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RESEARCH MEMORANDUM

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

By Sanford Gordon

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

FC
BAC

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON
February 25, 1958

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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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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)(°K)

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

T temperature, °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.

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

$$\frac{A_t}{w} = \frac{2791.6\ T_t}{P_t M_t a} \tag{2}$$

Characteristic velocity, ft/sec

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

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)(°K)

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

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.

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
Cleveland, Ohio, November 25, 1957

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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.

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, F_r, $\frac{(F)}{(O)} \div \frac{(F)}{(O)}$	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, $\frac{cal}{(g)(°K)}$	Specific heat, c_p, $\frac{cal}{(g)(°K)}$ (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	3.405	3612	0.0426	25.48	2531.6	2.5729	1.445	1.129	0.0127	5622
1.2	26.07	2.856	3628	.0422	24.05	2901.1	2.6815	1.818	1.131	.0125	5795
1.5	27.64	2.619	3612	.0408	22.96	3074.1	2.7297	1.700	1.134	.0119	5959
1.4	29.15	2.431	3576	.0382	22.70	3239.9	2.7740	1.520	1.139	.0110	5904
1.5	30.59	2.289	3518	.0344	22.05	3393.0	2.8146	1.285	1.145	.0092	5924
1.6	31.93	2.127	3456	.0290	21.41	3551.6	2.8513	1.059	1.156	.0069	5918
1.8	34.55	1.851	3205	.0167	20.17	3853.4	2.9142	.738	1.184	.0031	5832
2.0	37.01	1.702	2923	.0039	19.03	4105.8	2.9627	.555	1.215	.0009	5679
3.0	46.45	.974	1857	.0064	15.49	5181.4	3.0102	.701	1.285	.0114	4674
Percent fluorine in oxidant by weight, 15											
1.2	24.36	3.106	3735	0.0453	24.79	2868.5	2.7033	1.779	1.133	0.0131	5947
1.4	27.51	2.602	3634	.0412	22.25	3058.2	2.7307	1.572	1.144	.0118	6051
1.6	30.04	2.323	3553	.0342	21.15	3300.2	2.7650	1.207	1.157	.0088	6081
1.8	32.37	2.071	3331	.0244	20.06	3773.0	2.8264	.895	1.160	.0049	6022
2.0	34.92	1.864	3142	.0156	19.06	4026.7	2.9753	.716	1.208	.0021	5895
Percent fluorine in oxidant by weight, 30											
1.2	22.50	3.472	3806	0.0454	22.78	2674.8	2.7016	1.693	1.147	0.0136	6117
1.4	25.37	2.942	3746	.0437	21.81	3170.7	2.7867	1.578	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	2.268	3546	.0304	19.95	3702.5	2.9180	.992	1.180	.0069	6216
2.0	32.72	2.009	3369	.0219	19.06	3942.1	2.9667	.797	1.203	.0039	6115
Percent fluorine in oxidant by weight, 50											
1.2	20.05	3.892	4120	0.0458	22.10	2855.9	2.6600	1.520	1.156	0.0138	6366
1.4	22.72	3.421	4100	.0451	21.31	3120.2	2.7542	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	3703	.0234	19.05	3819.9	2.9282	.865	1.206	.0065	6421
Percent fluorine in oxidant by weight, 70.27											
1.0	14.85	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	.0426	21.20	3024.9	2.6855	1.406	1.171	.0125	6757
1.5	20.71	3.829	4479	.0431	20.93	3175.0	2.7138	1.357	1.169	.0126	6814
1.6	21.79	3.599	4396	.0420	20.37	3282.1	2.7302	1.351	1.167	.0126	6743
2.5	30.33	2.297	3696	.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	15.05	5.589	4305	.0611	26.63	3060.4	2.3189	1.375	1.157	.0148	5744
2.0	19.64	4.041	4206	.0454	26.42	3456.0	2.4019	1.203	1.121	.0056	5951
2.8	25.73	2.887	4262	.0326	24.72	4015.3	2.5000	1.670	1.105	.0071	6258
3.0	27.07	2.794	4243	.0322	24.41	4140.1	2.5129	1.639	1.105	.0075	6279
3.5	30.32	2.309	4172	.0310	23.76	4437.8	2.5634	1.510	1.112	.0078	6279
4.0	33.10	2.021	4041	.0294	23.26	4710.9	2.5931	1.295	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.

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 400 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, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_p$	Isentropic exponent, γ, $\left(\frac{\partial \ln p}{\partial \ln \rho}\right)_s$	Specific heat, c_p, cal/(g)(°K)	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, lb-sec/lb
r = 1.0; O/F = 5.40; percent fuel = 20.71											
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	25.547	-.3397	1.1155	1.8910	843	.00167	1.449	1.053	183.9
2800	22.397	1749.4	27.769	-.3407	1.1057	1.8292	763	.00146	5.146	1.493	260.9
2400	2.497	1352.6	29.139	.3470	1.0992	1.5619	680	.00112	30.570	1.833	320.5
2000	.211	990.5	30.422	-.1753	1.1055	1.0305	596	.00066	752.02	2.096	366.2
1600	.022	729.9	31.029	-.0376	1.1408	.5328	504	.00031	1718.1	2.267	396.0
900	.001	444.4	31.204	-.0000	1.2171	.3571	339	.00015	33282.	2.439	428.2
r = 1.4; O/F = 2.04; percent fuel = 26.07											
4000	1755.7	3244.6	23.302	-.3133	1.1413	1.7758	981	0.00185	.....	.....	.....
3600	548.54	2874.4	24.093	-.3206	1.1302	1.8191	907	.00174	1.626	0.248	48.3
3200	135.33	2469.9	25.017	-.3139	1.1202	1.7456	831	.00155	1.439	1.052	189.2
2800	25.883	2104.0	26.036	-.2697	1.1150	1.4847	753	.00115	4.545	1.462	263.4
2400	4.562	1764.7	26.906	-.1290	1.1324	.5586	675	.00054	17.934	1.746	314.5
2000	1.102	1534.3	27.150	-.0160	1.1920	.4929	597	.00035	65.823	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	1.2027	.4373	421	.00022	464.14	2.150	387.3
900	.009	1044.5	27.184	-.0000	1.1924	.4330	342	.00019	2757.3	2.231	401.9
r = 1.8; O/F = 2.61; percent fuel = 27.68											
4000	1787.0	3432.6	22.646	-.3015	1.1428	1.7138	974	0.00177	.....	.....	.....
3600	578.52	3063.0	23.379	-.3026	1.1337	1.6977	901	.00162	2.431	0.171	31.2
3200	153.49	2686.9	24.194	-.2759	1.1254	1.5375	827	.00136	1.335	1.008	183.6
2800	35.125	2329.3	24.985	-.1949	1.1295	1.2272	751	.00092	3.570	1.366	254.5
2400	8.693	2043.0	25.478	-.0654	1.1510	.6547	676	.00050	10.305	1.645	299.5
2000	2.543	1838.7	25.617	-.0097	1.1959	.4840	599	.00035	26.609	1.905	328.7
1600	.974	1648.3	25.637	-.0027	1.2275	.4517	511	.00028	74.711	1.934	352.2
1200	.177	1467.8	25.638	-.0000	1.2351	.4457	428	.00023	241.81	2.063	373.9
900	.022	1327.5	25.638	-.0000	1.1932	.4849	343	.00020	1154.1	2.141	389.8
r = 1.4; O/F = 2.47; percent fuel = 29.25											
3600	642.97	3251.[illegible]	22.655	-.2714	1.1321	1.5745	897	0.00147	.....	.....	.....
3200	188.06	2904.1	23.338	-.2465	1.1341	1.2626	824	.00115	1.197	0.934	171.5
2800	52.357	2578.4	23.912	-.1320	1.1442	.5269	751	.00074	2.435	1.307	239.9
2400	15.960	2323.1	24.212	-.0410	1.1554	.5868	678	.00047	6.217	1.539	282.4
2000	5.113	2118.2	24.298	-.0070	1.2055	.4862	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	.5022	345	.00021	451.39	2.059	377.8
r = 1.6; O/F = 2.83; percent fuel = 31.96											
3600	906.91	3687.1	21.218	-.2007	1.1554	1.1542	893	0.00116	.....	.....	.....
3200	328.53	3367.2	21.653	-.1407	1.1513	.9397	823	.00087	1.001	0.689	126.7
2800	118.890	3089.4	21.956	-.0707	1.1304	.7205	753	.00061	1.508	1.090	200.6
2400	44.037	2856.5	22.104	-.0232	1.2042	.5547	685	.00045	2.427	1.337	245.9
2000	15.629	2652.2	22.151	-.0043	1.2244	.4976	603	.00037	5.82[illegible]	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	.4750	517	.00030	14.022	1.676	308.3
1400	2.310	2363.6	22.160	-.0001	1.2297	.4801	474	.00028	23.995	1.748	321.5
1200	1.005	2266.7	22.160	-.0000	1.2236	.4937	426	.00026	45.465	1.819	334.4
1000	.362	2166.4	22.160	-.0000	1.2134	.5159	374	.00024	101.28	1.887	347.2
r = 1.8; O/F = 3.05; percent fuel = 34.53											
3600	1413.2	4128.5	19.890	-.1437	1.1749	0.9794	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	-.0448	1.2033	.6452	754	.00058	1.659	.634	151.2
2400	109.02	3349.2	20.449	-.0140	1.2249	.5488	684	.00046	1.626	1.129	206.5
2000	37.910	3142.5	20.479	-.0031	1.2407	.5036	605	.00038	2.99[illegible]	1.359	246.3
1600	12.164	2944.6	20.485	-.0002	1.2466	.4936	521	.00032	6.565	1.539	279.0
1200	2.508	2746.9	20.485	-.0000	1.2388	.5032	428	.00027	19.363	1.701	309.3
900	.594	2520.2	20.492	-.0069	1.2131	.5517	350	.00024	64.211	1.819	329.7
r = 3.0; O/F = 1.14; percent fuel = 46.85											
3600	883.10	5274.2	15.429	-.0334	1.2931	1.4408	567	0.00046	.....	.....	.....
3200	306.25	5152.9	15.527	-.0735	1.2787	1.3794	526	.00047	1.329	0.382	55.2
2800	247.22	5016.7	15.752	-.1491	1.2385	1.0599	494	.00056	1.050	1.541	152.5
2400	82.492	4840.6	16.278	-.2508	1.1771	1.8369	443	.00088	1.824	1.197	174.3
2000	19.191	4593.8	17.310	-.4051	1.1270	3.5691	407	.00151	7.421	1.566	227.6
900	2.971	4442.5	18.143	-.4369	1.1399	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 400 lb/sq in. abs.)

(b) Percent fluorine in oxidant, 15

Temperature, T, °K	Static pressure, p, lb/sq in. abs	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_p$	Isentropic exponent, γ, $\left(\frac{\partial \ln p}{\partial \ln \rho}\right)_s$	Specific heat, c_p, cal/(g)(°K)	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, lb-sec/lb
r = 1.2; O/F = 3.106; percent fuel = 24.56											
4000	1244.8	3170.6	22.881	-.1175	1.1574	.7430	1061	0.00197	.....	.....	.....
3600	399.74	2762.2	23.058	-.1358	1.1631	.7886	976	.00165	0.721	0.303	104.3
3200	101.77	2365.5	23.246	-.1441	1.1741	.7460	897	.00128	1.307	1.078	218.5
2800	20.803	2000.8	23.366	-.1477	1.1859	.6807	820	.00088	2.278	1.327	278.5
2400	3.140	1677.5	23.408	-.1477	1.1910	.5996	740	.00054	5.527	1.527	320.6
2000	.426	1401.0	23.417	-.1157	1.2137	.4747	657	.00037	16.[illegible]	1.691	356.1
r = 1.4; O/F = 3.662; percent fuel = 27.33											
4000	1332.3	3400.5	22.444	-.2211	1.1512	.7430	1080	0.00180	.....	.....	.....
3600	460.04	3071.3	22.835	-.2291	1.1463	.8021	1000	.00150	0.800	0.478	128.8
3200	157.84	2744.1	23.220	-.2306	1.1457	.7775	921	.00120	1.121	1.088	208.6
2800	54.200	2424.1	23.570	-.2270	1.1478	.6669	844	.00083	1.775	1.278	268.8
2400	19.207	2121.8	23.827	-.2127	1.1503	.5422	764	.00050	3.775	1.478	317.1
2000	7.055	1848.2	23.927	-.1550	1.1553	.4481	681	.00030	8.893	1.657	356.1
r = 1.6; O/F = 4.218; percent fuel = 30.04											
4000	1332.3	3514.8	21.129	-.1574	1.1631	.9595	1128	0.00128	.....	.....	.....
3600	460.04	3195.5	21.327	-.1631	1.1841	.8802	1038	.00098	0.798	0.478	103.4
3200	157.84	2875.1	21.527	-.1641	1.2139	.7202	947	.00065	1.407	1.088	205.5
2800	54.200	2557.0	21.729	-.1577	1.2447	.6357	856	.00037	2.903	1.278	262.5
2400	19.207	2244.2	21.924	-.1441	1.2744	.5446	762	.00022	5.833	1.478	311.4
2000	7.055	1939.4	22.000	-.1550	1.2964	.4481	664	.00013	13.[illegible]	1.657	349.1
r = 1.8; O/F = 2.071; percent fuel = 32.57											
4000	1332.3	3944.0	20.225	-.1574	1.1765	.9595	1180	0.00106	.....	.....	.....
3600	460.04	3677.8	20.437	-.1631	1.1841	.8802	1086	.00081	0.798	0.478	108.7
3200	157.84	3408.9	20.645	-.1641	1.2139	.7202	991	.00061	1.407	1.088	214.6
2800	54.200	3139.7	20.848	-.1577	1.2447	.6357	896	.00047	2.903	1.278	274.2
2400	19.207	2872.2	21.044	-.1441	1.2744	.5446	798	.00032	5.833	1.478	325.2
2000	7.055	2608.2	21.129	-.1550	1.2964	.4481	696	.00023	13.[illegible]	1.657	365.1
r = 2.0; O/F = 1.864; percent fuel = 34.92											
4000	1332.3	4376.7	19.037	-.0779	1.1874	.9595	1235	0.00076	.....	.....	.....
3600	460.04	4080.7	19.156	-.0797	1.2026	.8802	1135	.00064	0.798	0.478	113.6
3200	157.84	3785.2	19.276	-.0797	1.2276	.7202	1034	.00048	1.407	1.088	224.2
2800	54.200	3490.6	19.396	-.0797	1.2552	.6339	933	.00037	2.903	1.278	286.8
2400	19.207	3197.2	19.516	-.0797	1.2832	.5446	830	.00025	5.833	1.478	340.2
2000	7.055	2905.3	19.636	-.0797	1.3112	.4481	724	.00018	13.[illegible]	1.657	382.1
r = 2.2; O/F = 1.664; percent fuel = 37.41											
4000	1332.3	4672.2	18.153	-.0397	1.1881	.9595	1291	0.00056	.....	.....	.....
3600	460.04	4384.8	18.253	-.0406	1.2031	.8802	1188	.00047	0.798	0.478	118.1
3200	157.84	4097.4	18.353	-.0406	1.2281	.7202	1085	.00035	1.407	1.088	233.1
2800	54.200	3810.0	18.453	-.0406	1.2561	.6339	981	.00027	2.903	1.278	298.2
2400	19.207	3523.2	18.553	-.0406	1.2841	.5446	875	.00018	5.833	1.478	354.1
2000	7.055	3237.2	18.653	-.0406	1.3121	.4481	766	.00013	13.[illegible]	1.657	397.8

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

(Equilibrium composition during isentropic expansion or compression from chamber pressure of 100 lb/sq in. abs.)

(c) 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, $\left(\frac{\partial \ln \rho}{\partial \ln p}\right)_s$	Isentropic exponent, $\left(\frac{\partial \ln p}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Atomic ratio, α	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(°K)}$	Thrust coefficient, C_F	Specific impulse, I_s, $\frac{lb}{lb/sec}$
r = 1.22; O/F = 5.45; percent fluorine in fuel = 0.00										
4000	844.56	2992.8	22.536	1.31164	1.13506	0.7665	1.0304	0.00230	0.4478	3.3479
3600	297.44	2657.4	22.207	1.32227	1.12776	.7223	.0845	.00211	.4403	.3470
3200	97.42	2317.0	21.875	1.33448	1.12117	.7335	.0665	.00193	.4326	.3408
2800	29.52	1972.1	21.531	1.35144	1.11417	.7455	.0494	.00175	.4243	.3338
2400	7.69	1622.4	21.168	1.37291	1.10681	.7583	.0329	.00158	.4153	.3258
2000	1.54	1268.4	20.788	1.40068	1.09931	.7718	.0168	.00140	.4056	.3168
r = 1.41; O/F = 2.942; percent fluorine in fuel = 0.00										
4000	844.56	4002.8	22.536	1.31164	1.13506	0.7665	1.0304	0.00230	0.4478	3.3479
3600	297.44	3657.4	22.207	1.32227	1.12776	.7223	.0845	.00211	.4403	.3470
3200	97.42	3317.0	21.875	1.33448	1.12117	.7335	.0665	.00193	.4326	.3408
2800	29.52	2972.1	21.531	1.35144	1.11417	.7455	.0494	.00175	.4243	.3338
2400	7.69	2622.4	21.168	1.37291	1.10681	.7583	.0329	.00158	.4153	.3258
2000	1.54	2268.4	20.788	1.40068	1.09931	.7718	.0168	.00140	.4056	.3168
r = 1.61; O/F = 1.777; percent fluorine in fuel = 0.00										
4000	844.56	5002.8	22.536	1.31164	1.13506	0.7665	1.0304	0.00230	0.4478	3.3479
3600	297.44	4657.4	22.207	1.32227	1.12776	.7223	.0845	.00211	.4403	.3470
3200	97.42	4317.0	21.875	1.33448	1.12117	.7335	.0665	.00193	.4326	.3408
2800	29.52	3972.1	21.531	1.35144	1.11417	.7455	.0494	.00175	.4243	.3338
2400	7.69	3622.4	21.168	1.37291	1.10681	.7583	.0329	.00158	.4153	.3258
2000	1.54	3268.4	20.788	1.40068	1.09931	.7718	.0168	.00140	.4056	.3168
r = 2.00; O/F = 1.000; percent fluorine in fuel = 0.00										
4000	844.56	6002.8	22.536	1.31164	1.13506	0.7665	1.0304	0.00230	0.4478	3.3479
3600	297.44	5657.4	22.207	1.32227	1.12776	.7223	.0845	.00211	.4403	.3470
3200	97.42	5317.0	21.875	1.33448	1.12117	.7335	.0665	.00193	.4326	.3408
2800	29.52	4972.1	21.531	1.35144	1.11417	.7455	.0494	.00175	.4243	.3338
2400	7.69	4622.4	21.168	1.37291	1.10681	.7583	.0329	.00158	.4153	.3258
2000	1.54	4268.4	20.788	1.40068	1.09931	.7718	.0168	.00140	.4056	.3168

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

(Equilibrium composition during isentropic expansion or compression from chamber pressure of 100 lb/sq in. abs.)

(d) Percent fluorine in oxidant by weight, 100

Temperature, T, °K	Static pressure, p, lb/sq in. abs	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln \rho}{\partial \ln p}\right)_s$	Isentropic exponent, $\left(\frac{\partial \ln p}{\partial \ln \rho}\right)_s$	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Atomic ratio, α	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(°K)}$	Thrust coefficient, C_F	Specific impulse, I_s, $\frac{lb}{lb/sec}$
r = 1.22; O/F = 7.000; percent fluorine in fuel = 0.00										
4000	844.56	2992.8	22.536	1.31164	1.13506	0.7665	1.0304	0.00230	0.4478	3.3479
3600	297.44	2657.4	22.207	1.32227	1.12776	.7223	.0845	.00211	.4403	.3470
3200	97.42	2317.0	21.875	1.33448	1.12117	.7335	.0665	.00193	.4326	.3408
2800	29.52	1972.1	21.531	1.35144	1.11417	.7455	.0494	.00175	.4243	.3338
2400	7.69	1622.4	21.168	1.37291	1.10681	.7583	.0329	.00158	.4153	.3258
2000	1.54	1268.4	20.788	1.40068	1.09931	.7718	.0168	.00140	.4056	.3168
r = 1.41; O/F = 3.500; percent fluorine in fuel = 0.00										
4000	844.56	4002.8	22.536	1.31164	1.13506	0.7665	1.0304	0.00230	0.4478	3.3479
3600	297.44	3657.4	22.207	1.32227	1.12776	.7223	.0845	.00211	.4403	.3470
3200	97.42	3317.0	21.875	1.33448	1.12117	.7335	.0665	.00193	.4326	.3408
2800	29.52	2972.1	21.531	1.35144	1.11417	.7455	.0494	.00175	.4243	.3338
2400	7.69	2622.4	21.168	1.37291	1.10681	.7583	.0329	.00158	.4153	.3258
2000	1.54	2268.4	20.788	1.40068	1.09931	.7718	.0168	.00140	.4056	.3168
r = 1.61; O/F = 2.333; percent fluorine in fuel = 0.00										
4000	844.56	5002.8	22.536	1.31164	1.13506	0.7665	1.0304	0.00230	0.4478	3.3479
3600	297.44	4657.4	22.207	1.32227	1.12776	.7223	.0845	.00211	.4403	.3470
3200	97.42	4317.0	21.875	1.33448	1.12117	.7335	.0665	.00193	.4326	.3408
2800	29.52	3972.1	21.531	1.35144	1.11417	.7455	.0494	.00175	.4243	.3338
2400	7.69	3622.4	21.168	1.37291	1.10681	.7583	.0329	.00158	.4153	.3258
2000	1.54	3268.4	20.788	1.40068	1.09931	.7718	.0168	.00140	.4056	.3168
r = 2.00; O/F = 1.750; percent fluorine in fuel = 0.00										
4000	844.56	6002.8	22.536	1.31164	1.13506	0.7665	1.0304	0.00230	0.4478	3.3479
3600	297.44	5657.4	22.207	1.32227	1.12776	.7223	.0845	.00211	.4403	.3470
3200	97.42	5317.0	21.875	1.33448	1.12117	.7335	.0665	.00193	.4326	.3408
2800	29.52	4972.1	21.531	1.35144	1.11417	.7455	.0494	.00175	.4243	.3338
2400	7.69	4622.4	21.168	1.37291	1.10681	.7583	.0329	.00158	.4153	.3258
2000	1.54	4268.4	20.788	1.40068	1.09931	.7718	.0168	.00140	.4056	.3168

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.]

(r) Percent fluorine in oxidant by weight, 75.57

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, $\frac{cal}{(g)(°K)}$	Coefficient of viscosity, μ, micropoises	Coefficient of 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 = 5.743; percent fuel = 14.85											
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	.8664	1474	.00144	4.015	0.105	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	1.0059	1025	.00114	4.045	1.436	276.9
2400	11.395	1539.6	24.487	-.4313	1.1331	2.3246	936	.00227	7.648	1.570	302.6
2200	3.537	1326.1	25.523	-.5057	1.1160	3.3205	846	.00287	19.755	1.721	331.9
2000	.819	1093.1	26.815	-.5244	1.1046	3.6467	746	.00279	67.915	1.873	361.1
1800	.141	852.2	28.321	-.5068	1.0961	3.3413	659	.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 = 4.100; percent fuel = 19.63											
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	1.2858	1559	.00219	1.432	0.321	67.4
4000	230.67	2691.3	21.804	-.2357	1.1674	1.1434	1459	.00183	1.096	.858	180.3
3600	95.692	2390.1	22.292	-.1812	1.1737	.9283	1352	.00140	1.720	1.154	242.3
3200	40.662	2132.7	22.660	-.0929	1.2058	.6357	1233	.00092	3.012	1.356	284.9
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	22.823	-.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	.4229	669	.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	.3358	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	1534	.00224	1.313	0.359	76.1
4000	220.25	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	.4935	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	975	.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	.3863	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	.3361	556	.00025	87.599	1.887	399.6
r = 1.6; O/F = 3.583; 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	7.550	1929.8	22.636	-.0135	1.2745	.4201	997	.00053	9.992	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	720	.00034	34.879	1.811	379.8
1200	.444	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 = 2.097; percent fuel = [illegible]											
4000	737.24	4208.2	20.326	-.1657	1.1677	1.0699	1563	0.00186	-------	-------	-------
3600	326.65	3908.2	20.651	-.1343	1.1816	.8348	1459	.00147	1.001	0.604	138.5
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	.6131	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	2811.2	21.327	-.0005	1.2789	.4277	772	.00042	16.734	1.695	338.2
1200	.952	2647.4	21.331	-.0020	1.2970	.4097	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.]

(r) Percent fluorine in oxidant by weight, [illegible] (mole percent [illegible])

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, $\frac{cal}{(g)(°K)}$	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 = 8.094; percent fuel = 11.01											
4400	667.85	2957.2	23.300	-0.4356	1.1476	2.9730	1112	0.00179	-------	-------	-------
4000	191.08	2614.9	24.241	-.4347	1.1522	3.9019	984	.00158	1.161	0.251	165.3
3600	54.944	2351.1	25.152	-.4064	1.1172	4.0707	871	.00134	1.714	1.479	241.5
3200	4.976	1961.9	27.546	-.3477	1.1050	4.4051	744	.00101	16.026	1.270	305.6
2400	.330	1150.0	33.364	-.2412	1.0869	4.2218	474	.00072	[illegible]	1.623	357.8
r = 1.5; O/F = 5.759; percent fuel = 15.45											
4400	1154.1	3325.4	28.007	-0.2202	1.1679	1.1023	1246	0.00149	-------	-------	-------
4000	548.26	3054.5	26.647	-.2507	1.1562	1.3652	1129	.00178	3.275	0.117	22.6
3600	189.24	2754.4	27.067	-.2563	1.1737	1.6716	1022	.00200	1.195	.915	173.4
3200	103.33	2529.6	29.159	-.2648	1.1316	2.1169	902	.00212	1.677	1.124	202.4
3000	46.924	2417.6	29.947	-.2658	1.1240	2.3050	[illegible]	[illegible]	1.795	1.175	216.5
2800	7.352	2050.9	30.479	-.2529	1.0879	3.6138	746	.00241	11.760	1.558	296.1
2400	.527	1697.5	32.330	-.4056	1.0845	3.6752	740	.00225	[illegible]	1.592	355.6
2000	.110	1390.4	33.409	-.4353	1.0857	2.9755	736	.00184	[illegible]	1.175	381.2
r = 2.0; O/F = 4.041; percent fuel = 19.84											
4400	970.85	3912.2	26.264	-0.1341	1.1155	1.3451	1223	0.00177	-------	-------	-------
4000	364.25	3302.4	26.583	-.1179	1.1422	1.0483	1122	.00139	1.002	0.625	115.6
3600	142.62	3037.5	26.900	-.1140	1.1321	.8579	1124	.00111	1.374	1.052	190.8
3200	49.281	2775.5	27.356	-.1310	1.1220	1.1697	[illegible]	[illegible]	2.715	1.315	245.5
2800	9.575	2470.0	29.421	-.1143	1.1001	2.1262	[illegible]	[illegible]	4.850	1.623	290.2
2400	.881	2000.6	33.46	-.0462	1.0943	2.7993	624	.00202	31.634	1.924	355.9
2000	.028	1674.7	35.432	-.1236	1.1141	.2621	765	.00084	658.56	2.152	398.1
r = 2.5; O/F = 2.867; percent fuel = 25.73											
4400	622.71	4152.0	24.584	-0.1717	1.1029	1.7445	1452	0.00155	-------	-------	-------
4000	277.77	3757.8	25.005	-.1102	1.1067	1.4249	1365	.00137	1.017	0.769	149.1
3600	81.794	3400.2	25.461	-.1108	1.1021	1.1545	1207	.00251	1.305	1.191	231.0
3200	27.080	3102.4	25.860	-.0985	1.1465	.7988	[illegible]	[illegible]	4.345	1.452	281.5
2800	10.150	2979.3	26.254	-.0788	1.1657	.6800	1835	.00140	[illegible]	1.547	300.0
2600	9.480	2861.8	26.149	-.1021	1.1593	.7230	[illegible]	[illegible]	3.148	1.475	316.5
2400	2.241	2561.5	26.757	-.1595	1.1335	.9702	1477	[illegible]	5.744	1.621	333.0
2200	1.000	2444.2	27.079	-.1613	1.1484	.7635	1315	.00167	16.675	1.667	349.5
2000	.462	2331.9	27.245	-.0524	1.1779	.5685	1134	.00074	101.56	1.973	362.6
r = 3.0; O/F = 2.694; percent fuel = 27.07											
4400	650.95	4295.2	24.153	-0.1772	1.1026	1.7742	1288	0.00175	-------	-------	-------
4000	264.34	3891.4	24.687	-.1312	1.1288	1.5507	1150	.00155	1.029	0.755	147.1
3600	82.996	3517.9	25.184	-.1514	1.1177	1.2903	1207	.00200	1.372	1.195	232.7
3200	24.019	3188.2	25.602	-.1550	1.1319	.9405	[illegible]	[illegible]	4.862	1.477	287.8
2800	7.505	2919.6	26.004	-.0612	1.1710	.6297	1435	.141	11.731	1.675	325.9
2400	2.157	2705.1	26.186	-.0868	1.1731	.5897	1045	.00112	37.018	1.614	353.4
2000	.522	2496.4	26.403	-.0192	1.1901	.4797	1553	.00078	33.835	1.241	379.2
1600	.200	2323.1	26.458	-.0006	1.2231	.4125	1097	.00055	230.29	2.041	397.6
r = 3.5; O/F = 2.309; percent fuel = 30.22											
4400	1135.2	4667.8	23.551	-0.1742	1.1205	1.6970	2327	0.00413	-------	-------	-------
4000	564.22	4271.6	23.945	-.1867	1.1164	1.4353	2477	.00281	[illegible]	0.617	120.3
3600	118.58	3917.5	24.400	-.1947	1.1306	1.1139	2445	.00257	1.154	1.090	212.8
3200	59.451	3619.8	24.010	-.1172	1.1481	.8400	[illegible]	[illegible]	3.249	1.371	267.5
2800	13.015	3481.8	24.278	-.0125	1.1567	.7408	2190	.00178	4.810	1.478	299.4
2600	7.802	3242.7	25.026	-.0434	1.1739	.5975	1512	.00129	10.972	1.652	322.5
2400	4.518	3174.8	25.305	-.0202	1.1854	.5442	1710	.00110	16.576	1.725	336.7
2000	1.440	2937.6	25.582	-.0072	1.2070	.4715	1435	.00082	40.271	1.851	351.3
1600	.460	2757.3	25.398	-.0006	1.2194	.4255	1152	.00061	103.50	1.959	362.5
r = 4.0; O/F = 2.021; percent fuel = 33.10											
4400	1114.7	5047.0	22.957	-0.1618	1.1145	1.5209	2579	0.00421	-------	-------	-------
4000	549.22	4674.9	23.302	-.1152	1.1278	1.2537	2653	.00416	1.255	0.590	56.0
3600	124.12	4345.9	23.708	-.1419	1.1490	1.0050	2533	.00380	1.180	[illegible]	176.2
3200	64.202	4021.4	24.044	-.1527	1.1533	[illegible]	[illegible]	[illegible]	2.159	1.258	239.0
2800	27.916	3723.7	24.335	-.0705	1.1640	.6001	[illegible]	[illegible]	4.172	1.464	282.7
2400	7.911	3554.5	24.522	-.0517	1.1796	.5756	1732	.00117	10.437	1.640	316.7
2000	2.474	3351.0	24.601	-.0077	1.1985	.4394	1457	.00087	35.774	1.78[illegible]	344.0
1600	.668	3172.0	24.618	-.0007	1.2147	.4076	1172	.00055	71.199	1.901	367.1
r = 5.0; O/F = 1.617; percent fuel = 38.22											
4400	1179.5	5630.3	20.509	-0.1505	1.1414	1.0946	2778	0.00455	-------	-------	-------
4000	604.09	5310.4	20.837	-.1174	1.1499	.8417	2676	.00471	1.[illegible]	0.452	84.5
3600	174.19	4961.1	21.289	-.1307	1.1558	.6[illegible]	[illegible]	[illegible]	1.[illegible]	.905	180.3
3200	71.061	4667.5	21.152	-.0847	1.1656	.7[illegible]	[illegible]	[illegible]	2.[illegible]	1.167	272.7
2800	30.[illegible]	4[illegible]	[illegible]	-.0[illegible]	1.1[illegible]6	.6[illegible]	1772	.00[illegible]	5.[illegible]	1.490	326.4
2400	9.[illegible]	3[illegible]	22.535	-.0[illegible]	1.1[illegible]	.5344	1491	.00[illegible]	1[illegible]	1.[illegible]	371.1
2000	3.[illegible]	3[illegible]	22.549	-.0[illegible]	1.2074	.4[illegible]	1[illegible]	.00[illegible]	4[illegible]	1.812	399.5
1600	.5[illegible]	3[illegible]	[illegible]	-.0001	1.2[illegible]	.4[illegible]	[illegible]	.00[illegible]	1[illegible]	1.9[illegible]	[illegible]

TABLE IV. - THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 8 FOR JP-4 FUEL

WITH SEVERAL FLUORINE-OXYGEN MIXTURES

1.000	600.00	3612	0.0426	2531.6	25.48	-.333	1.128	1.845						
1.020	588.24	3605	.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
1.724	348.00	3456	.0402	2382.7	25.87	-.336	1.123	1.871	1.000	.0003	.655	.0135		113.8
2.155	278.40	3380	.0393	2324.3	26.03	-.339	1.121	1.879	1.034	-.0026	.769	.0135		174.3
4.000	150.00	3248	.0367	2164.4	26.47	-.339	1.117	1.893	1.359	-.0021	1.015	.0129		177.5
8.000	75.00	3061	.0339	2007.3	26.95	-.343	1.110	1.886	2.105	-.0039	1.222	.0124		213.6
1.000	600.00	3628	0.0422	2601.1	24.03	-.320	1.131	1.818						
1.020	588.24	3612	.0421	2590.2	24.05	-.321	1.131	1.818	3.45	0.0016	0.126	0.0140		22.7
1.040	576.92	3616	.0420	2579.4	24.06	-.320	1.131	1.819	2.347	.0017	.177	.0140		32.0
1.200	500.00	3571	.0413	2547.0	24.16	-.321	1.129	1.823	1.241	.0009	.381	.0139		66.6
1.439	417.07	3516	.0404	2394.3	24.28	-.321	1.126	1.829	1.037	.0006	.535	.0137		95.4
1.726	347.56	3461	.0395	2341.4	24.40	-.321	1.126	1.837	1.000	-.0001	.653	.0135		117.5
2.158	278.05	3397	.0384	[illegible]	24.55	-.320	1.125	1.913	1.034	-.0027	.770	.0133		133.6
4.000	150.00	3267	.0354	[illegible]	24.95	-.316	1.121	1.775	1.357	-.0024	1.016	.0127		183.2
8.000	75.00	3051	.0314	2244.5	25.39	-.305	1.117	1.896	[illegible]	-.0046	1.222	.0121		253.1
1.000	600.00	3612	0.0408	3074.1	23.70	-.302	1.134	1.733						
1.020	588.24	3605	.0407	3068.1	23.72	-.301	1.134	1.792	3.49	0.0018	0.125	0.0135		23.[illegible]
1.040	576.92	3599	.0405	3062.1	23.73	-.300	1.134	1.792	2.350	.0017	.178	.0136		34.3
1.200	500.00	3553	.0397	3016.7	23.87	-.302	1.132	1.795	1.240	.0012	.381	.0135		69.5
1.441	416.51	3495	.0386	2964.3	23.99	-.303	1.131	1.798	1.037	.0005	.537	.0133		97.7
1.729	347.09	3439	.0375	2911.2	24.10	-.303	1.130	1.800	1.000	.0000	.654	.0131		11[illegible]
2.161	277.68	3371	.0362	2847.7	24.24	-.301	1.129	1.803	1.033	-.0027	.771	.0129		141.4
4.000	150.00	3193	.0324	[illegible]	24.61	-.301	1.125	1.853	1.331	[illegible]	[illegible]	[illegible]		165.1
8.000	75.00	3003	.0269	2553.7	24.90	-.244	1.125	1.859	[illegible]	-.0023	1.241	.0124		242.4
1.000	600.00	3576	0.0382	3233.[illegible]	21.70	-.271	1.134	1.820						
1.020	588.24	3569	.0381	3233.7	21.71	-.272	1.132	1.814	0.0[illegible]	0.0[illegible]	[illegible]	[illegible]		[illegible]
1.040	576.92	3563	.0380	3227.7	21.72	-.271	1.132	1.812	2.353	.0018	.178	.0139		34.[illegible]
1.200	500.00	3514	.0373	3185.5	21.80	-.272	1.131	1.827	1.242	.0015	.382	.0137		70.1
1.444	415.57	3453	.0356	3127.4	22.91	-.274	1.129	1.827	1.036	.0[illegible]	.535	.0125		98.9
1.733	346.31	3393	.0343	3073.4	23.01	-.274	1.128	1.831	1.000	[illegible]	.656	[illegible]		[illegible]
2.166	277.05	3321	.0326	3005.7	23.13	-.274	1.127	1.833	1.033	[illegible]	.773	.0119		142.5
4.000	150.00	3128	.0279	2847.2	23.45	-.272	1.125	1.839	1.329	-.0043	1.026	.0111		205.5
8.000	75.00	2913	.0200	2664.2	23.77	-.241	1.143	1.897	2.154	-.0053	1.243	.0100		253.5
1.000	600.00	3436	0.0290	3551.[illegible]	21.41	-.180	1.156	1.882						
1.020	588.24	3428	.0288	3545.3	21.42	-.179	1.156	1.884	3.475	0.0033	[illegible]	[illegible]		[illegible]
1.040	576.92	3420	.0286	3539.2	21.44	-.179	1.156	1.886	2.363	[illegible]	[illegible]	[illegible]		37.[illegible]
1.200	500.00	3364	.0271	3494.6	21.54	-.179	1.157	1.894	1.247	.0014	.383	.0129		70.7
1.457	411.91	3288	.0252	3434.7	21.67	-.157	1.159	1.906	1.033	.0012	.540	.0126		101.9
1.748	343.27	3217	.0233	3375.1	21.74	-.144	1.161	[illegible]	[illegible]	[illegible]	.664	[illegible]		[illegible]
2.185	274.61	3130	.0210	3301.[illegible]	21.92	-.142	1.163	1.924	[illegible]	[illegible]	.776	[illegible]		143.4
4.000	150.00	2892	.0135	3149.3	21.90	-.135	1.175	1.934	[illegible]	[illegible]	[illegible]	[illegible]		195.[illegible]
8.000	75.00	2615	.0051	2975.7	22.34	-.145	1.192	[illegible]	1.694	[illegible]	1.216	[illegible]		243.[illegible]
1.000	600.00	3205	0.0187	3839.4	[illegible].17	-.095	1.194	1.793						
1.020	588.24	3196	.0185	3837.1	20.17	-.093	1.195	1.794	3.[illegible]	0.0016	0.1[illegible]	0.0[illegible]		[illegible]
1.040	576.92	3187	.0183	3835.7	20.18	-.093	1.195	1.795	2.390	[illegible]	[illegible]	[illegible]		[illegible]
1.200	500.00	3122	.0167	3796.[illegible]	20.21	-.092	1.196	1.798	1.258	[illegible]	[illegible]	[illegible]		[illegible]
1.475	406.86	3028	.0144	3725.[illegible]	20.26	-.07[illegible]	1.194	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
1.770	339.05	2946	.0124	3667.[illegible]	20.30	[illegible]	1.196	[illegible]	1.000	-.0030	.675	[illegible]		1[illegible].5
2.212	271.24	2845	.0098	3601.[illegible]	[illegible]	[illegible]	1.201	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		142.[illegible]
4.000	150.00	2578	.0042	3447.[illegible]	[illegible]	[illegible]	1.214	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		194.7
8.000	75.00	2277	-.0004	3243.[illegible]	[illegible]	[illegible]	1.231	[illegible]	[illegible]	[illegible]	1.251	[illegible]		2[illegible].7
1.000	600.00	1657	0.0264	5100.4	15.44	[illegible]	1.205	1.701						
1.020	588.24	1650	.0267	5104.2	15.50	[illegible]	1.2[illegible]	[illegible]	3.391	[illegible]	[illegible]	[illegible]		12.1
1.040	576.92	1644	.0271	5107.1	15.56	[illegible]	1.204	[illegible]	2.442	[illegible]	[illegible]	[illegible]		26.7
1.200	500.00	1596	.0295	5135.4	15.95	[illegible]	1.197	[illegible]	1.275	[illegible]	[illegible]	[illegible]		59.[illegible]
1.504	399.00	1526	.0334	5180.4	16.79	-.098	1.217	[illegible]	1.131	-.0[illegible]	[illegible]	[illegible]		91.[illegible]
1.805	332.50	1475	.0365	[illegible]	[illegible]	-.115	1.257	[illegible]	[illegible]	[illegible]	.627	[illegible]		1[illegible]
2.256	266.00	1418	.0397	[illegible]	[illegible]	-.141	1.243	[illegible]	1.033	.0017	[illegible]	[illegible]		117.5
4.000	150.00	1296	.0475	[illegible]	[illegible]	[illegible]	1.210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		1[illegible]
8.000	75.00	1187	.0478	[illegible]	[illegible]	[illegible]	1.173	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

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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

1.000	600.00	4007	0.0351	2594.0	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
1.766	339.67	3706	.0312	2397.4	22.56	-.192	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	-.0069	.789	.0119		152.2
4.000	150.00	3319	.0249	2147.3	23.01	-.167	1.186	.816	1.315	-.0036	1.020	.0111		196.7
8.000	75.00	3020	.0[illegible]	1959.0	23.34	-.138	1.189	.739	1.978	-.0062	1.217	.0101		234.7
1.000	600.00	4464	0.[illegible]	3364.9	21.20	-.272	1.171	1.301						
1.020	588.24	4454	[illegible]	3356.6	21.21	-.271	1.170	1.304	3.285	0.0029	0.128	0.0155		26.6
1.040	576.92	4444	[illegible]	3348.5	21.23	-.270	1.170	1.301	2.375	.0027	.180	.0155		37.5
1.200	500.00	4372	.0412	2937.6	21.34	-.267	1.169	1.281	1.251	.0021	.385	.0152		80.9
1.460	411.02	4275	.0394	2810.9	21.45	-.261	1.164	1.253	1.035	.0011	.551	.0149		115.8
1.752	342.50	4187	.0377	2835.6	21.56	-.254	1.168	1.219	1.000	-.0006	.667	.0146		140.0
2.193	274.01	4080	.0357	2754.9	21.70	-.244	1.167	1.178	1.031	-.0013	.782	.0142		164.2
4.000	150.00	3803	.0293	2535.6	21.95	-.216	1.164	1.047	1.328	-.0052	1.015	.0131		213.9
8.000	75.00	3490	.0203	2313.3	22.41	-.159	1.178	.950	2.055	-.0111	1.218	.0118		255.7
1.000	600.00	4479	0.0431	3175.0	20.95	-.276	1.169	1.257						
1.020	588.24	4469	.0429	3168.6	20.96	-.275	1.168	1.254	3.293	0.0027	0.128	0.0156		27.0
1.040	576.92	4460	.0427	3161.4	20.97	-.275	1.167	1.252	2.374	.0029	.180	.0155		38.0
1.200	500.00	4388	.0415	3109.5	21.07	-.271	1.167	1.231	1.251	.0019	.385	.0153		81.0
1.459	411.36	4293	.0399	3038.9	21.19	-.265	1.166	1.202	1.035	.0009	.550	.0150		116.6
1.750	342.80	4205	.0381	2946.4	21.31	-.259	1.165	1.171	1.000	-.0002	.666	.0147		141.0
2.189	274.24	4102	.0361	2875.3	21.44	-.251	1.165	1.130	1.034	-.0014	.781	.0143		165.5
4.000	150.00	3827	.0300	2642.5	21.79	-.235	1.165	1.101	1.359	-.0051	1.018	.0132		215.7
8.000	75.00	3522	.0219	2413.3	21.16	-.173	1.171	.924	2.014	-.0102	1.218	.0119		254.0
1.000	600.00	4396	0.0426	3262.1	20.97	-.270	1.167	1.351						
1.020	588.24	4386	.0424	3254.8	20.98	-.270	1.174	1.344	3.[illegible]	0.0027	0.128	.0152		26.8
1.040	576.92	4377	.0423	3246.8	21.00	-.270	1.173	1.338	2.373	.0027	.180	.0151		37.7
1.200	500.00	4307	.0417	3207.1	21.09	-.267	1.172	1.297	1.251	.0021	.385	.0149		80.8
1.459	411.39	4213	.0401	3130.0	21.21	-.260	1.170	1.251	1.035	.0012	.550	.0145		115.4
1.750	342.81	4127	.0381	3057.9	21.32	-.252	1.169	1.218	1.000	-.0000	.665	.0142		139.6
2.189	274.26	4023	.0359	2973.4	21.45	-.244	1.169	1.187	1.031	-.0012	.781	.0138		163.9
4.000	150.00	3764	.0296	2757.7	21.77	-.224	1.168	1.152	1.315	-.0044	1.018	.0124		213.8
8.000	75.00	3483	.0206	2530.0	22.07	-.158	1.178	.978	2.032	-.0111	1.216	.0109		254.9
1.000	600.00	3898	0.0306	4128.5	20.41	-.159	1.172	1.017						
1.020	588.24	3889	.0297	4121.3	20.42	-.158	1.172	1.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		2[illegible].0
1.040	576.92	3879	.0305	4114.0	20.43	-.158	1.172	1.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		35.9
1.200	500.00	3809	.0294	4060.6	20.44	-.151	1.175	.974	1.254	.0016	.388	.0[illegible]		77.1
1.467	408.97	3710	.0276	3987.4	20.56	-.144	1.178	.930	.994	.0010	[illegible]	.0095		113.7
1.761	340.81	3621	.0258	3922.9	20.63	-.137	1.181	.893	1.000	.0001	.671	[illegible]		133.[illegible]
2.201	272.65	3512	.0235	3846.5	20.72	-.127	1.184	.851	[illegible]	[illegible]	[illegible]	[illegible]		156.[illegible]
4.000	150.00	3226	.0174	3614.3	20.92	-.100	1.193	.751	1.312	-.0042	1.[illegible]	[illegible]		[illegible]
8.000	75.00	4901	.0095	3453.0	21.10	-.065	1.205	.648	1.956	-.0[illegible]	1.[illegible]	[illegible]		[illegible]

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 500 lb/sq in. abs.]

[Percent fluorine by weight, 100 - percent oxygen]

Pressure ratio, P_c/P	Static temperature, T, °R	Temperature ratio, T_c/T	Temperature exponent, $\left(\frac{\partial \ln T}{\partial \ln P}\right)_s$	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln P}\right)_s$	Isentropic vapor heat, $\left(\frac{\partial \ln i}{\partial \ln P}\right)_s$	Specific heat, c_p, cal/(g)(°R)	Area ratio, A	Area-ratio exponent, $\left(\frac{\partial \ln A}{\partial \ln P}\right)_T$	Thrust coefficient, C_F	Specific impulse exponent, $\left(\frac{\partial \ln I_s}{\partial \ln P}\right)_T$	Specific impulse, I_s, lb-sec/lb
$P_c = 1.0$; F = 5.60; percent fuel = 20.0													
10	60.00	3010	0.0330	1957.6	27.10	-.339	1.111	1.880	2.46	-.0143	1.279	0.0122	223.5
15	40.00	2921	.0314	1869.8	27.38	-.336	1.109	1.864	3.30	-.0154	1.373	.0119	240.0
20	30.00	2861	.0303	1809.7	27.57	-.334	1.107	1.849	4.10	-.0161	1.434	.0117	250.6
30	20.00	2779	.0287	1727.7	27.84	-.329	1.105	1.831	5.60	-.0171	1.514	.0114	264.5
40	15.00	2722	.0276	1671.4	28.03	-.326	1.104	1.796	7.03	-.0178	1.566	.0112	273.6
60	10.00	2645	.0259	1594.6	28.29	-.320	1.102	1.755	9.72	-.0189	1.634	.0109	285.5
80	7.50	2592	.0247	1541.9	28.47	-.315	1.101	1.723	12.29	-.0196	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	1316.5	29.27	-.279	1.099	1.521	36.96	-.0133	1.861	.0098	325.1
400	1.50	2316	.0179	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	1.351	65.39	-.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
$P_c = 1.2$; F = 2.856; percent fuel = 20.0													
10	60.00	2996	0.0341	2291.8	25.53	-.300	1.116	1.661	2.45	-.0053	1.278	0.0119	230.3
15	40.00	2909	.0329	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	2744	.0237	2049.6	26.17	-.251	1.115	1.433	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	317.4
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	-.0083	1580.5	27.12	-.034	1.172	.551	43.70	-.0333	1.882	.0075	339.0
600	1.00	1971	-.0189	1520.2	27.16	-.013	1.184	.462	61.29	-.0372	1.924	.0068	346.6
800	.75	1884	-.0243	1479.6	27.17	-.007	1.189	.458	75.73	-.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
$P_c = 1.0$; F = 2.018; percent fuel = 25.0													
10	60.00	2943	0.0451	2452.3	24.72	-.231	1.126	1.295	2.43	-.0072	1.277	0.0111	232.6
15	40.00	2835	.0416	2358.5	24.92	-.205	1.128	1.169	3.25	-.0095	1.370	.0106	249.5
20	30.00	2757	.0394	2294.5	25.06	-.179	1.132	1.070	4.31	-.0116	1.430	.0102	260.5
30	20.00	2646	.0356	2207.9	25.23	-.139	1.140	.924	5.94	-.0151	1.508	.0096	274.5
40	15.00	2564	.0317	2149.0	25.33	-.112	1.147	.824	6.79	-.0178	1.558	.0092	283.7
60	10.00	2443	.0237	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	2282	-.0050	1975.4	25.54	-.041	1.172	.584	13.71	-.0266	1.698	.0076	309.2
150	4.00	2149	-.0098	1905.6	25.59	-.024	1.184	.526	18.75	-.0295	1.751	.0068	318.9
200	3.00	2054	-.0124	1858.5	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	.0054	338.9
600	1.00	1711	-.0177	1699.6	25.64	-.001	1.206	.451	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	-.0158	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	112.84	-.0324	1.976	.0037	359.8
$P_c = 1.2$; F = 1.4[illegible]; percent fuel = 25.0													
10	60.00	2843	0.0172	2610.4	23.86	-.143	1.146	0.929	2.40	-.0103	1.275	0.0097	214.0
15	40.00	2713	.0124	2516.9	24.00	-.109	1.155	.809	3.19	-.0138	1.367	.0089	230.8
20	30.00	2618	.0091	2453.5	24.09	-.085	1.162	.731	3.91	-.0164	1.426	.0084	241.6
30	20.00	2479	.0027	2368.4	24.17	-.055	1.174	.635	5.26	-.0199	1.501	.0076	255.4
40	15.00	2378	-.0023	2311.0	24.22	-.038	1.182	.580	6.51	-.0224	1.549	.0071	264.3
60	10.00	2234	-.0070	2234.3	24.26	-.022	1.193	.531	8.80	-.0267	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	-.0107	2144.7	24.29	-.009	1.204	.493	12.91	-.0267	1.682	.0054	308.7
150	4.00	1919	-.0118	2074.9	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	-.0127	1937.6	24.31	-.001	1.215	.462	37.13	-.0270	1.835	.0036	336.6
600	1.00	1503	-.0125	1885.9	24.31	-.000	1.216	.460	50.90	-.0269	1.871	.0032	343.2
800	.75	1424	-.0119	1851.5	24.31	-.000	1.215	.461	63.69	-.0266	1.894	.0030	347.6
1000	.60	1371	-.0129	1825.2	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	.463	104.30	-.0261	1.941	.0026	356.8

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 500 lb/sq in. abs.]

[Percent fluorine by weight, 100 - percent oxygen]

Pressure ratio, P_c/P	Static temperature, T, °R	Temperature ratio, T_c/T	Temperature exponent, $\left(\frac{\partial \ln T}{\partial \ln P}\right)_s$	Enthalpy, h, cal/g	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln P}\right)_s$	Isentropic vapor heat, $\left(\frac{\partial \ln i}{\partial \ln P}\right)_s$	Specific heat, c_p, cal/(g)(°R)	Area ratio, A	Area-ratio exponent, $\left(\frac{\partial \ln A}{\partial \ln P}\right)_T$	Thrust coefficient, C_F	Specific impulse exponent, $\left(\frac{\partial \ln I_s}{\partial \ln P}\right)_T$	Specific impulse, I_s, lb-sec/lb
$P_c = 1.0$; F = 4.56; percent fuel = 4.56													
1.000	4[illegible].00	3735	0.0439	2888.3	23.39	-.343	1.138	1.779					
1.040	574.92	3721	.0437	2875.9	23.42	-.323	1.138	1.780	2.352	0.0017	0.176	0.0147	32.9
1.042	41[illegible].34	3613	.0420	2774.7	23.64	-.324	1.134	1.788	1.037	.0006	.538	.0144	99.4
1.135	344.78	3535	.0410	2719.9	23.77	-.325	1.133	1.790	1.000	.0000	.635	.0142	121.0
2.161	277.43	3486	.0399	2654.5	23.92	-.325	1.131	1.790	1.033	-.0007	.772	.0140	142.6
1[illegible].000	40.00	3063	.0316	2247.2	24.93	-.311	1.120	1.691	2.633	-.0055	1.478	.0122	238.2
2[illegible].000	50.00	2804	.0277	2084.1	25.34	-.292	1.118	1.577	4.635	-.0080	1.431	.0119	264.5
2[illegible].414	29.39	2896	.0276	2074.5	25.37	-.291	1.118	1.573	4.094	-.0081	1.435	.0119	263.3
4[illegible].00	15.00	2713	.0231	1932.5	25.74	-.255	1.118	1.390	8.882	-.0114	1.560	.0112	288.6
4[illegible].029	14.70	2728	.0229	1928.2	25.78	-.253	1.118	1.383	8.993	-.0115	1.564	.0112	289.0
6[illegible].000	10.00	2641	.0194	1844.9	25.99	-.243	1.120	1.243	9.683	-.0140	1.627	.0106	300.7
7[illegible].000	8.00	2522	.0138	1764.6	26.24	-.180	1.126	1.048	16.280	-.0178	1.724	.0102	311.9
8[illegible].000	6.00	2224	.0014	1521.7	26.93	-.074	1.164	.663	34.530	-.0301	1.845	.0094	334.0
9[illegible].000	1.00	2024	-.0147	1401.7	27.73	-.040	1.191	.479	59.890	-.0364	1.919	.0079	352.8
10[illegible].000	.40	1862	-.0345	1347.9	28.76	-.000	1.208	.412	89.480	-.0440	1.968	.0065	363.7
$P_c = 1.0$; F = [illegible]; percent fuel = 25.0													
1.000	4[illegible].00	3494	0.0412	3274.2	22.25	-.286	1.144	1.572					
1.040	574.92	3400	.0409	3183.3	22.34	-.265	1.144	1.568	2.337	0.0020	0.176	0.0140	33.5
1.044	41[illegible].00	3305	.0385	3087.3	22.44	-.279	1.141	1.530	1.036	.0007	.541	.0135	101.7
1.135	345.03	3302	.0371	3030.3	22.59	-.275	1.140	1.503	1.000	.0000	.657	.0133	123.6
2.169	276.47	3427	.0354	2962.7	22.72	-.269	1.139	1.466	1.033	-.0009	.774	.0130	145.6
1[illegible].000	40.00	2945	.0215	2544.7	23.53	-.190	1.143	1.054	2.397	-.0096	1.276	.0108	239.9
2[illegible].000	5[illegible].00	2724	.0192	2377.7	23.81	-.140	1.157	.827	3.923	-.0154	1.424	.0097	264.2
2[illegible].414	29.39	2717	.0190	2375.1	23.82	-.138	1.158	.820	3.986	-.0156	1.430	.0096	265.9
4[illegible].00	15.00	2482	.0223	2225.4	24.00	-.160	1.180	.632	6.533	-.0228	1.550	.0083	291.5
4[illegible].029	14.70	2479	.0018	2225.4	24.01	-.159	1.180	.627	6.634	-.0230	1.553	.0083	292.1
6[illegible].000	10.00	2340	-.0057	2146.7	24.07	-.035	1.193	.551	8.837	-.0276	1.613	.0075	303.3
7[illegible].000	8.00	2131	-.0115	2054.1	24.12	-.018	1.208	.494	12.950	-.0297	1.683	.0065	316.6
8[illegible].000	6.00	1769	-.0194	1877.2	24.13	-.001	1.227	.443	25.080	-.0320	1.808	.0047	340.1
9[illegible].000	1.00	1554	-.0154	1787.6	24.15	-.001	1.229	.443	50.430	-.0315	1.871	.0035	352.0
10[illegible].000	.40	1413	-.0140	1726.3	24.15	-.001	1.228	.447	74.790	-.0308	1.912	.0033	359.6
$P_c = 1.0$; F = [illegible]; percent fuel = [illegible]													
1.000	4[illegible].00	3383	0.0342	3500.2	21.15	-.213	1.157	1.207					
1.040	574.92	3337	.0337	3447.1	21.31	-.212	1.157	1.198	2.366	0.0029	0.176	0.0120	33.8
1.044	41[illegible].19	3474	.0303	3377.0	21.37	-.194	1.158	1.116	1.035	.0011	.544	.0113	103.5
1.135	345.06	3362	.0280	3319.6	21.42	-.183	1.159	1.071	1.000	.0000	.664	.0109	125.4
2.[illegible]	276.75	3275	.0259	3256.9	21.52	-.178	1.161	1.012	1.032	-.0015	.779	.0105	147.3
1[illegible].000	[illegible]	3471	.0042	837.7	22.00	-.038	1.194	.636	2.913	-.0134	1.270	.0073	240.1
2[illegible].000	[illegible]	[illegible]	.0022	2677.7	22.08	-.024	1.215	.537	3.696	-.0181	1.414	.0058	267.2
2[illegible].414	29.39	2775	.0014	2673.3	22.09	-.024	1.215	.535	3.739	-.0182	1.417	.0058	267.9
4[illegible].00	15.00	2515	.0071	2534.9	22.13	-.018	1.231	.486	6.027	-.0265	1.529	.0044	294.1
4[illegible].029	14.70	2509	.0072	2534.1	22.13	-.018	1.231	.485	6.179	-.0265	1.532	.0045	294.6
6[illegible].000	10.00	2350	.0083	2464.2	22.14	-.004	1.238	.471	8.056	-.0211	1.587	.0040	300.0
7[illegible].000	8.00	2167	-.0094	2381.1	22.15	-.001	1.242	.460	11.696	-.0211	1.651	.0033	318.1
8[illegible].000	6.00	1474	-.0093	2224.4	22.15	-.000	1.244	.457	26.480	-.0404	1.763	.0024	333.2
9[illegible].000	1.00	1354	-.0092	2141.6	22.15	-.000	1.250	.463	44.840	-.0199	1.815	.0019	343.8
10[illegible].000	.40	1320	-.0099	2089.3	22.15	-.000	1.255	.472	66.440	-.0194	1.855	.0017	350.6
$P_c = 1.0$; F = [illegible]; percent fuel = [illegible]													
1.000	4[illegible].00	3391	0.0344	3775.6	20.08	-.131	1.180	0.895					
1.040	574.92	3375	.0340	3759.9	20.09	-.129	1.181	.886	2.387	0.0036	0.181	0.0088	33.8
1.044	41[illegible].31	3314	.0320	3647.1	20.40	-.126	1.186	.812	1.023	.0013	.555	.0080	104.7
1.135	345.03	3299	.0319	3573.3	20.42	-.095	1.190	.774	1.000	.0000	.674	.0075	126.1
2.167	277.31	3039	.0151	3523.4	20.52	-.081	1.195	.730	1.033	-.0016	.788	.0071	147.5
1[illegible].000	[illegible]	3344	.0308	3121.6	20.54	-.015	1.235	.545	2.287	-.0104	1.265	.0030	236.8
2[illegible].000	[illegible]	[illegible]	.0338	2941.5	20.54	-.015	1.249	.489	3.510	-.0114	1.472	.0030	262.4
2[illegible].414	29.39	2041	.0338	2877.5	20.54	-.015	1.250	.488	3.539	-.0118	1.474	.0030	263.1
4[illegible].00	15.00	1763	.0331	2855.3	20.57	-.001	1.257	.473	5.660	-.0120	1.511	.0023	282.9
4[illegible].029	14.70	1775	.0331	2844.8	20.57	-.001	1.257	.472	5.742	-.0120	1.514	.0023	283.4
6[illegible].000	[illegible]	1640	.0331	2784.3	20.57	-.000	1.259	.470	7.542	-.0118	1.564	.0020	293.0
7[illegible].000	8.00	1478	.0033	2709.5	20.57	-.000	1.260	.468	10.900	-.0115	1.625	.0016	304.2
8[illegible].000	6.00	1.79	.0044	2569.2	20.57	-.000	1.263	.478	24.540	-.0110	1.779	.0012	334.6
9[illegible].000	1.00	1027	.0041	2493.6	20.57	-.002	1.265	.494	41.480	-.0102	1.781	.0009	333.4
10[illegible].000	.40	1.[illegible]	.0034	2447.4	20.57	-.004	1.258	.511	61.480	-.0096	1.815	.0008	339.6
$P_c = 1.0$; F = [illegible]; percent fuel = [illegible]													
1.000	4[illegible].00	3143	0.0136	4024.7	18.07	-.072	1.208	0.718					
1.040	574.92	3133	.0131	4013.9	19.07	-.070	1.205	.712	2.407	0.0034	0.182	0.0057	33.6
1.044	41[illegible].19	3043	.0110	3900.8	19.12	-.058	1.217	.636	1.034	.0011	.571	.0044	104.6
1.134	345.45	2932	.0091	3844.0	19.17	-.044	1.224	.633	1.000	.0000	.684	.0044	125.6
2.135	277.75	2741	.0070	3791.4	19.20	-.035	1.228	.604	1.030	-.0014	.797	.0041	146.1
1[illegible].000	[illegible]	2944	-.0016	3432.3	19.28	-.003	1.264	.498	2.164	-.0057	1.282	.0028	231.8
2[illegible].000	50.00	1769	-.0025	3275.4	19.28	-.001	1.272	.483	3.383	-.0059	1.395	.0024	255.5
2[illegible].414	29.39	1755	-.0026	3271.5	19.28	-.001	1.272	.482	3.429	-.0059	1.396	.0024	256.1
4[illegible].00	15.00	1522	-.0041	3152.2	19.28	-.000	1.275	.475	5.422	-.0054	1.470	.0021	274.7
4[illegible].029	14.70	1515	-.0042	3152.0	19.28	-.000	1.275	.475	5.500	-.0052	1.472	.0021	275.2
6[illegible].000	[illegible]	1395	-.0060	3095.3	19.29	-.000	1.276	.471	7.204	-.0043	1.531	.0020	284.9
7[illegible].000	8.00	1250	-.0045	3028.8	19.29	-.000	1.274	.476	10.380	-.0048	1.618	.0018	299.7
8[illegible].000	2.00	992	-.0073	2902.6	19.29	-.000	1.266	.565	23.270	-.0007	1.797	.0015	332.7
9[illegible].000	1.00	878	-.0127	2834.6	19.29	-.002	1.268	.763	39.680	-.0001	1.734	.0009	341.8
10[illegible].000	.40	8[illegible]	-.0057	2791.7	19.29	-.117	1.146	.838	60.630	-.0077	1.784	.0011	347.7

TABLE V. - Continued. THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FOR JP-4 FUEL

WITH SEVERAL FLUORINE-OXYGEN MIXTURES

1.000	410.00	3268	0.0434	2874.6	22.78	-.318	1.147	1.693															
1.040	374.02	3557	.0432	2861.6	22.81	-.319	1.146	1.694	2.758	0.0017	0.178	0.0155	33.8										
1.140	415.00	3734	.0434	2755.3	23.04	-.321	1.143	1.708	1.026	.0006	.541	.0151	104.8										
1.235	442.04	3871	.0434	2693.2	23.14	-.322	1.141	1.713	1.000	.0000	.658	.0149	123.0										
2.169	278.47	3595	.0419	2625.9	23.32	-.323	1.139	1.718	1.023	-.0007	.774	.0146	147.8										
10.000	60.00	3141	.0329	2197.5	24.35	-.316	1.126	1.668	2.416	-.0039	1.277	.0131	242.8										
20.000	50.00	2962	.0287	2024.5	24.79	-.311	1.122	1.584	3.099	-.0054	1.459	.0124	271.7										
30.000	45.00	2957	.0266	2021.6	24.81	-.310	1.122	1.580	3.071	-.0053	1.433	.0124	274.5										
40.000	43.00	2793	.0248	1864.0	25.21	-.273	1.122	1.444	4.501	-.0111	1.557	.0117	296.0										
45.029	42.00	2738	.0238	1864.5	25.23	-.272	1.122	1.437	4.510	-.0113	1.560	.0117	296.7										
50.000	41.00	2698	.0229	1780.6	25.45	-.266	1.122	1.308	5.476	-.0138	1.623	.0113	308.6										
100.000	40.00	2578	.0154	1674.0	25.72	-.242	1.127	1.117	14.316	-.0176	1.690	.0107	323.0										
200.000	41.00	2234	.0094	1470.7	24.17	-.243	1.161	.705	51.226	-.0370	1.878	.0092	349.5										
1000.000	40.00	2075	.0036	1355.9	24.30	-.249	1.198	.501	80.226	-.0418	1.962	.0080	363.5										
	40.00	1903	.0337	1273.2	24.34	-.251	1.220	.404	88.176	-.0487	1.960	.0070	372.8										
1.000	410.00	3734	.0452	3170.7	21.01	-.292	1.152	1.348															
1.040	372.02	3820	.0451	3157.0	21.04	-.292	1.151	1.355	2.761	0.0024	0.175	0.0147	34.5										
1.140	414.12	3955	.0451	3044.2	22.05	-.284	1.151	1.415	1.036	.0007	.543	.0142	109.9										
1.239	442.24	4034	.0450	2982.2	22.17	-.247	1.147	1.429	1.000	.0000	.659	.0142	127.6										
2.175	275.55	3844	.0437	2917.8	22.31	-.245	1.145	1.504	1.033	-.0009	.776	.0139	149.8										
10.000	60.00	3332	.0251	2475.3	23.19	-.213	1.143	1.164	2.390	-.0090	1.275	.0118	246.3										
20.000	50.00	3154	.0214	2294.6	23.52	-.196	1.153	.948	3.013	-.0145	1.425	.0107	275.3										
30.414	44.99	3053	.0211	2291.5	23.52	-.196	1.153	.921	3.072	-.0147	1.429	.0107	276.0										
40.029	43.00	2955	.0204	2141.7	23.74	-.188	1.174	.760	4.536	-.0223	1.549	.0094	299.2										
45.027	42.00	2918	.0200	2137.3	23.77	-.186	1.177	.694	4.636	-.0228	1.552	.0094	299.8										
50.000	41.00	2846	.0198	2051.4	23.95	-.133	1.192	.588	6.849	-.0275	1.612	.0086	311.4										
100.000	40.00	2714	.0134	1952.3	23.63	-.074	1.212	.350	12.640	-.0312	1.683	.0075	325.0										
200.000	41.00	2464	.0084	1771.4	23.04	-.072	1.241	.228	26.310	-.0369	1.827	.0054	352.1										
1000.000	40.00	2407	.0034	1671.5	23.09	-.091	1.246	.221	46.820	-.0367	1.870	.0044	361.4										
	40.00	2455	.0319	1611.8	23.09	-.091	1.246	.224	73.500	-.0340	1.910	.0038	368.8										
1.000	390.00	3744	.0451	3441.8	20.07	-.237	1.161	1.291															
1.041	374.02	3729	.0452	3431.9	20.09	-.237	1.161	1.284	2.770	0.0032	0.179	0.0131	34.8										
1.141	411.95	3855	.0451	3313.2	21.07	-.245	1.161	1.315	1.035	.0011	.544	.0127	106.4										
1.240	441.04	3937	.0450	3243.1	21.17	-.245	1.161	1.173	1.000	.0000	.664	.0126	129.1										
2.178	274.24	3757	.0436	3181.3	21.27	-.245	1.161	1.117	1.034	-.0014	.765	.0120	151.6										
10.000	60.00	3331	.0251	2574.3	21.94	-.241	1.188	.703	2.321	-.0137	1.271	.0089	247.1										
20.000	50.00	3154	.0214	2371.6	22.04	-.241	1.213	.567	3.774	-.0200	1.415	.0073	275.0										
30.414	44.99	3053	.0211	2369.4	22.05	-.241	1.213	.564	3.768	-.0202	1.415	.0073	275.8										
40.029	43.00	2955	.0204	2247.4	22.31	-.215	1.235	.487	6.146	-.0244	1.531	.0058	297.6										
45.027	42.00	2918	.0200	2243.5	22.33	-.215	1.236	.465	6.135	-.0245	1.534	.0058	298.2										
50.000	41.00	2846	.0198	2154.2	22.53	-.207	1.266	.462	8.077	-.0257	1.565	.0051	308.9										
100.000	40.00	2714	.0134	2054.2	22.14	-.157	1.255	.434	11.880	-.0273	1.653	.0043	321.3										
200.000	41.00	2464	.0084	1877.4	22.14	-.157	1.261	.434	24.200	-.0258	1.766	.0030	342.9										
1000.000	40.00	2407	.0034	1777.8	22.14	-.153	1.263	.435	44.020	-.0252	1.820	.0024	353.7										
	40.00	2455	.0319	1711.9	22.14	-.153	1.254	.440	64.810	-.0248	1.855	.0021	360.8										
1.000	390.00	3744	.0451	3722.3	19.25	-.183	1.180	.992															
1.041	374.02	3729	.0452	3722.4	19.25	-.183	1.180	.986	2.793	0.0036	0.183	0.0108	34.9										
1.141	411.95	3855	.0451	3584.5	20.11	-.192	1.183	.905	1.034	.0013	.539	.0100	107.8										
1.240	441.04	3937	.0450	3504.3	20.18	-.192	1.184	.864	1.000	.0000	.672	.0098	129.9										
2.178	274.24	3757	.0436	3434.4	20.24	-.115	1.195	.814	1.031	-.0017	.787	.0091	152.1										
10.000	60.00	3334	.0251	3014.7	20.59	-.029	1.233	.544	2.238	-.0131	1.266	.0058	244.8										
20.000	50.00	3154	.0214	2817.6	20.84	-.010	1.254	.486	3.525	-.0191	1.474	.0043	271.8										
30.414	44.99	3053	.0211	2815.7	20.84	-.010	1.254	.485	3.573	-.0193	1.477	.0043	271.8										
40.029	43.00	2955	.0204	2719.5	20.85	-.002	1.268	.459	5.344	-.0171	1.514	.0039	292.4										
45.027	42.00	2918	.0201	2718.2	20.85	-.002	1.268	.457	5.345	-.0171	1.514	.0039	292.4										
50.000	41.00	2847	.0199	2644.5	20.84	-.001	1.272	.450	7.545	-.0173	1.567	.0026	302.8										
100.000	40.00	2721	.0134	2554.9	20.44	-.002	1.275	.446	10.930	-.0169	1.627	.0024	314.3										
200.000	41.00	2487	.0084	2393.2	20.44	-.002	1.275	.445	24.090	-.0161	1.730	.0014	334.1										
1000.000	40.00	2434	.0034	2322.8	20.44	-.003	1.265	.453	40.330	-.0155	1.781	.0013	344.0										
	40.00	2482	.0319	2282.4	20.44	-.003	1.265	.457	59.270	-.0148	1.813	.0012	350.2										
1.000	400.00	3389	.0451	3962.1	19.04	-.175	1.203	0.797															
1.042	384.02	3397	.0451	3962.4	19.08	-.175	1.204	.789	2.403	0.0038	0.182	0.0103	35.1										
1.142	422.12	3474	.0451	3863.4	19.17	-.172	1.211	.746	1.032	.0013	.569	.0097	108.1										
1.241	452.24	3524	.0451	3804.5	19.27	-.166	1.218	.658	1.000	.0000	.682	.0097	129.6										
2.127	281.44	3381	.0441	3679.5	19.27	-.166	1.218	.658	1.030	-.0018	.795	.0087	151.8										
10.000	65.00	2225	.0219	3280.5	19.42	-.074	1.248	.498	2.171	-.0093	1.202	.0033	239.9										
20.000	55.00	2117	.0193	3119.5	19.44	-.072	1.261	.464	3.384	-.0101	1.395	.0024	263.2										
30.414	51.00	2114	.0192	3109.5	19.44	-.072	1.261	.457	3.430	-.0102	1.395	.0024	263.8										
40.029	49.00	2111	.0190	3084.5	19.44	-.070	1.268	.457	3.498	-.0100	1.393	.0018	265.1										
45.027	48.00	2111	.0189	3084.5	19.44	-.070	1.268	.457	3.474	-.0100	1.393	.0018	265.1										
50.000	47.00	2081	.0188	3042.5	19.44	-.069	1.272	.449	7.146	-.0093	1.551	.0015	294.9										
100.000	46.00	1995	.0127	2945.5	19.44	-.069	1.275	.446	10.340	-.0087	1.634	.0013	305.8										
200.000	47.00	1843	.0079	2775.5	19.44	-.068	1.275	.449	22.600	-.0085	1.703	.0009	316.6										
1000.000	46.00	1787	.0031	2707.5	19.44	-.067	1.266	.452	37.860	-.0080	1.732	.0008	321.1										
	46.00	1835	.0294	2662.4	19.44	-.067	1.266	.455	56.940	-.0076	1.755	.0010	324.5										

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TABLE 7. - Continued. THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FOR JP-4 FUEL

WITH SEVERAL FLUORINE-OXYGEN MIXTURES

1.000	400.00	4120	0.0454	2933.0	22.10	-.301	1.158	1.548															
1.040	402.00	4123	.0454	2931.6	22.15	-.301	1.158	1.541	2.366	0.0018	0.175	0.0157	35.5										
1.140	433.04	4164	.0453	2721.2	22.36	-.303	1.154	1.547	1.036	.0006	.541	.0154	106.3										
1.242	456.45	4191	.0427	2657.0	22.46	-.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	3705	.0314	2139.6	23.67	-.295	1.137	1.313	2.388	-.0059	1.275	.0133	253.1										
20.000	50.00	3593	.0290	1934.0	24.13	-.291	1.132	1.146	3.036	-.0083	1.425	.0126	282.6										
30.414	45.00	3077	.0290	1930.0	24.13	-.291	1.132	1.146	3.008	-.0084	1.429	.0126	283.5										
40.029	43.00	2895	.0248	1784.8	24.55	-.275	1.125	1.395	4.475	-.0111	1.557	.0119	307.8										
45.027	42.00	2890	.0247	1782.0	24.54	-.273	1.124	1.377	4.783	-.0118	1.551	.0119	308.5										
50.000	41.00	2790	.0223	1674.0	24.79	-.255	1.130	1.159	5.174	-.0132	1.618	.0115	320.7										
100.000	40.00	2462	.0154	1541.0	25.57	-.215	1.163	.531	13.760	-.0171	1.890	.0110	335.5										
200.000	41.00	2167	.0094	1344.0	25.57	-.179	1.163	.531	33.370	-.0246	1.842	.0096	362.7										
1000.000	40.00	2117	.0034	1224.5	25.73	-.136	1.214	.495	37.140	-.0435	1.898	.0083	376.1										
	40.00	2157	.0319	1144.8	25.77	-.092	1.266	.364	85.110	-.0533	1.944	.0073	385.9										
1.000	400.00	4100	0.0451	3120.8	21.71	-.263	1.183	1.447															
1.041	404.02	4142	.0449	3105.1	21.74	-.263	1.182	1.438	2.370	0.0020	0.174	0.0155	36.1										
1.141	435.04	4202	.0447	2980.6	21.94	-.271	1.178	1.438	1.035	.0007	.548	.0150	110.2										
1.241	459.45	4240	.0415	2915.5	21.98	-.271	1.176	1.431	1.000	.0000	.664	.0148	133.5										
2.187	274.53	3975	.0400	2847.5	21.97	-.271	1.176	1.419	1.032	-.0006	.779	.0145	154.8										
10.000	60.00	3914	.0294	2464.3	22.75	-.237	1.153	1.216	2.367	-.0081	1.274	.0124	254.5										
20.000	50.00	3864	.0283	2178.2	23.12	-.187	1.193	1.009	3.873	-.0138	1.423	.0114	286.3										
30.414	46.00	2974	.0280	2172.6	23.13	-.187	1.193	1.009	3.921	-.0139	1.425	.0115	287.1										
40.029	45.00	2958	.0278	2000.4	23.43	-.132	1.273	.774	6.454	-.0207	1.545	.0104	311.0										
45.027	44.00	2958	.0278	2000.4	23.44	-.132	1.274	.767	6.574	-.0210	1.549	.0104	311.7										
50.000	43.00	2891	.0277	1917.7	23.54	-.080	1.293	.641	8.772	-.0258	1.611	.0097	323.6										
100.000	42.00	2737	.0216	1807.8	23.67	-.037	1.323	.505	12.840	-.0296	1.674	.0085	337.3										
200.000	43.00	2412	.0154	1611.1	23.75	-.036	1.363	.455	28.930	-.0323	1.815	.0061	364.4										
1000.000	42.00	2357	.0091	1511.8	23.75	-.036	1.383	.452	48.570	-.0325	1.862	.0050	374.7										
	42.00	2397	.0118	1477.0	23.79	-.035	1.393	.451	70.690	-.0322	1.880	.0043	382.4										
1.000	400.00	4120	0.0454	3356.1	20.24	-.247	1.172	1.277															
1.041	404.02	4142	.0453	3352.4	20.27	-.246	1.172	1.273	2.374	0.0027	0.181	0.0144	36.4										
1.141	435.04	4164	.0447	3224.4	20.77	-.238	1.173	1.230	1.035	.0010	.552	.0139	111.3										
1.241	459.45	4172	.0370	3155.6	20.97	-.238	1.169	1.214	1.000	.0000	.667	.0138	135.8										
2.187	274.53	3975	.0360	3079.2	21.00	-.238	1.169	1.164	1.032	-.0014	.792	.0133	159.5										
10.000	60.00	4114	.0165	2053.6	21.72	-.123	1.184	.784	2.316	-.0131	1.271	.0104	257.6										
20.000	50.00	4114	.0147	1919.4	21.94	-.107	1.211	.610	3.711	-.0205	1.415	.0089	288.7										
30.414	47.00	4114	.0147	1919.4	21.94	-.107	1.211	.606	3.765	-.0208	1.419	.0089	287.3										
40.029	46.00	4101	.0146	1823.0	22.04	-.048	1.241	.492	6.039	-.0277	1.531	.0072	310.8										
45.027	45.00	4101	.0145	1823.5	22.04	-.048	1.241	.492	6.129	-.0278	1.534	.0072	310.8										
50.000	44.00	4037	.0144	1757.5	22.08	-.037	1.262	.454	8.031	-.0354	1.585	.0064	321.8										
100.000	43.00	3737	.0116	1677.0	22.09	-.015	1.297	.454	11.586	-.0343	1.655	.0050	331.3										
200.000	44.00	3115	.0149	1507.3	22.11	-.055	1.273	.451	25.600	-.0327	1.762	.0037	357.0										
1000.000	43.00	3101	.0147	1501.0	22.12	-.037	1.291	.359	47.460	-.0325	1.815	.0030	364.0										
	43.00	3175	.0193	1753.4	22.12	-.000	1.296	.354	61.070	-.0319	1.850	.0026	374.8										
1.000	400.00	4155	-.0361	3850.8	19.78	-.194	1.197	1.058															
1.041	404.02	4177	.0359	3845.5	19.80	-.193	1.197	1.038	2.388	0.0036	0.181	0.0128	36.5										
1.141	435.04	4214	.0357	3693.5	20.05	-.184	1.190	.914	1.033	.0012	.554	.0119	111.0										
1.241	459.45	4271	.0307	3593.5	20.05	-.184	1.190	.937	1.000	.0000	.674	.0115	135.1										
2.187	274.53	4071	.0270	3505.5	21.15	-.151	1.214	.821	1.031	-.0018	.784	.0110	159.2										
10.000	60.00	4114	-.0332	2848.2	20.53	-.026	1.228	.580	2.865	-.0183	1.267	.0074	233.8										
20.000	50.00	4114	-.0317	2675.1	20.73	-.023	1.255	.496	3.537	-.0201	1.474	.0061	283.8										
30.414	47.00	4114	-.0317	2670.3	20.73	-.023	1.255	.496	3.585	-.0204	1.478	.0061	284.5										
40.029	46.00	4101	-.0292	2524.8	20.77	-.017	1.281	.453	5.084	-.0232	1.515	.0047	306.0										
45.027	45.00	4101	-.0292	2520.8	20.77	-.017	1.281	.452	5.745	-.0232	1.518	.0047	306.8										
50.000	44.00	4037	-.0291	2446.7	20.78	-.011	1.291	.449	7.497	-.0239	1.569	.0040	316.9										
100.000	43.00	3737	-.0116	2355.1	20.78	-.001	1.310	.414	10.720	-.0250	1.624	.0035	328.9										
200.000	44.00	3125	-.0149	2157.8	20.78	-.027	1.314	.321	23.470	-.0232	1.749	.0023	349.2										
1000.000	43.00	3125	-.0149	2157.5	20.78	-.027	1.314	.329	36.550	-.0229	1.778	.0018	359.1										
	43.00	3175	-.0193	2087.5	20.78	-.033	1.317	.400	55.820	-.0222	1.878	.0016	365.5										
1.000	400.00	4155	-.0361	3919.7	19.03	-.197	1.206	0.863															
1.041	404.02	4177	-.0359	3919.7	19.04	-.197	1.207	.857	2.403	0.0037	0.182	0.0103	36.1										
1.141	435.04	4214	-.0357	3872.3	19.11	-.196	1.211	.801	1.032	.0013	.569	.0094	113.1										
1.241	459.45	4271	-.0307	3807.4	19.11	-.196	1.211	.770	1.000	.0000	.682	.0092	136.0										
2.187	274.53	4071	-.0270	3750.3	19.11	-.196	1.211	.755	1.030	-.0017	.795	.0087	158.8										
10.000	60.00	4114	-.0332	3054.6	19.45	-.124	1.264	.513	2.174	-.0132	1.264	.0053	232.2										
20.000	50.00	4114	-.0317	2921.5	19.65	-.107	1.288	.458	3.199	-.0162	1.397	.0040	278.9										
30.414	47.00	4114	-.0317	2921.5	19.65	-.107	1.288	.457	3.245	-.0163	1.401	.0040	279.6										
40.029	46.00	4101	-.0292	2764.7	19.68	-.081	1.308	.439	5.188	-.0171	1.505	.0030	300.8										
45.027	45.00	4101	-.0292	2762.5	19.68	-.081	1.308	.439	5.194	-.0171	1.505	.0030	300.8										
50.000	44.00	4037	-.0291	2715.1	19.67	-.077	1.315	.441	7.009	-.0170	1.554	.0026	310.1										
100.000	43.00	3737	-.0116	2634.3	19.67	-.066	1.327	.411	10.000	-.0165	1.609	.0021	321.2										
200.000	44.00	3125	-.0149	2419.3	19.73	-.044	1.347	.329	21.740	-.0119	1.724	.0013	340.0										
1000.000	43.00	3125	-.0149	2419.3	19.73	-.044	1.347	.335	33.950	-.0118	1.749	.0013	349.1										
	43.00	3175	-.0193	2372.0	20.01	-.001	1.368	1.441	53.050	-.0145	1.778	.0016	354.5										

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 500 lb/sq in. abs.)

(a) Percent fluorine in oxidant by weight, 100

Pressure ratio, P_c/P	Chamber pressure, P_c, lb/sq in. abs	Temperature, T, °K	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln P}\right)_T$	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln P}\right)_T$	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, $\frac{lb\text{-}sec}{lb}$
			$\left(\frac{\partial \ln T}{\partial \ln P}\right)_\rho$		$\left(\frac{\partial \ln T}{\partial \ln P}\right)_\rho$						
				$r = 1.0$; O/F = 5.745; percent fuel = 14.[illegible]							
10	60.00	2926	0.0151	1902.7	23.44	-.121	1.194	0.687	2.29	-.0105	1.470	0.0097	244.9
15	40.00	2756	.0167	1905.3	23.61	-.128	1.197	.692	3.00	-.0099	1.357	.0091	261.6
20	30.00	2645	.0171	1740.1	23.74	-.192	1.182	.676	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	1.528	.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	10.84	.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	319.5
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	335.5
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	1.109	3.608	40.53	.0011	1.815	.0102	349.8
600	1.00	2025	.0382	1122.9	26.54	-.524	1.104	3.646	57.20	-.0002	1.854	.0102	357.5
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	1047.5	27.02	-.523	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	[illegible]	-.0034	1.936	.0101	373.3
10	60.00	3387	0.0163	2445.4	22.51	-.137	1.185	0.774	2.32	-.0135	1.271	0.0113	267.0
15	40.00	3192	.0081	2128.1	22.67	-.090	1.207	.629	3.05	-.0196	1.369	.0103	285.5
20	30.00	3042	.0003	2049.6	22.74	-.055	1.232	.525	3.70	-.0251	1.415	.0095	297.3
30	20.00	2810	-.0111	1946.0	22.81	-.017	1.273	.385	4.89	-.0331	1.486	.0083	312.0
40	15.00	2639	-.0172	1877.7	22.92	-.003	1.293	.365	5.92	-.0383	1.530	.0074	321.4
60	10.00	2419	.0271	1788.7	22.96	-.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	1695.7	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	1931	-.0139	1440.7	23.94	-.151	1.176	.906	35.36	-.0161	1.790	.0064	375.9
600	1.00	1842	-.0121	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	61.95	-.0369	1.847	.0058	387.9
1000	.60	1660	-.0227	1304.4	24.23	-.020	1.273	.405	72.13	-.0433	1.864	.0055	391.4
1500	.40	1517	-.0347	1251.5	24.42	-.002	1.302	.352	97.34	-.0499	1.861	[illegible]	[illegible]
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	.0147	2220.7	22.43	-.121	1.196	.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	-.0074	2025.4	22.64	-.058	1.221	.552	5.00	-.0255	1.489	.0090	315.3
40	15.00	2789	-.0165	1960.7	22.70	-.038	1.242	.499	6.13	-.0295	1.535	.0083	325.0
60	10.00	2558	-.0091	1856.3	22.75	-.034	1.253	.466	8.16	-.0303	1.553	.0074	337.4
80	7.50	2422	-.0035	1803.9	22.79	-.044	1.243	.438	10.04	-.0279	1.631	.0069	345.4
100	6.00	2322	-.0073	1757.8	22.85	-.058	1.250	.475	11.82	-.0297	1.658	.0064	351.2
150	4.00	2140	-.0144	1679.2	22.90	-.018	1.275	.416	15.89	-.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	1.324	.351	42.73	-.0396	1.825	.0037	386.4
800	.75	1439	-.0235	1421.6	22.92	-.000	1.333	.347	52.44	-.0395	1.844	.0034	390.4
1000	.60	1361	-.0238	1394.6	22.92	-.000	1.337	.344	61.55	-.0394	1.858	.0031	393.6
1500	.40	1267	-.0240	1349.1	22.93	-.001	1.344	.339	82.25	-.0395	1.882	.0027	398.6
10	60.00	3351	0.0183	2461.1	22.16	-.142	1.164	0.900	2.39	-.0126	1.274	0.0105	267.3
15	40.00	3215	.0174	2341.4	22.31	-.111	1.181	.755	3.11	-.0158	1.364	.0097	286.1
20	30.00	3045	.0087	2260.8	22.43	-.088	1.197	.666	3.81	-.0188	1.421	.0092	298.1
30	20.00	2921	.0015	2153.0	22.51	-.057	1.221	.558	5.07	-.0238	1.494	.0083	313.4
40	15.00	2746	-.0045	2082.1	22.56	-.039	1.238	.499	6.21	-.0269	1.541	.0075	323.1
60	10.00	2519	-.0135	1997.8	22.61	-.021	1.261	.445	8.27	-.0339	1.600	.0068	335.6
80	7.50	2390	-.0133	1954.6	22.64	-.013	1.275	.419	10.13	-.0329	1.638	.0061	343.6
100	6.00	2277	-.0156	1879.4	22.65	-.009	1.284	.403	11.84	-.0318	1.665	.0057	349.3
150	4.00	2080	-.0177	1802.1	22.66	-.004	1.297	.396	15.81	-.0351	1.711	.0050	358.8
200	3.00	1948	-.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	1.325	.357	42.49	-.0356	1.831	.0031	384.1
800	.75	1393	-.0201	1551.3	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	391.2
1500	.40	1219	-.0203	1479.3	22.67	-.001	1.341	.347	81.89	-.0358	1.888	.0023	396.1
10	60.00	3797	0.0068	3343.7	21.13	-.057	1.210	0.617	2.27	-.0137	1.267	0.0065	252.9
15	40.00	3412	.0025	3230.9	21.22	-.039	1.221	.567	2.96	-.0134	1.353	.0058	270.0
20	30.00	3262	.0005	3242.3	21.26	-.028	1.229	.535	3.60	-.0124	1.408	.0053	280.8
30	20.00	3175	-.0042	3131.4	21.29	-.016	1.241	.499	4.77	-.0173	1.475	.0046	294.5
40	15.00	3175	-.0063	3071.7	21.31	-.010	1.249	.479	5.84	-.0185	1.520	.0042	303.3
60	10.00	[illegible]	-.0079	2992.6	21.32	-.005	1.259	.457	7.78	-.0195	1.576	.0037	314.4
80	7.50	2904	-.0099	2945.4	21.32	-.003	1.265	.446	9.55	-.0196	1.612	.0033	321.6
100	6.00	2861	-.0094	2902.5	21.32	-.002	1.272	.439	11.21	-.0198	1.637	.0031	326.7
150	4.00	2811	-.0097	2836.7	21.33	-.001	1.277	.430	15.02	-.0199	1.680	.0027	335.3
200	3.00	2772	-.0097	2793.9	21.33	-.001	1.280	.426	18.51	-.0197	1.708	.0024	340.8
300	2.00	2412	-.0100	2737.4	21.33	-.001	1.284	.418	24.86	-.0195	1.744	.0021	347.9
400	1.50	2335	-.0095	2720.9	21.33	-.001	1.291	.414	30.67	-.0195	1.767	.0020	352.5
600	1.00	2213	-.0084	2692.4	21.33	-.002	1.294	.409	41.27	-.0192	1.796	.0017	358.4
800	.75	2134	-.0085	2661.4	21.33	-.004	1.294	.410	50.96	-.0184	1.815	.0016	362.2
1000	.60	2077	-.0074	2632.4	21.34	-.009	1.293	.415	61.04	-.0174	1.829	.0015	364.9
1500	.40	[illegible]	-.0073	2582.5	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 500 lb/sq in. abs.)

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

Pressure ratio, P_c/P	Chamber pressure, P_c, lb/sq in. abs	Temperature, T, °K	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln P}\right)_T$	Molecular weight, M	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln P}\right)_T$	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 = 8.085; percent fuel = 11.01							
1.000	500.00	[illegible]	[illegible]	27.41	-0.458	1.146	[illegible]	-------	-----	-----	
1.140	438.92	[illegible]	[illegible]	27.46	-.458	1.146	2.052	[illegible]	0.178	71.3	
1.445	415.36	[illegible]	[illegible]	27.51	-.461	1.141	3.119	[illegible]	.140	94.6	
1.754	346.06	[illegible]	[illegible]	28.00	-.457	1.139	3.222	1.000	.657	115.5	
2.167	279.94	[illegible]	[illegible]	29.24	-.454	1.136	3.231	1.075	.774	135.7	
10.000	50.00	[illegible]	[illegible]	29.69	-.501	1.121	3.345	2.45	1.078	224.2	
20.000	25.00	[illegible]	[illegible]	30.05	-.515	1.116	4.157	[illegible]	1.471	251.0	
30.414	[illegible]	[illegible]	[illegible]	30.65	-.514	1.115	4.246	[illegible]	1.495	261.7	
40.000	12.50	[illegible]	[illegible]	31.37	-.515	1.110	4.279	[illegible]	1.560	273.6	
40.827	14.696	[illegible]	[illegible]	31.45	-.515	[illegible]	4.282	7.00	1.563	274.3	
60.000	10.00	[illegible]	[illegible]	31.81	-.508	1.107	4.339	5.55	1.627	285.4	
100.000	5.00	[illegible]	[illegible]	32.35	-.540	1.104	4.791	14.45	1.774	299.0	
200.000	2.50	[illegible]	[illegible]	33.51	-.540	1.098	4.415	30.06	1.849	324.5	
500.000	1.00	[illegible]	[illegible]	34.25	-.544	1.094	4.774	66.12	1.975	338.2	
1000.000	.50	[illegible]	[illegible]	34.76	-.545	1.092	4.316	101.09	1.981	347.6	
1500.000	.33	[illegible]	[illegible]	35.17	-.540	1.090	4.055	145.69	2.021	354.6	
				$r = 1.5$; O/F = 5.849; percent fuel = 15.65							
1.000	500.00	[illegible]	[illegible]	26.63	-0.284	1.157	1.775	-------	-----	-----	
1.143	438.02	[illegible]	[illegible]	26.66	-.287	1.156	1.591	[illegible]	0.179	51.9	
1.449	414.02	[illegible]	[illegible]	26.95	-.311	1.151	1.538	[illegible]	.144	97.1	
1.759	346.02	[illegible]	[illegible]	27.09	-.325	1.148	1.622	1.000	.663	117.6	
2.174	276.02	[illegible]	[illegible]	27.29	-.337	1.145	1.726	1.055	.776	138.6	
10.000	50.00	[illegible]	[illegible]	28.06	-.402	1.126	2.264	2.71	1.277	223.0	
20.000	25.00	[illegible]	[illegible]	29.09	-.418	1.121	2.733	5.99	1.429	250.1	
30.414	[illegible]	[illegible]	[illegible]	30.41	-.416	1.121	2.341	4.06	1.455	265.8	
40.000	12.50	[illegible]	[illegible]	31.94	-.396	1.106	2.565	6.81	1.557	277.9	
40.827	14.696	[illegible]	[illegible]	32.09	-.391	1.107	2.598	6.86	1.561	278.6	
60.000	10.00	[illegible]	[illegible]	32.21	-.367	1.095	2.660	3.42	1.625	289.7	
100.000	5.00	[illegible]	[illegible]	32.76	-.364	1.065	3.129	14.54	1.769	305.4	
200.000	2.50	[illegible]	[illegible]	33.97	-.365	1.065	3.028	30.55	1.844	329.2	
500.000	1.00	[illegible]	[illegible]	34.87	-.396	1.084	3.187	66.00	1.974	343.5	
1000.000	.50	[illegible]	[illegible]	35.46	-.404	1.084	3.103	102.81	1.976	353.7	
1500.000	.33	[illegible]	[illegible]	35.95	-.406	1.085	3.009	147.43	2.019	360.5	
				$r = 2.0$; O/F = 4.041; percent fuel = 19.84							
1.000	500.00	[illegible]	[illegible]	27.42	-0.129	1.121	1.035	-------	-----	-----	
1.140	438.02	[illegible]	[illegible]	28.45	-.124	1.122	1.131	2.347	0.177	32.8	
1.445	415.02	[illegible]	[illegible]	28.54	-.121	1.129	1.087	1.036	.158	99.5	
1.752	346.02	[illegible]	[illegible]	28.80	-.117	1.133	1.051	1.000	.655	121.1	
2.164	277.00	[illegible]	[illegible]	28.87	-.114	1.139	.970	1.055	.771	142.7	
10.000	50.00	[illegible]	[illegible]	29.06	-.172	1.159	1.065	2.38	1.272	235.5	
20.000	25.00	[illegible]	[illegible]	29.63	-.143	1.116	1.439	3.93	1.421	262.9	
30.414	[illegible]	[illegible]	[illegible]	29.64	-.142	1.117	1.513	3.99	1.435	263.7	
40.000	12.50	[illegible]	[illegible]	29.85	-.091	1.105	1.917	6.74	1.547	282.2	
40.827	14.696	[illegible]	[illegible]	29.85	-.093	1.104	1.927	6.85	1.561	286.9	
60.000	10.00	[illegible]	[illegible]	29.78	-.510	1.101	2.101	9.55	1.613	298.4	
100.000	5.00	[illegible]	[illegible]	30.50	-.549	1.097	2.244	14.71	1.689	312.4	
200.000	2.50	[illegible]	[illegible]	31.51	-.549	1.094	2.275	35.71	1.872	338.9	
500.000	1.00	[illegible]	[illegible]	32.53	-.547	1.095	2.174	64.52	1.910	352.4	
1000.000	.50	[illegible]	[illegible]	33.10	-.538	1.095	1.972	100.29	1.953	363.2	
1500.000	.33	[illegible]	[illegible]	33.37	-.526	1.097	1.817	142.05	2.003	370.5	
				$r = 2.5$; O/F = 3.887; percent fuel = 20.73							
1.000	500.00	[illegible]	[illegible]	24.72	-0.178	1.105	1.070	-------	-----	-----	
1.040	438.02	[illegible]	[illegible]	24.74	-.177	1.105	1.062	2.452	0.176	34.2	
1.450	415.02	[illegible]	[illegible]	24.85	-.180	[illegible]	1.094	1.078	.528	102.3	
1.761	346.02	[illegible]	[illegible]	24.92	-.182	[illegible]	1.092	1.000	.646	125.2	
2.144	279.00	[illegible]	[illegible]	25.00	-.191	1.110	1.098	1.074	.764	148.1	
10.000	50.00	[illegible]	[illegible]	25.58	-.145	1.128	1.045	2.45	1.279	247.7	
20.000	25.00	[illegible]	[illegible]	25.92	-.104	1.145	.918	[illegible]	1.452	277.6	
30.414	[illegible]	[illegible]	[illegible]	26.55	-.105	1.145	.812	4.09	1.476	278.4	
40.000	12.50	[illegible]	[illegible]	27.01	-.081	1.134	.678	6.74	1.560	302.4	
40.827	14.696	[illegible]	[illegible]	27.02	-.081	1.134	.678	6.84	1.563	303.0	
60.000	10.00	[illegible]	[illegible]	26.13	-.098	1.160	.719	9.16	[illegible]	315.0	
100.000	5.00	[illegible]	[illegible]	[illegible]	-.145	1.144	.775	15.06	1.848	323.3	
200.000	2.50	[illegible]	[illegible]	29.11	-.154	1.134	.916	35.51	1.934	355.5	
500.000	1.00	[illegible]	[illegible]	[illegible]	-.102	1.148	.705	58.06	1.976	359.5	
1000.000	.50	[illegible]	[illegible]	31.21	-.056	1.178	.581	89.26	1.954	378.8	
1500.000	.33	[illegible]	[illegible]	31.97	-.039	1.186	.496	125.76	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, $\left(\frac{\partial \ln M}{\partial \ln T}\right)_s$	Partial derivative, $\left(\frac{\partial \ln M}{\partial \ln P}\right)_s$	Isentropic exponent, γ_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 = 5.0; O/F = 2.034; percent fuel = 27.07											
1.000	600.00	4149	4140.1	24.41	-0.184	1.105	1.093	-------	-----	-----	
1.040	576.92	4056	4046.5	24.42	-.185	1.105	1.092	2.552	0.176	34.3	
1.429	419.58	4129	4013.6	24.54	-.188	1.107	1.081	1.078	.528	102.8	
1.715	349.81	4068	3959.1	24.61	-.190	1.108	1.064	1.000	.646	125.6	
2.144	279.66	3924	3885.6	24.69	-.190	1.109	1.047	1.054	.784	146.8	
10.000	60.00	3436	3427.2	25.32	-.175	1.150	1.179	2.47	1.278	249.0	
20.000	30.00	3223	3244.0	25.56	-.146	1.159	.999	4.07	1.413	273.2	
20.414	29.392	3226	3236.8	25.52	-.145	1.159	.995	4.13	1.417	260.0	
40.000	15.00	3045	3074.4	25.50	-.107	.141	.915	6.87	1.563	304.5	
40.827	14.696	3036	3070.0	25.65	-.106	1.141	.911	6.94	1.566	305.1	
60.000	10.00	2905	2992.2	25.94	-.079	1.152	.709	9.59	1.609	317.4	
100.000	6.00	2717	2870.5	26.05	-.043	1.170	.597	15.94	1.705	332.1	
200.000	2.00	2422	2660.5	26.24	-.057	1.173	.489	42.42	1.840	358.6	
300.000	1.00	2104	2546.6	26.37	-.035	1.185	.526	57.35	1.911	372.4	
600.000	.60	1940	2454.9	26.42	-.011	1.202	.462	85.47	1.957	381.7	
1000.000	.40	1811	2411.7	26.45	-.005	1.212	.434	117.58	1.990	387.3	
r = 5.0; O/F = 2.334; percent fuel = 30.02											
1.000	600.00	4172	4437.6	25.76	-0.180	1.112	1.060	-------	-----	-----	
1.040	576.92	4158	4424.1	25.77	-.185	1.112	1.050	2.555	0.177	34.5	
1.434	418.54	4045	4314.2	25.90	-.198	1.115	1.478	1.057	.531	103.7	
1.721	348.00	3961	4253.5	25.97	-.186	1.117	1.428	1.000	.649	126.6	
2.151	278.89	3902	4180.7	24.06	-.185	1.119	1.356	1.074	.766	143.6	
10.000	60.00	3554	3745.6	24.66	-.136	1.141	.956	2.42	1.276	248.9	
20.000	30.00	3369	3546.2	24.[illegible]	-.1[illegible]4	1.1[illegible]	[illegible]	3.96	1.427	278.5	
20.414	29.392	3321	3541.2	24.[illegible]	-.107	1.153	.753	4.02	1.431	279.5	
40.000	15.00	3141	3382.6	25.29	-.074	1.163	.677	6.72	1.552	302.0	
40.827	14.696	3133	3376.0	25.10	-.073	1.164	.674	6.73	1.556	303.7	
60.000	10.00	3090	3295.9	25.18	-.058	1.170	.626	9.30	1.617	315.5	
100.000	6.00	3003	3159.5	25.27	-.040	1.178	.570	15.51	1.682	329.6	
200.000	2.00	2812	2990.7	25.37	-.012	1.196	.447	41.15	1.828	354.8	
300.000	1.00	2660	2882.3	25.39	-.004	1.208	.454	55.50	1.885	367.9	
600.000	.60	2520	2810.6	25.40	-.001	1.215	.444	78.73	1.926	376.3	
1000.000	.40	2460	2757.9	25.43	-.001	1.219	.435	102.50	1.919	382.5	
r = 4.0; O/F = 2.021; percent fuel = 33.10											
1.000	600.00	4041	4710.9	25.26	-0.167	1.126	1.245	-------	-----	-----	
1.040	576.92	4026	4697.4	25.26	-.166	1.127	1.275	2.749	0.178	34.5	
1.445	415.75	3938	4599.9	25.40	-.162	1.132	1.190	1.036	.538	105.9	
1.732	346.46	3867	4527.2	25.47	-.158	1.134	1.144	1.000	.655	126.8	
2.165	277.17	3789	4450.8	25.55	-.152	1.137	1.090	1.023	.772	149.0	
10.000	60.00	3145	4011.6	24.99	-.104	1.155	.808	2.59	1.273	245.8	
20.000	30.00	2984	3840.0	24.86	-.078	1.162	.717	3.88	1.422	274.5	
20.414	29.392	2976	3840.1	24.89	-.078	1.162	.715	3.93	1.426	275.3	
40.000	15.00	2829	3683.1	24.45	-.055	1.170	.657	6.47	1.544	298.2	
40.827	14.696	2822	3684.7	24.45	-.055	1.170	.655	6.57	1.548	298.8	
60.000	10.00	2483	3694.9	24.49	-.038	1.176	.596	8.78	1.607	310.2	
100.000	6.00	2593	3505.9	24.55	-.014	1.184	.551	12.97	1.677	323.8	
200.000	2.00	1972	3318.1	24.61	-.004	1.201	.488	30.70	1.803	348.1	
300.000	1.00	1717	3.16.0	24.62	-.001	1.210	.476	51.96	1.878	360.7	
600.000	.60	1570	3149.5	24.62	-.001	1.216	.465	77.44	1.910	368.7	
1000.000	.40	1490	3096.7	24.62	------	1.220	.464	106.30	1.943	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	2.565	0.179	35.4	
1.452	413.04	3601	5075.4	22.[illegible]	-.114	1.151	.927	1.035	.545	101.8	
1.742	344.37	3475	5019.7	22.70	-.110	1.152	.864	1.000	.661	125.5	
2.176	275.49	3394	4951.4	22.76	-.106	1.153	.877	1.052	.777	145.1	
10.000	60.00	2792	4545.5	23.13	-.069	1.164	.747	2.55	1.372	257.6	
20.000	30.00	2553	4397.1	23.25	-.077	1.170	.679	3.90	1.419	265.1	
20.414	29.392	2542	4390.7	23.25	-.058	1.172	.657	3.97	1.413	265.8	
40.000	15.00	2295	4244.1	23.37	-.040	1.181	.585	6.74	1.540	287.6	
40.827	14.696	2288	4240.1	23.40	-.040	1.181	.580	6.44	1.543	288.2	
60.000	10.00	2157	4167.1	23.42	-.012	1.187	.558	8.59	1.601	299.0	
100.000	6.00	1990	4076.9	23.44	-.006	1.193	.535	12.97	1.679	311.8	
200.000	2.00	1656	3[illegible]	23.45	-.001	1.205	.501	31.49	1.792	334.8	
300.000	1.00	1471	3914.4	23.45	------	1.217	.447	53.50	1.868	348.5	
600.000	.60	1344	3[illegible]	23.[illegible]	------	1.217	.477	80.[illegible]	1.8[illegible]	354.1	
1000.000	.40	1299	3[illegible]	23.[illegible]	------	1.221	.470	107.[illegible]	1.[illegible]	356.6	

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

	4000	3612	3600	3200	2800	2400	2000	1600	900
r = 5.0; O/F = 2.034; percent fuel = 27.07									
$C_{(g)}$	0.23473	0.21540	0.21467	0.18574	0.14517	0.09229	0.03652	0.00482	------
$CO_{(g)}$	.16604	.19995	.20015	.24590	.30633	.38148	.45811	.50082	0.50734
$CO_{2(g)}$	.02986	.02369	.02349	.01701	.01069	.00535	.00120	.00005	------
$F_{(g)}$	.04573	.04043	.04025	.03374	.02609	.01723	.00790	.00151	------
$F_{2(g)}$	------	------	------	------	------	------	------	------	------
$HF_{(g)}$	.27686	.30785	.30892	.34566	.38672	.43007	.46877	.48919	.49265
$H_{(g)}$	.04324	.03303	.03270	.02123	.01259	.00499	.00088	.00002	------
$H_{2(g)}$	.15025	.09621	.09603	.06716	.03847	.02055	.00303	------	------
$O_{(g)}$	------	------	------	------	------	------	------	------	------
$O_{2(g)}$	.10329	.08444	.08380	.06246	.04055	.02046	.00607	.00056	------
r = 5.0; O/F = 2.334; percent fuel = 30.02									
	4000	3628	3600	3200	2800	2400	2000	1600	1200	900
$C_{(g)}$	0.29586	0.28284	0.28163	0.24076	0.18308	0.20684	0.19393	0.17833	0.14424	0.09103
$CO_{(g)}$	.13902	.16572	.16805	.20614	.25264	.22456	.31277	.32898	.36710	.41631
$CO_{2(g)}$	.03379	.03125	.03067	.02235	.01460	.00636	.00141	.00011	------	------
$F_{(g)}$	.07136	.06578	.06534	.05569	.04335	.04993	.05688	.07284	.10668	.16019
$F_{2(g)}$	------	------	------	------	------	------	------	------	------	------
$HF_{(g)}$	.28698	.31844	.32097	.35401	.39859	.42933	.43399	.41973	.38568	.33246
$H_{(g)}$	.03105	.02262	.02198	.01117	.00557	.00094	.00002	------	------	------
$H_{2(g)}$	.04793	.04189	.04132	.03084	.02034	.00315	.00007	------	------	------
$O_{(g)}$	------	------	------	------	------	------	------	------	------	------
$O_{2(g)}$	.06912	.07146	.07004	.04920	.02739	.00888	.00092	.00002	------	------
r = 4.0; O/F = 2.021; percent fuel = 33.10										
	4000	3612	3600	3200	2800	2400	2000	1600	1200	900
$C_{(g)}$	0.32446	0.31453	0.31416	0.29935	0.26220	0.26944	0.25858	0.23870	0.19676	0.12234
$CO_{(g)}$	.12367	.14724	.14847	.17747	.21222	.23474	.24835	.26862	.31055	.37501
$CO_{2(g)}$	.04364	.03378	.03350	.02143	.01132	.00574	.00116	.00008	------	------
$F_{(g)}$	.09777	.08240	.08223	.07242	.05374	.07736	.08865	.10909	.15109	.21551
$F_{2(g)}$	------	------	------	------	------	------	------	------	------	------
$HF_{(g)}$	.28633	.31891	.31995	.35415	.38953	.40691	.40280	.38349	.34157	.27714
$H_{(g)}$	.02475	.01475	.01451	.00379	.00285	.00030	.00001	------	------	------
$H_{2(g)}$	.03091	.02490	.02458	.01[illegible]	.00579	.00042	.00001	------	------	------
$O_{(g)}$	------	------	------	------	------	------	------	------	------	------
$O_{2(g)}$	.07347	.06119	.05960	.03967	.01938	.00490	.00045	.00001	------	------
r = 5.0; O/F = 1.617; percent fuel = 38.22										
	3600	3576	3200	2800	2400	2000	1600	1200	900
$C_{(g)}$	0.34489	0.34444	0.33630	0.31751	0.31695	0.30847	0.28526	0.24044	0.17069
$CO_{(g)}$	.12765	.12914	.13670	.17144	.19527	.19855	.22166	.26690	.33665
$CO_{2(g)}$	.03552	.03438	.03447	.01371	.00561	.00096	.00007	------	------
$F_{(g)}$	.10270	.10447	.10996	.10074	.13824	.12157	.14436	.19023	.25998
$F_{2(g)}$	------	------	------	------	------	------	------	------	------
$HF_{(g)}$	.31341	.31534	.34559	.37047	.37843	.37018	.34824	.30243	.23268
$H_{(g)}$	.01165	.01124	.00535	.00133	.00011	------	------	------	------
$H_{2(g)}$	.01316	.01324	.00711	.00188	.00015	------	------	------	------
$O_{(g)}$	------	------	------	------	------	------	------	------	------
$O_{2(g)}$	.05038	.04523	.03064	.01490	.00204	.00025	.00001	------	------
r = 4.0; O/F = 1.617; percent fuel = 38.22									
	3600	3436	3200	2800	2400	2000	1600	1200	
$C_{(g)}$	0.19663	0.32669	0.34624	0.34412	0.38849	0.37743	0.35488	0.30979	
$CO_{(g)}$	.16894	.09344	.09949	.10938	.11709	.12975	.15246	.19656	
$CO_{2(g)}$	.03660	.03110	.03344	.01145	.00122	.00068	.00004	------	
$F_{(g)}$	.15384	.15462	.15681	.14369	.17355	.18735	.21034	.25647	
$F_{2(g)}$	------	------	------	------	------	------	------	------	
$HF_{(g)}$	.26788	.29328	.30468	.31167	.31540	.30473	.28228	.23619	
$H_{(g)}$	.00499	.00343	.00177	.00031	.00002	------	------	------	
$H_{2(g)}$	.00753	.00248	.00128	.00023	.00001	------	------	------	
$O_{(g)}$	------	------	------	------	------	------	------	------	
$O_{2(g)}$	.01139	.03488	.01633	.00573	.00113	.00009	------	------	
r = 5.0; O/F = 1.617; percent fuel = 38.22									
	3600	3205	3200	2800	2400	2000	1600	1200	900
$C_{(g)}$	------	------	------	------	------	------	------	------	0.00016
$CO_{(g)}$	0.47431	0.47519	0.43519	0.43475	0.43042	0.42044	0.40078	0.35968	.29689
$CO_{2(g)}$	.05622	.05430	.05436	.02445	.00604	.00676	.00056	.00766	.21046
$F_{(g)}$	.09447	.10280	.10044	.10542	.00296	.00050	.00003	------	------
$F_{2(g)}$	------	------	------	------	------	------	------	------	------
$HF_{(g)}$	.11659	.21942	.11942	.14779	.14713	.24907	.26912	.31024	.37262
$H_{(g)}$	------	------	------	------	------	------	------	------	------
$H_{2(g)}$	------	------	------	------	------	------	------	------	------
$O_{(g)}$	------	------	------	------	------	------	------	------	------
$O_{2(g)}$	.23943	.25101	.25111	.25566	.25293	.24317	.22351	.18241	.11987
r = 4.0; O/F = 1.617; percent fuel = 43.[illegible]									
	.000	1457	1600	1.00	900				
$C_{(g)}$	------	------	------	------	------				
$CO_{(g)}$	------	.00130	0.00213	0.00[illegible]	0.14454				
$CO_{2(g)}$	0.00[illegible]	.01146	.01[illegible]	.1[illegible]	.01304				
$F_{(g)}$	.1[illegible]	.50424	.50393	.45[illegible]	.27290				
$F_{2(g)}$	.00062	.01187	.00576	.02[illegible]	.09009				
$HF_{(g)}$	------	------	------	------	------				
$H_{(g)}$	.00031	.00001	.00001	------	------				
$H_{2(g)}$	.14[illegible]	.47[illegible]14	.47333	.44475	.41695				
$O_{(g)}$	------	------	------	------	------				
$O_{2(g)}$	.1[illegible]	.1[illegible]	.1[illegible]	.02932	.06247				

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 [illegible] lb/sq in. abs.]

(b) Percent fluorine in mixture by weight, 15

Mole fraction[a] at temperature, T

r = [illegible]; O/F = [illegible]; percent fuel = [illegible]

K	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CO	0.24715	0.27896	0.27178	0.25329	0.22509	0.19752	0.18528	0.17223
CO_2	.11543	.12887	.13996	.17545	.23122	.26369	.28095	.29453
F	.00778	.00196	.00141	.00079	.00029	.00006	.00000	.00000
H	.04214	.03600	.03284	.02745	.01440	.00637	.00138	.00010
H_2	.05383	.05443	.05457	.04859	.04264	.03991	.04548	.05886
[illegible]	.13566	.13772	.13975	.14605	.15257	.15790	.15967	.15986
H_2O	.13242	.21795	.23904	.26046	.29453	.32165	.32630	.31440
O	.00431	.02974	.03966	.01535	.00650	.00111	.00002	.00000
O_2	.04433	.04321	.04102	.03152	.01729	.00347	.00007	.00000
OH	.04342	.06962	.08378	.04515	.02544	.00833	.00084	.00002

r = [illegible]; F = [illegible] percent fuel = [illegible]

K	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CO	0.33771	0.33350	0.33184	0.32715	0.31404	0.30209	0.29747	0.28627	0.23671
CO_2	.17737	.18148	.18335	.19885	.14983	.16301	.17452	.19340	.22348
F	.00192	.00127	.00108	.00047	.00013	.00002	.00000	.00000	.00000
H	.02243	.01157	.03977	.02669	.01477	.00535	.00100	.00007	.00000
H_2	.05755	.08840	.09755	.08437	.08473	.09188	.10243	.12251	.16211
[illegible]	.13972	.13643	.13756	.13222	.13604	.13799	.13853	.13801	.13801
H_2O	.13172	.22411	.23113	.26033	.29197	.29226	.28331	.26863	.24709
O	.00351	.01453	.01418	.00659	.00187	.00014	.00000	.00000	.00000
O_2	.01310	.01559	.01421	.00740	.00214	.00017	.00000	.00000	.00000
OH	.04346	.05156	.04755	.02952	.01347	.00278	.00024	.00000	.00000

r = [illegible]; F = [illegible] percent fuel = [illegible]

K	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.00070	0.00050	0.00039	0.00001	0.00000	0.00000	0.00000	0.00000	0.00001
CO	.34002	.36742	.34754	.37932	.37314	.36542	.34612	.30671	.24775
CO_2	.17553	.17396	.24143	.20221	.23243	.11069	.13019	.16960	.22655
F	.00044	.00065	.00026	.00004	.00001	.00000	.00000	.00000	.00000
H	.04133	.04240	.03649	.01938	.00424	.00075	.00005	.00000	.00000
H_2	.13416	.13423	.13003	.14354	.15253	.16471	.18452	.22397	.28291
[illegible]	.13136	.11617	.11003	.12115	.12300	.12229	.12214	.12235	.12235
H_2O	.11726	.21372	.23351	.24448	.24504	.23605	.21679	.17798	.11843
O	.00423	.00631	.00219	.00134	.00043	.00000	.00000	.00000	.00000
O_2	.00373	.00367	.00143	.00124	.00002	.00000	.00000	.00000	.00000
OH	.01592	.02975	.01613	.00557	.00131	.00003	.00000	.00000	.00000

r = [illegible]; F = [illegible] percent fuel = [illegible]

K	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00011
CO	.42231	.41734	.41184	.41734	.41626	.40807	.39166	.35719	.30415
CO_2	.14734	.15570	.20214	.23645	.26237	.37133	.40740	.12218	.17342
F	.00042	.00025	.00015	.00003	.00000	.00000	.00000	.00000	.00000
H	.00624	.00338	.02396	.01105	.00341	.00057	.00003	.00000	.00000
[illegible]	.19591	.19594	.20544	.21431	.22470	.24156	.27586	.32680
[illegible]	.11429	.11747	.11466	.10624	.10949	.10949	.10950	.10952
[illegible]	.13415	.14082	.15570	.14354	.14580	.14935	.17507	.08400
O	.00175	.00071	.00011	.00001	.00000	.00000	.00000	.00000
O_2	.00054	.00027	.00004	.00000	.00000	.00000	.00000	.00000
OH	.01351	.01332	.00255	.00035	.00004	.00000	.00000	.00000

r = [illegible]; F = [illegible] percent fuel = [illegible]

K	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00015	0.00140
CO	.44371	.44443	.42293	.43533	.42373	.39655	.37175	.35433
CO_2	.12433	.13127	.03521	.03561	.04577	.05847	.08566	.11045	.12782
F	.00002	.00027	.00002	.00001	.00000	.00000	.00000	.00000	.00000
H	.00318	.00495	.00324	.00075	.00042	.00003	.00000	.00000	.00000
[illegible]	.05267	.05626	.06418	.07162	.07965	.08858	.09977	.34419	.35840
[illegible]	.03772	.00787	.03154	.03834	.03907	.03909	.03909	.03912	.03937
H_2O	.14317	.14541	.14702	.14825	.14875	.12611	.09893	.07433	.05867
C	.00125	.00019	.00003	.00000	.00000	.00000	.00000	.00000	.00000
CO_2	.00004	.00004	.00001	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00424	.00320	.00132	.00024	.00002	.00000	.00000	.00000	.00000

[a] Mole fractions were computed for all 15 substances listed in this report but were printed if less than 0.0001.

[b] Interpolation 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 [illegible] lb/sq in. abs.]

(b) Percent fluorine in mixture by weight, 5

Mole fraction[a] at temperature, T

r = [illegible]; F = [illegible] percent fuel = [illegible]

K	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CO	0.27896	0.27490	0.26599	0.24609	0.21749	0.18873	0.17742	0.16738
CO_2	.12577	.09365	.11053	.14424	.18952	.23194	.24774	.25828
F	.00778	.00457	.00444	.00214	.00077	.00015	.00001	.00000
H	.03443	.01400	.03398	.02484	.01410	.00203	.00126	.00009
H_2	.04575	.04743	.04101	.03627	.03134	.02683	.03299	.04339
[illegible]	.13777	.13194	.10732	.31848	.32162	.32219
[illegible]	.11355	.14331	.16532	.19209	.21388	.21796	.20481
H_2O	.23434	.25204	.22994	.01774	.00752	.00126	.00003	.00000
O	.00474	.01497	.03319	.01116	.00772	.00365	.00007	.00000
O_2	.00337	.00500	.00434	.00370	.00304	.00726	.00071	.00001
OH	.02447	.02771	.01021	.01047	.00134	.00513	.00000	.00000

r = [illegible]; F = [illegible] percent fuel = [illegible]

K	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CO	0.33447	0.32271	0.31021	0.31047	0.30134	0.29513	0.28741	0.27196	0.23990
CO_2	.13333	.17342	.20427	.19149	.12641	.13459	.14746	.16367	.19574
F	.00343	.01434	.00205	.00127	.00034	.00005	.00000	.00000	.00000
H	.00471	.04527	.04150	.02826	.01543	.00550	.00161	.00007	.00000
H_2	.09792	.09145	.06974	.06671	.06671	.07209	.08177	.09780	.12990
[illegible]	.14437	.13965	.14001	.14694	.15719	.16137	.16448	.18264	.18265
[illegible]	.13560	.13700	.13113	.13148	.13654	.14438	.15115	.16386	.15180
H_2O	.19445	.21442	.21177	.21795	.19264	.00016	.00003	.00000	.00000
O	.00723	.00645	.01331	.00813	.00231	.00018	.00000	.00000	.00000
O_2	.00508	.00494	.00434	.00444	.00253	.00021	.00000	.00000	.00000
OH	.02516	.02485	.01511	.01431	.00547	.00033	.00000	.00000	.00000

r = [illegible]; F = [illegible] percent fuel = [illegible]

K	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00009
CO	.42231	.41734	.41184	.41734	.41626	.40807	.39166	.35719	.30415
CO_2	.14734	.15570	.20214	.23645	.26237	.37133	.40740	.12218	.17342
F	.00042	.00025	.00015	.00003	.00000	.00000	.00000	.00000	.00000
H	.00624	.00338	.02396	.01105	.00341	.00057	.00003	.00000	.00000
[illegible]	.19591	.19594	.20544	.21431	.22470	.24156	.27586	.32680
[illegible]	.11429	.11747	.11466	.10624	.10949	.10949	.10950	.10952
[illegible]	.13415	.14082	.15570	.14354	.14580	.14935	.17507	.08400
O	.00175	.00071	.00011	.00001	.00000	.00000	.00000	.00000
O_2	.00054	.00027	.00004	.00000	.00000	.00000	.00000	.00000
OH	.01351	.01332	.00255	.00035	.00004	.00000	.00000	.00000

r = [illegible]; F = [illegible] percent fuel = [illegible]

K	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00011	0.00113
CO	.44371	.44443	.42293	.43533	.42373	.39655	.37175	.35433	.34833
CO_2	.12433	.13127	.03521	.03561	.04577	.05847	.08566	.11045	.12782
F	.00002	.00027	.00002	.00001	.00000	.00000	.00000	.00000	.00000
H	.00318	.00495	.00324	.00075	.00042	.00003	.00000	.00000	.00000
[illegible]	.05267	.05626	.06418	.07162	.07965	.08858	.09977	.34419	.35840
[illegible]	.03772	.00787	.03154	.03834	.03907	.03909	.03909	.03912	.03937
H_2O	.14317	.14541	.14702	.14825	.14875	.12611	.09893	.07433	.05867
C	.00125	.00019	.00003	.00000	.00000	.00000	.00000	.00000	.00000
CO_2	.00004	.00004	.00001	.00000	.00000	.00000	.00000	.00000	.00000
OH	.00424	.00320	.00132	.00024	.00002	.00000	.00000	.00000	.00000

[a] Mole fractions were computed for all 15 substances listed in this report but were printed if less than 0.0001.

[b] Interpolation temperature.

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

FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Nonstoichiometric equation of composition for combustion chamber pressure of 600 lb/sq in. abs.]

(a) Percent fuel by weight, 50.57

Mole fractions[a] at temperature T

F = 0.1; F = 0.9; percent fuel = 50.57

T, °K	4400	T_c[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	0.20347	0.16636	.16467	.14054	.11887	.08143	.03218	-------
CO_2	.02381	.03547	.03774	.05447	.08103	.10945	.13275	.17058	.22012	.25246
F	.25416	.25010	.25007	.25013	.25325	.25568	.25400	.16218	.06429	-------
F_2	.00007	.00006	.00006	.00005	.00004	.00004	.00003	.00001	-------	-------
H	.00801	.00339	.00335	.00102	.00021	.00002	-------	-------	-------	-------
HF	.00058	.00018	.00018	.00004	-------	-------	-------	-------	-------	-------
H_2	.43456	.45235	.45143	.47531	.47665	.4[illegible]80	.50491	.55292	.61765	.66011
H_2O	.00078	.00027	.00027	.00009	.00002	-------	-------	-------	-------	-------
O	.04677	.03517	.03454	.01155	.00089	.00233	.00030	.00004	-------	-------
O_2	.01865	.02039	.02042	.01934	.01414	.00491	.00077	.00011	.00002	-------
OH	.03542	.00294	.00240	.00115	.00049	.00003	-------	-------	-------	-------

F = 0.4; F = 0.6; percent fuel = 19.60

T, °K	4600	T_c[b] 4464	4400	4000	3600	3200	2800	2400	2000	1600	1200
C(GAS)	0.00009	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
CF_4	.00007	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
CO	.26924	0.29436	0.29530	0.30053	0.30343	0.30274	0.30108	0.30035	0.31018	0.01521	0.01530
CO_2	.00225	.00312	.00374	.00542	.00837	.01523	.01894	.02014	.03108	.03597	.03607
F	.14374	.12348	.11956	.09563	.07408	.06179	.05801	.05559	.01744	.00034	-------
F_2	.00051	.00001	.00001	-------	-------	-------	-------	-------	-------	-------	-------
H	.06281	.04781	.04492	.0[illegible]737	.01241	.00313	.00030	.00001	-------	-------	-------
HF	.00871	.00913	.00913	.00467	.00187	.00035	.00002	-------	-------	-------	-------
H_2	.47487	.50784	.51421	.55342	.58854	.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	-------	-------	-------	-------

F = 0.6; F = 0.4; percent fuel = 29.71

T, °K	4800	T_c[b] 4479	4400	4000	3600	3200	2800	2400	2000	1600	1200
C(GAS)	0.00141	0.00099	0.00093	0.00060	0.00028	0.00006	-------	-------	-------	-------	-------
GRAPHITE	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	0.00005
F	.00128	.00117	.00114	.00092	.00055	.00023	0.00005	-------	-------	-------	-------
F_2	.00005	.00005	.00005	.00004	.00003	.00002	.00001	0.00001	-------	-------	-------
H	.00001	.00001	.00001	.00001	-------	-------	.00001	.00002	-------	-------	-------
HF	-------	-------	-------	-------	-------	.00001	.00004	.00139	0.00311	0.00374	.00328
H_2	.00028	.00042	.00046	.00077	.00115	.00145	.00156	.00092	.00008	-------	-------
CO	.30145	.30754	.30907	.31682	.32426	.32965	.33313	.33499	.33647	.33661	.33651
CO_2	.00002	.00001	.00001	-------	-------	-------	-------	-------	-------	-------	.00065
F	.12128	.10077	.09556	.06942	.04493	.02421	.01243	.00577	.00052	.00001	-------
F_2	.00001	.00001	-------	-------	-------	-------	-------	-------	-------	-------	-------
H	.07694	.06245	.05877	.04020	.02282	.00920	.00179	.00013	.00001	-------	-------
HF	.01705	.01423	.01346	.00962	.00591	.00258	.00052	.00003	.00001	-------	-------
H_2	.44004	.51231	.52649	.56184	.60065	.63229	.63044	.65673	.65979	.65910	.66011
H_2O	.00001	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
O	.00001	.00001	.00002	-------	-------	-------	-------	-------	-------	-------	-------
OH	.00074	.00001	.00001	-------	-------	-------	-------	-------	-------	-------	-------

F = 0.8; F = 0.2; percent fuel = 41.79

T, °K	4400	T_c[b] 4396	4000	3600	3200	2800	2400	2000	1600	1200	900
C(GAS)	0.00411	0.00409	0.00255	0.00078	0.00013	0.00001	-------	-------	-------	-------	-------
GRAPHITE	-------	-------	-------	.01261	.02196	.02433	0.02463	0.02467	0.02468	0.02473	.02915
F	.00420	.00419	.00285	.00106	.00019	.00001	-------	-------	-------	-------	-------
F_2	.00015	.00015	.00010	.00004	.00001	-------	-------	-------	-------	-------	-------
H	.00002	.00002	.00001	-------	-------	-------	-------	-------	-------	-------	-------
HF	.00746	.00748	.00923	.00484	.00105	.00010	-------	-------	-------	-------	-------
H_2	.30364	.30371	.31108	.31387	.31621	.31857	.31977	.32014	.32020	.32010	.31135
CO	-------	-------	-------	-------	-------	-------	-------	-------	-------	.00005	.00439
CO_2	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
F	.06782	.06758	.04358	.02554	.01084	.00246	.00026	.00001	-------	-------	-------
F_2	.07002	.06986	.05143	.03458	.01655	.00623	.00253	.00040	.00002	-------	-------
H	.02311	.02341	.00150	.00444	.00468	.00186	.00184	.00154	.01449	.01449	.01460
HF	.01485	.01249	.00234	.00245	.00014	.00002	.00000	.00000	.00000	.44042	.44042
H_2	.51732	.55941	.55289	.57037	.61332	.63386	.64081	.64009	.64000	-------	.00002
H_2O	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

F = 50; F = 50; percent fuel = 50.55

T, °K	4000	T_c[b] 3898	3600	3200	2800	2400	2000	1600	1200	900
C(GAS)	0.00090	0.00069	0.00021	.00004	-------	-------	-------	-------	-------	-------
GRAPHITE	.14771	.14447	.15304	.15560	0.15708	0.15785	0.15813	0.15819	0.15831	0.16450
CF	.00066	.00047	.00015	.00002	-------	-------	-------	-------	-------	-------
CF_2	.00001	.00001	-------	-------	-------	-------	-------	-------	-------	-------
F	.00163	.00114	.00035	.00005	-------	-------	-------	-------	-------	-------
F_2	.00002	.00002	.00001	.00001	.00001	.00001	.00001	.00001	.00003	.00013
CO	.23341	.22998	.22560	.21907	.21301	.21114	.23155	.23162	.23147	.22037
CO_2	-------	-------	-------	-------	-------	-------	-------	-------	.00007	.00493
F	.00790	.00660	.00352	.00116	.00025	.00003	-------	-------	-------	-------
F_2	.00950	.00463	.00260	.00056	.01172	.00424	.00070	.00004	-------	-------
H	.11259	.11438	.12044	.13333	.13705	.14447	.14549	.14685	.14679	.14520
H_2	.45318	.45859	.44[illegible]	.45686	.45979	.46228	.46332	.46327	.46330	.46340
H_2O	-------	-------	-------	-------	-------	-------	-------	.00001	.00007	.00147

[a]Mole fractions were computed for all 15 substances considered in this report but were omitted if less than 10^-5.

[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.]

(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	b3962	3800	3200	2800	2400
C(gas)	0.00017	0.00015	0.00007	0.00002	0.00001	-------
CF	.06477	.00453	.00277	.00158	.00054	0.00014
CF_2	.00441	.00430	.00421	.00202	.00105	.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	.47[illegible]	.42394	.33799	.25259	.19285	.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	b4008	4000	3600	3400	3200	2800	2400	2200
C(gas)	0.00123	0.00043	0.00043	0.00017	0.00009	0.00005	0.00001	-------	-------
Graphite	-------	-------	-------	-------	-------	-------	.00521	0.11790	0.14672
CF	.01[illegible]	.00752	.00725	.00401	.00253	.00190	.00070	.00012	.00003
CF_2	.00398	.00351	.00349	.00276	.00230	.00185	[illegible]	.00027	.00010
CF_3	.00429	.00462	.00463	.00447	.00410	.00356	.00229	.00069	.00043
CF_4	.00671	.01327	.01347	.02623	.03517	.04580	.07236	.11270	.13145
C_2F_2	.13180	.13462	.13464	.13565	.13553	.13534	.12918	.04386	.01942
F	.27491	.25679	.25629	.22651	.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	.00025	.00010	.00006	.00003	.00001	-------	-------
HF	.55657	.57484	.57524	.59778	.61[illegible]	.62678	.65952	.62059	.62062

r = 2.0; O/F = 4.041; percent fuel = 19.84

T, °K	4400	b4206	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	.10924	.16354	0.22331	0.24328
CF	.01472	.01170	.00880	.00451	.00153	.00044	.00005	-------
CF_2	.00133	.00124	.00116	.00107	.00092	.00052	.00014	.00001
CF_3	.00059	.00059	.00042	.00062	.00105	.00105	.00016	.00008
CF_4	.00016	.00022	.00034	.00132	.00799	.03016	.05811	.08095
C_2F_2	.15232	.14101	.12232	.12378	.11257	.07035	.02305	.00249
F	.10112	.10592	.10546	.10500	.09465	.08091	.05452	.01600
F_2	.00001	.00001	.00001	-------	-------	-------	-------	-------
H	.03515	.02577	.01729	.00618	.00163	.00033	.00008	.00001
H_2	.00945	.00577	.00317	.00076	.00013	.00002	-------	-------
HF	.64009	.65115	.65650	.66822	.67013	.65291	.63925	.65118

r = 2.8; O/F = 2.687; percent fuel = 25.73

T, °K	4400	b4202	4000	3600	3200	3000	2800	2400	2200	2000
C(gas)	0.00501	0.00332	0.00224	0.00067	0.00010	0.00003	0.00001	-------	-------	-------
Graphite	.13513	.24836	.28916	.29213	.30360	.30584	.30714	0.31727	0.32194	0.32398
CF	.00774	.00645	.00429	.00192	.00067	.00035	.00017	.00002	-------	-------
CF_2	.00043	.00057	.00027	.00016	.00011	.00010	.00009	.00003	.00001	-------
CF_3	.00008	.00008	.00005	.00003	.00004	.00005	.00009	.00008	.00004	.00001
CF_4	.00002	.00002	.00002	.00002	.00008	.00026	.00117	.00869	.01353	.01452
C_2F_2	.04898	.04176	.03051	.01853	.01335	.01087	.01055	.00520	.00178	.00038
F	.05720	.05286	.05140	.04616	.03964	.03533	.03074	.01522	.00711	.00222
H	.03117	.04509	.03348	.01710	.00558	.00250	.00064	.00011	.00004	.00001
H_2	.03526	.01859	.01147	.00456	.00098	[illegible]	.00010	.00001	-------	-------
HF	.57498	.58071	.59754	.61890	.63616	.64255	.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.

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	b4243	4000	3600	3200	2800	2400	2000	1600
C(gas)	0.00481	0.00356	0.00210	0.00066	0.00011	0.00001	-------	-------	-------
Graphite	.26112	.27409	.29257	.31598	.32568	.33259	0.33425	0.33635	0.33661
CF	.00750	.00502	.00240	.00136	.00058	.00007	.00001	-------	-------
CF_2	.00033	.00026	.00016	.00008	.00003	.00001	.00001	-------	-------
CF_3	.00005	.00004	.00003	.00001	.00001	-------	.00001	-------	-------
CF_4	.00001	.00001	.0000[illegible]	.00001	.00001	.00002	.00075	.00294	.00527
C_2F_2	.03731	.07008	.07015	.00943	.00585	.00182	.00142	.00014	-------
F	.04479	.01365	.04072	.04200	.02188	.01235	.00739	.00108	.00002
H	.05507	.04601	.03696	.02538	.01041	.00243	.00013	.00001	-------
H_2	.02909	.02373	.01751	.00837	.00336	.00068	.00004	-------	-------
HF	.56116	.57054	.58550	.61022	.63529	.64942	.65593	.65946	.66009

r = 3.5; O/F = 2.309; percent fuel = 30.22

T, °K	4400	b4172	4000	3600	3200	3000	2800	2400	2000	1600
C(gas)	0.00557	0.00231	0.00154	0.00044	0.00007	0.00002	-------	-------	-------	-------
Graphite	.35864	.31993	.32652	.34205	.34872	.35065	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	.01960	.01223	.00735	.00214	.00034	.00011	.00001	-------	-------	-------
F	.02850	.02517	.02165	.01272	.00497	.00250	.00047	.00015	.00001	-------
H	.06251	.05545	.05015	.03767	.02506	.01891	.00835	.00465	.00086	.00005
H_2	.04938	.04127	.03727	.02239	.03504	.03165	.03920	.04097	.04268	.04330
HF	.52716	.54081	.55083	.57206	.56771	.53268	.59895	.60045	.60178	.60204

r = 4.0; O/F = 2.021; percent fuel = 33.10

T, °K	4400	b4041	4000	3600	3200	2800	2400	2000	1600
C(gas)	0.00257	0.00114	0.00102	0.00026	0.00004	-------	-------	-------	-------
Graphite	.33569	.34619	.34941	.35907	.36279	0.36377	0.36757	0.36852	0.36847
CF	.00270	.00116	.00104	.00026	.00004	-------	-------	-------	-------
CF_2	.00010	.00004	.00003	.00001	-------	-------	-------	-------	-------
CF_3	.00001	-------	-------	-------	-------	-------	-------	-------	-------
C_2F_2	.01157	.00442	.00190	.00030	.00013	.00001	-------	-------	-------
CH_4	.00002	.00001	.00001	-------	-------	-------	-------	-------	-------
F	.01652	.01310	.01245	.00655	.00232	.00056	.00007	-------	-------
H	.06478	.05526	.05409	.04144	.02753	.01410	.00491	.00091	.00006
H_2	.07259	.06600	.06564	.06576	.07054	.07674	.08143	.08563	.08409
HF	.49349	.51067	.51240	.52696	.53681	.54281	.54596	.54714	.54758

r = 5.0; O/F = 1.617; percent fuel = 38.22

T, °K	4000	b3708	3600	3200	2800	2400	2000	1600	1200
C(gas)	0.00046	0.00016	0.00011	0.00001	-------	-------	-------	-------	-------
Graphite	.37652	.38045	.38160	.38601	0.38749	0.38905	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	.00510	.00448	.00089	.00021	.00003	-------	-------	-------
H	.04003	.04012	.03759	.02534	.01171	.00401	.00075	.00005	-------
H_2	.12417	.12595	.12743	.13794	.14027	.14400	.14546	.14686	.14688
HF	.44750	.44949	.45155	.45675	.46030	.46250	.46411	.46527	.46529

[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	3512	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	19[illegible]8	5918	1.530	6.09	281.5
1.8	34.59	1.891	3205	1661	5852	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	285.0
1.40	27.31	2.562	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	3491	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	2739	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	625[illegible]	1.534	6.135	298.2
1.80	30.41	2.288	3586	1902	6213	1.516	5.745	292.9
2.00	32.69	2.059	3363	1657	6115	1.503	5.474	285.6
Percent fluorine in oxidant by weight, 50								
1.20	20.03	3.992	4120	2830	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	3.629	4479	2758	6814	1.538	6.22	325.7
1.6	21.79	3.589	4536	2736	6749	1.544	6.30	323.8
2.5	30.33	2.297	3898	2168	6420	1.525	5.92	303.9
Percent fluorine in oxidant, 100 (zero percent oxygen)								
1.0	11.91	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	4006	2891	5951	1.551	6.856	286.9
2.8	25.73	2.887	4262	2964	6256	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	1.549	6.566	298.8
5.0	38.22	1.617	3708	2298	6009	1.543	6.441	288.2

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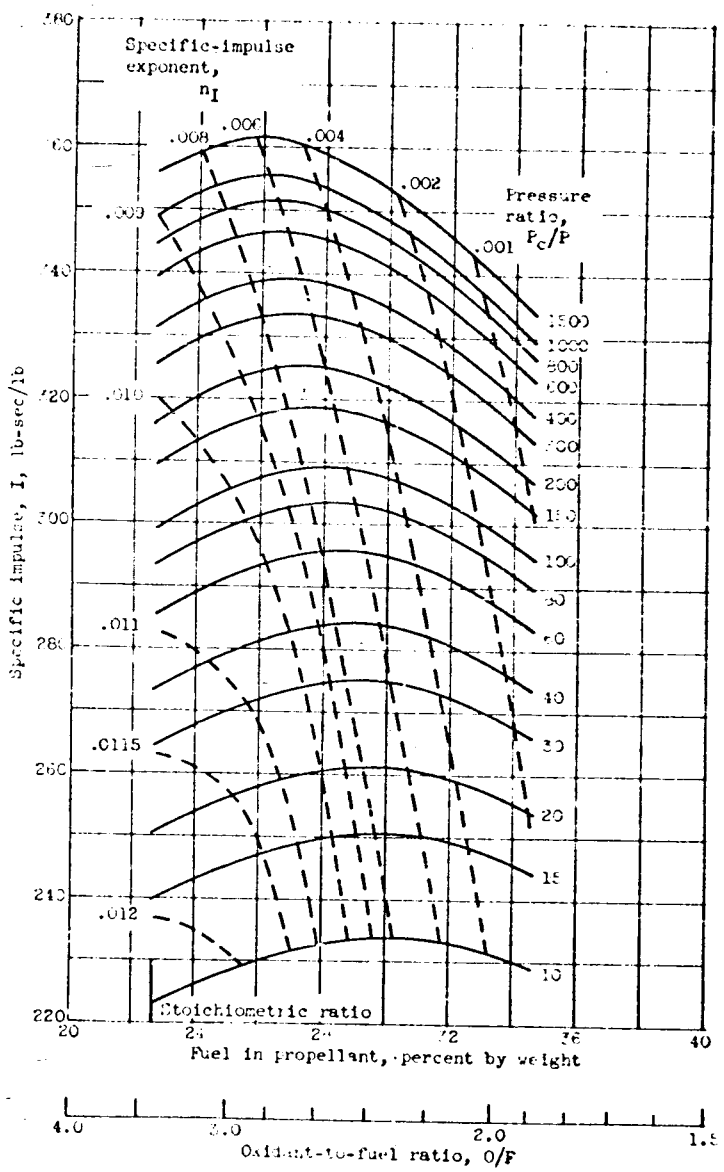
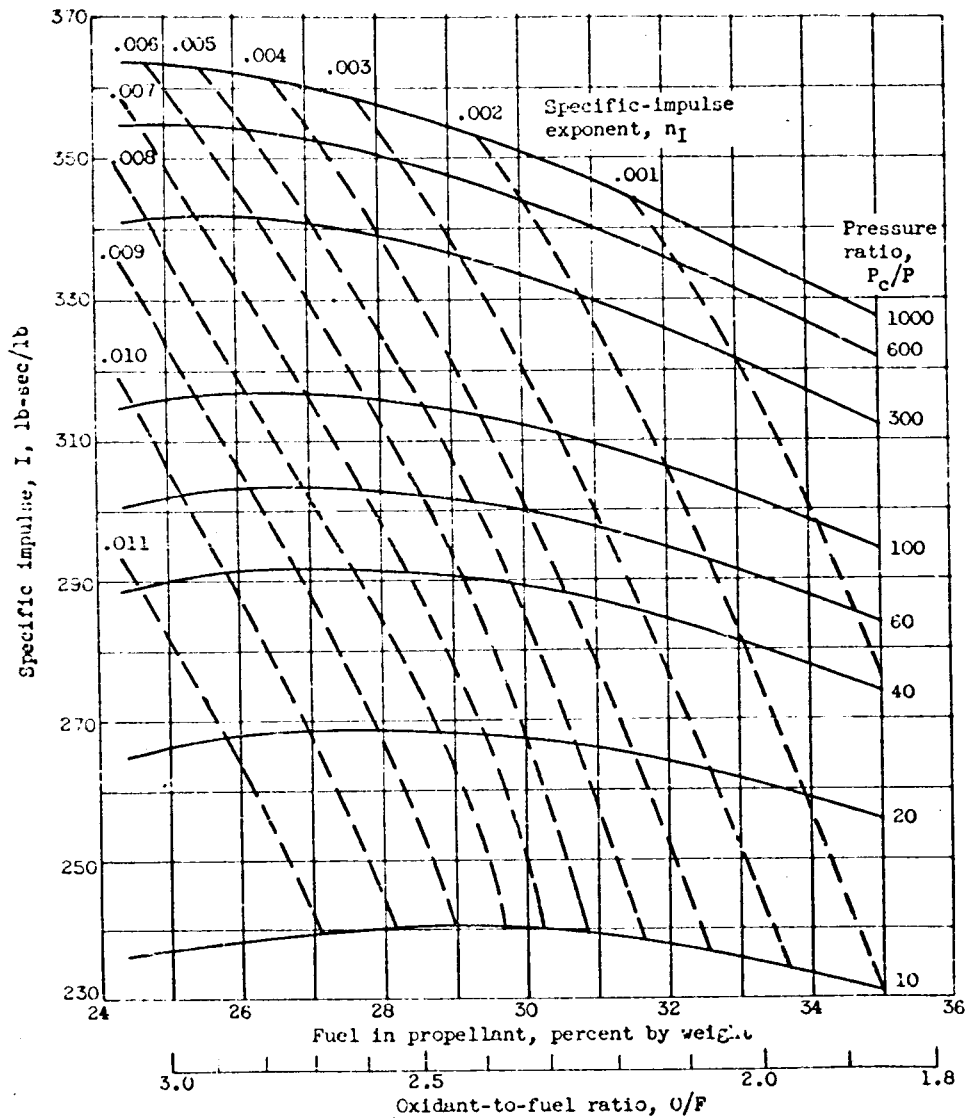


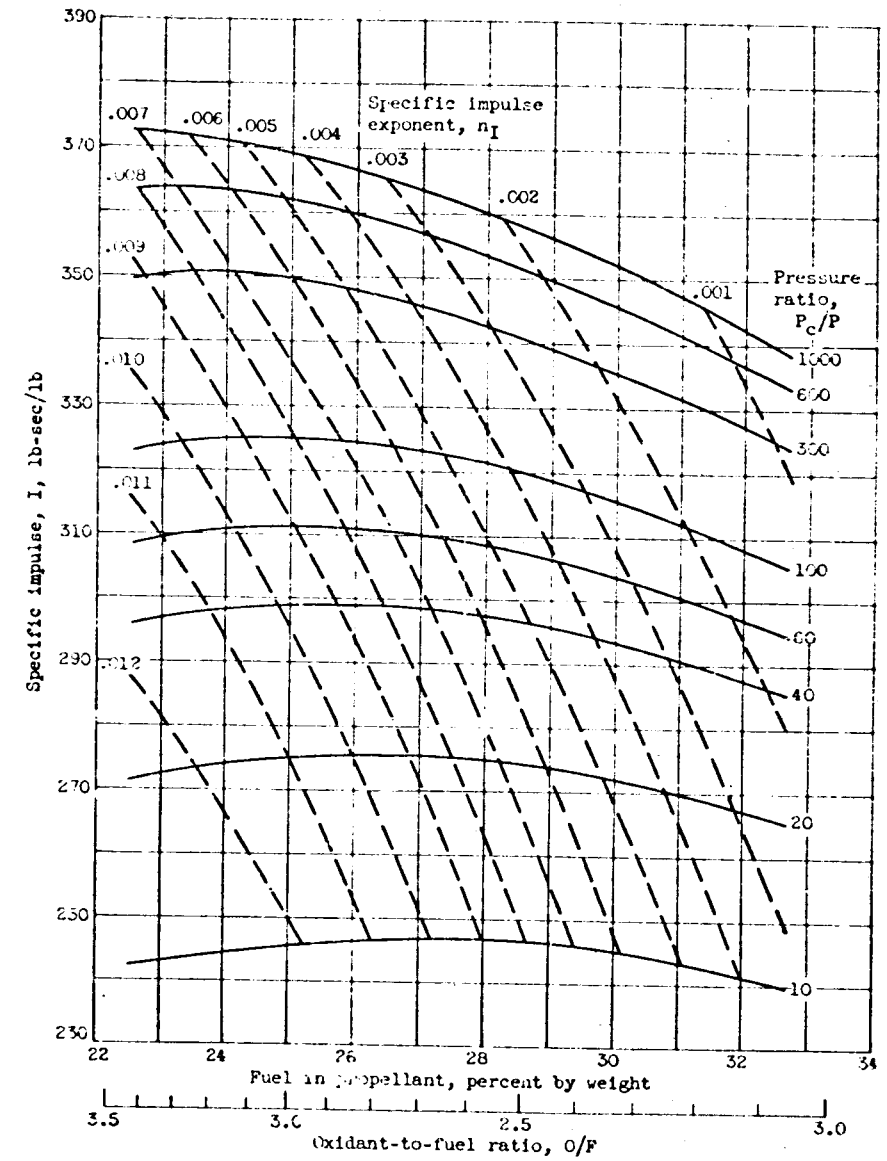
(a) Percent fluorine in oxidant, 0 (100 percent oxygen). Exponent n_I for use in equation $I = I_{600}(P_c/600)^{n_I}$.

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.



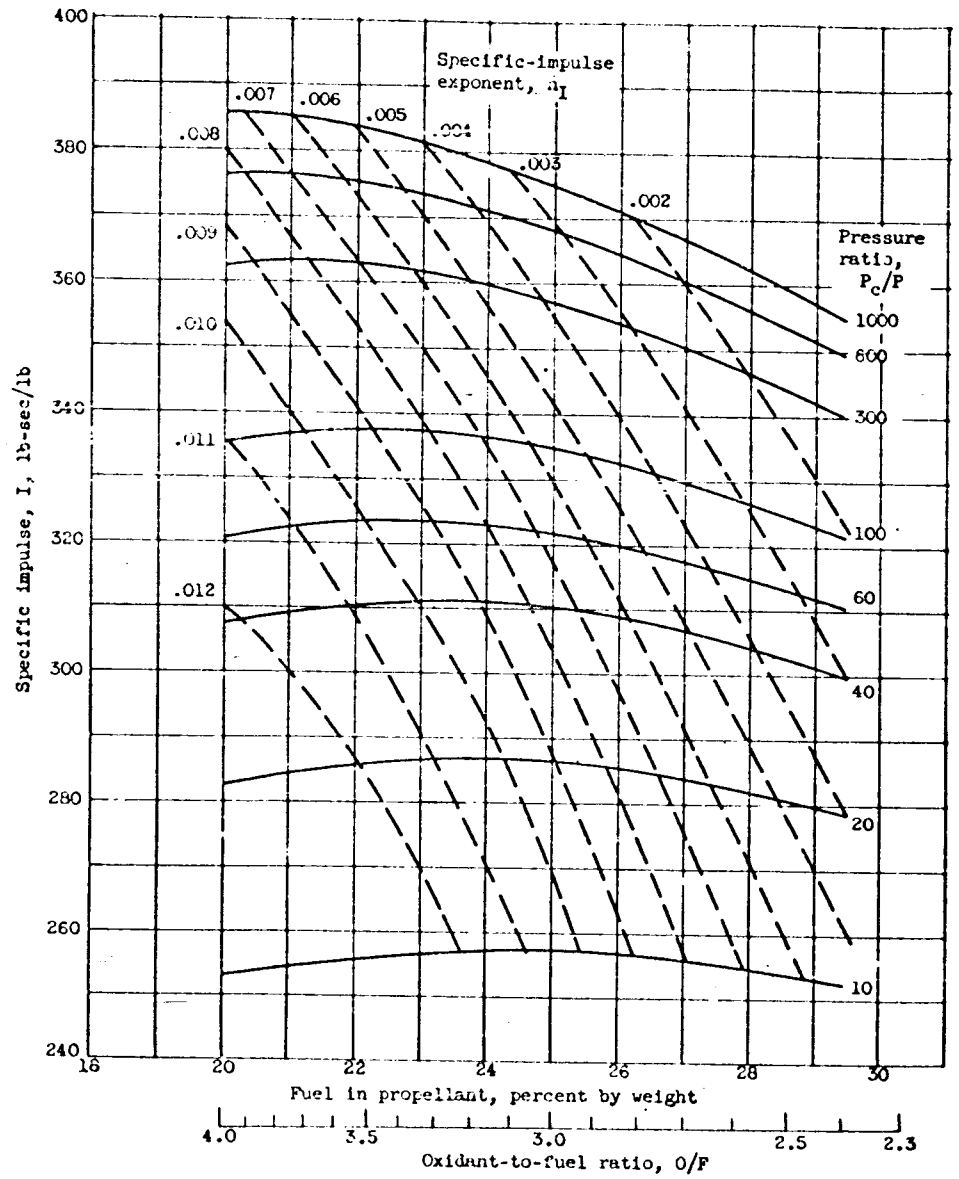
(b) Percent fluorine in oxidant by weight, 15. Exponent n_I for use in equation $I = I_{600}(P_c/600)^{n_I}$.

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.



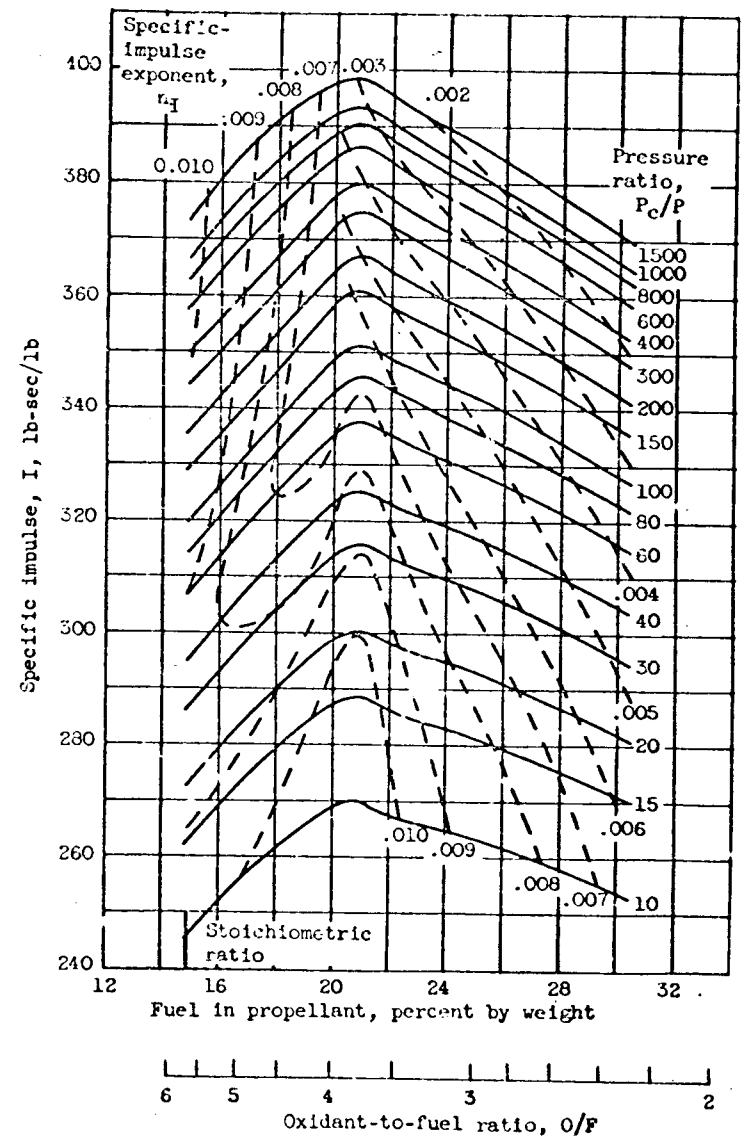
(c) Percent fluorine in oxidant by weight, 30. Exponent n_I for use in equation $I = I_{600}(P_c/600)^{n_I}$.

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.



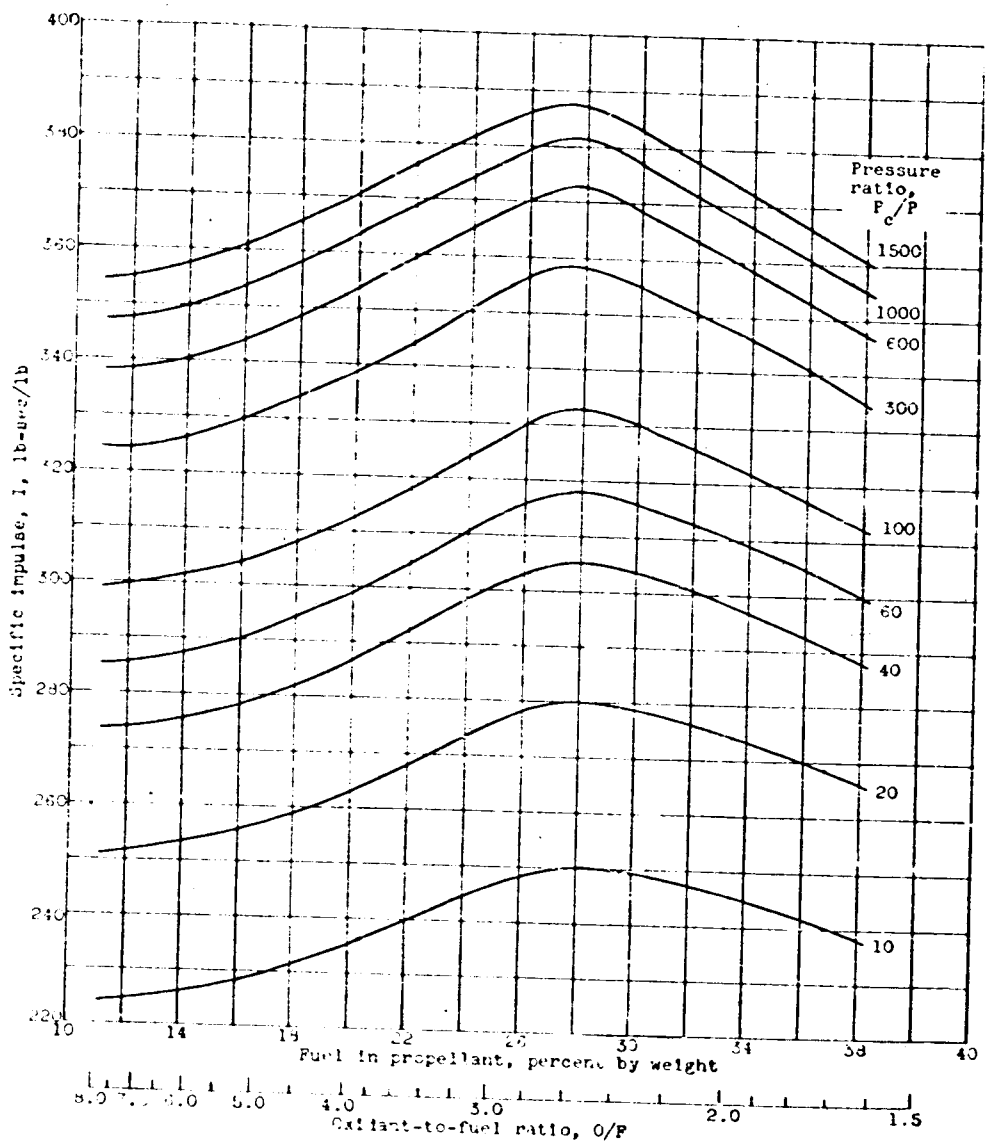
(d) Percent fluorine in oxidant by weight, 50. Exponent n_I for use in equation $I = I_{600}(P_c/600)^{n_I}$.

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.



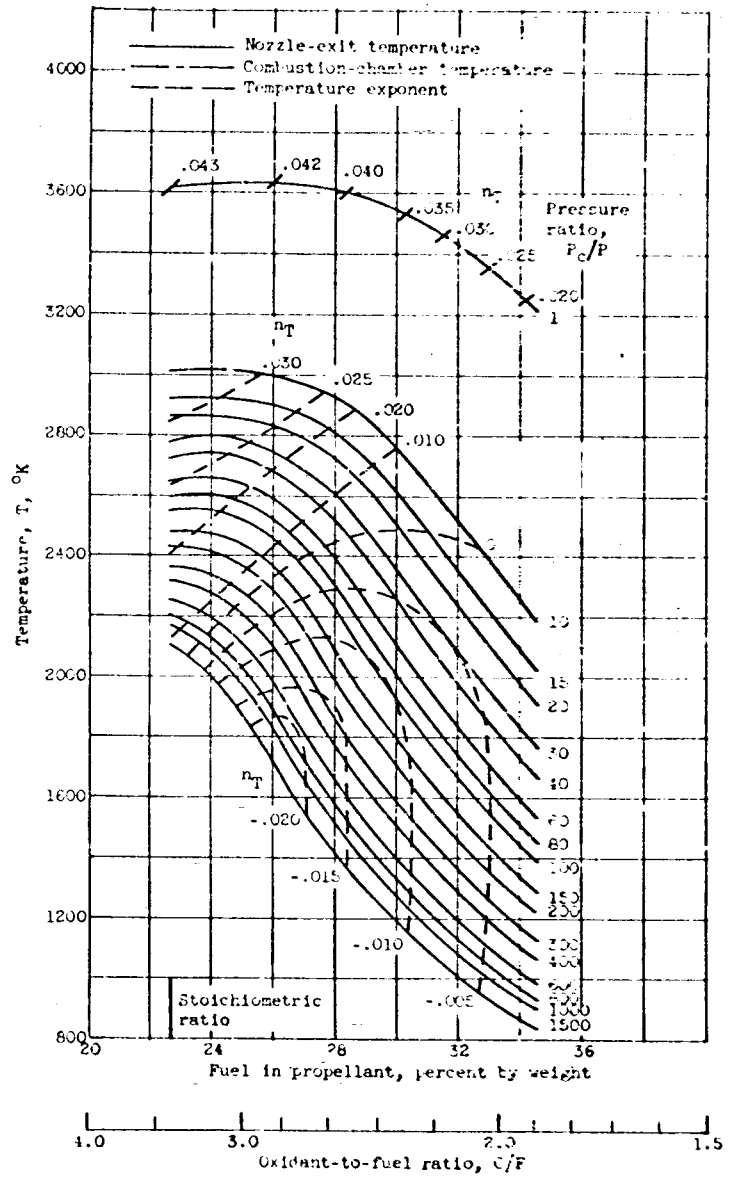
(e) Percent fluorine in oxidant by weight, 70.37. Exponent n_I for use in equation $I = I_{600}(P_c/600)^{n_I}$.

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.



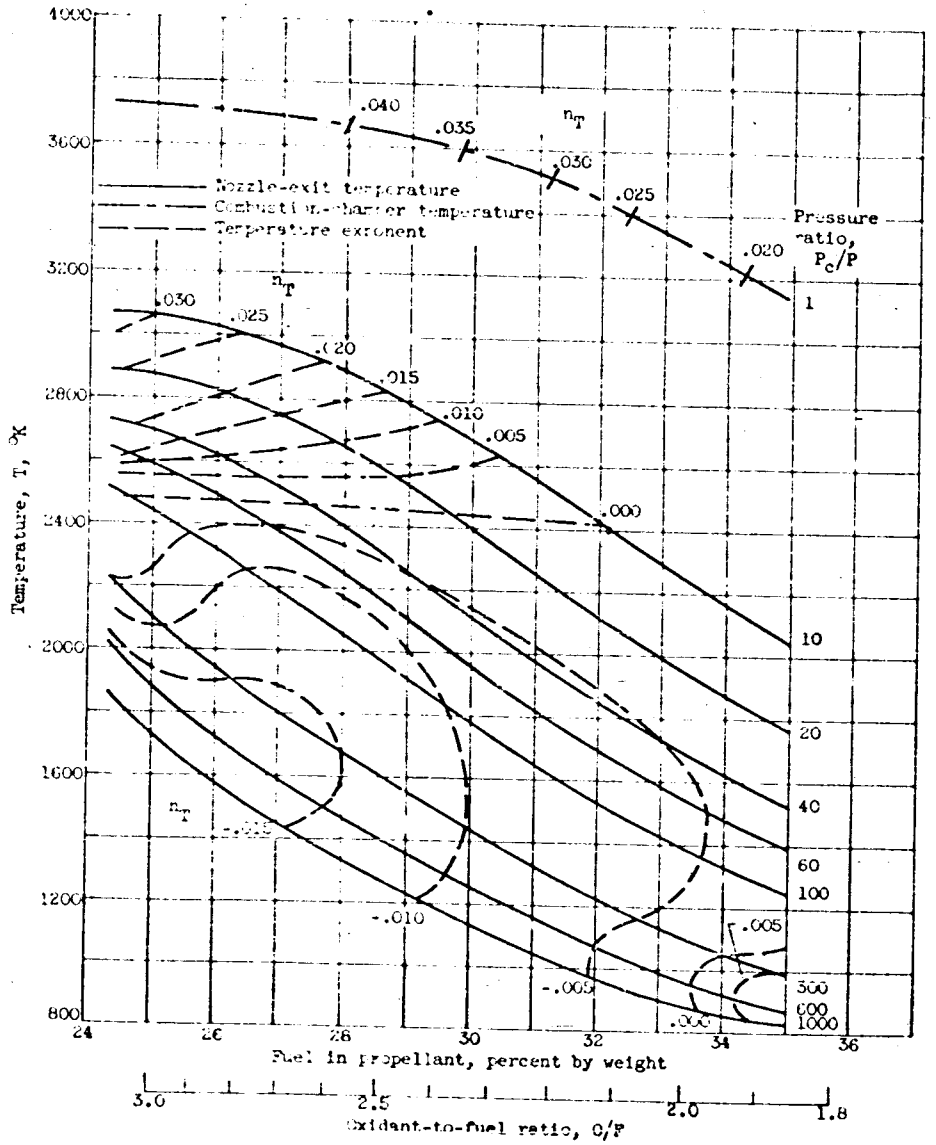
(f) Percent fluorine in oxidant, 100 (0 percent oxygen).

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.



(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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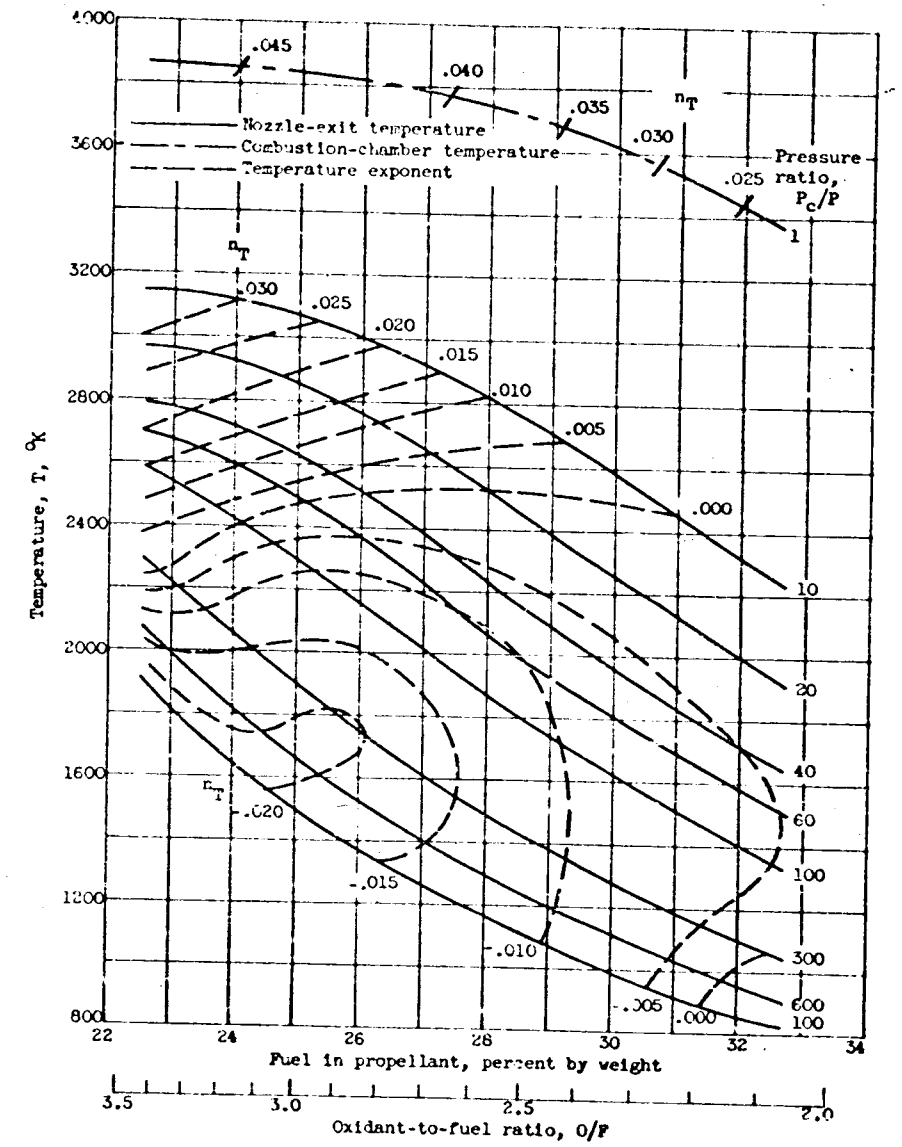
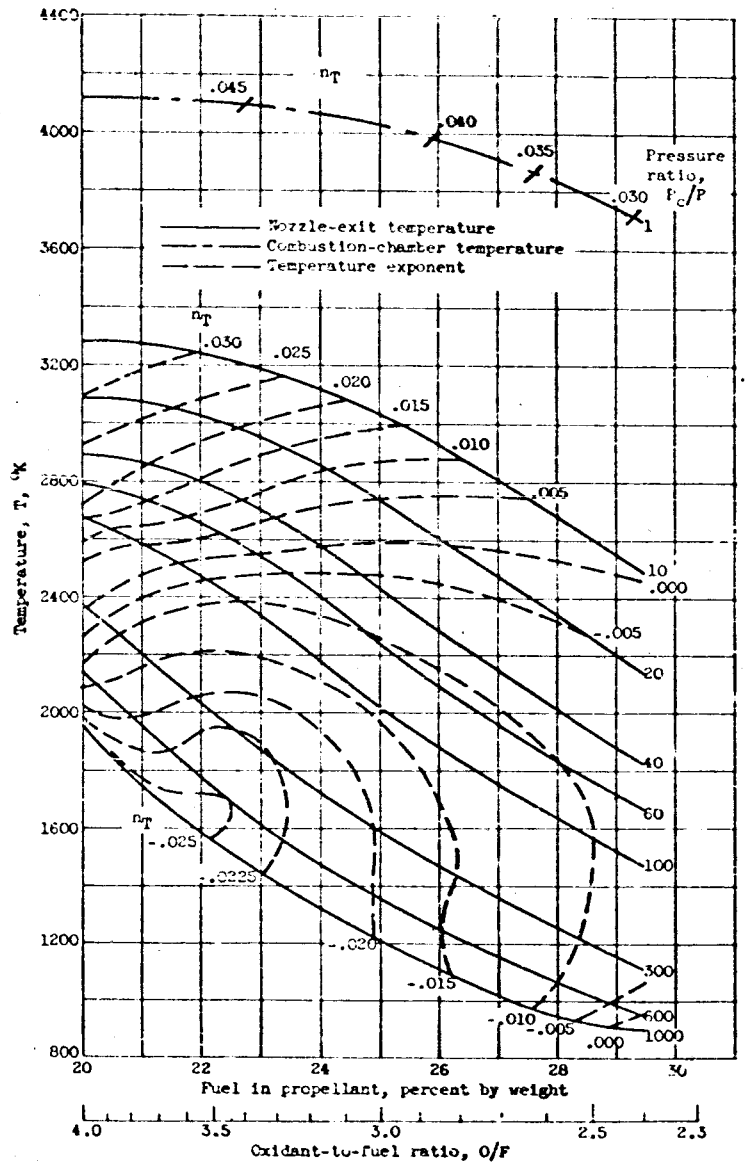


(c) Percent fluorine in oxidant by weight, 30. Exponent n_T for use in equation $T = T_{600}(P_c/600)^{n_T}$.

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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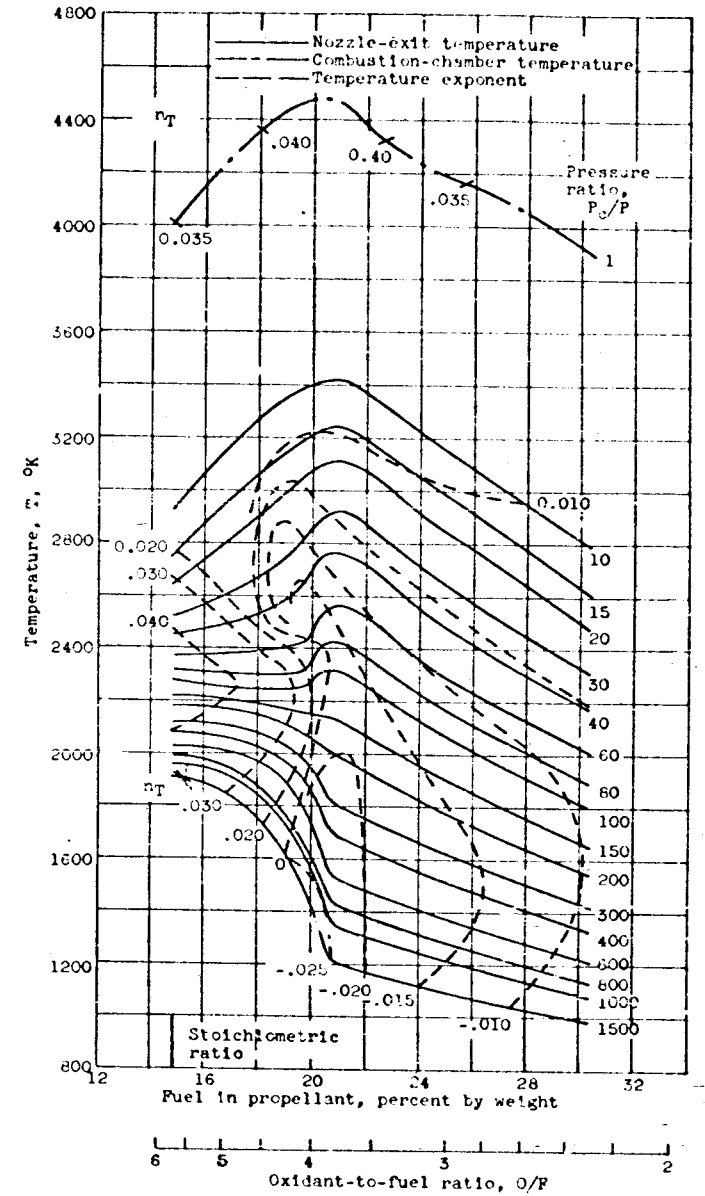
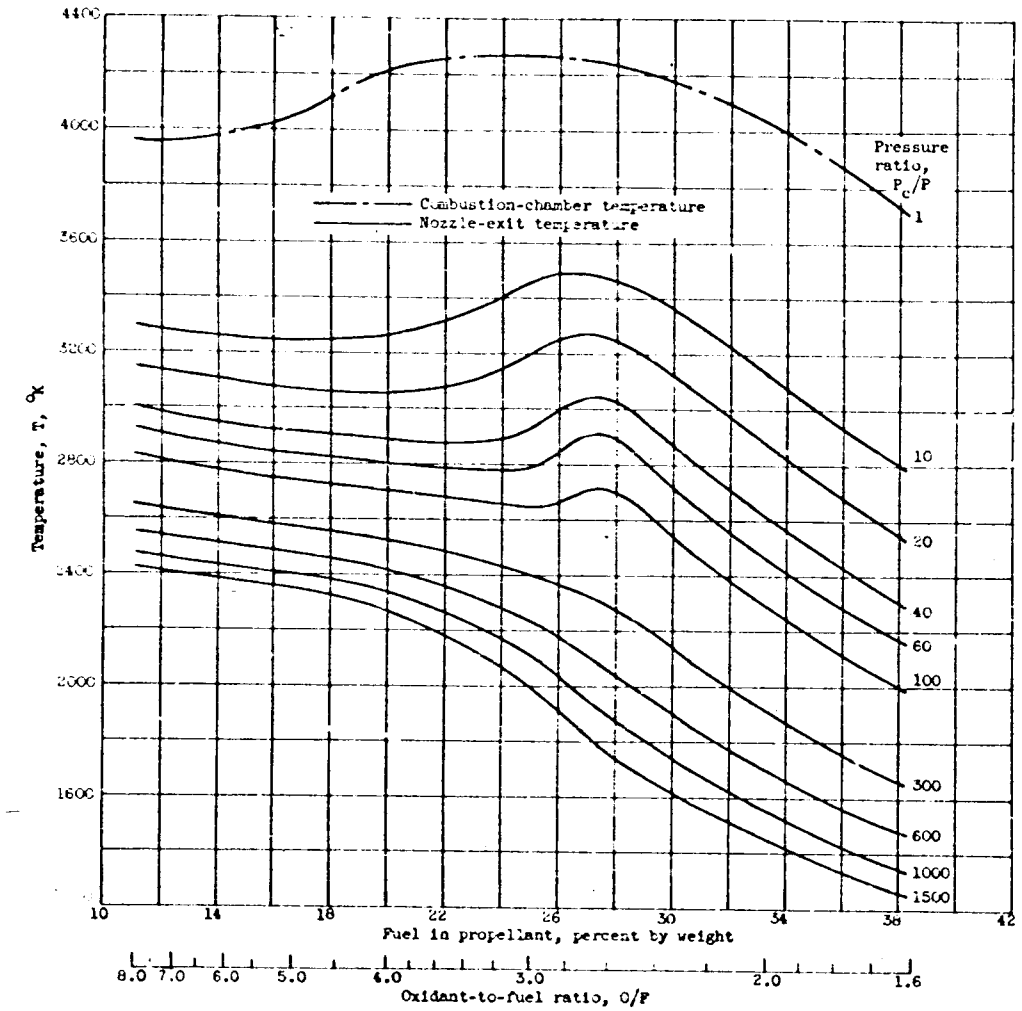


(e) Percent fluorine in oxidant by weight, 70.37. Exponent n_T for use in equation $T = T_{600}(P_c/600)^{n_T}$.

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.



(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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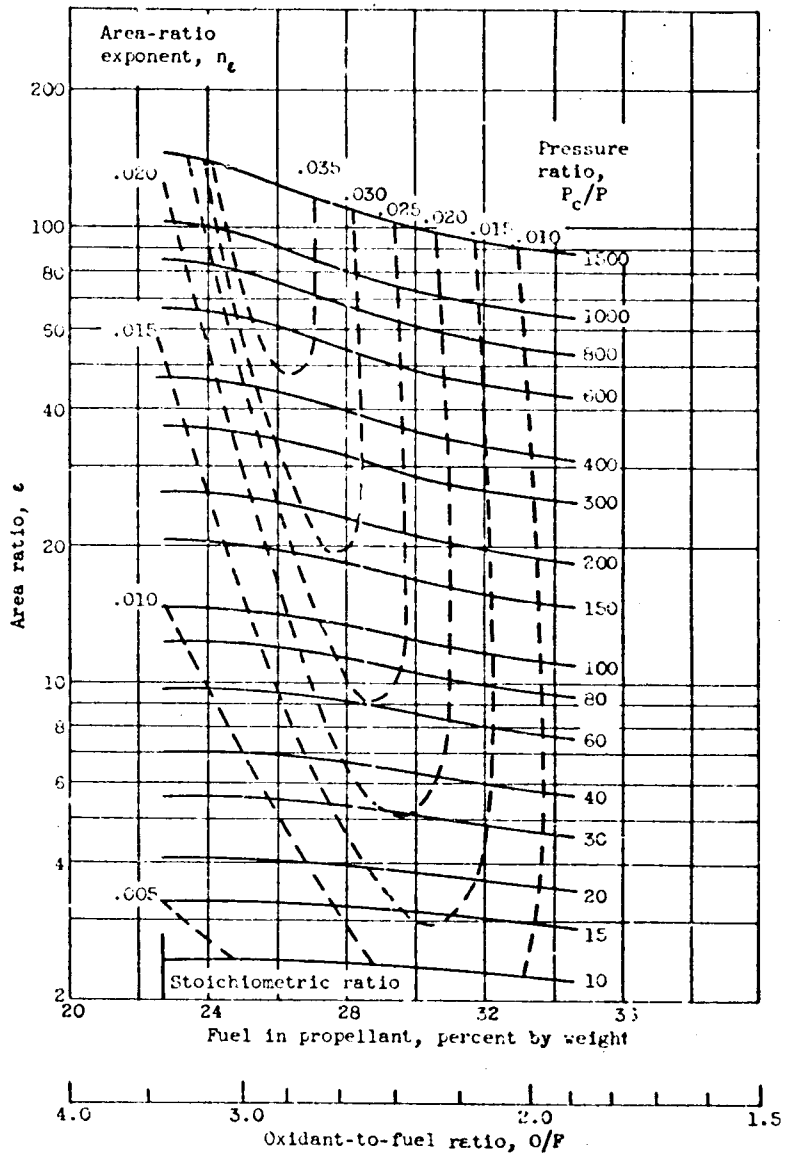
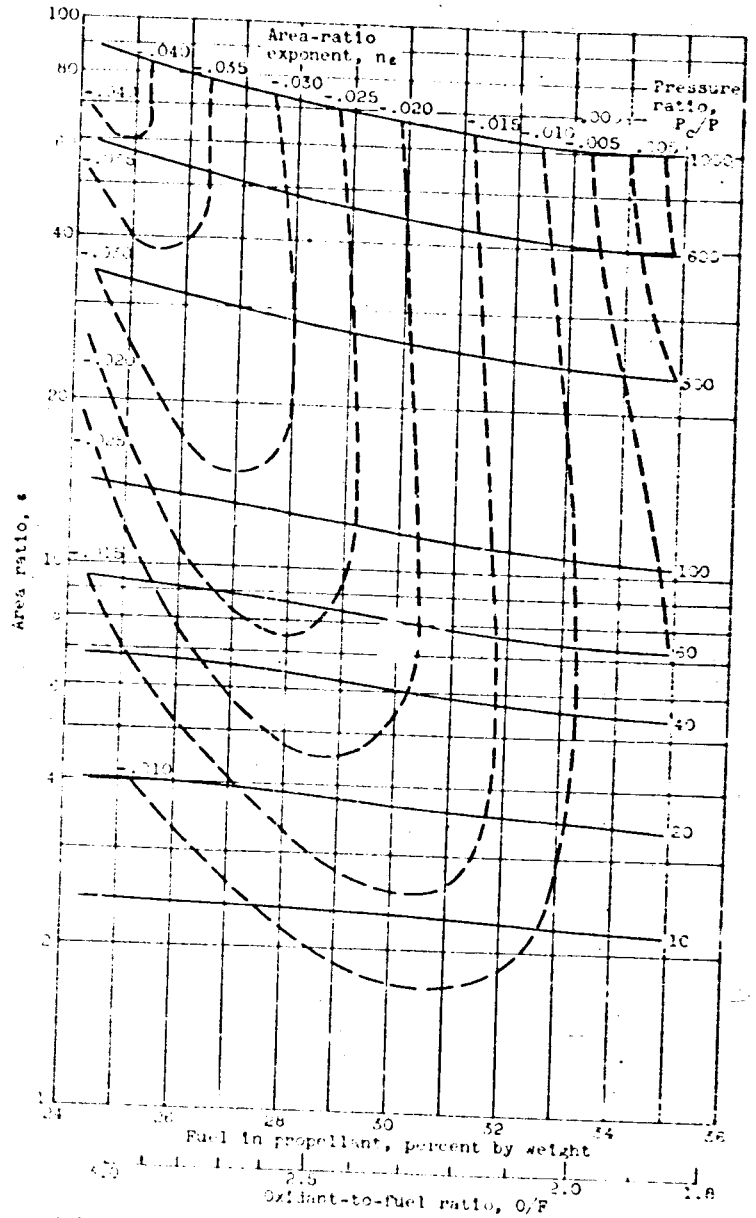


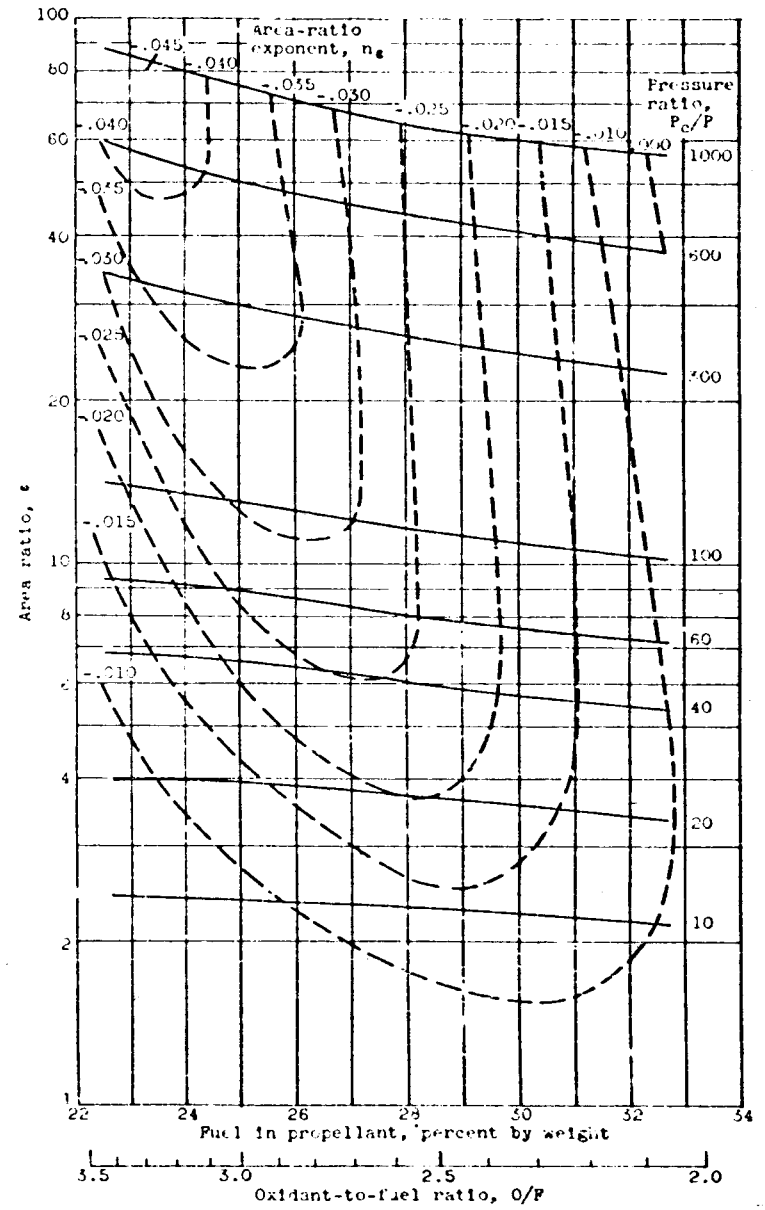
(a) Percent fluorine in oxidant, 0 (100 percent oxygen). Exponent n_ϵ for use in equation $\epsilon = \epsilon_{600}(P_c/600)^{n_\epsilon}$.

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.



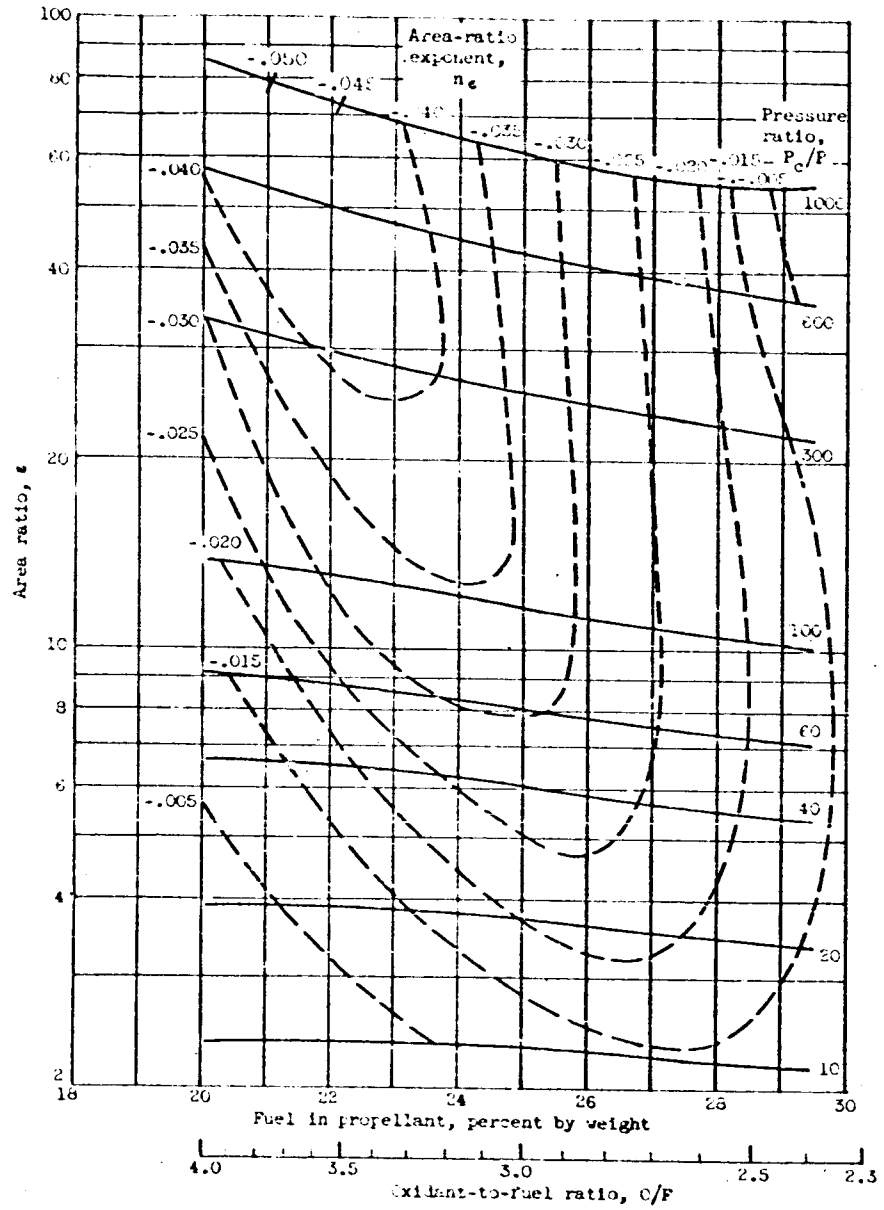
(b) Percent fluorine in oxidant by weight, 15. Exponent n_ϵ for use in equation $\epsilon = \epsilon_{600}(P_c/600)^{n_\epsilon}$.

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.



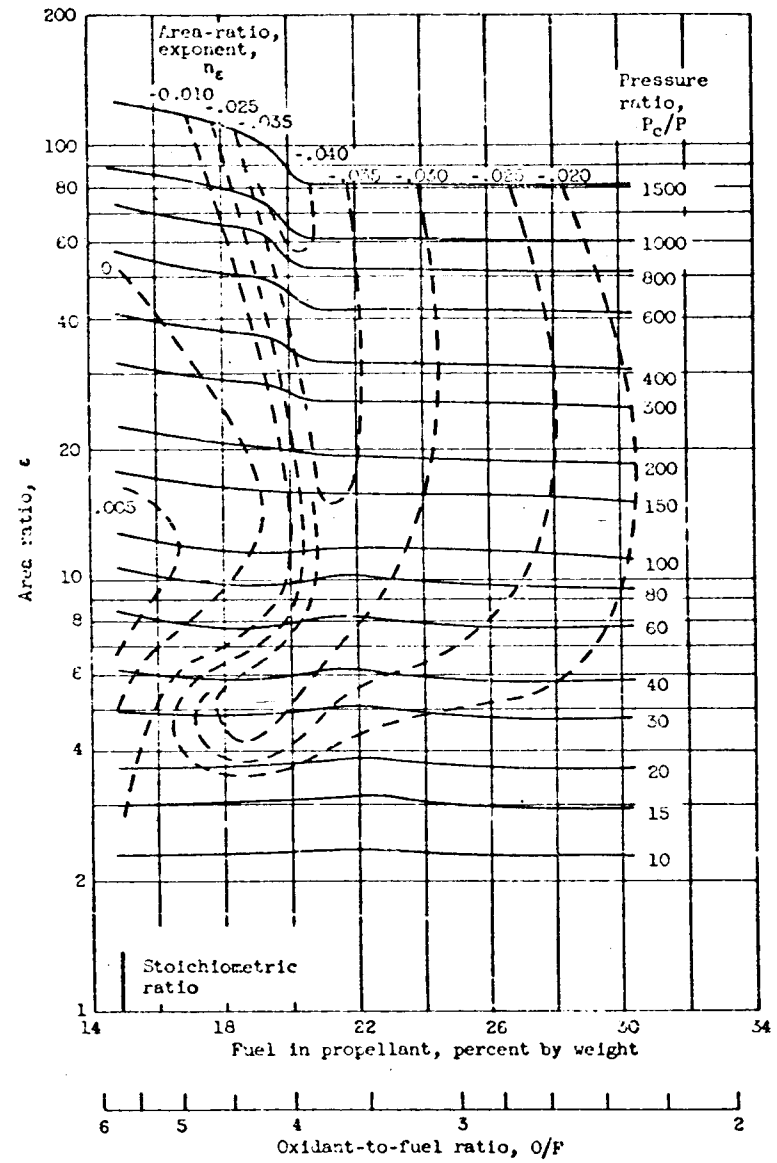
(c) Percent fluorine in oxidant by weight, 30. Exponent n_ϵ for use in equation $\epsilon = \epsilon_{600}(P_c/600)^{n_\epsilon}$.

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.



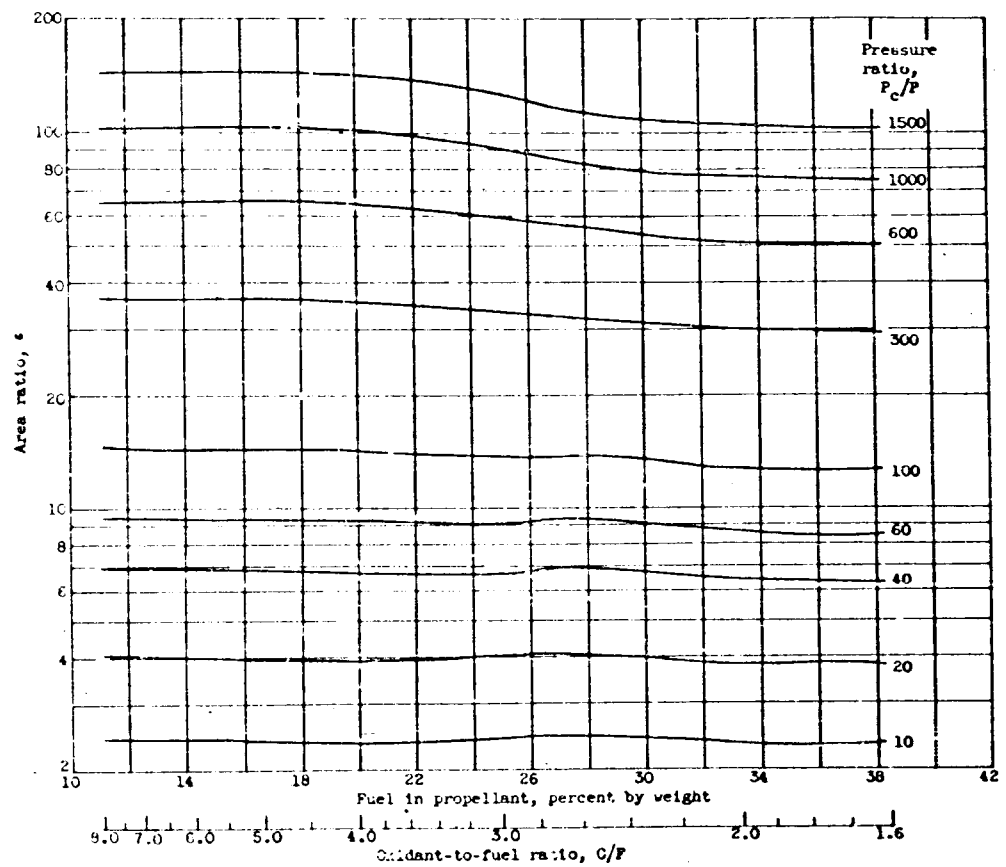
(d) Percent fluorine in oxidant by weight, 50. Exponent n_ϵ for use in equation $\epsilon = \epsilon_{600}(P_c/600)^{n_\epsilon}$.

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.



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

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.



(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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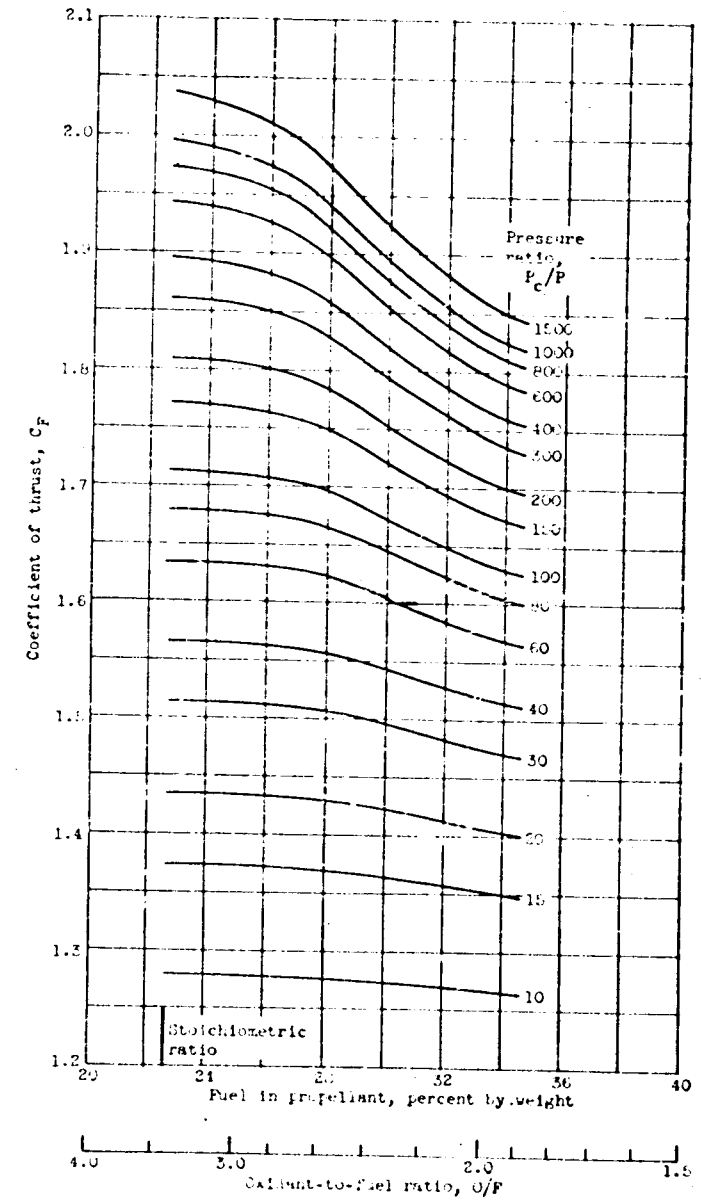
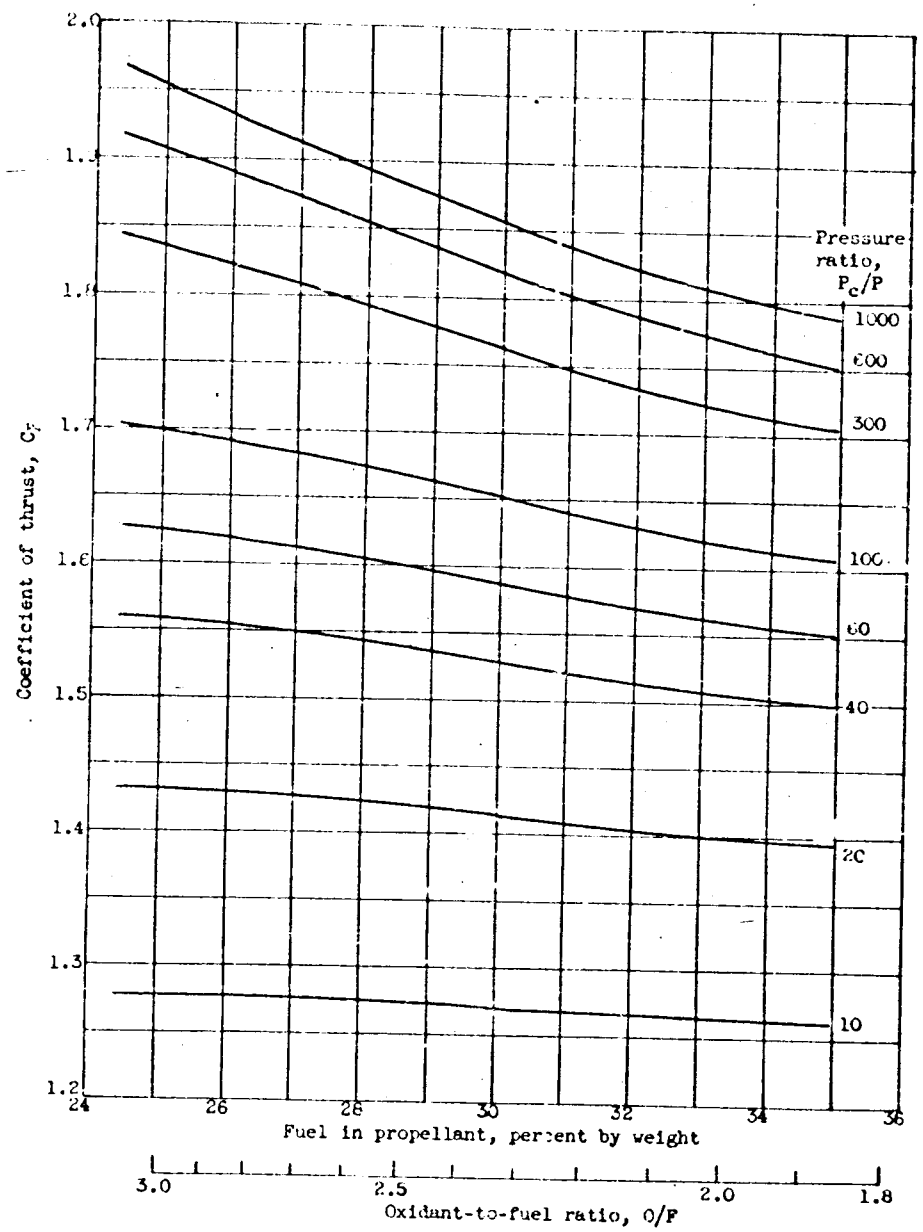


(a) Percent fluorine in oxidant, 0 (100 percent oxygen).

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.

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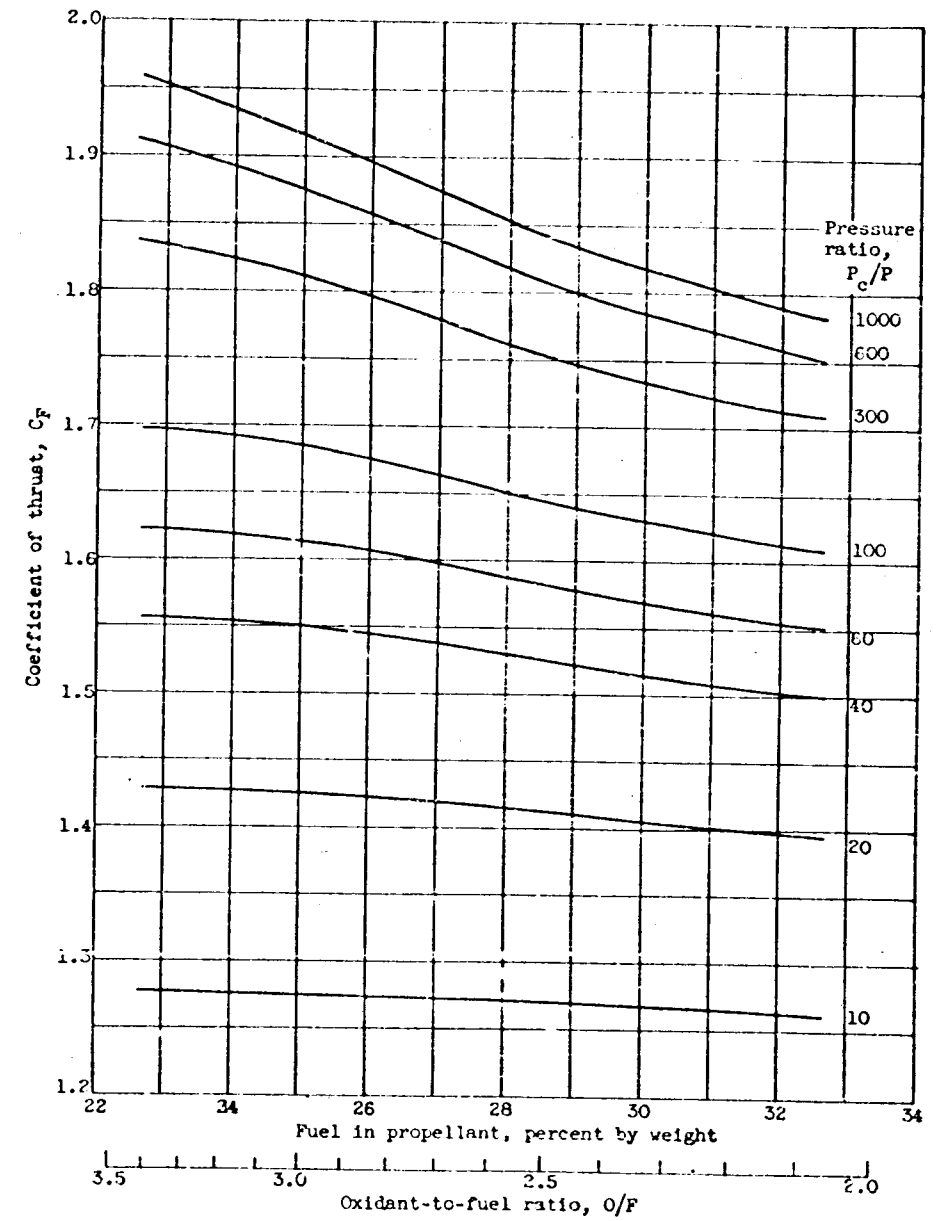
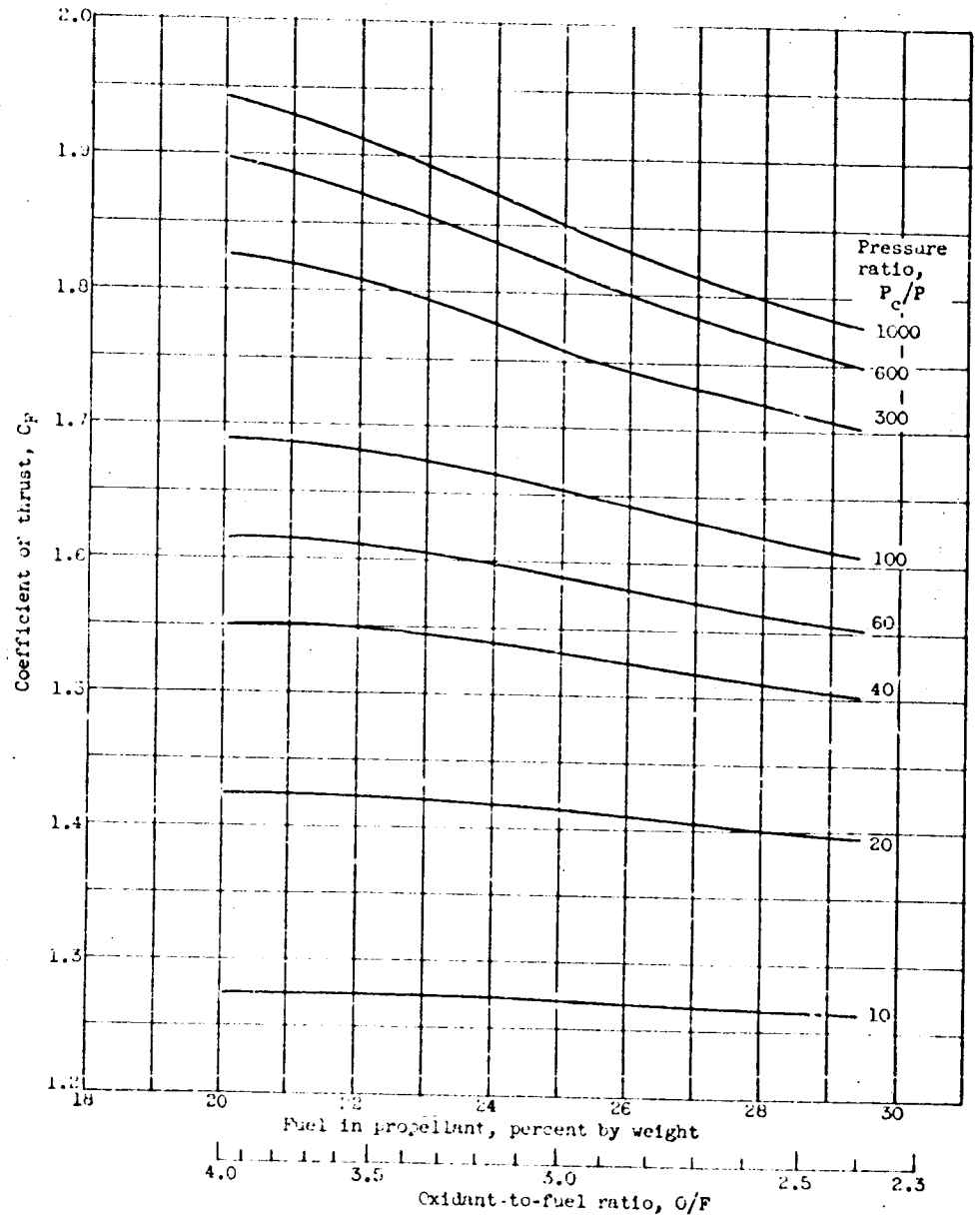


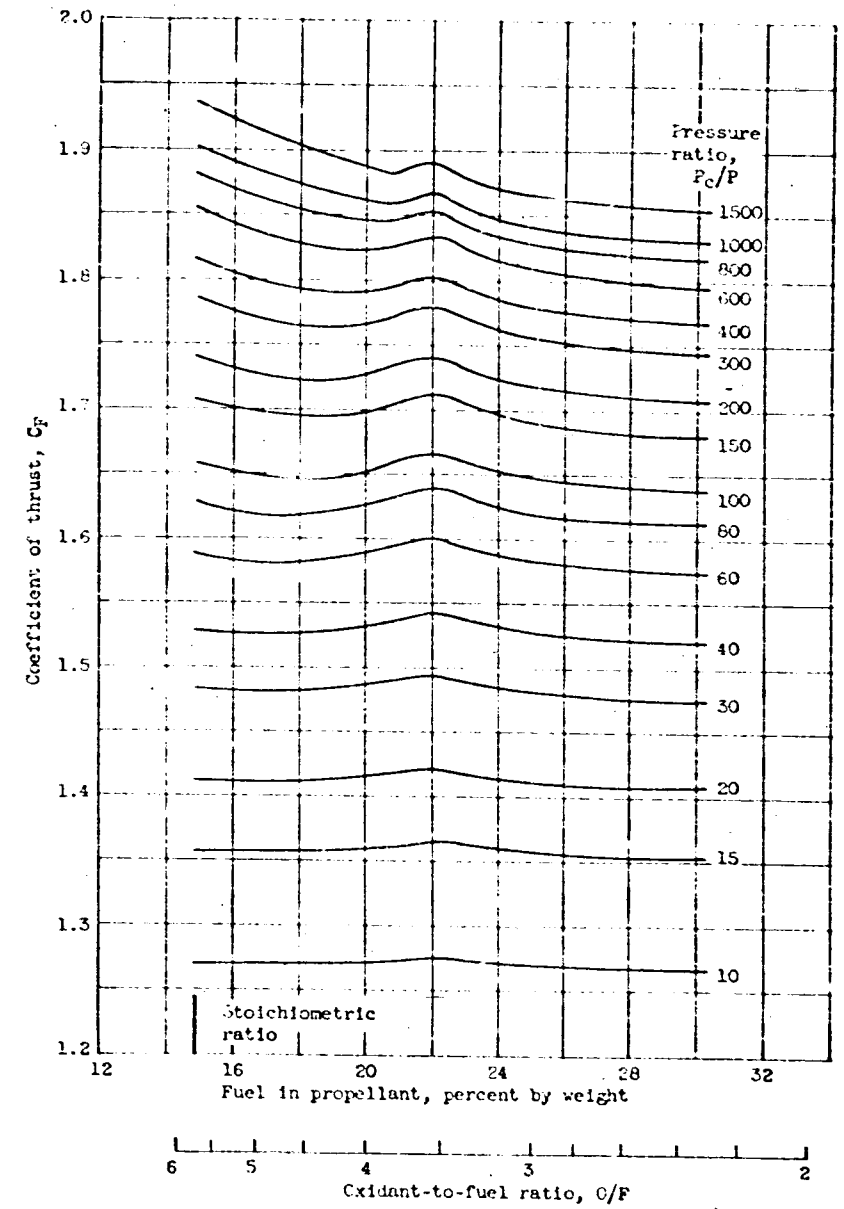
(c) Percent fluorine in oxidant by weight, 30.

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.



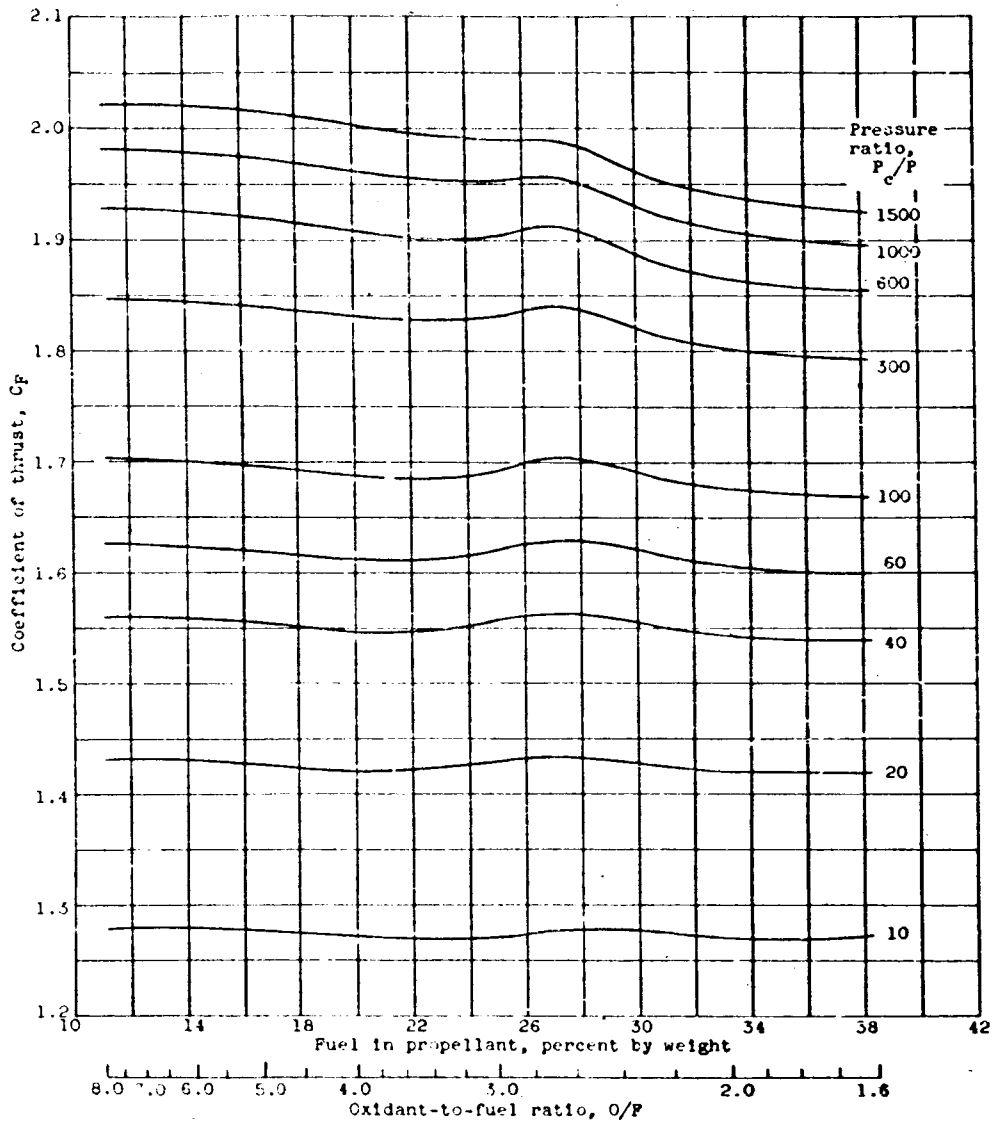
(d) Percent fluorine in oxidant by weight, 50.

Figure 4. - Continued. Theoretical coefficient of thrust for JF-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.



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

Figure 4. - Continued. Theoretical coefficient of thrust for JF-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 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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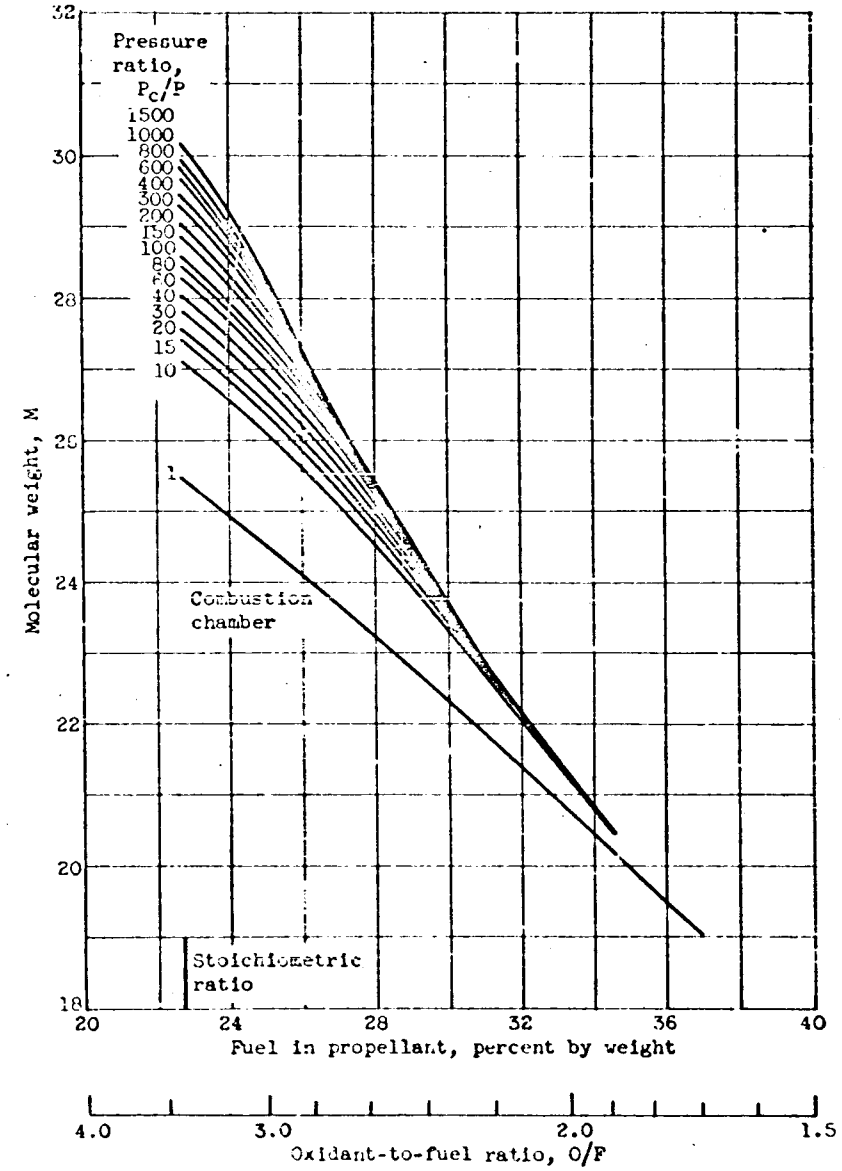
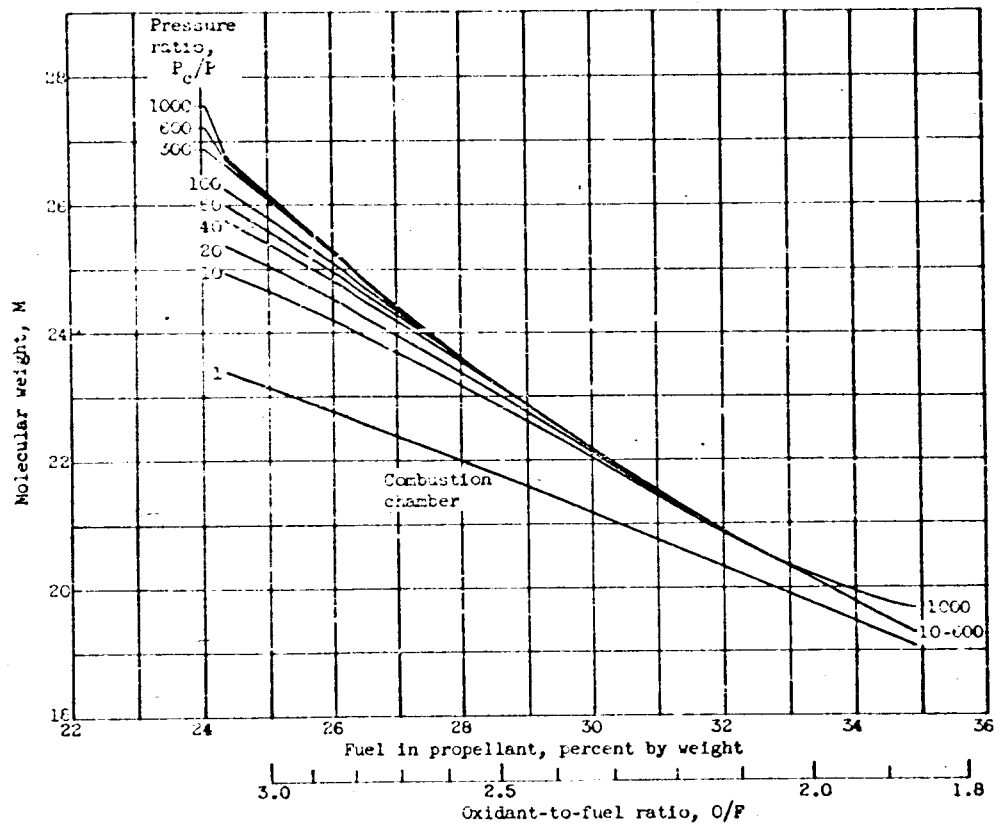


(a) Percent fluorine in oxidant, 0 (100 percent oxygen).

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.



(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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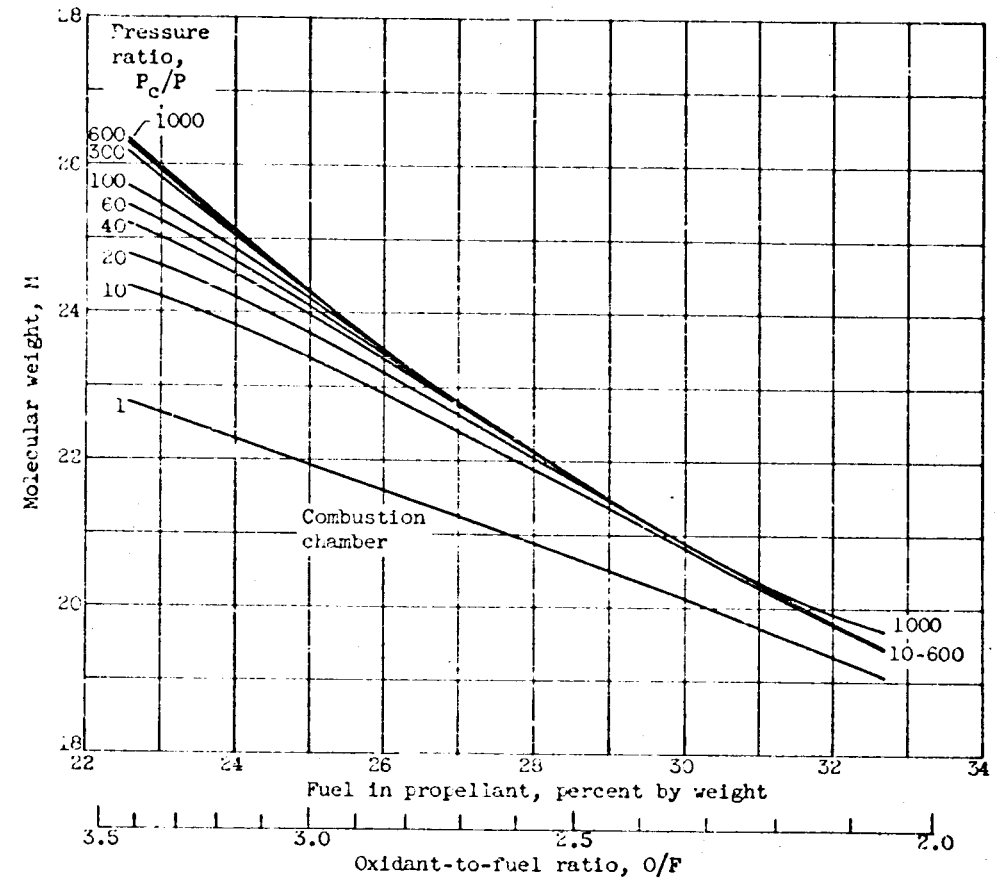
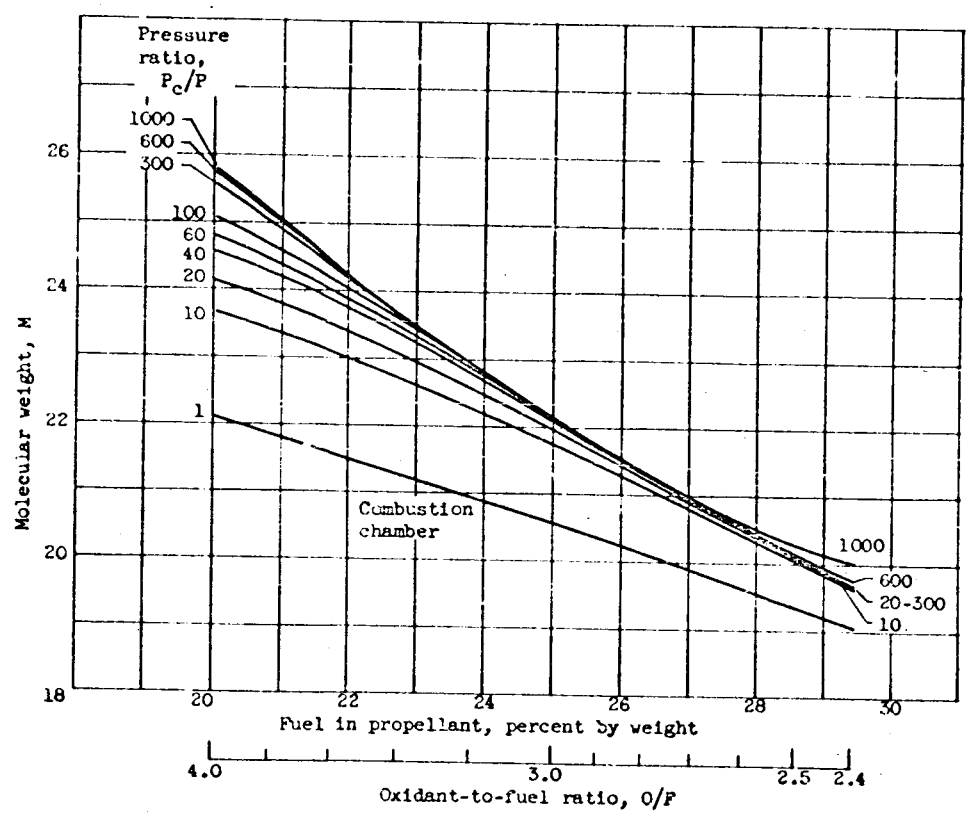


(c) Percent fluorine in oxidant by weight, 30.

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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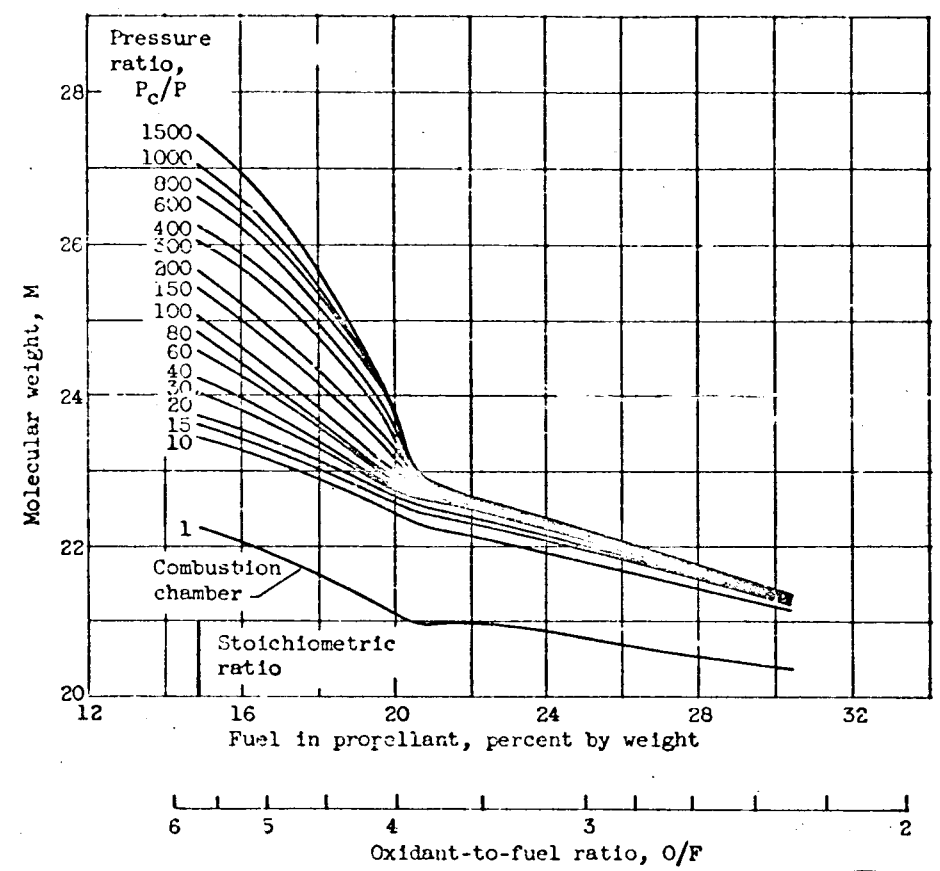
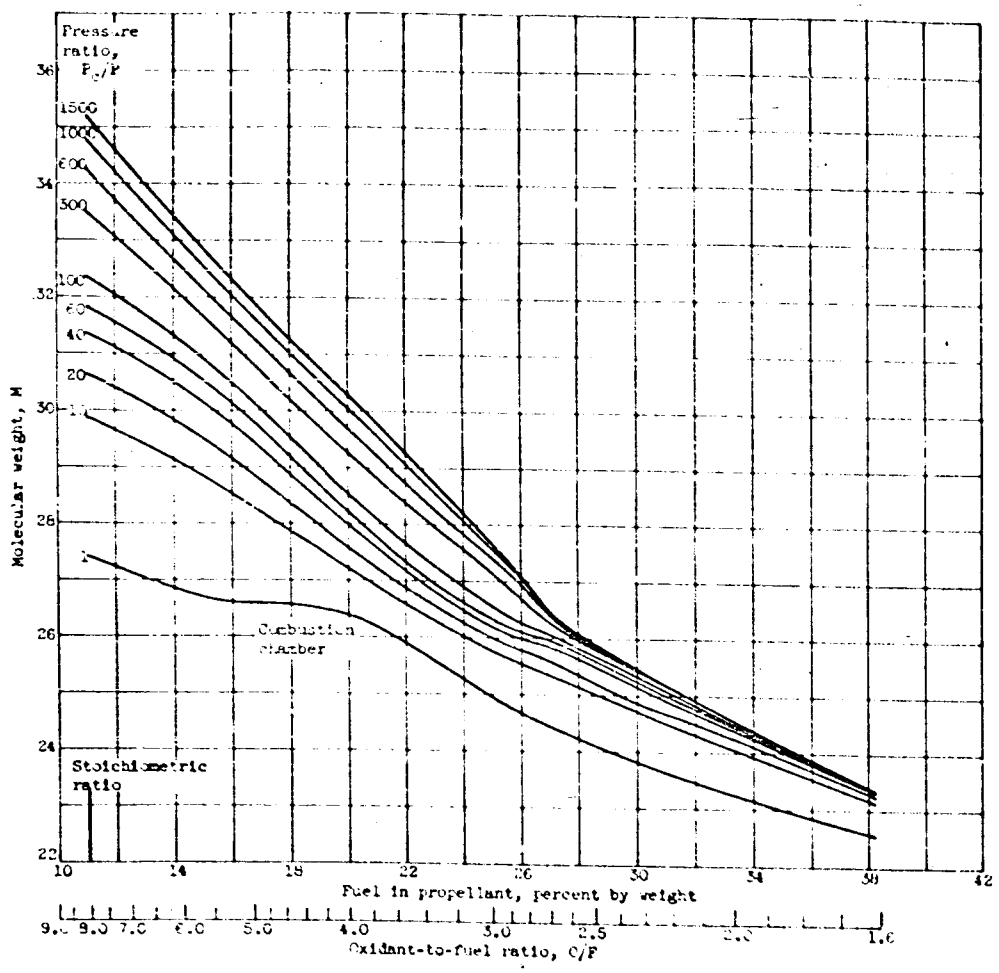


(e) Percent fluorine in oxidant by weight, 70.37.

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.

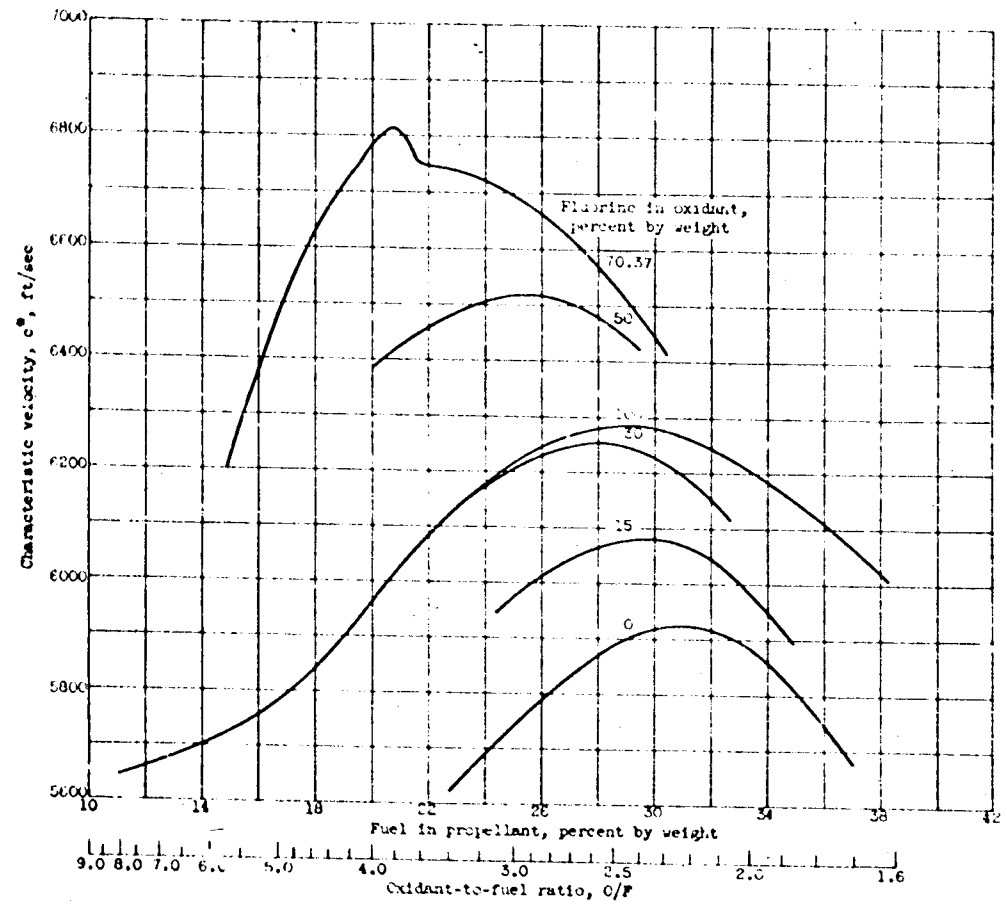


Figure 6. - Theoretical characteristic velocity for JP-4 fuel with several fluorine-oxygen mixtures. Isentropic expansion assuming equilibrium composition from combustion-chamber pressure of 600 pounds per square inch absolute.

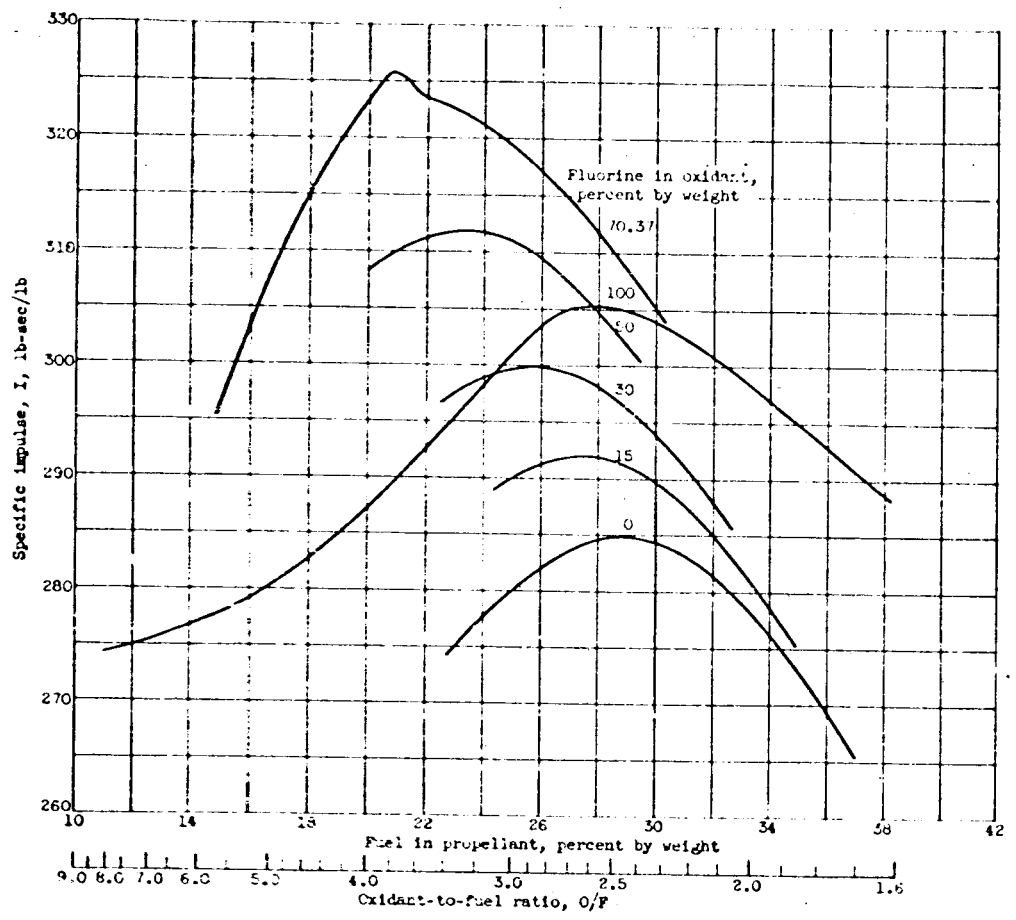


Figure 7. - Theoretical specific impulse for JP-4 fuel with several fluorine-oxygen mixtures. Isentropic expansion assuming equilibrium composition from combustion-chamber pressure of 600 pounds per square inch absolute to exit pressure of 1 atmosphere.

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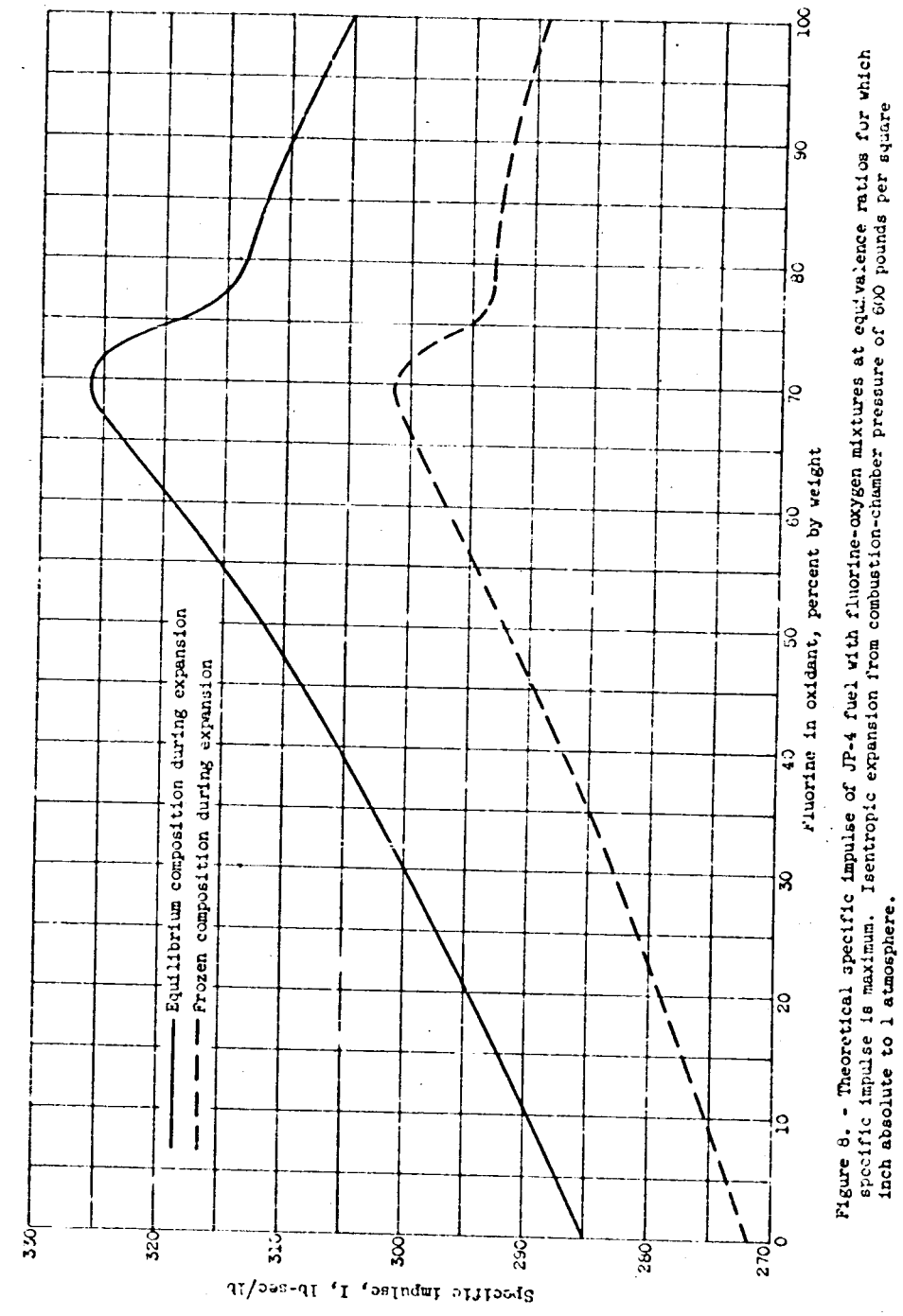

Figure 8. - Theoretical specific impulse of JP-4 fuel with fluorine-oxygen mixtures at equivalence ratios for which specific impulse is maximum. Isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to 1 atmosphere.

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