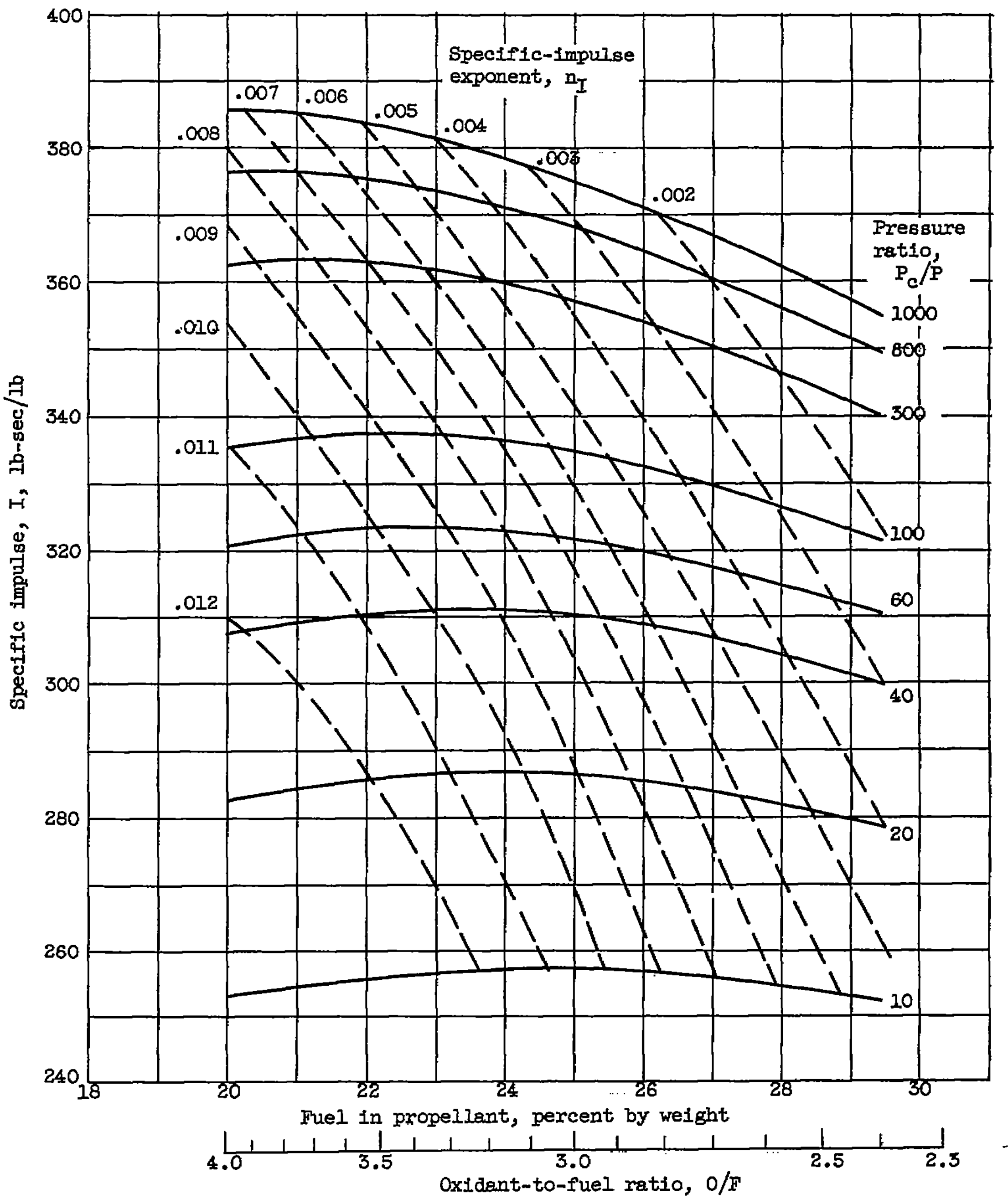


(c) Percent fluorine in oxidant by weight, 30. Exponent n_I for use in equation $I = I_{600}(P_c/600)^{n_I}$.

Figure 1. - Continued. Theoretical specific impulse of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



(d) Percent fluorine in oxidant by weight, 50. Exponent n_I for use in equation $I = I_{600}(P_c/600)^{n_I}$.

Figure 1. - Continued. Theoretical specific impulse of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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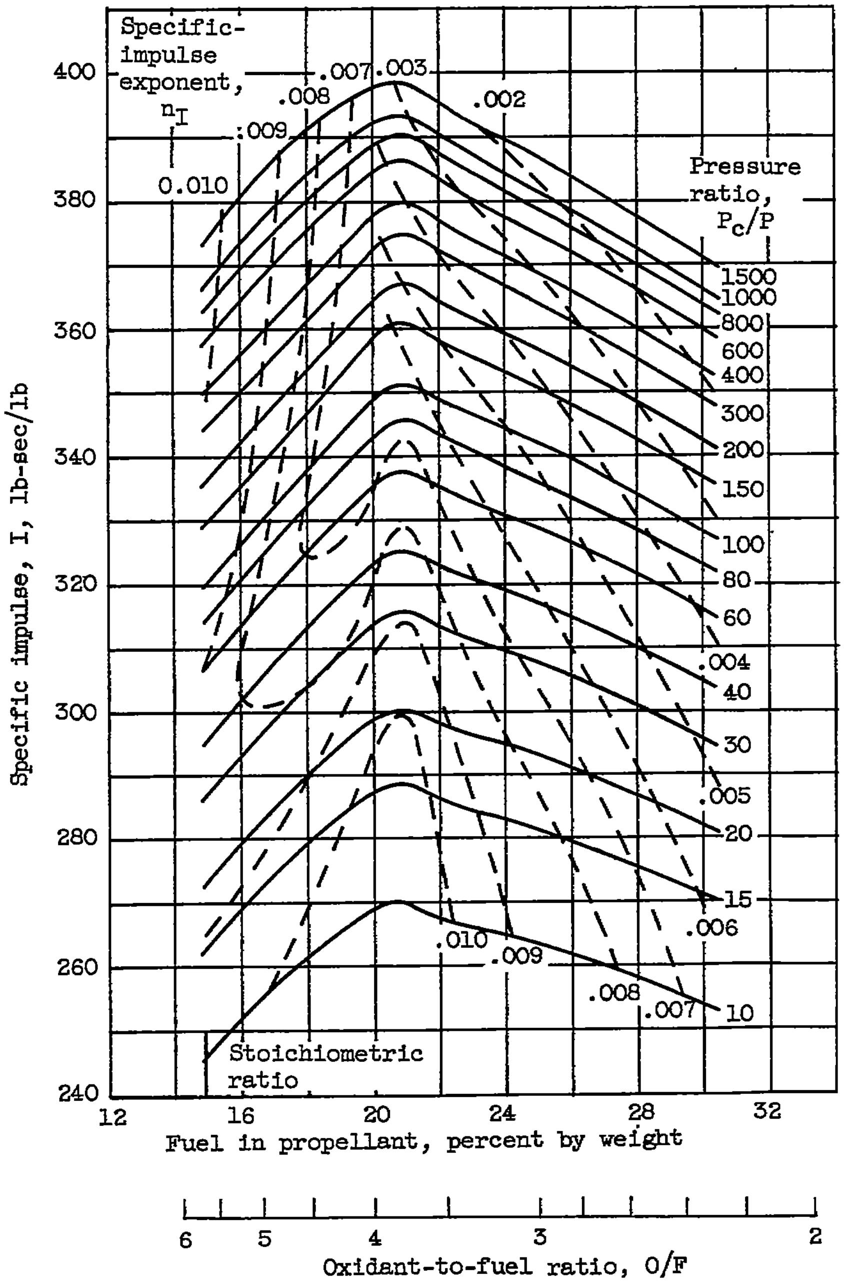
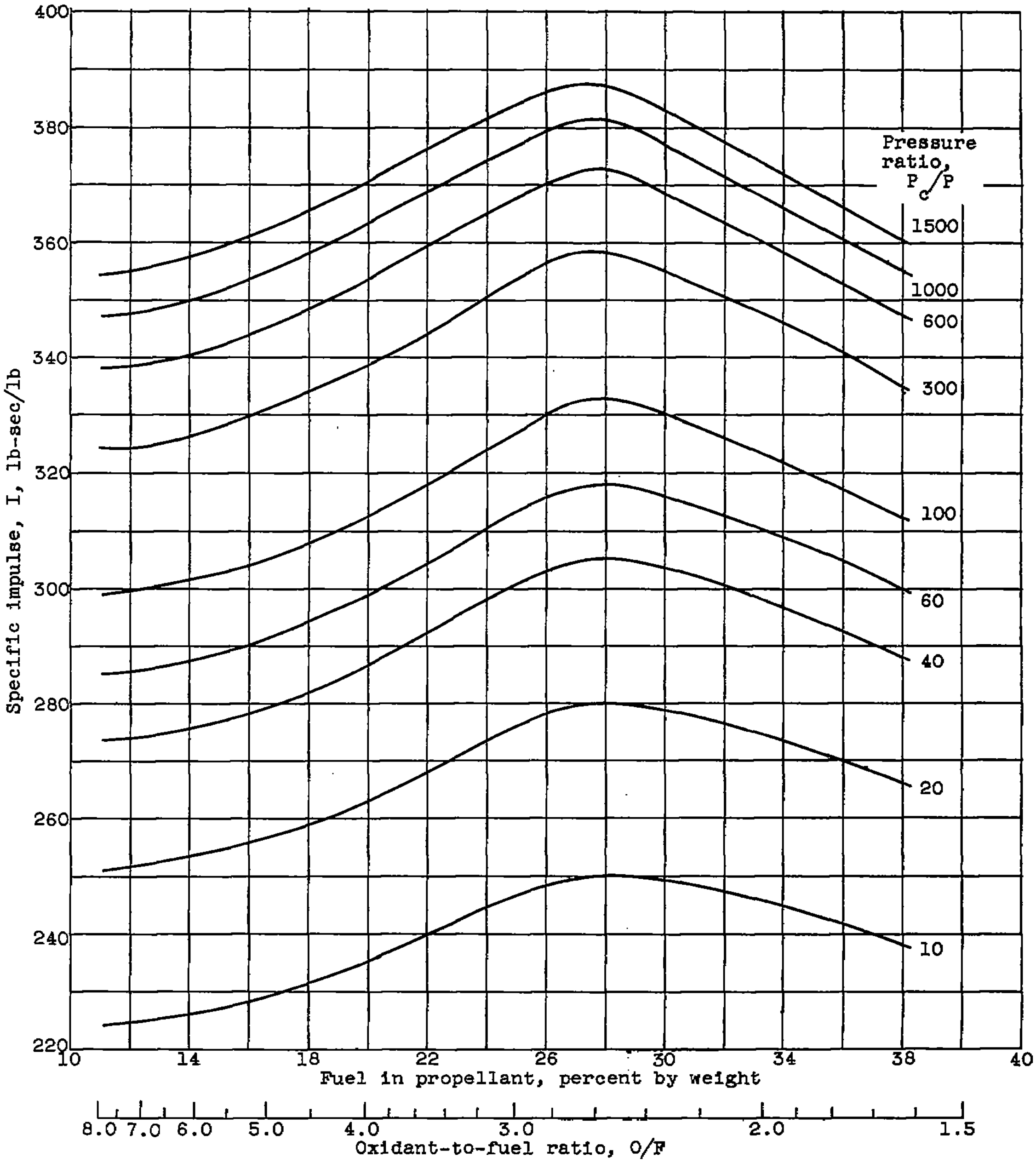


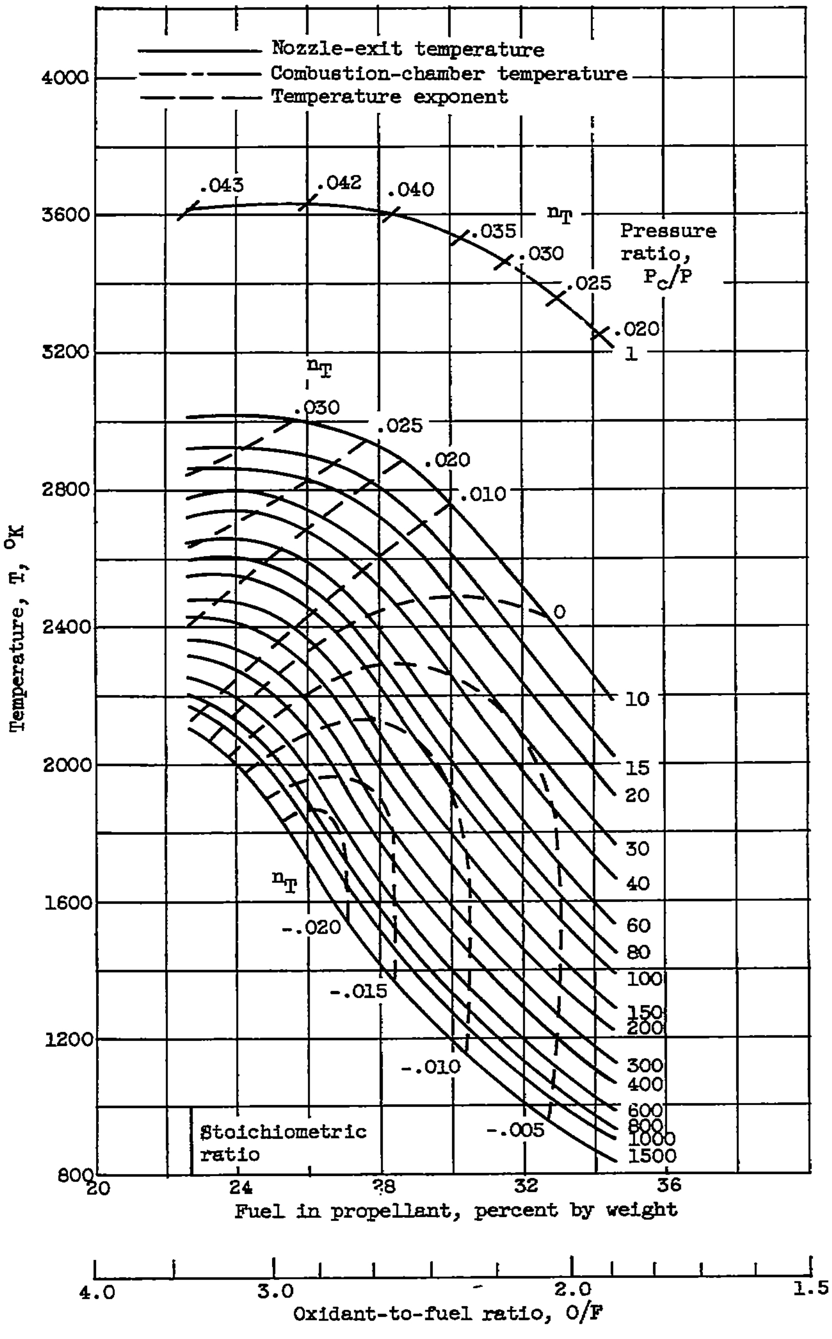
(e) Percent fluorine in oxidant by weight, 70.37. Exponent n_I for use in equation $I = I_{600}(P_c/600)^{n_I}$.

Figure 1. - Continued. Theoretical specific impulse of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



(f) Percent fluorine in oxidant, 100 (0 percent oxygen).

Figure 1. - Concluded. Theoretical specific impulse of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



(a) Percent fluorine in oxidant, 0 (100 percent oxygen).
Exponent n_T for use in equation $T = T_{600}(P_c/600)^{n_T}$.

Figure 2. - Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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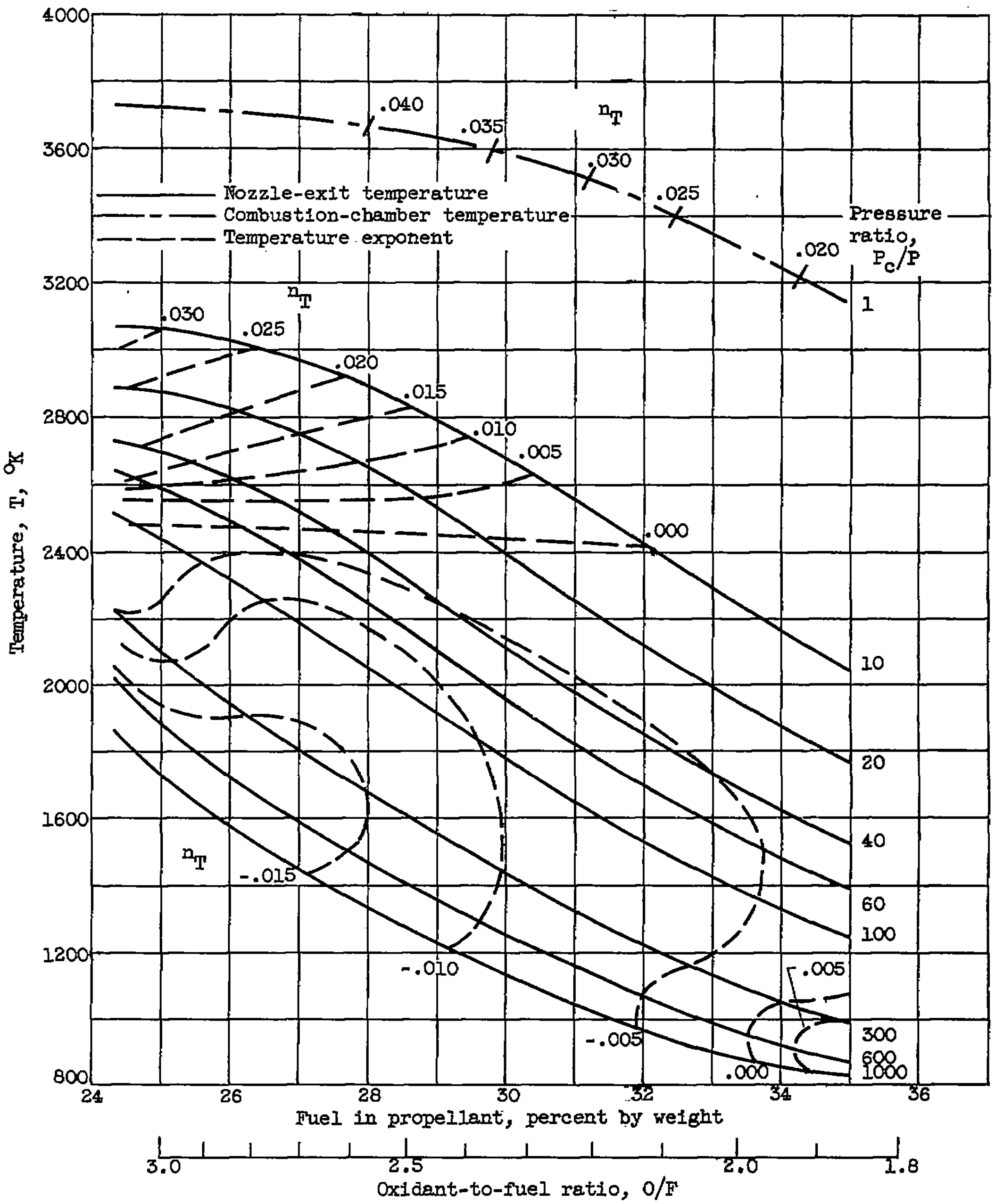

(b) Percent fluorine in oxidant by weight, 15. Exponent n_T for use in equation $T = T_{600}(P_c/600)^{n_T}$.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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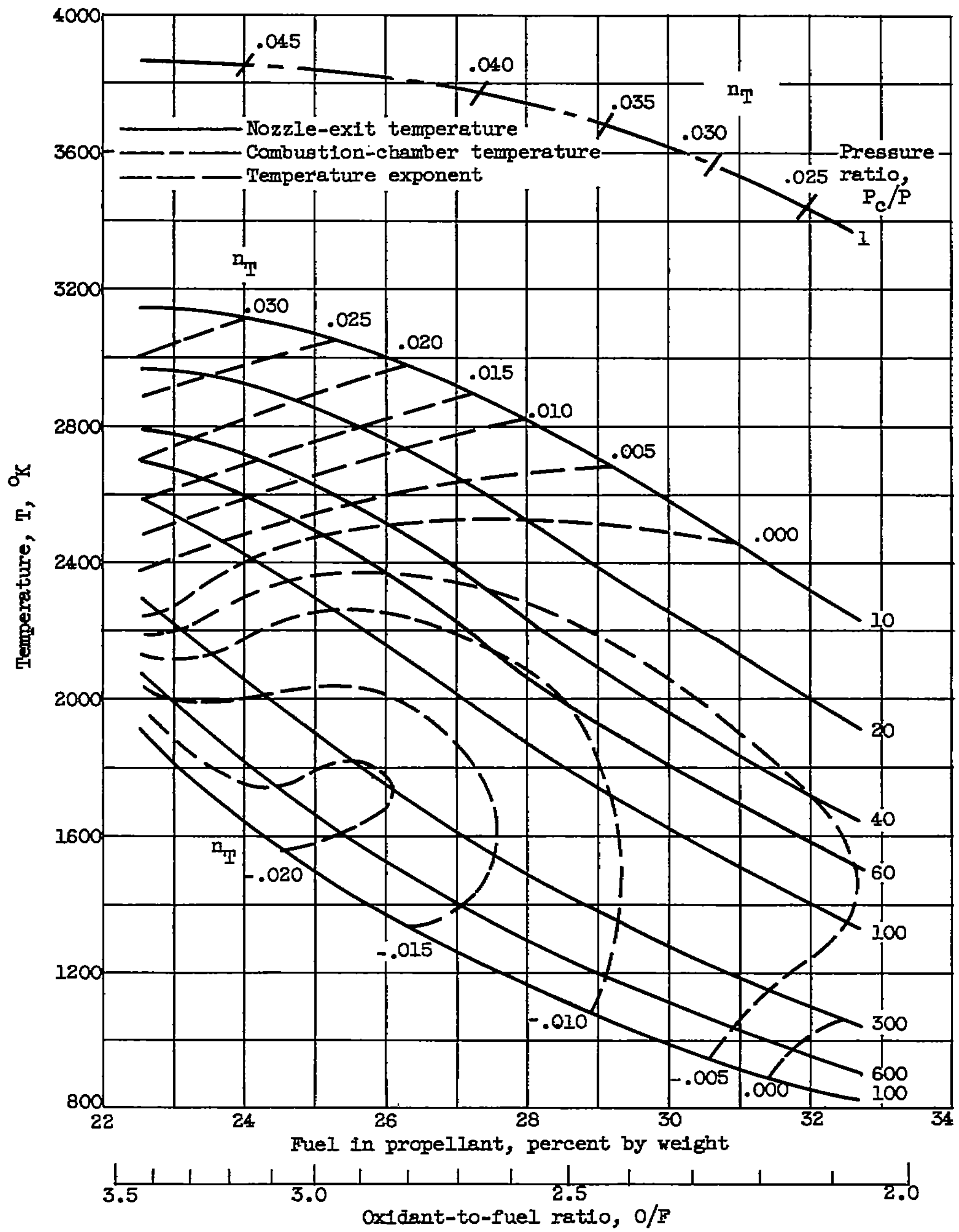
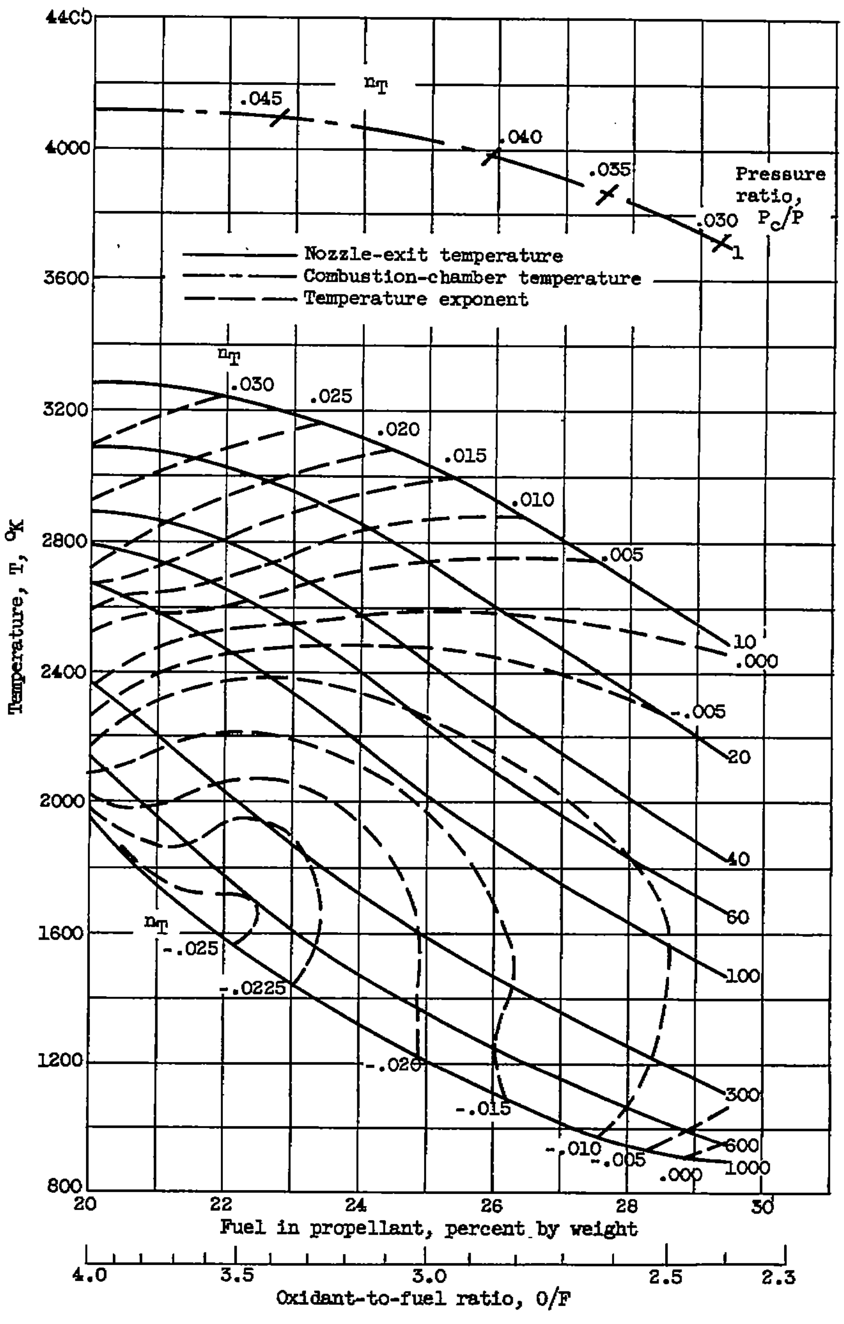


(c) Percent fluorine in oxidant by weight, 30. Exponent n_T for use in equation $T = T_{600}(P_c/600)^{n_T}$.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



(d) Percent fluorine in oxidant by weight, 50. Exponent n_T for use in equation $T = T_{600}(P_c/600)^{n_T}$.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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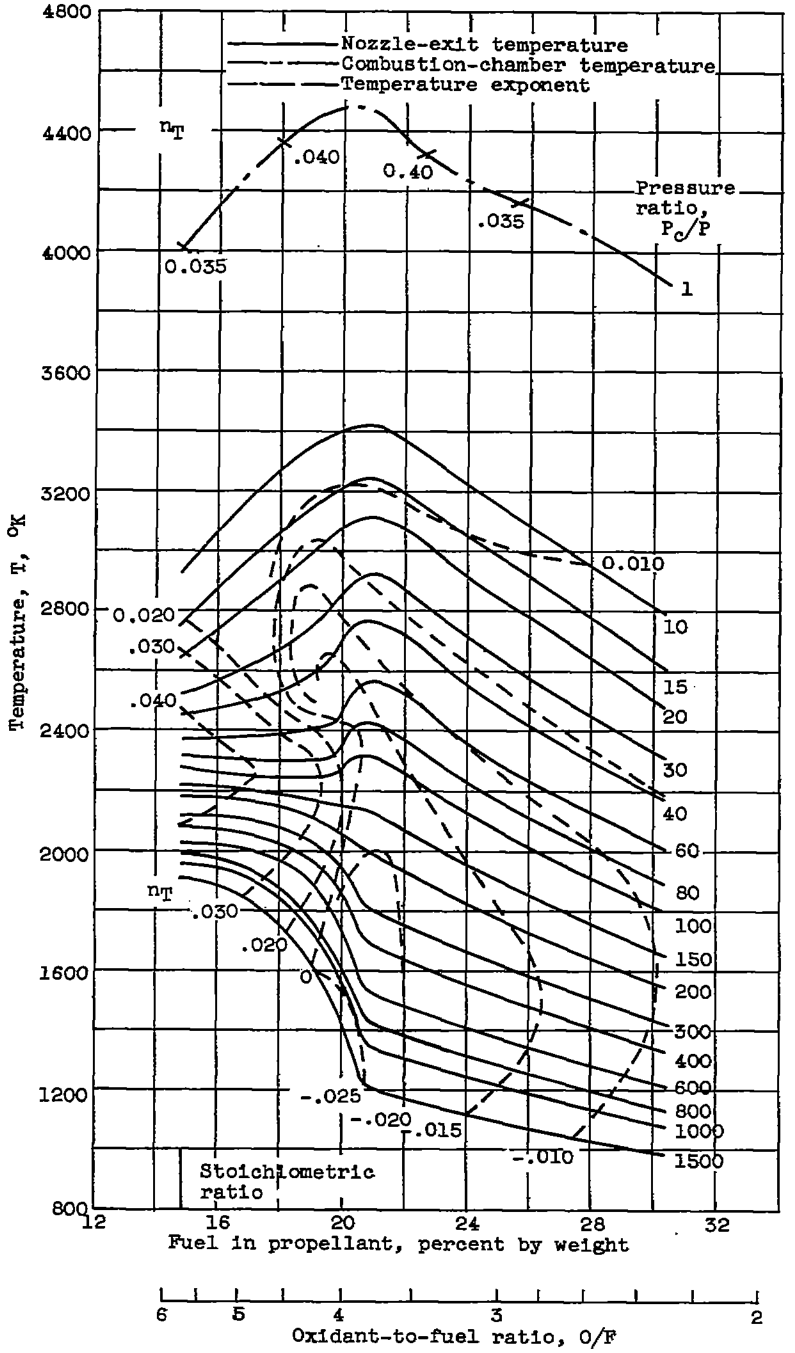

(e) Percent fluorine in oxidant by weight, 70.37. Exponent n_T for use in equation $T = T_{600}(P_c/600)^{n_T}$.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium combustion during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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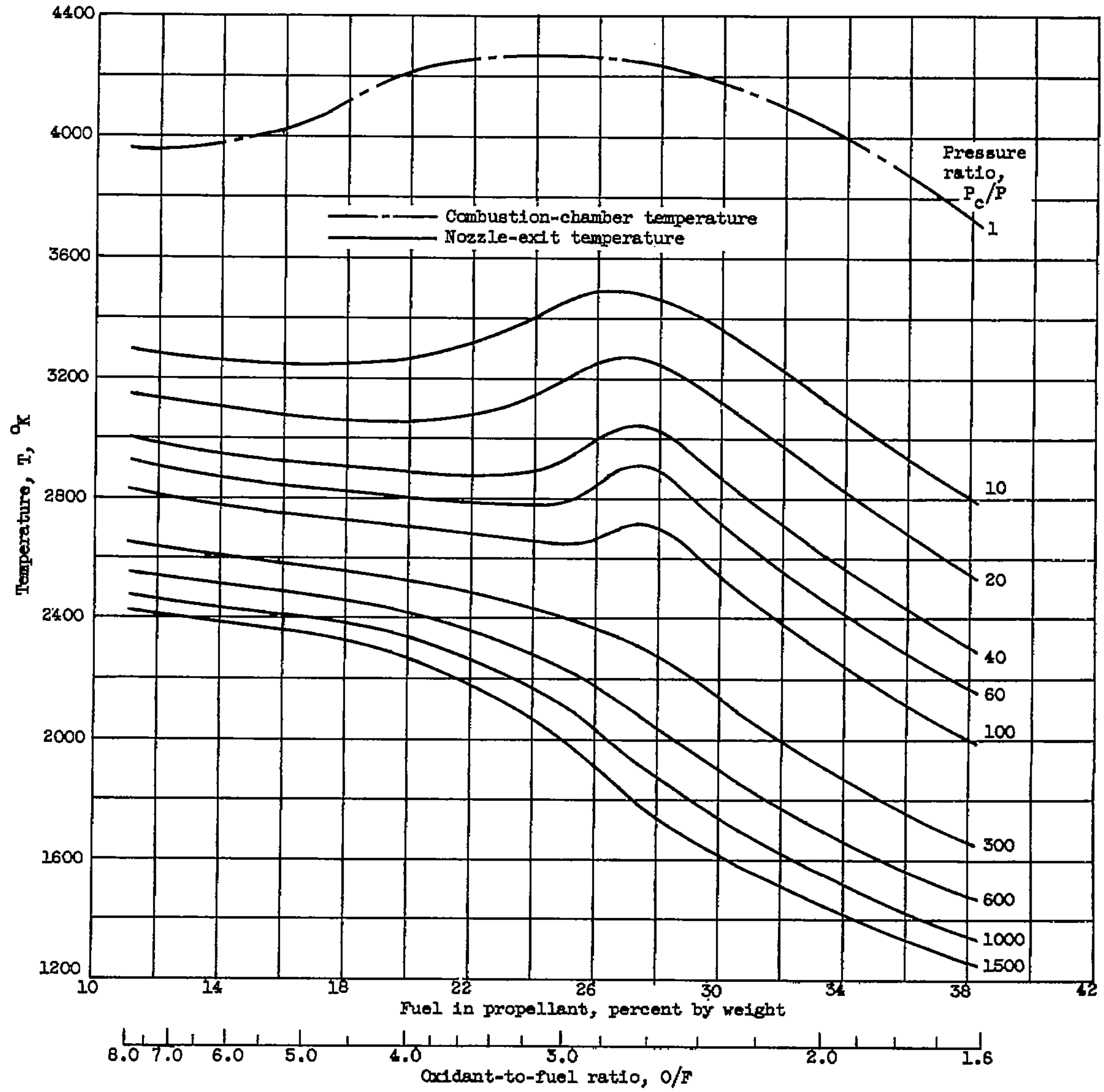

(f) Percent fluorine in oxidant, 100 (0 percent oxygen).

Figure 2. - Concluded. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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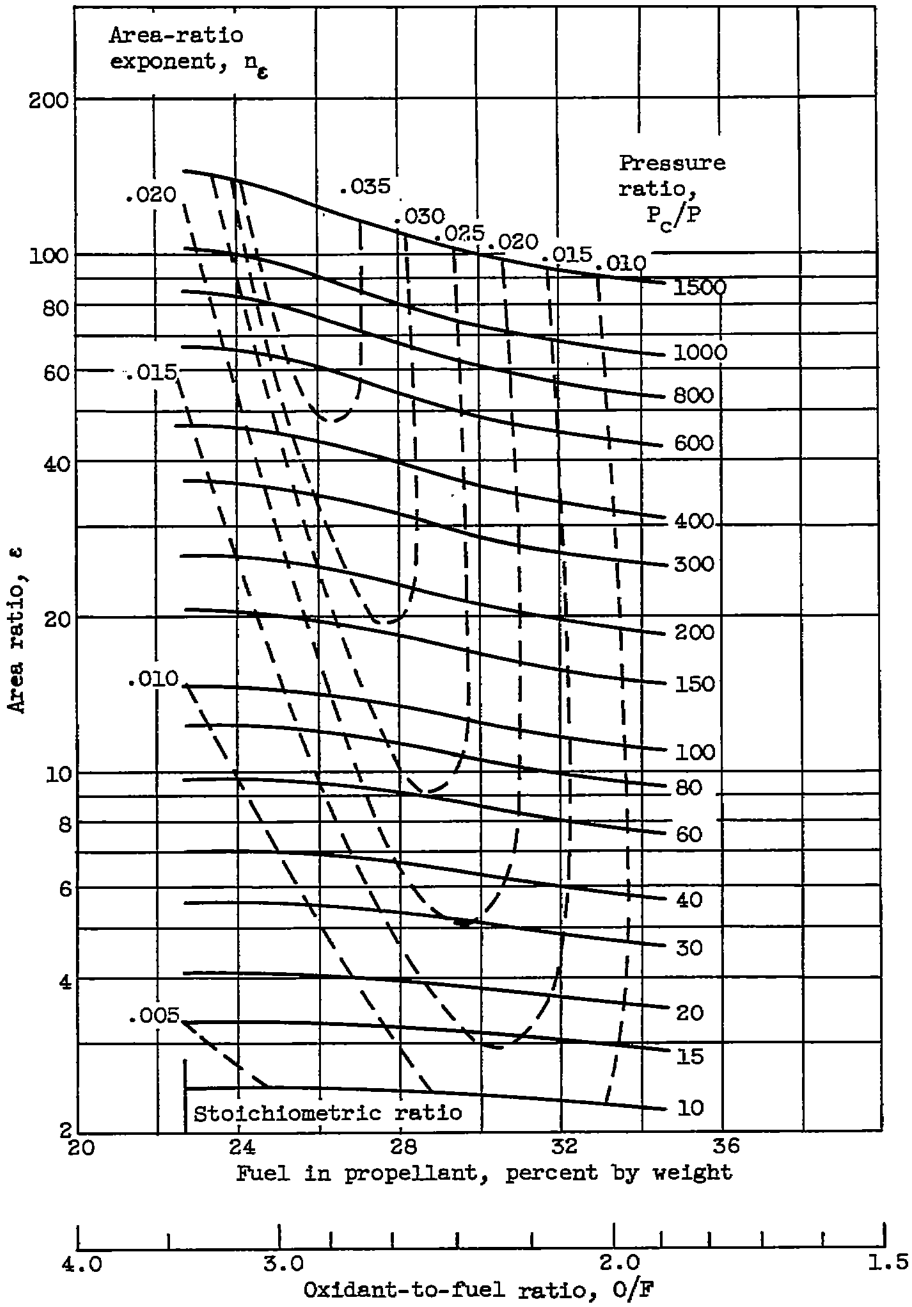

(a) Percent fluorine in oxidant, 0 (100 percent oxygen). Exponent n_ε for use in equation $\varepsilon = \varepsilon_{600}(P_c/600)^{n_\varepsilon}$.

Figure 3. - Theoretical ratio of nozzle area to throat area for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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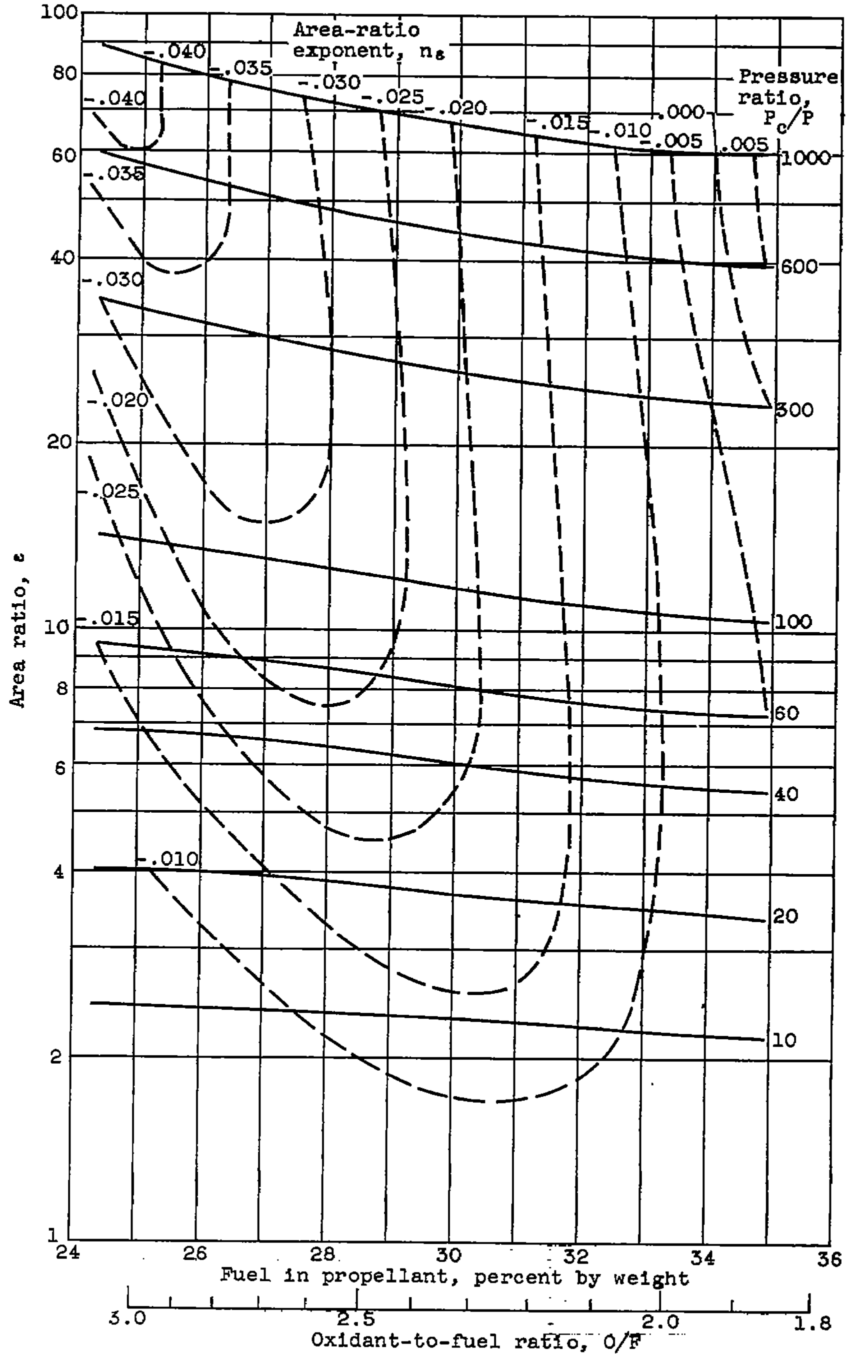

(b) Percent fluorine in oxidant by weight, 15. Exponent n_ε for use in equation $\varepsilon = \varepsilon_{600}(P_c/600)^{n_\varepsilon}$.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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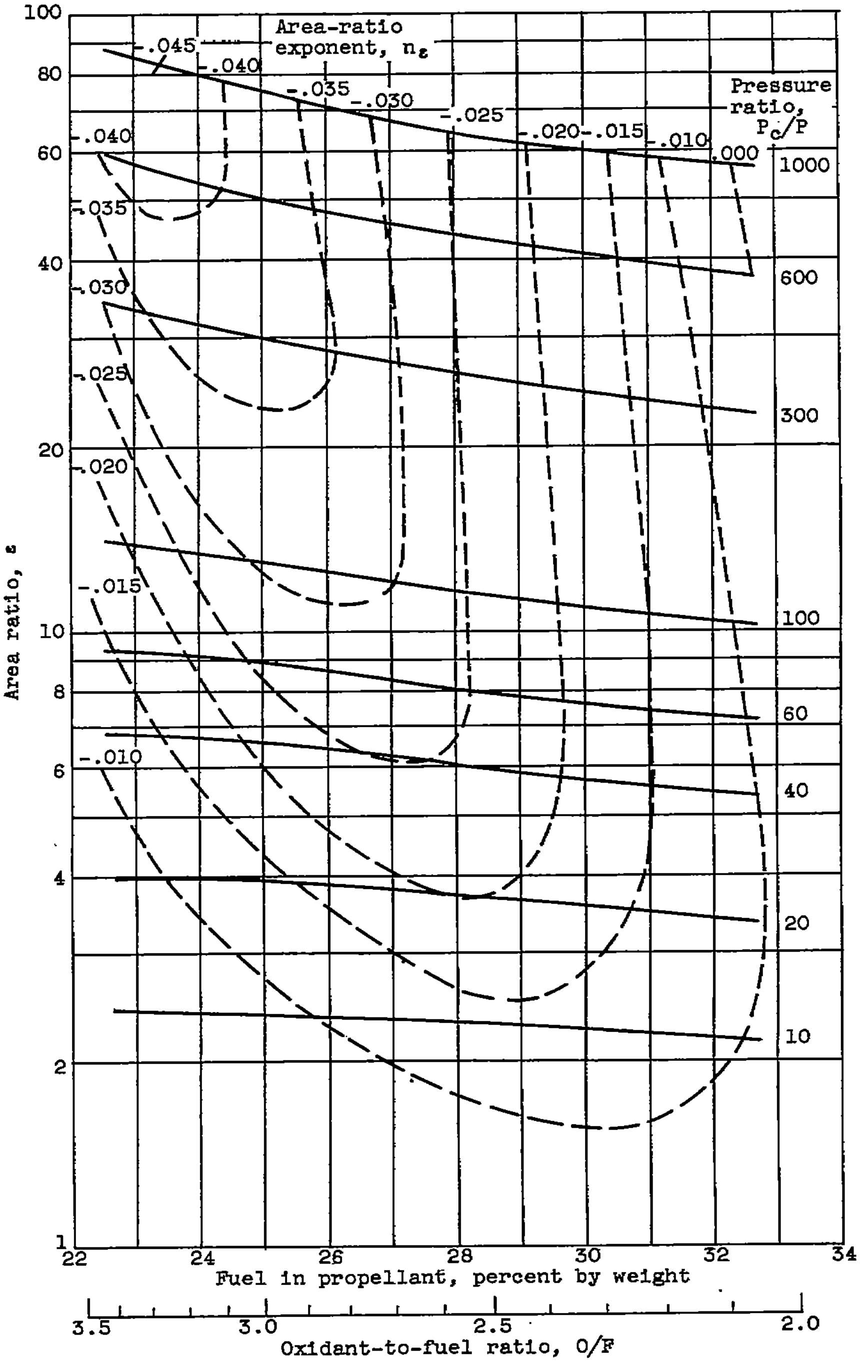
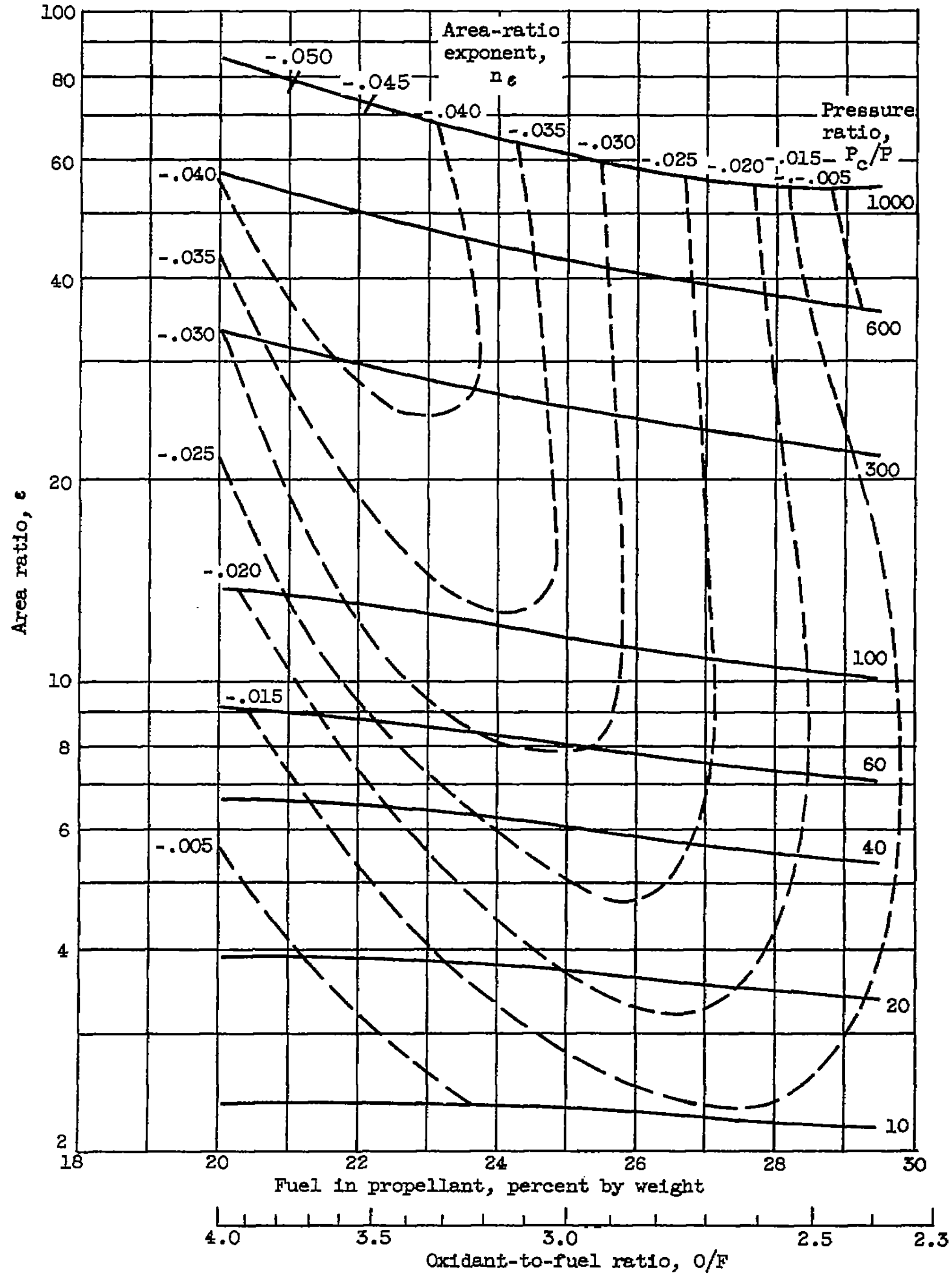


(c) Percent fluorine in oxidant by weight, 30. Exponent n_ε for use in equation $\varepsilon = \varepsilon_{600}(P_c/600)^{n_\varepsilon}$.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



(d) Percent fluorine in oxidant by weight, 50. Exponent n_ε for use in equation $\varepsilon = \varepsilon_{600}(P_c/600)^{n_\varepsilon}$.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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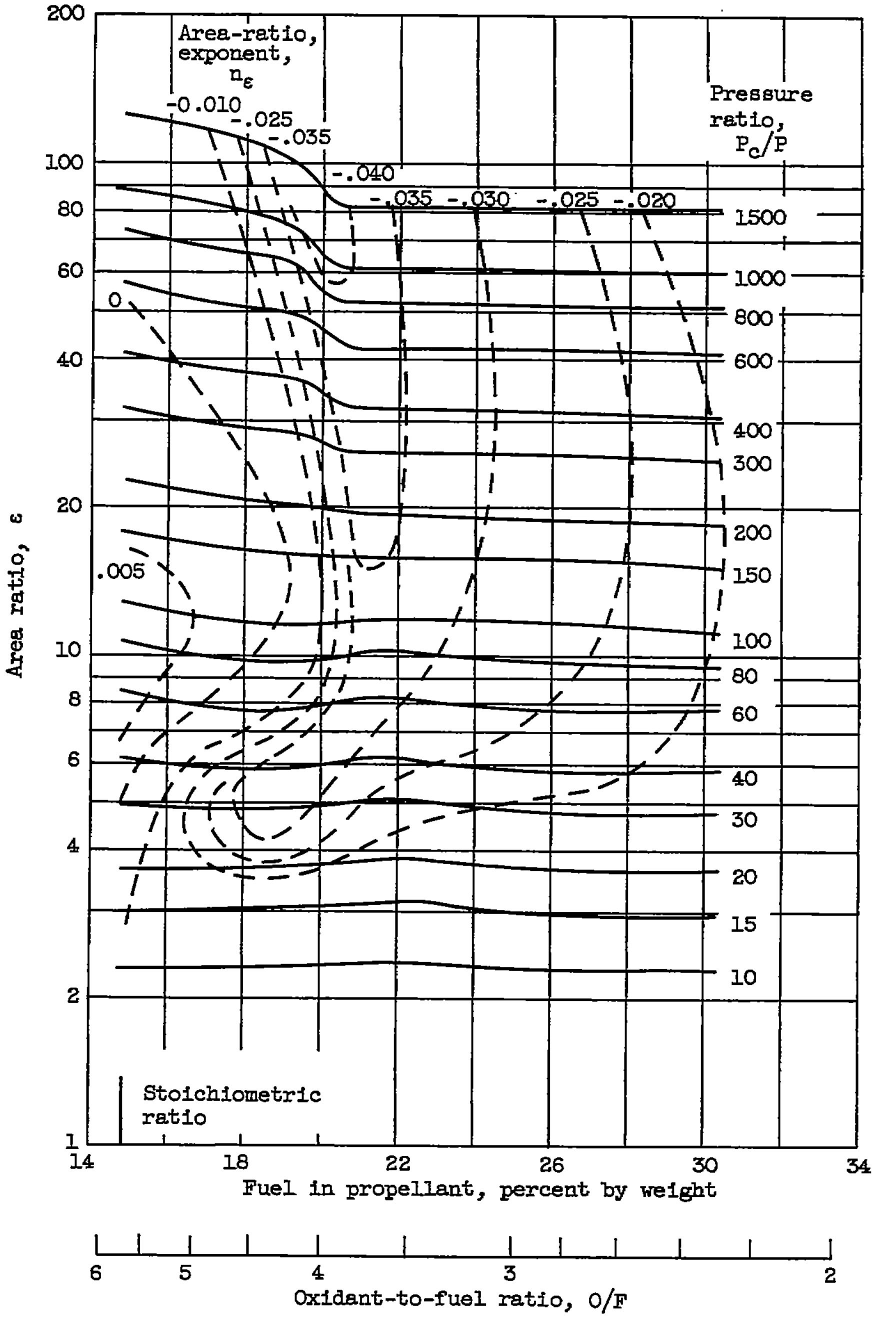

(e) Percent fluorine in oxidant by weight, 70.37. Exponent n_ε for use in equation $\varepsilon = \varepsilon_{600}(P_c/600)^{n_\varepsilon}$.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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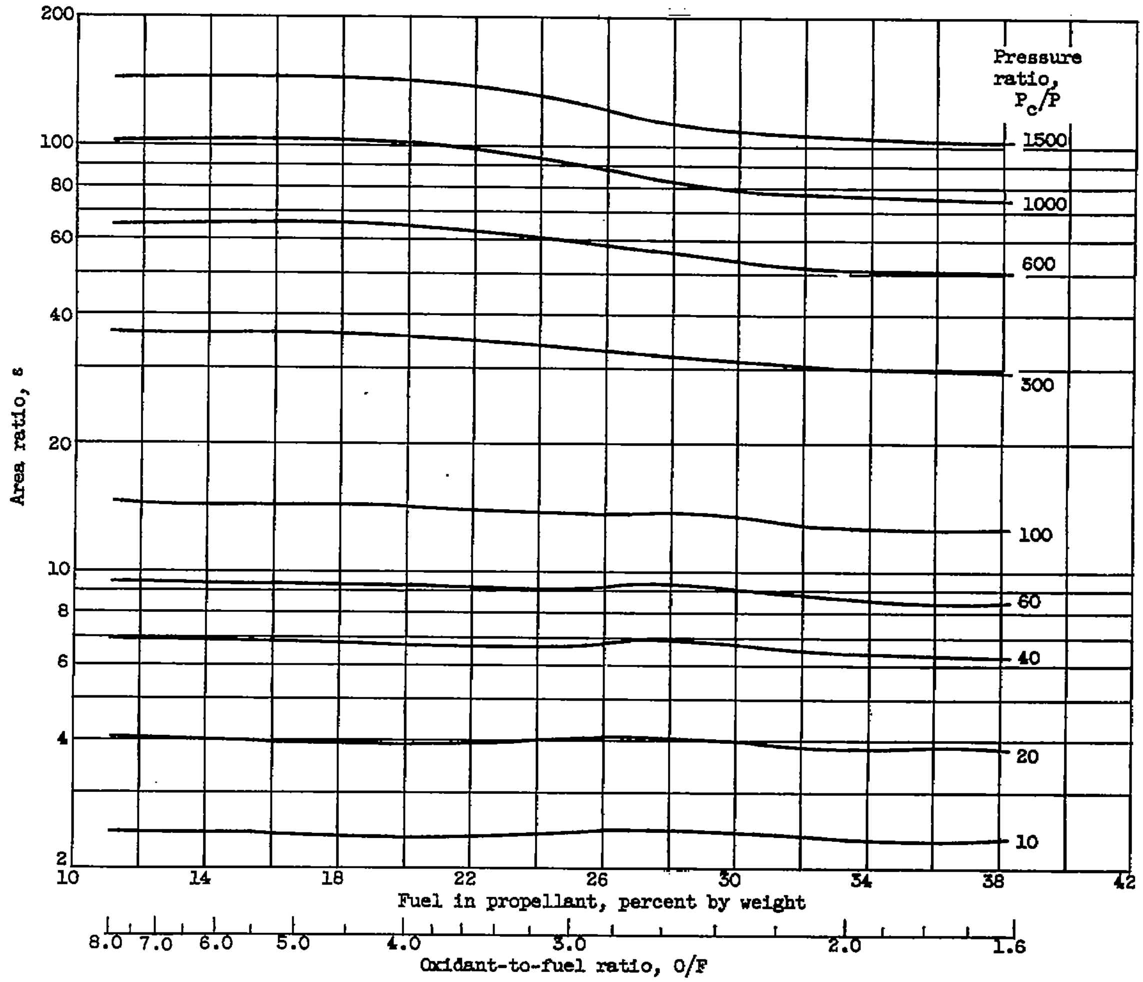

(f) Percent fluorine in oxidant, 100 (0 percent oxygen).

Figure 3. - Concluded. Theoretical ratio of nozzle area to throat area for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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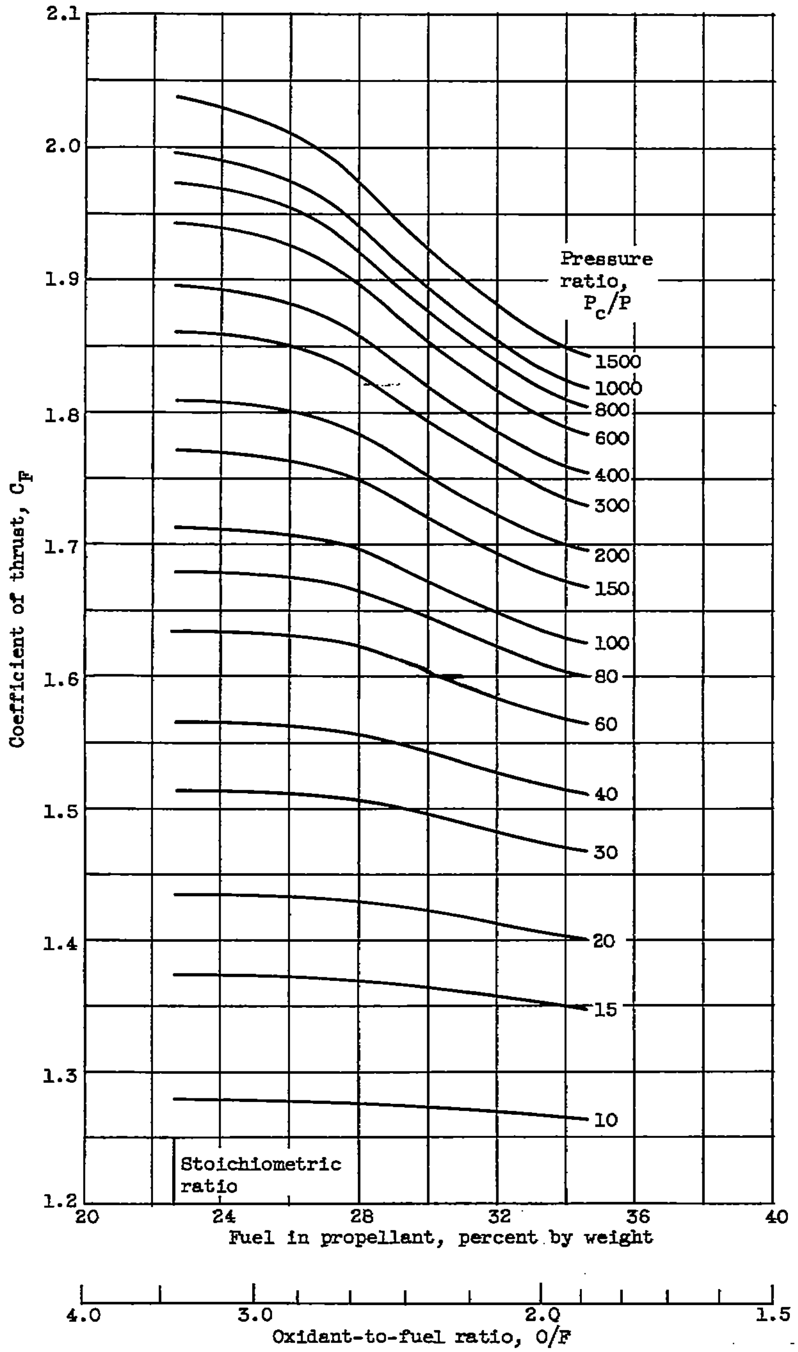
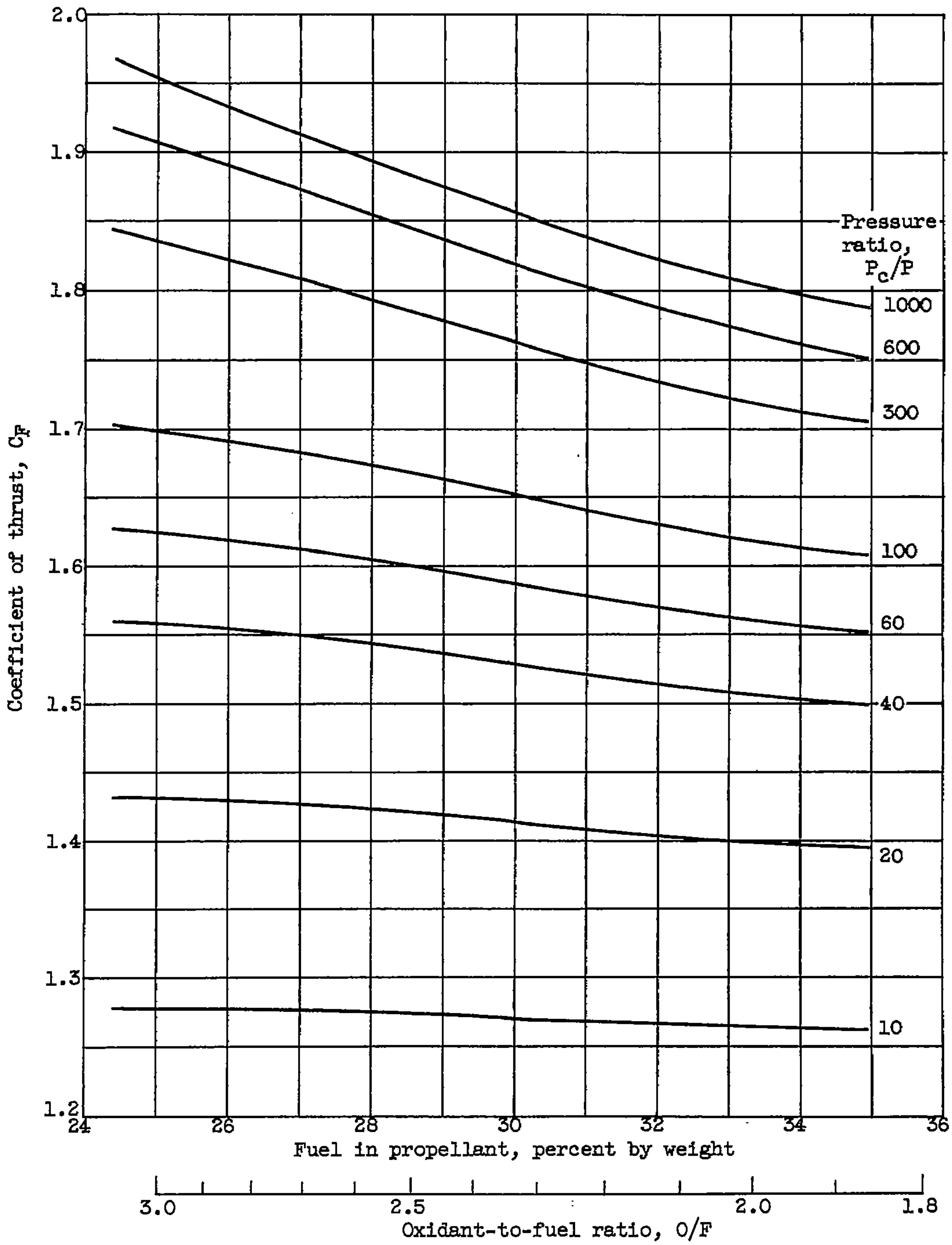


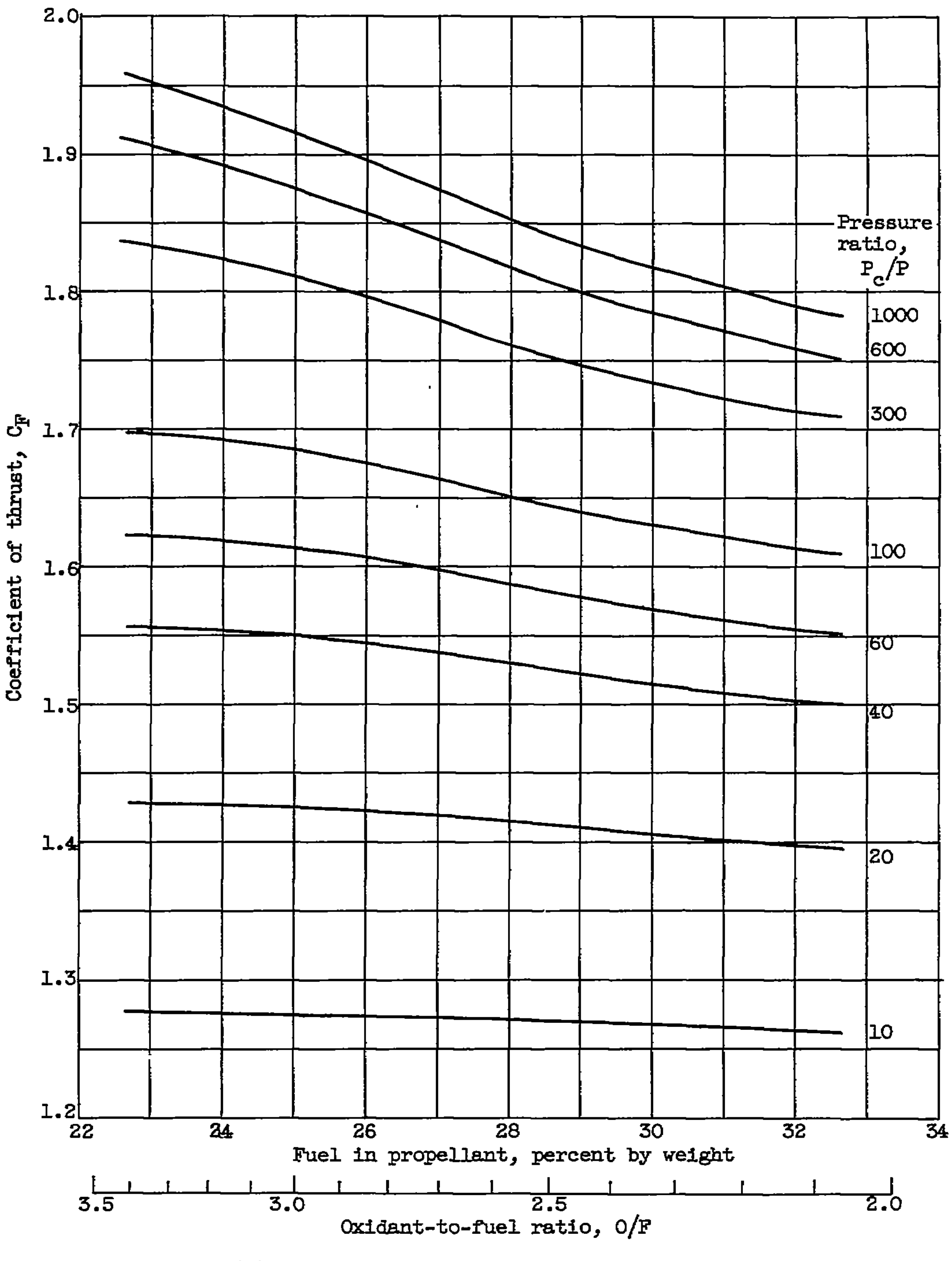
(a) Percent fluorine in oxidant, 0 (100 percent oxygen).

Figure 4. - Theoretical coefficient of thrust for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



(b) Percent fluorine in oxidant by weight, 15.

Figure 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



(c) Percent fluorine in oxidant by weight, 30.

Figure 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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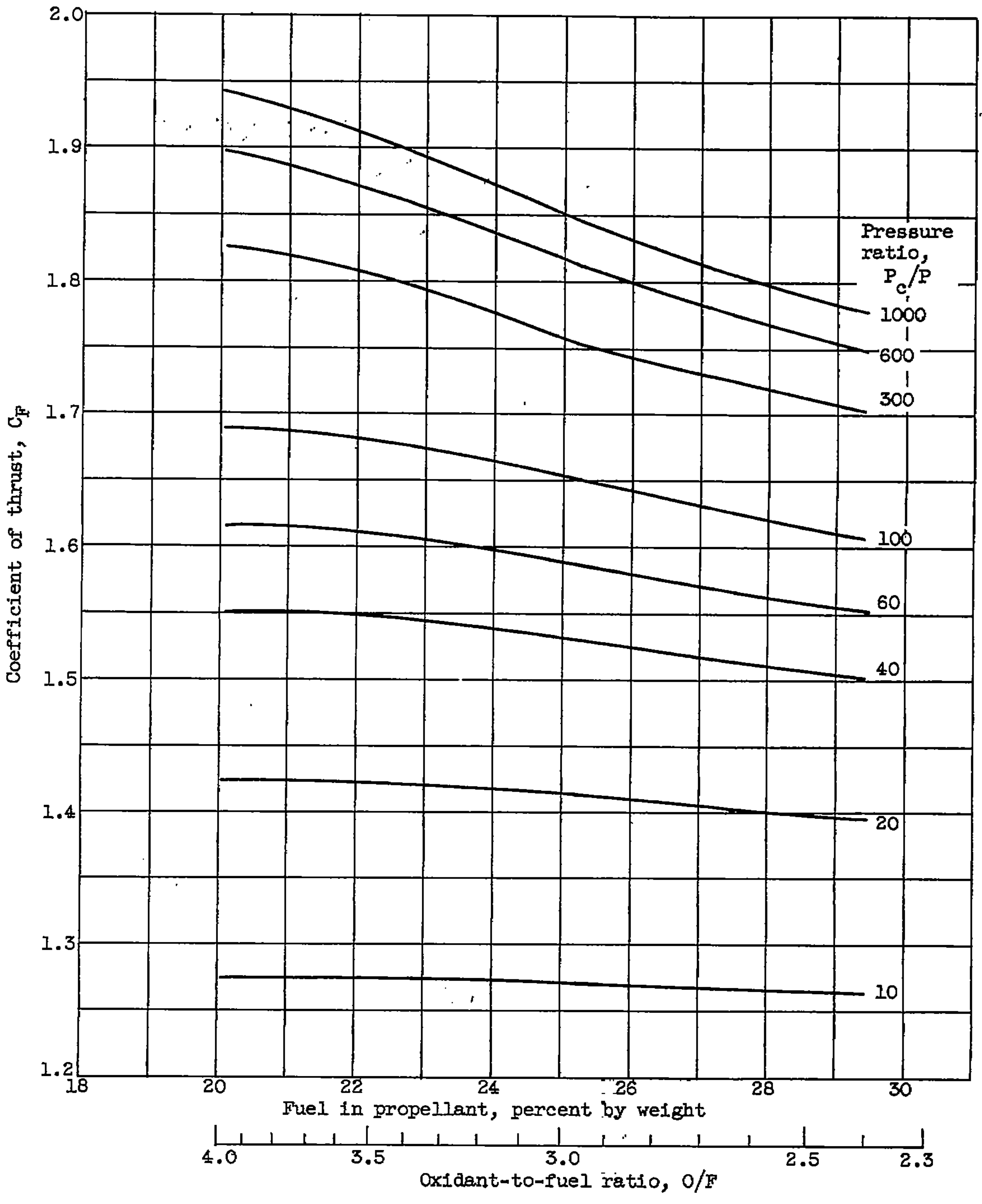

(d) Percent fluorine in oxidant by weight, 50.

Figure 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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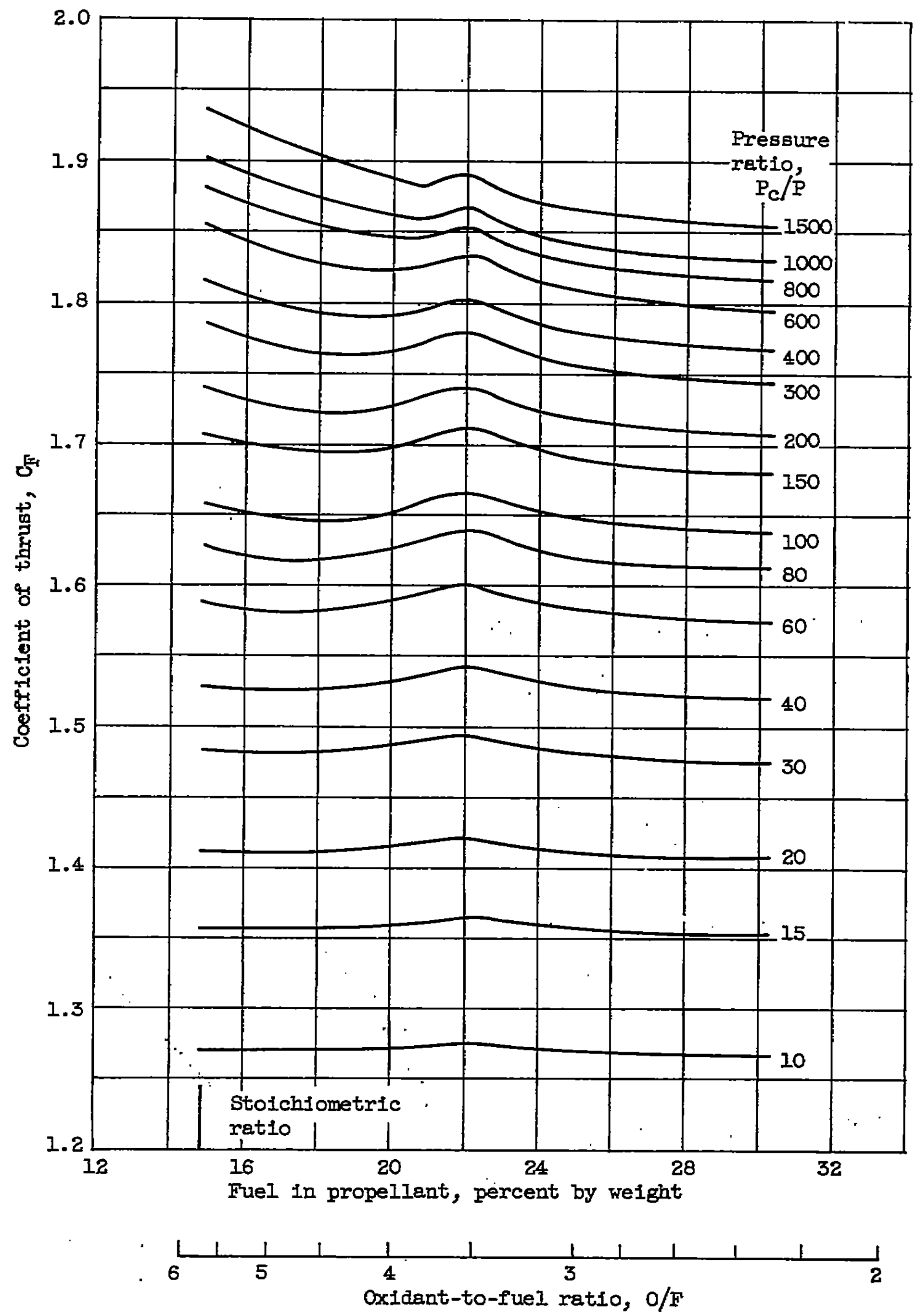

(e) Percent fluorine in oxidant by weight, 70.37.

Figure 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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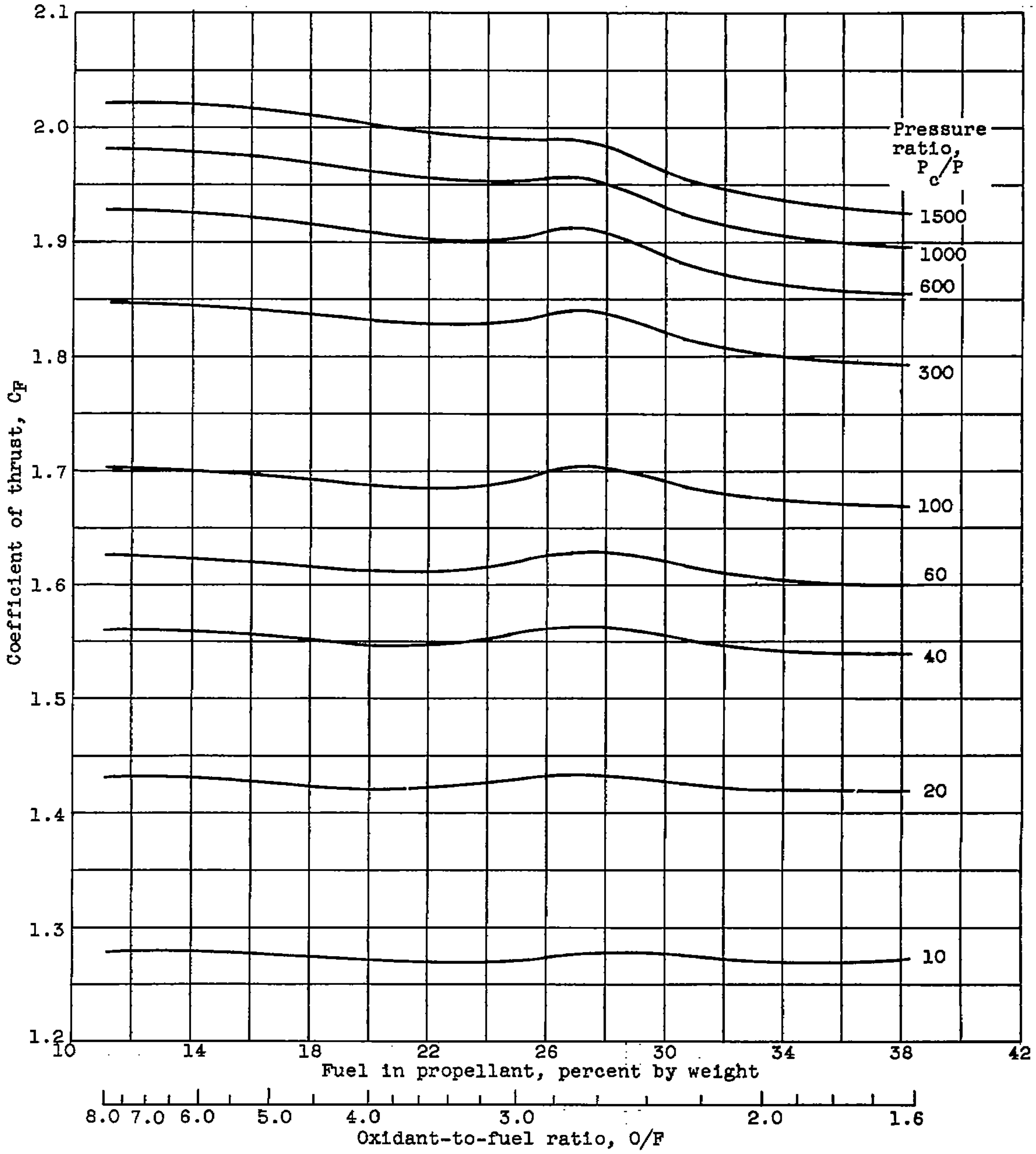

(f) Percent fluorine in oxidant, 100 (0 percent oxygen).

Figure 4. - Concluded. Theoretical coefficient of thrust for JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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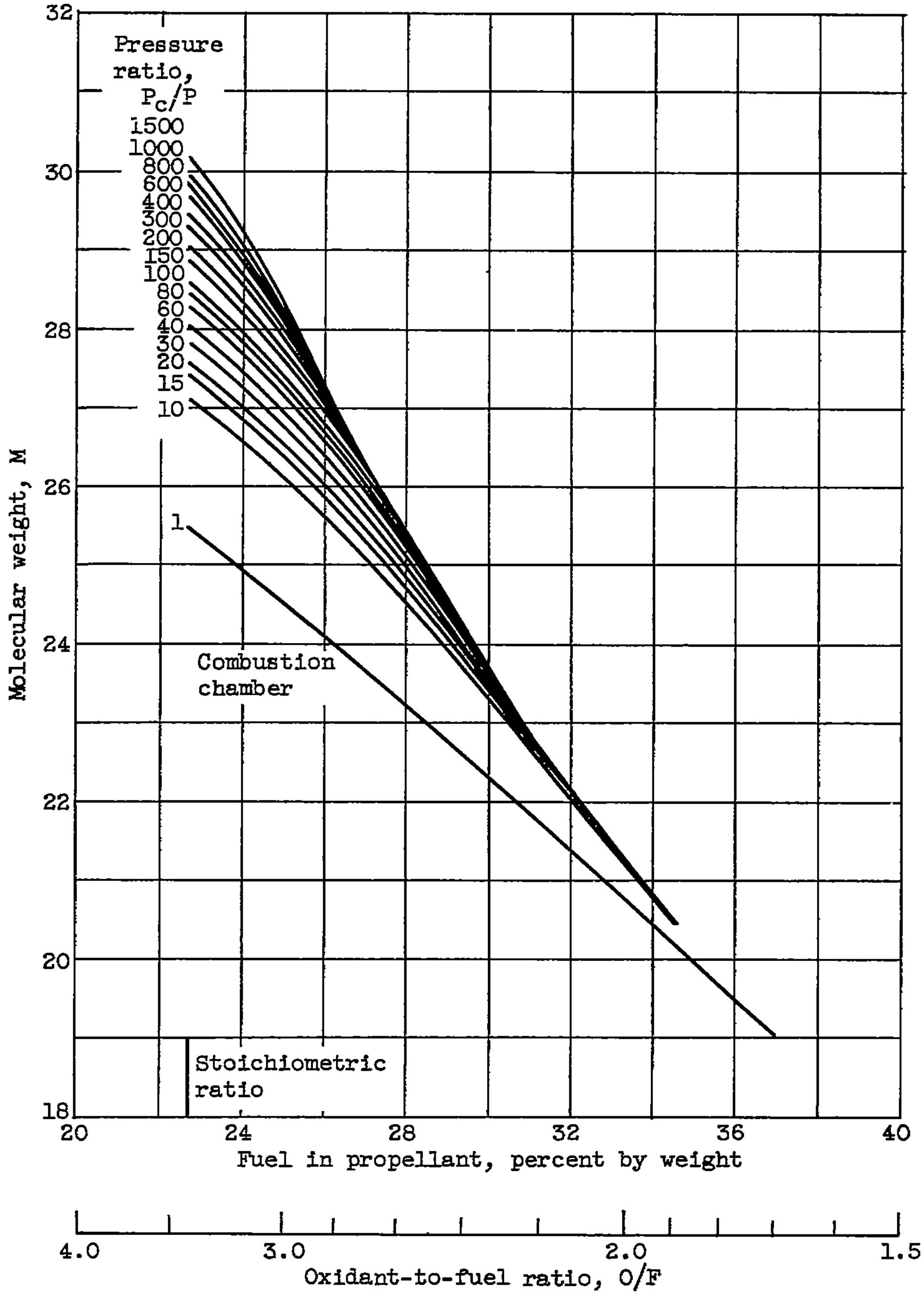

(a) Percent fluorine in oxidant, 0 (100 percent oxygen).

Figure 5. - Theoretical molecular weight of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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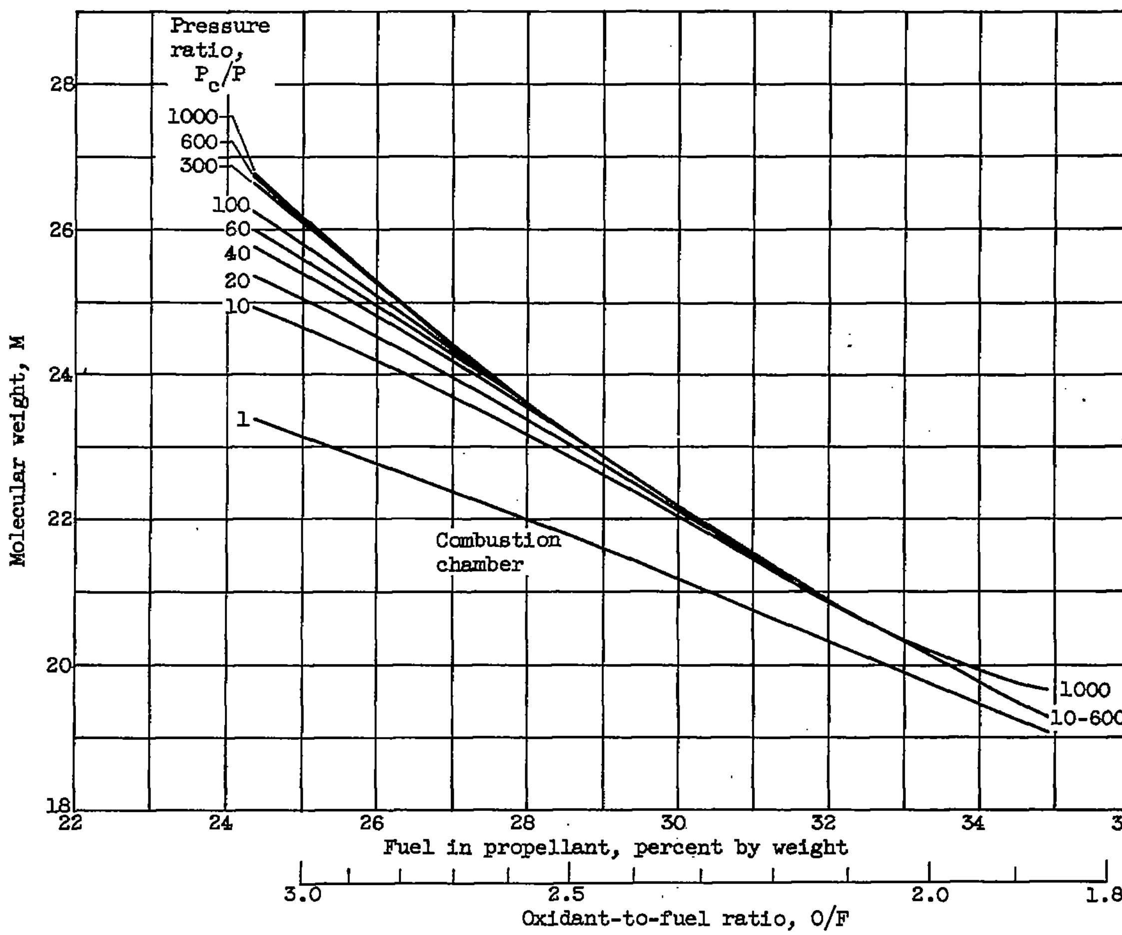

(b) Percent fluorine in oxidant by weight, 15.

Figure 5. - Continued. Theoretical molecular weight of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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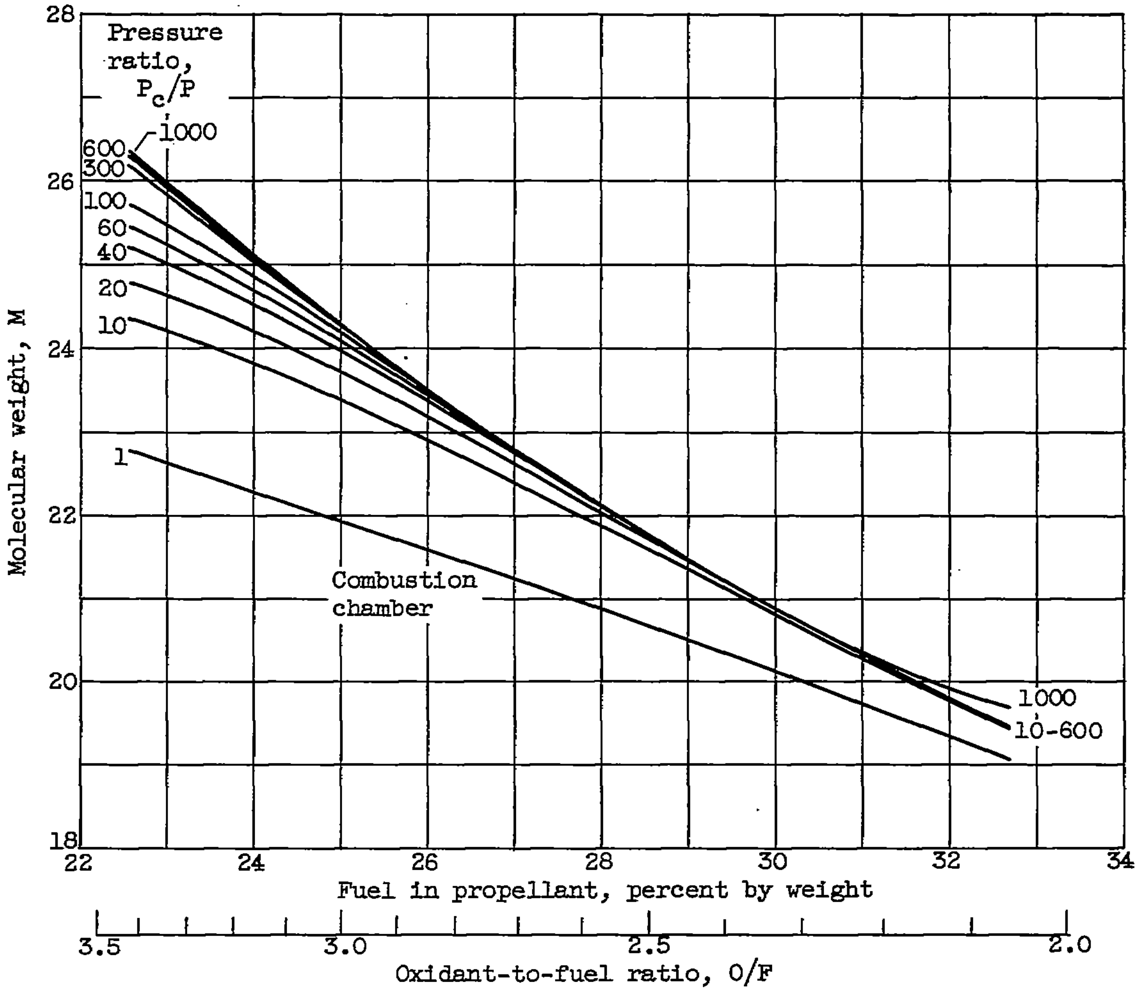
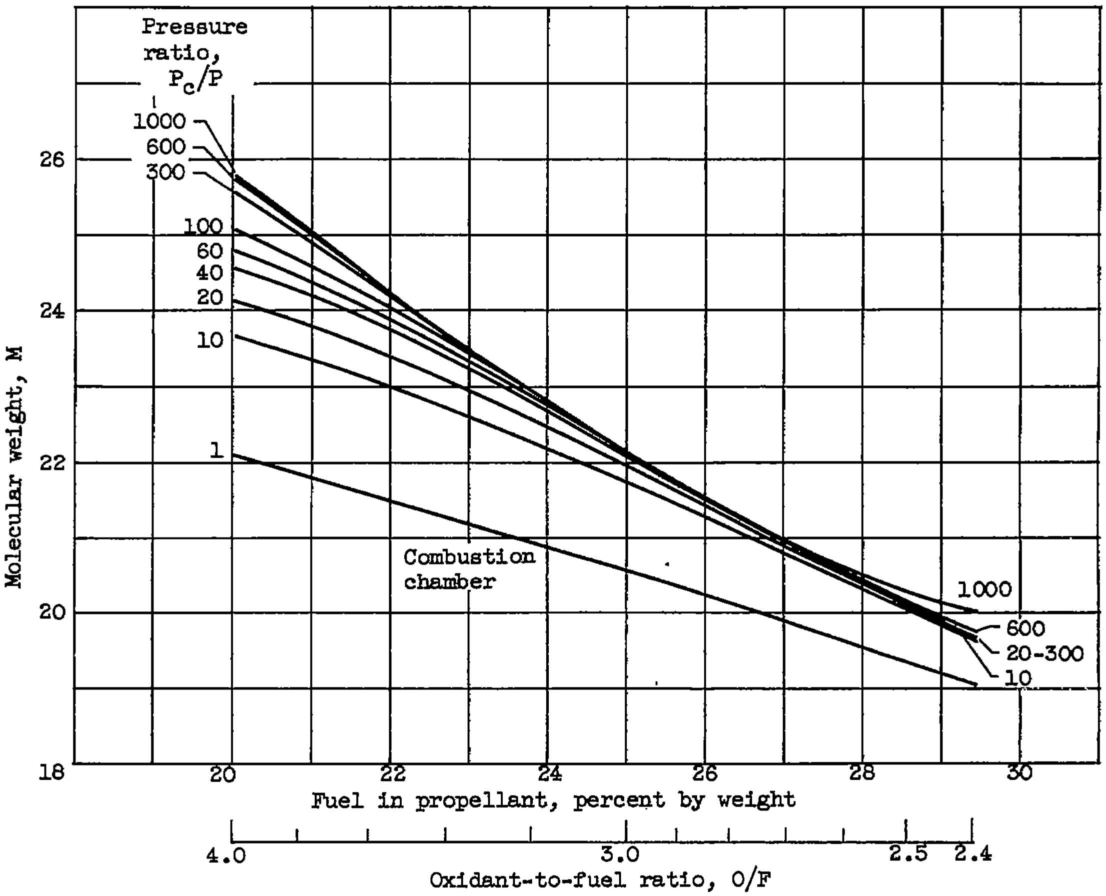


(c) Percent fluorine in oxidant by weight, 30.

Figure 5. - Continued. Theoretical molecular weight of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



(d) Percent fluorine in oxidant by weight, 50.

Figure 5. - Continued. Theoretical molecular weight of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

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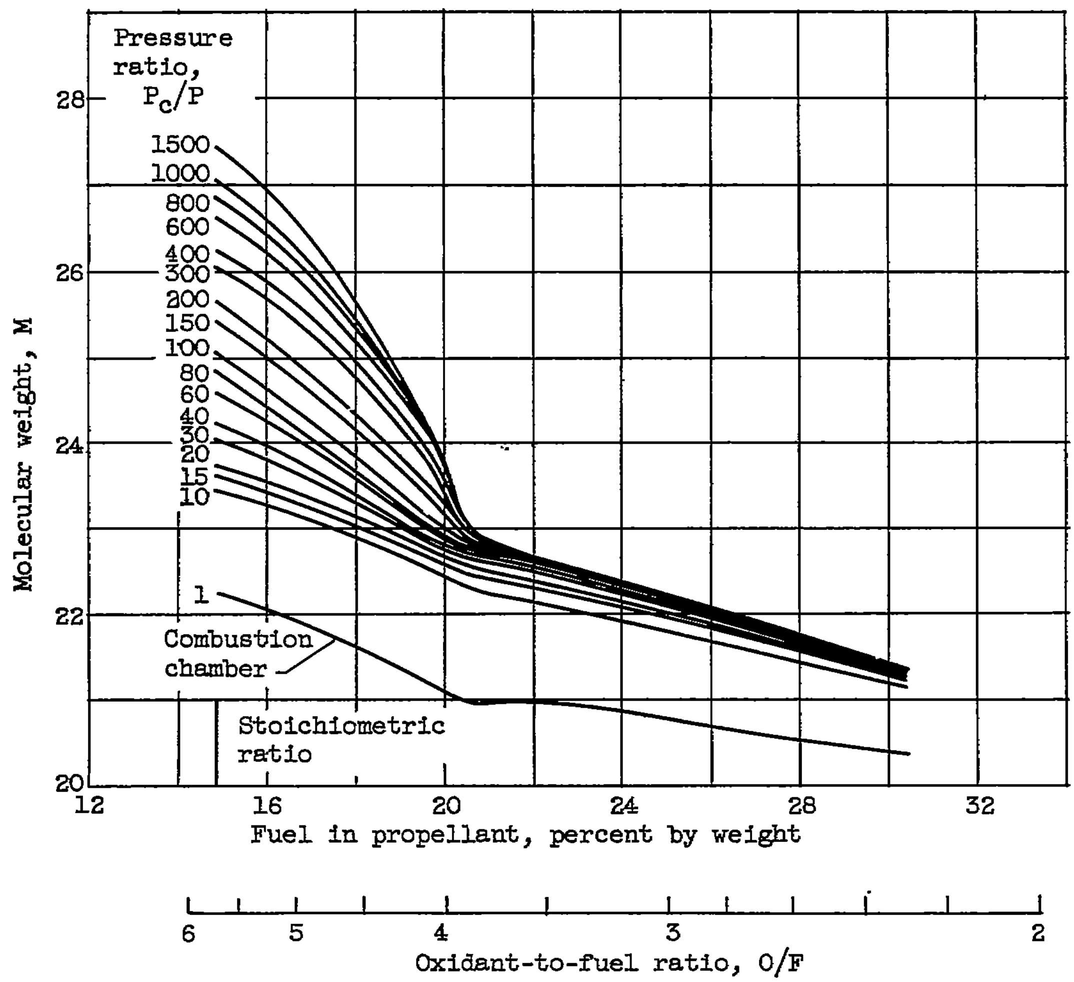
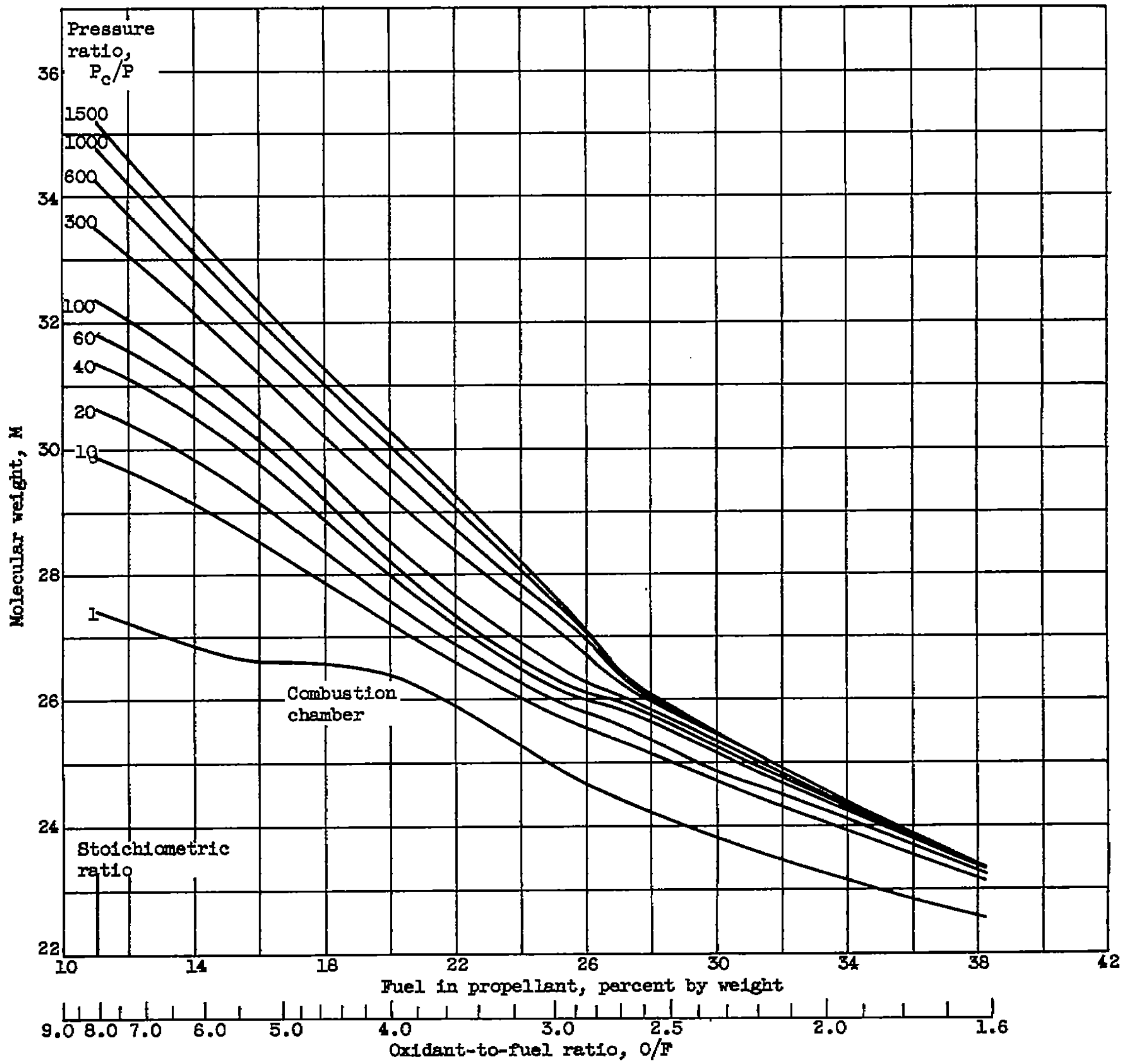


(e) Percent fluorine in oxidant by weight, 70.37.

Figure 5. - Continued. Theoretical molecular weight of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



(f) Percent fluorine in oxidant, 100 (0 percent oxygen).

Figure 5. - Concluded. Theoretical molecular weight of JP-4 fuel with several fluorine-oxygen mixtures. Equilibrium composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

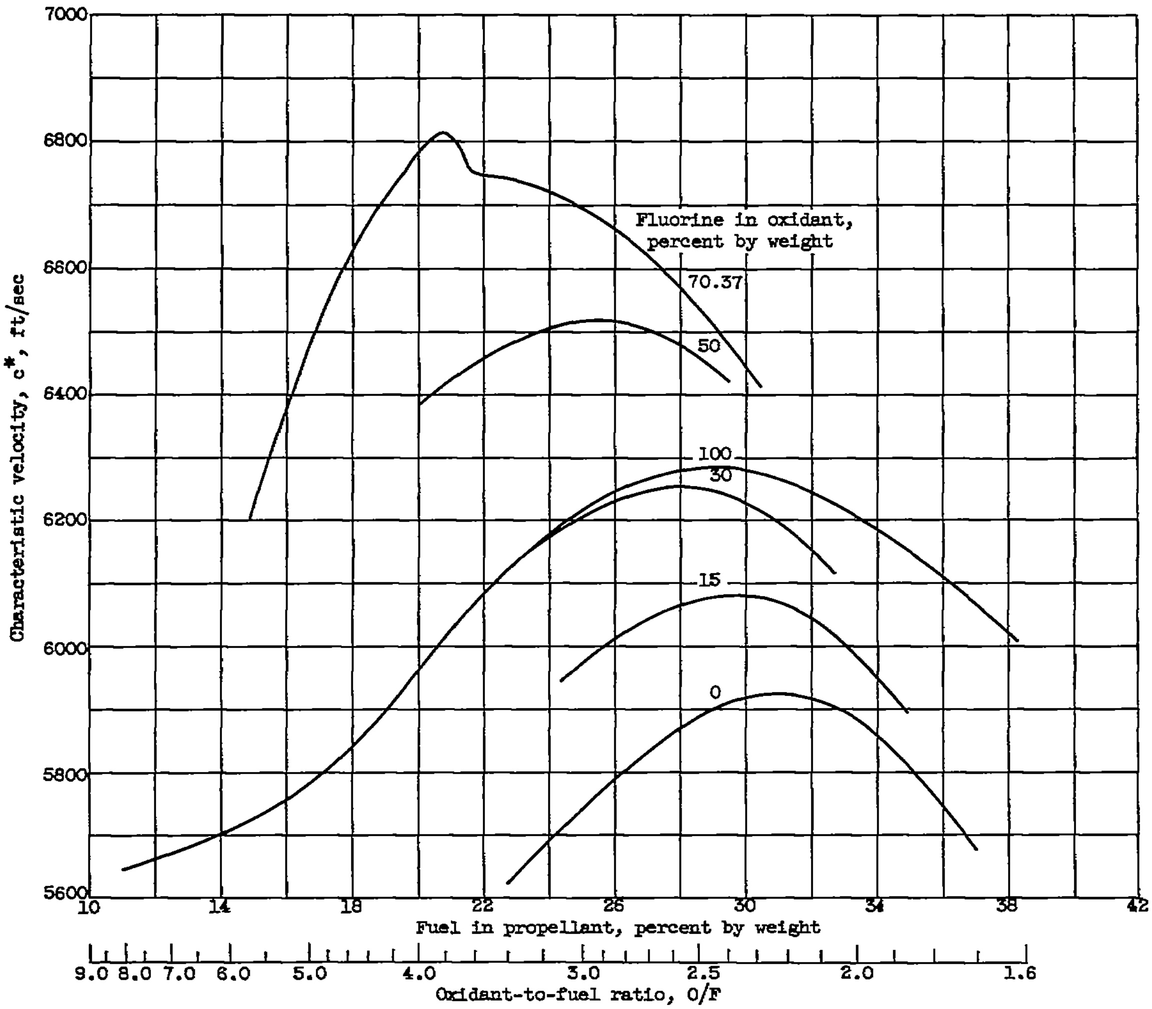


Figure 6. - Theoretical characteristic velocity for JP-4 fuel with several fluorine-oxygen mixtures. Isentropic expansion assuming equilibrium composition from combustion-chamber pressure of 600 pounds per square inch absolute.

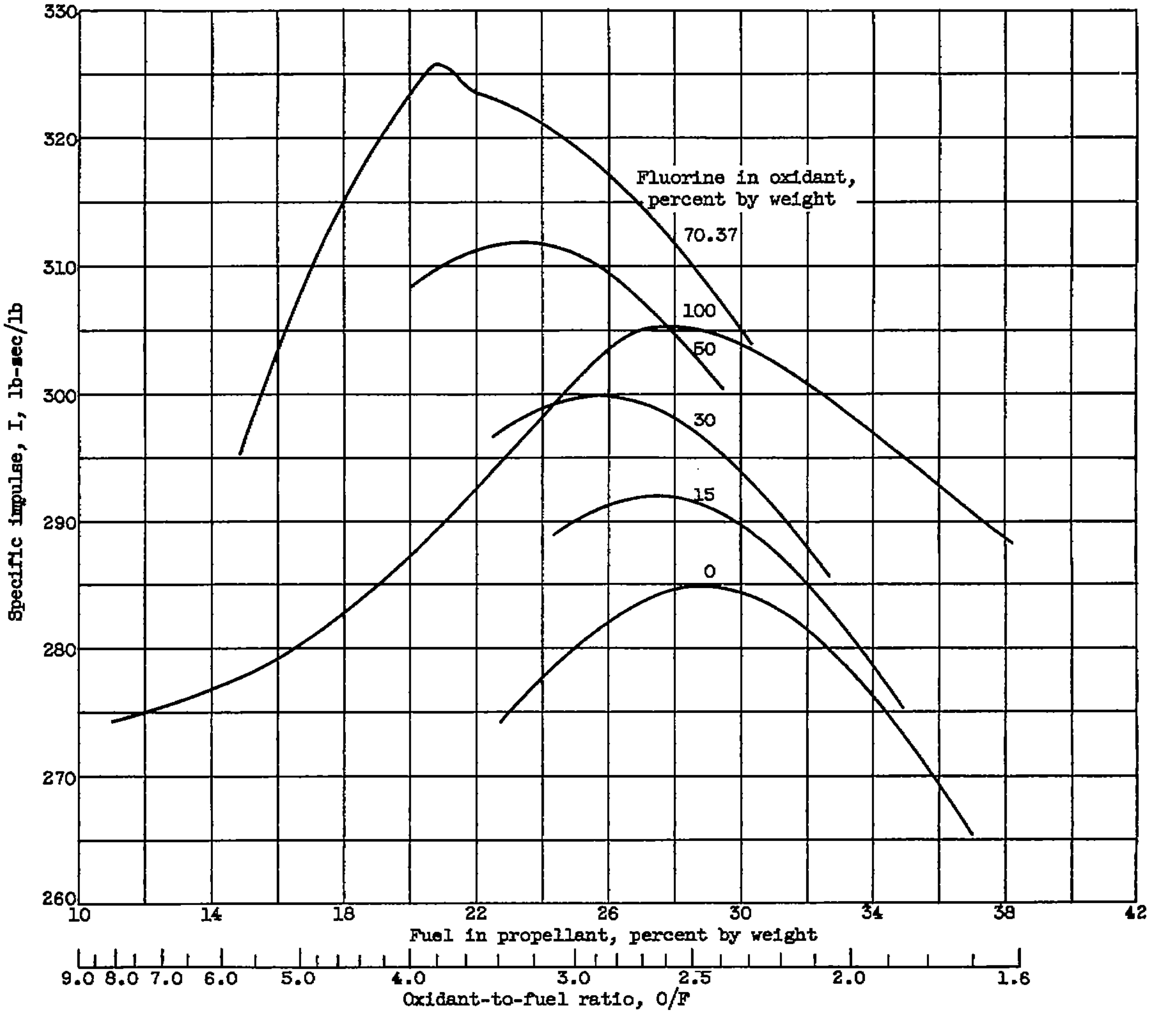


Figure 7. - Theoretical specific impulse for JP-4 fuel with several fluorine-oxygen mixtures. Isentropic expansion assuming equilibrium composition from combustion-chamber pressure of 600 pounds per square inch absolute to exit pressure of 1 atmosphere.

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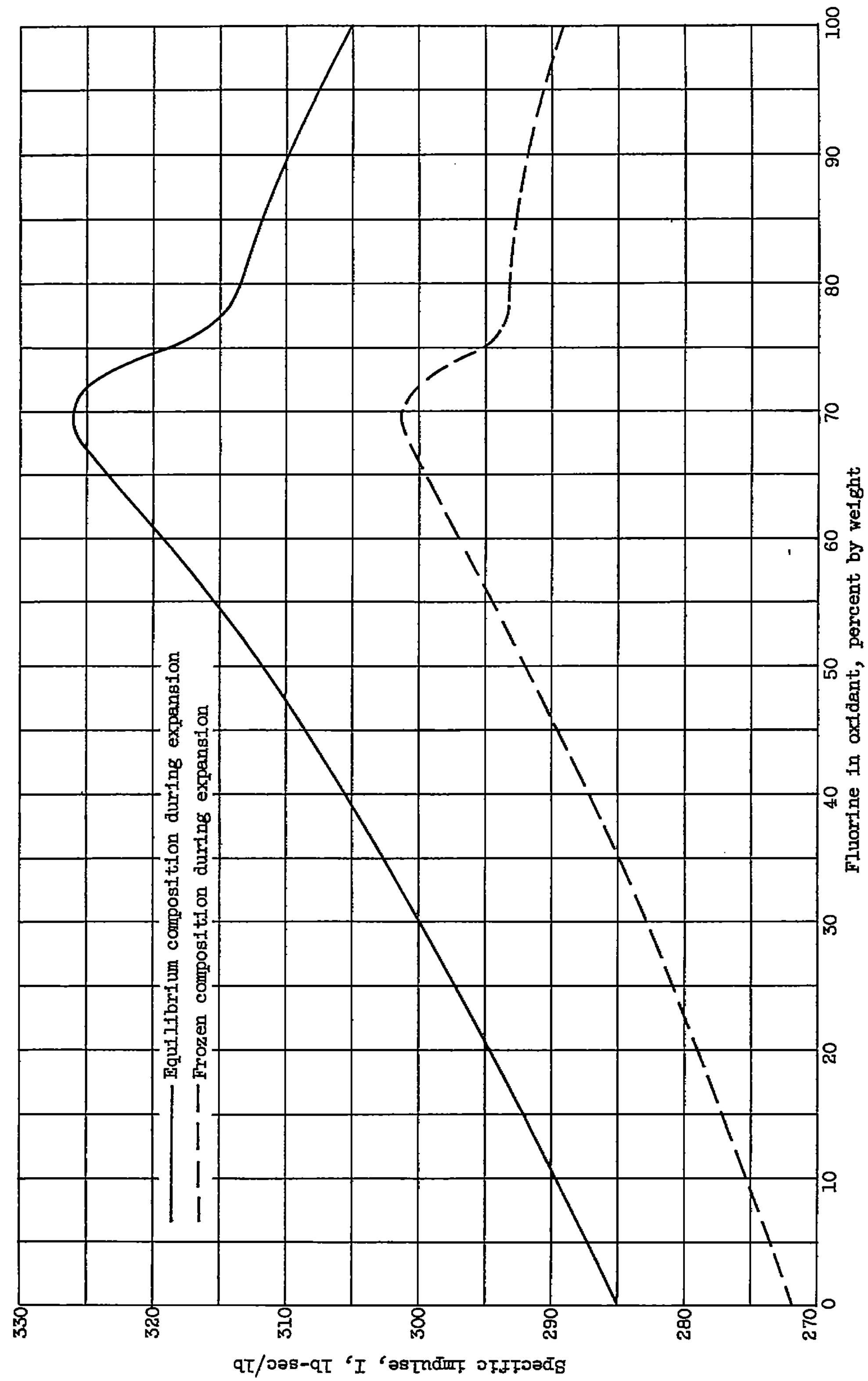

Figure 8. - Theoretical specific impulse of JP-4 fuel with fluorine-oxygen mixtures at equivalence ratios for which specific impulse is maximum. Isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to 1 atmosphere.