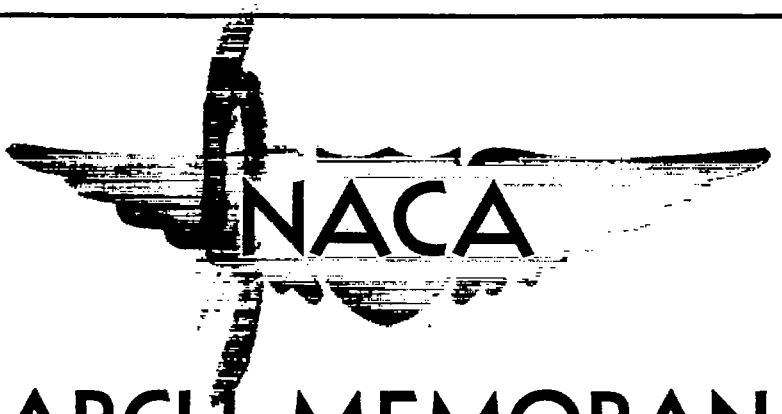

RESEARCH MEMORANDUM

THEORETICAL ROCKET PERFORMANCE OF LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES ASSUMING FROZEN COMPOSITION

By Sanford Gordon and Michael E. Kastner

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE
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WASHINGTON
May 20, 1958

NACA RM E58B20

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SUMMARY

Theoretical rocket performance for frozen composition during expansion was calculated for liquid methane 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, and thermal conductivity.

The maximum calculated 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 315.3 for 79.67 percent fluorine in the oxidant.

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. References 1 to 3 present data for JP-4 fuel with several mixtures of oxygen and fluorine. These data show that mixtures of fluorine and oxygen exist that give higher performance with JP-4 fuel than either 100 percent oxygen or fluorine because fluorine burns preferentially with hydrogen, and oxygen with carbon.

A hydrocarbon fuel with a higher hydrogen-carbon atom ratio than that of JP-4 fuel (1.942 hydrogen-carbon atom ratio) might be expected to yield even higher values of specific impulse with mixtures of fluorine and oxygen than were obtained with JP-4 fuel. Calculations were, therefore, made at the NACA Lewis laboratory in order to determine the performance of liquid methane with several mixtures of liquid fluorine and oxygen.

SYMBOLS

The following symbols are used in this report:

A	nozzle area, sq in.
a	local velocity of sound, ft/sec
C_F	coefficient of thrust, $C_F = g_c I/c^* = F/P_c A_t$
C_p^o	molar specific heat at constant pressure, cal/(mole)(^oK)
c_p	specific heat at constant pressure, $\frac{\sum_i x_i (C_p^o)_i}{M(1 - x_k)}$, cal/(g)($^oK$)
c_v	specific heat at constant volume
c^*	characteristic velocity, $g_c P_c A_t/w$, ft/sec
F	thrust, lb
g_c	gravitational conversion factor, 32.174 (lb mass/lb force)(ft/sec^2)
H_T^o	sum of sensible enthalpy and chemical energy at temperature T, cal/mole
h	sum of sensible enthalpy and chemical energy per unit mass, $\frac{\sum_i x_i (H_T^o)_i}{M(1 - x_k)}$, cal/g
I	specific impulse, (lb force)(sec)/lb mass
k	coefficient of thermal conductivity, cal/(sec)(cm)(^oK)
M	molecular weight, $\frac{\sum_i x_i M_i}{1 - x_k}$, g/g-mole or lb/lb-mole
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)(^oK)

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

T temperature, ^oK

w mass-flow rate, lb/sec

x mole fraction

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

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

s constant entropy

t nozzle throat

Superscript:

o thermodynamic standard reference state

CALCULATION OF PERFORMANCE DATA

Performance data were obtained for liquid methane with several fluorine-oxygen mixtures for a range of equivalence and pressure ratios. Frozen 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 4 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 4. Data for graphite were taken from reference 5, for carbon monofluoride from reference 6, for the remainder of the

fluorocarbons from reference 7, and for water from reference 8. Data for methane were determined by the rigid-rotator - harmonic-oscillator approximation using spectroscopic data from reference 9. The base used in this report for assigning absolute values to enthalpy is the same as in reference 4.

The dissociation energy of fluorine was assumed to be 35.6 kilocalories per mole and the heat of sublimation of graphite at 298.16° K was assumed to be 171.698 kilocalories per mole (ref. 10). The heat of solution of oxygen and fluorine was omitted.

Physical, thermochemical, and viscosity data. - Several properties of the propellants taken from references 4, 10, 11, and 12 are listed in table I. The viscosity data for the individual combustion products were either taken from the literature when available, or estimated. The viscosities of F, H, H_2, and HF are given in reference 13. The viscosities of the remaining substances except H_2O were calculated using similar techniques. The viscosity of H_2O was obtained from a modified Sutherland equation (ref. 14).

Formulas

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

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

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

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

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

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

Characteristic velocity, ft/sec

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

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

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

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

$$c_p = \frac{\sum_i x_i (C_p^o)_i}{M(1 - x_k)} \tag{7}$$

Isentropic exponent

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

When the composition is frozen,

$$\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s = \frac{c_p}{c_p - \frac{R}{M}} = \frac{c_p}{c_v}$$

Absolute viscosity, poises

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

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.

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The fluorine-oxygen atom ratios selected are 0(100 percent oxygen), 0.2, 0.5, 1.0, 2.0, 3.0, 3.3, 3.4, 3.7, and 4.0, which correspond to the following percentages of fluorine in the oxidant by weight: 0, 19.19, 37.25, 54.29, 70.37, 78.08, 79.67, 80.15, 81.46, and 82.61. The range of oxidant-fuel ratios selected for each percentage of fluorine is greater for the fluorine percentages up to 70 than for those over 70. For the fluorine percentages over 70, closely spaced oxidant-fuel ratios were selected primarily to determine maximum specific impulse.

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 the assigned pressure ratios given in table IV. Properties at the throat in table IV may be found where the ratio of nozzle area to throat area ε is 1.000. The values adjacent to the throat correspond to pressures of 1.2 and 0.8 times the throat pressure. Table V presents the equilibrium composition in the combustion chamber. Solid graphite did not appear as a combustion product for any of the conditions considered in this report and is therefore omitted from table V. The mole fractions of carbon tetrafluoride and methane were always less than 5×10^{-6} for all the conditions considered in this report and therefore these substances were also omitted from table V. Performance data for expansion from combustion-chamber pressure to 1 atmosphere are summarized in table VI.

Curves

The performance parameters are plotted in figures 1 to 7. Curves of specific impulse are presented in figure 1 for assigned pressure ratios as functions of percentages of fuel by weight.

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

In figure 2(f) the combustion temperatures for 78.08, 79.67, 80.15, 81.46, and 82.61 percent fluorine in the oxidant by weight are presented as separate curves. However, the exit curves coincided so closely that only one curve is given for each pressure ratio covering the range of 78.08 to 82.61 percent fluorine.

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

Figures 4 and 5 present curves of molecular weight and characteristic velocity, respectively, as functions of percentages of fuel by weight.

Effect of fluorine-oxygen ratio. - The specific-impulse data for expansion from chamber pressure to 1 atmosphere (table VI) are plotted in figure 6 to show the effect of fluorine-oxygen ratios on performance. Specific impulse increases with increasing percentages of fluorine to about 80 percent fluorine in the oxidant. Increasing the amount of fluorine in the oxidant above 80 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	282.8
19.19	289.0
37.25	295.3
54.29	301.8
70.37	310.0
78.08	315.1
79.67	315.3
80.15	315.2
81.46	314.2
82.61	312.7

The data of the preceding table are plotted in figure 7; it may be seen from this figure that a specific impulse value of about 315 may be obtained from about 77 to 81 percent fluorine in the oxidant. Specific impulse increases from 282.8 to 315.3 for 0 to 79.67 percent fluorine in the oxidant and decreases from 315.3 to 312.7 for 79.67 to 82.61 percent fluorine in the oxidant. A curve for JP-4 fuel with mixtures of fluorine

and oxygen (fig. 8 of ref. 2) is also given in figure 7 for comparison. The maximum value of specific impulse for JP-4 fuel is 301.6 at about 70 percent fluorine in the oxidant as compared with 315.3 at 79.67 percent fluorine in the oxidant for liquid methane.

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 may be used to calculate the pressure at the injector face.

SUMMARY OF RESULTS

A theoretical investigation of the performance of liquid methane with fluorine-oxygen mixtures was made for the following conditions: fluorine in oxidant by weight from 0 to 82.61 percent for various equivalence ratios, pressure ratios from 1 to 300, and frozen composition during expansion from 600 pounds per square inch absolute in the combustion chamber. The maximum values of specific impulse calculated for an exit pressure of 1 atmosphere (pressure ratio, 40.827) ranged from 282.8 to 315.3 for 0 to 79.67 percent fluorine in the oxidant and from 315.3 to 312.7 for 79.67 to 82.61 percent fluorine in the oxidant.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, February 27, 1958

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TABLE I. - PROPERTIES OF LIQUID PROPELLANTS

Property	Propellant		
	Oxygen, O_2	Fluorine, F_2	Methane, CH_4
Molecular weight, M	32.00	38.00	16.042
Density, g/cc	[a]1.1415	[b]1.54	[c]0.4245
Freezing point, °C	[d,e]-218.76	[d]-217.96	[d,f]-182.48
Boiling point, °C	[d]-182.97	[d]-187.92	[d]-161.49
Enthalpy of formation at boiling point from elements at 25° C, kcal/mole	[g]-3.080	[g]-3.030	[d,h]-21.352
Enthalpy of vaporization, kcal/mole	[d,i]1.630	[d,j]1.51	[d,k]1.955
Enthalpy of fusion, kcal/mole	[d,l]0.106	[d,m]0.372	[d,n]0.225

[a]At -182.0° C; ref. 11.
[b]At -196° C; ref. 12.
[c]At -161.5° C; ref. 11.
[d]Ref. 10.
[e]At 1.1 mm Hg.
[f]At 87.7 mm Hg.
[g]Ref. 4.
[h]Unpublished NACA calculations based on data of ref. 9.
[i]At -182.97° C.
[j]At -187.92° C.
[k]At -161.49° C.
[l]At -218.76° C.
[m]At -217.96° C.
[n]At -182.48° C.

TABLE II. - THERMODYNAMIC PROPERTIES OF COMBUSTION-CHAMBER GASES AND CHARACTERISTIC VELOCITY FOR LIQUID METHANE WITH SEVERAL MIXTURES OF FLUORINE AND OXYGEN

Equivalence ratio, r, $\frac{4(C)+(H)}{2(O)+(F)}$	Fuel, percent by weight	Oxidant-to-fuel weight ratio, O/F	Temperature, T, °K	Molecular weight, M	Enthalpy, h, cal/g (a)	Entropy, s, $\frac{cal}{(g)(^oK)}$	Specific heat, c_p, $\frac{cal}{(g)(^oK)}$ (b)	Isentropic exponent, γ (b)	Characteristic velocity, c*, ft/sec (b)
Percent fluorine in oxidant, 0 (100 percent oxygen)									
1.00	20.04	3.990	3497	22.87	2645.8	2.8259	0.519	1.201	5700
1.30	24.58	3.069	3444	20.54	3237.1	3.0420	.565	1.207	5959
1.40	25.98	2.850	3372	19.80	3419.6	3.1038	.578	1.210	5998
1.50	27.32	2.660	3272	19.08	3595.5	3.1604	.590	1.215	6011
1.60	28.62	2.493	3147	18.39	3765.0	3.2121	.600	1.220	5996
1.80	31.09	2.216	2855	17.10	4086.6	3.3011	.618	1.231	5901
Percent fluorine in oxidant by weight, 19.19									
1.20	21.10	3.740	3622	20.83	3017.6	2.9809	0.521	1.224	6036
1.40	23.78	3.206	3536	19.59	3359.2	3.1015	.548	1.227	6145
1.50	25.05	2.992	3460	18.99	3521.4	3.1556	.560	1.230	6169
1.60	26.28	2.805	3362	18.40	3678.2	3.2056	.571	1.233	6172
1.80	28.62	2.493	3119	17.28	3977.0	3.2936	.591	1.242	6118
Percent fluorine in oxidant by weight, 37.25									
1.30	20.35	3.913	3753	19.88	3145.8	3.0158	0.505	1.247	6248
1.50	22.77	3.391	3650	18.86	3447.2	3.1221	.530	1.248	6324
1.60	23.93	3.179	3572	18.36	3591.2	3.1701	.541	1.250	6336
1.70	25.05	2.992	3479	17.87	3730.9	3.2147	.552	1.252	6333
1.90	27.19	2.677	3258	16.95	3998.3	3.2945	.571	1.258	6282
Percent fluorine in oxidant by weight, 54.29									
1.30	18.26	4.475	3957	19.60	3100.6	2.9706	0.476	1.271	6416
1.40	19.40	4.156	3917	19.16	3238.7	3.0222	.488	1.270	6459
1.50	20.50	3.879	3864	18.73	3373.1	3.0708	.499	1.270	6489
1.60	21.57	3.636	3798	18.30	3503.9	3.1165	.511	1.270	6506
1.80	23.63	3.232	3628	17.48	3755.1	3.1994	.531	1.272	6503
Percent fluorine in oxidant by weight, 70.37									
1.40	17.22	4.809	4209	19.08	3178.8	2.9530	0.458	1.294	6664
1.50	18.22	4.488	4157	18.69	3299.0	2.9988	.469	1.293	6694
1.60	19.20	4.208	4091	18.30	3416.3	3.0419	.480	1.292	6711
1.70	20.16	3.960	4014	17.93	3530.8	3.0823	.490	1.292	6717
Percent fluorine in oxidant by weight, 78.08									
1.55	17.55	4.697	4333	18.59	3317.5	2.9700	0.460	1.303	6833
1.60	18.02	4.551	4298	18.40	3372.4	2.9890	.465	1.303	6841
1.65	18.48	4.413	4228	18.31	3426.7	3.0041	.470	1.300	6807
Percent fluorine in oxidant by weight, 79.67									
1.48	16.66	5.003	4418	18.89	3232.1	2.9282	0.450	1.305	6840
1.51	16.94	4.904	4402	18.78	3265.2	2.9399	.453	1.305	6848
1.55	17.31	4.777	4351	18.70	3309.0	2.9531	.457	1.303	6827
Percent fluorine in oxidant by weight, 80.15									
1.46	16.40	5.098	4440	18.98	3207.7	2.9157	0.447	1.306	6839
1.48	16.59	5.029	4431	18.91	3229.8	2.9236	.449	1.306	6846
1.50	16.77	4.962	4408	18.86	3251.8	2.9306	.451	1.305	6838
Percent fluorine in oxidant by weight, 81.46									
1.38	15.45	5.471	4498	19.32	3113.3	2.8700	0.436	1.309	6817
1.40	15.64	5.393	4493	19.25	3135.6	2.8783	.438	1.308	6828
1.42	15.83	5.317	4476	19.20	3157.7	2.8859	.440	1.308	6825
Percent fluorine in oxidant by weight, 82.61									
1.30	14.53	5.882	4527	19.65	3019.9	2.8241	0.425	1.312	6776
1.33	14.85	5.735	4528	19.53	3057.2	2.8386	.429	1.311	6799
1.40	15.48	5.462	4480	19.41	3131.0	2.8633	.436	1.307	6793
1.50	16.40	5.098	4395	19.23	3239.7	2.8965	.448	1.300	6772

[a]The base used for enthalpy is given in ref. 4.

[b]Parameters based on frozen composition.

TABLE III. - THEORETICAL ROCKET PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion or compression from combustion-chamber pressure of 600 lb/sq in. abs.]

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

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^oK)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(cm)(sec)(^oK)}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r, 1.00; percent fuel, 20.04; O/F, 3.990									
3600	714.07	2699.4	1.200	0.5212	895	0.00056	---	---	---
3200	354.07	2492.4	1.204	.5138	829	.00052	1.00	0.652	115.5
2800	161.89	2288.6	1.208	.5047	761	.00047	1.26	.995	176.3
2400	66.796	2089.0	1.214	.4933	688	.00041	2.09	1.242	220.1
2000	24.097	1894.5	1.222	.4783	609	.00036	4.16	1.443	255.7
1600	7.240	1707.1	1.234	.4578	523	.00030	9.90	1.613	285.8
1200	1.668	1529.4	1.254	.4289	427	.00023	29.56	1.759	311.7
900	.423	1404.8	1.277	.4008	346	.00018	82.96	1.855	328.6
600	.071	1289.4	1.309	.3684	252	.00012	317.07	1.939	343.5
r, 1.30; percent fuel, 24.58; O/F, 3.089									
3600	777.80	3325.6	1.205	0.5679	870	0.00049	---	---	---
3200	391.56	3100.0	1.209	.5597	807	.00045	1.02	0.590	109.2
2800	182.10	2878.0	1.214	.5497	740	.00041	1.19	.954	176.8
2400	76.607	2660.6	1.220	.5372	669	.00036	1.91	1.209	224.0
2000	28.272	2448.8	1.228	.5206	593	.00031	3.68	1.414	261.9
1600	8.733	2244.9	1.241	.4978	510	.00025	8.50	1.587	293.8
1200	2.085	2051.9	1.262	.4657	417	.00019	24.44	1.734	321.1
900	.547	1916.7	1.286	.4350	337	.00015	66.20	1.830	339.0
600	.095	1791.2	1.318	.4013	245	.00010	242.19	1.915	354.7
r, 1.40; percent fuel, 25.98; O/F, 2.850									
3600	875.72	3551.9	1.208	0.5825	864	0.00061	---	---	---
3200	444.25	3320.5	1.212	.5740	802	.00056	1.09	0.498	92.9
2800	208.39	3092.9	1.217	.5637	736	.00051	1.12	.904	168.6
2400	88.535	2869.9	1.223	.5508	665	.00045	1.74	1.173	218.7
2000	33.048	2652.8	1.232	.5338	590	.00039	3.29	1.386	258.3
1600	10.348	2443.7	1.245	.5103	507	.00032	7.46	1.563	291.4
1200	2.512	2245.8	1.266	.4775	415	.00025	21.01	1.714	319.6
900	.669	2107.2	1.290	.4463	336	.00019	55.96	1.813	337.9
600	.118	1978.3	1.322	.4124	244	.00013	200.88	1.900	354.1
r, 1.50; percent fuel, 27.32; O/F, 2.660									
3600	1034.4	3790.2	1.211	0.5967	860	0.00062	---	---	---
3200	529.34	3553.2	1.215	.5880	798	.00057	1.45	0.324	60.6
2800	250.76	3320.1	1.220	.5774	732	.00052	1.05	.829	154.8
2400	107.73	3091.7	1.226	.5641	663	.00046	1.55	1.121	209.4
2000	40.739	2869.4	1.235	.5466	587	.00040	2.84	1.345	251.3
1600	12.952	2655.3	1.249	.5226	505	.00033	6.29	1.531	286.0
1200	3.202	2452.6	1.270	.4892	413	.00026	17.30	1.688	315.3
900	.866	2310.5	1.295	.4578	335	.00020	45.21	1.790	334.4
600	.156	2178.2	1.326	.4239	244	.00014	158.99	1.880	351.2
r, 1.60; percent fuel, 28.62; O/F, 2.493									
3200	658.21	3796.8	1.219	0.6016	795	0.00059	---	---	---
2800	315.14	3558.3	1.224	.5907	730	.00053	1.00	0.720	134.1
2400	137.03	3324.6	1.230	.5771	660	.00047	1.35	1.050	195.8
2000	52.543	3097.2	1.240	.5592	586	.00041	2.39	1.293	241.1
1600	16.978	2878.2	1.253	.5348	504	.00034	5.14	1.491	277.8
1200	4.278	2670.7	1.275	.5009	413	.00026	13.76	1.656	308.6
900	1.177	2525.0	1.299	.4693	335	.00020	35.24	1.762	328.5
600	.216	2389.3	1.330	.4357	244	.00014	121.26	1.856	346.0
r, 1.80; percent fuel, 31.09; O/F, 2.216									
3200	1105.3	4301.3	1.227	0.6279	792	0.00061	---	---	---
2800	540.68	4058.3	1.232	.6164	727	.00055	1.57	0.297	54.6
2400	240.90	3808.5	1.239	.6022	658	.00049	1.06	.848	155.5
2000	94.990	3571.2	1.249	.5837	584	.00043	1.64	1.155	211.8
1600	31.710	3342.4	1.263	.5585	503	.00035	3.28	1.387	254.5
1200	8.301	3125.6	1.285	.5242	412	.00028	8.27	1.577	289.2
900	2.359	2973.0	1.309	.4926	335	.00021	20.27	1.697	311.3
600	.450	2830.1	1.338	.4598	246	.00015	66.74	1.803	330.6

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TABLE III. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion or compression from combustion-chamber pressure of 600 lb/sq in. abs.]

(b) Percent fluorine in oxidant by weight, 19.19

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^\circ K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(cm)(sec)(^\circ K)}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r, 1.20; percent fuel, 21.10; O/F, 3.740									
4000	1034.9	3215.7	1.221	0.5270	1046	0.00068	--------	-------	-------
3600	580.20	3006.1	1.284	.5209	975	.00062	2.60	0.169	31.7
3200	306.35	2799.1	1.228	.5136	901	.00057	1.01	.735	137.9
2800	150.21	2595.4	1.233	.5047	823	.00051	1.29	1.022	191.7
2400	67.048	2395.7	1.240	.4936	740	.00045	2.04	1.240	232.6
2000	26.464	2201.1	1.249	.4790	652	.00039	3.76	1.421	266.6
1600	8.830	2013.3	1.262	.4592	557	.00032	8.14	1.576	295.6
1200	2.304	1834.7	1.283	.4319	452	.00025	21.55	1.710	320.8
900	.651	1708.9	1.307	.4065	363	.00019	54.35	1.799	337.5
r, 1.40; percent fuel, 23.78; O/F, 3.208									
3600	660.58	3394.0	1.227	0.5492	956	0.00065	--------	-------	-------
3200	350.70	3175.8	1.231	.5414	883	.00059	1.00	0.661	126.3
2800	173.03	2961.1	1.236	.5320	807	.00053	1.31	.974	186.1
2400	77.787	2750.5	1.242	.5202	727	.00047	1.86	1.205	230.1
2000	30.965	2545.4	1.252	.5047	641	.00040	3.37	1.393	266.1
1600	10.440	2347.6	1.266	.4835	548	.00033	7.16	1.553	296.7
1200	2.761	2159.7	1.287	.4545	445	.00026	18.65	1.692	323.1
900	.791	2027.3	1.311	.4277	358	.00020	46.34	1.782	340.4
r, 1.50; percent fuel, 25.05; O/F, 2.992									
3600	742.44	3600.1	1.228	0.5629	948	0.00066	--------	-------	-------
3200	395.86	3376.5	1.233	.5548	877	.00060	1.03	0.586	112.3
2800	196.27	3156.5	1.238	.5451	802	.00054	1.14	.929	178.2
2400	88.732	2940.8	1.244	.5329	722	.00048	1.71	1.172	224.8
2000	35.554	2730.7	1.254	.5170	637	.00041	3.06	1.368	262.3
1600	12.088	2528.0	1.268	.4953	544	.00034	6.42	1.533	294.0
1200	3.226	2335.5	1.290	.4656	442	.00026	16.80	1.675	321.2
900	.932	2199.9	1.314	.4384	356	.00020	40.57	1.769	339.1
r, 1.60; percent fuel, 26.28; O/F, 2.805									
3600	862.51	3814.7	1.231	0.5762	942	0.00067	--------	-------	-------
3200	468.26	3585.8	1.235	.5679	871	.00061	1.13	0.468	89.7
2800	230.81	3360.6	1.240	.5578	797	.00055	1.07	.867	166.2
2400	104.91	3139.9	1.247	.5453	718	.00049	1.55	1.128	216.4
2000	42.363	2924.9	1.257	.5290	634	.00042	2.71	1.336	256.0
1600	14.528	2717.5	1.271	.5068	542	.00035	5.60	1.507	289.1
1200	3.928	2520.6	1.293	.4766	441	.00027	14.17	1.655	317.4
900	1.144	2381.6	1.317	.4491	355	.00021	34.42	1.751	335.9
r, 1.80; percent fuel, 28.82; O/F, 2.493									
3200	684.23	4024.8	1.241	0.5931	864	0.00064	--------	-------	-------
2800	345.76	3789.6	1.246	.5824	790	.00057	1.00	0.672	127.7
2400	159.76	3559.1	1.253	.5693	712	.00051	1.24	1.003	190.7
2000	65.650	3334.7	1.263	.5533	629	.00044	2.03	1.243	236.4
1600	28.980	3118.1	1.278	.5293	538	.00036	4.02	1.438	273.4
1200	6.356	2912.3	1.300	.4983	438	.00028	9.79	1.601	304.4
900	1.893	2766.9	1.323	.4706	354	.00022	23.13	1.706	324.5

(c) Percent fluorine in oxidant by weight, 37.25

r, 1.30; percent fuel, 20.35; O/F, 3.913									
4000	828.94	3271.0	1.244	0.5088	1163	0.00074	--------	-------	-------
3600	486.36	3068.7	1.248	.5029	1080	.00068	1.21	0.422	81.9
3200	270.01	2868.9	1.252	.4960	994	.00062	1.03	.799	155.2
2800	139.97	2672.1	1.258	.4876	904	.00055	1.32	1.045	203.0
2400	66.513	2479.0	1.265	.4773	809	.00049	2.01	1.240	240.9
2000	28.192	2290.7	1.275	.4638	708	.00042	3.49	1.405	272.8
1600	10.215	2108.6	1.289	.4456	601	.00034	7.01	1.547	300.4
1200	2.935	1935.1	1.311	.4212	483	.00026	16.92	1.671	324.6
900	.908	1811.9	1.334	.3994	386	.00020	39.35	1.754	340.7
r, 1.50; percent fuel, 22.77; O/F, 3.391									
4000	953.46	3633.8	1.245	0.5355	1136	0.00076	--------	-------	-------
3600	559.97	3420.9	1.249	.5292	1056	.00070	1.88	0.244	47.9
3200	311.25	3210.7	1.253	.5218	973	.00064	1.00	.730	143.6
2800	161.59	3003.7	1.259	.5129	885	.00057	1.23	1.000	196.5
2400	76.929	2800.7	1.266	.5018	793	.00050	1.84	1.207	237.2
2000	32.686	2602.7	1.276	.4875	695	.00043	3.16	1.379	271.1
1600	11.882	2411.4	1.291	.4681	590	.00035	6.28	1.528	300.2
1200	3.431	2229.1	1.313	.4432	475	.00027	15.04	1.657	325.6
900	1.060	2099.8	1.336	.4193	380	.00021	34.72	1.742	342.4
r, 1.60; percent fuel, 23.93; O/F, 3.179									
3600	684.14	3606.5	1.250	0.5418	1047	0.00071	--------	-------	-------
3200	347.56	3391.3	1.254	.5343	964	.00065	1.00	0.670	131.9
2800	180.83	3179.4	1.260	.5250	878	.00058	1.17	.961	189.3
2400	86.307	2971.6	1.267	.5137	787	.00051	1.72	1.179	232.2
2000	36.781	2768.9	1.277	.4989	690	.00044	2.92	1.358	267.5
1600	13.420	2573.1	1.292	.4790	586	.00036	5.75	1.511	297.6
1200	3.893	2386.6	1.314	.4525	473	.00028	13.66	1.644	323.8
900	1.207	2254.3	1.337	.4292	379	.00021	31.36	1.732	341.1
r, 1.70; percent fuel, 25.06; O/F, 2.992									
3600	711.74	3798.1	1.251	0.5543	1039	0.00072	--------	-------	-------
3200	397.32	3578.0	1.256	.5463	957	.00066	1.03	0.586	115.4
2800	207.32	3361.3	1.261	.5369	872	.00059	1.11	.911	179.3
2400	99.279	3148.8	1.269	.5258	782	.00052	1.58	1.143	225.1
2000	42.477	2941.6	1.279	.5101	686	.00045	2.65	1.331	262.1
1600	15.572	2741.4	1.294	.4897	583	.00037	5.16	1.491	293.4
1200	4.543	2550.7	1.316	.4627	470	.00028	12.15	1.628	320.5
900	1.416	2415.4	1.339	.4391	377	.00022	27.70	1.719	338.3
r, 1.80; percent fuel, 27.19; O/F, 2.677									
3600	979.82	4195.1	1.254	0.5782	1027	0.00074	--------	-------	-------
3200	550.10	3965.5	1.259	.5698	946	.00068	1.70	0.274	53.5
2800	289.12	3739.5	1.265	.5598	862	.00061	1.01	.769	150.1
2400	139.61	3518.0	1.272	.5475	774	.00054	1.32	1.047	204.4
2000	60.317	3308.0	1.283	.5317	679	.00046	2.11	1.261	246.1
1600	22.367	3093.4	1.298	.5105	578	.00038	4.00	1.437	280.6
1200	6.614	2894.5	1.321	.4828	467	.00029	9.18	1.587	309.9
900	2.088	2753.2	1.343	.4588	376	.00023	20.55	1.686	329.2
600	.445	2619.0	1.368	.4361	272	.00016	60.97	1.774	346.4

TABLE III. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR LIQUID METHANE WITH SEVERAL FLUORINE OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion or compression from combustion-chamber pressure of 600 lb/sq in. abs.]

(d) Percent fluorine in oxidant by weight, 54.29

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(cm)(sec)(°K)}$	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r, 1.30; percent fuel, 18.26; O/F, 4.475									
4000	631.23	3121.1	1.270	0.4764	1320	0.00080	------	------	------
3600	385.83	2931.6	1.274	.4709	1221	.00073	1.02	0.608	121.3
3200	224.06	2744.4	1.279	.4646	1117	.00066	1.08	.883	176.0
2800	122.09	2560.0	1.285	.4571	1010	.00059	1.40	1.087	216.9
2400	61.351	2379.0	1.293	.4479	898	.00052	2.07	1.256	250.6
2000	27.708	2202.1	1.303	.4359	781	.00044	3.43	1.402	279.6
1600	10.800	2030.8	1.318	.4200	657	.00036	6.44	1.530	305.1
1200	3.379	1866.8	1.340	.3992	523	.00028	14.38	1.643	327.7
900	1.117	1749.7	1.362	.3816	415	.00021	31.19	1.719	342.9
600	.251	1637.6	1.384	.3656	296	.00015	88.76	1.789	356.8
r, 1.40; percent fuel, 19.40; O/F, 4.156									
4000	662.09	3279.2	1.269	0.4890	1302	0.00081	------	------	------
3600	404.03	3084.7	1.273	.4834	1204	.00074	1.04	0.577	115.8
3200	234.21	2892.6	1.278	.4769	1103	.00067	1.06	.865	173.5
2800	127.38	2703.4	1.284	.4691	997	.00060	1.37	1.075	215.8
2400	63.873	2517.5	1.291	.4596	887	.00052	2.02	1.248	250.5
2000	28.782	2336.1	1.302	.4478	772	.00045	3.34	1.396	280.3
1600	11.192	2160.4	1.317	.4307	649	.00036	6.29	1.526	306.3
1200	3.493	1992.2	1.340	.4092	518	.00028	14.07	1.641	329.3
900	1.153	1872.2	1.361	.3909	411	.00021	30.54	1.718	344.8
600	.259	1757.5	1.383	.3743	293	.00015	87.01	1.788	359.0
r, 1.50; percent fuel, 20.50; O/F, 3.879									
4000	706.24	3441.1	1.268	0.5014	1285	0.00081	------	------	------
3600	430.53	3241.7	1.272	.4955	1189	.00075	1.07	0.530	106.9
3200	249.30	3044.8	1.277	.4886	1089	.00068	1.04	.838	169.0
2800	135.43	2850.8	1.283	.4809	986	.00060	1.33	1.057	213.2
2400	67.833	2660.4	1.291	.4710	878	.00053	1.95	1.235	249.0
2000	30.528	2474.5	1.301	.4582	764	.00045	3.22	1.387	279.6
1600	11.856	2294.4	1.317	.4412	643	.00037	6.05	1.519	306.4
1200	3.696	2122.2	1.339	.4190	513	.00028	13.52	1.636	329.9
900	1.219	1999.4	1.361	.4002	407	.00022	29.34	1.714	345.7
600	.274	1881.9	1.383	.3831	291	.00015	83.57	1.786	360.2
r, 1.60; percent fuel, 21.57; O/F, 3.636									
4000	786.30	3607.4	1.268	0.5135	1270	0.00082	------	------	------
3600	466.93	3403.2	1.272	.5075	1176	.00076	1.15	0.463	93.6
3200	270.26	3201.6	1.277	.5005	1078	.00069	1.02	.808	162.2
2800	146.77	3002.9	1.283	.4923	976	.00061	1.26	1.032	208.8
2400	73.482	2808.0	1.291	.4821	869	.00054	1.86	1.217	246.1
2000	33.062	2617.7	1.301	.4689	757	.00046	3.05	1.373	277.7
1600	12.839	2433.4	1.317	.4514	638	.00037	5.72	1.509	305.2
1200	4.003	2257.3	1.339	.4286	509	.00029	12.76	1.629	329.4
900	1.320	2131.6	1.361	.4094	405	.00022	27.65	1.709	345.6
600	.297	2011.4	1.383	.3920	290	.00015	78.68	1.782	360.4
r, 1.80; percent fuel, 25.63; O/F, 3.232									
4000	949.09	3953.8	1.268	0.5371	1244	0.00085	------	------	------
3600	578.65	3740.2	1.273	.5306	1154	.00078	2.54	0.178	36.0
3200	338.21	3529.4	1.278	.5232	1059	.00070	1.00	.693	140.1
2800	182.25	3321.9	1.284	.5144	959	.00063	1.16	.961	194.2
2400	91.383	3118.2	1.292	.5036	855	.00055	1.64	1.165	235.4
2000	41.197	2919.4	1.302	.4897	746	.00047	2.64	1.334	269.7
1600	16.039	2727.0	1.318	.4713	629	.00039	4.90	1.480	299.1
1200	5.017	2543.1	1.341	.4475	504	.00030	10.81	1.607	324.7
900	1.659	2411.8	1.362	.4276	401	.00023	23.30	1.692	341.9
600	.374	2286.3	1.384	.4099	288	.00016	65.93	1.769	357.5

(e) Percent fluorine in oxidant by weight, 70.37

r, 1.40; percent fuel, 17.22; O/F, 4.809									
4400	730.04	3266.7	1.292	0.4606	1593	0.00094	------	------	------
4000	479.98	3083.6	1.296	.4559	1478	.00087	1.20	0.440	91.1
3600	303.43	2902.0	1.300	.4508	1361	.00079	1.00	.749	155.2
3200	168.83	2722.8	1.305	.4451	1239	.00071	1.15	.962	199.2
2800	103.78	2546.1	1.312	.4383	1114	.00063	1.51	1.133	234.6
2400	54.588	2372.4	1.320	.4298	985	.00055	2.18	1.279	264.9
2000	25.967	2202.6	1.331	.4190	850	.00047	3.47	1.407	291.5
1600	10.745	2037.7	1.347	.4047	709	.00038	6.20	1.521	315.1
1200	3.605	1879.4	1.369	.3865	560	.00029	13.00	1.623	336.3
900	1.266	1765.6	1.389	.3720	440	.00022	26.61	1.693	350.7
600	.305	1655.9	1.407	.3602	312	.00015	70.88	1.758	364.0
r, 1.50; percent fuel, 18.22; O/F, 4.488									
4400	771.99	3413.6	1.291	0.4723	1573	0.00095	------	------	------
4000	506.70	3225.7	1.295	.4674	1460	.00088	1.32	0.384	79.9
3600	319.72	3039.8	1.299	.4621	1344	.00080	1.00	.722	150.2
3200	192.27	2856.1	1.304	.4562	1225	.00072	1.13	.944	196.3
2800	108.91	2675.0	1.310	.4491	1102	.00064	1.47	1.120	233.0
2400	57.152	2497.0	1.318	.4404	974	.00056	2.12	1.270	264.2
2000	27.117	2323.0	1.329	.4298	841	.00047	3.38	1.401	291.4
1600	11.190	2154.2	1.345	.4144	702	.00038	6.04	1.517	315.6
1200	3.743	1992.0	1.368	.3957	555	.00029	12.69	1.621	337.2
900	1.311	1875.6	1.388	.3806	437	.00022	26.03	1.692	351.9
600	.315	1763.3	1.406	.3685	309	.00016	69.48	1.757	365.5
r, 1.60; percent fuel, 19.20; O/F, 4.206									
4400	828.48	3564.9	1.289	0.4837	1584	0.00096	------	------	------
4000	543.03	3372.5	1.293	.4787	1443	.00089	1.62	0.296	61.7
3600	342.17	3182.1	1.298	.4732	1329	.00081	1.00	.684	142.8
3200	205.47	2994.0	1.303	.4670	1211	.00073	1.10	.919	191.7
2800	116.20	2808.6	1.309	.4597	1090	.00065	1.42	1.102	229.9
2400	60.878	2626.4	1.317	.4508	964	.00057	2.04	1.257	262.2
2000	28.834	2448.3	1.328	.4392	833	.00048	3.25	1.391	290.2
1600	11.875	2275.6	1.344	.4240	696	.00039	5.81	1.510	315.0
1200	3.963	2109.7	1.367	.4047	550	.00030	12.20	1.616	337.2
900	1.386	1990.7	1.387	.3892	433	.00023	25.06	1.689	352.2
600	.333	1875.9	1.405	.3767	307	.00016	66.97	1.758	366.1
r, 1.70; percent fuel, 20.16; O/F, 3.960									
4400	901.95	3720.8	1.289	0.4950	1537	0.00097	------	------	------
4000	590.64	3523.8	1.293	.4897	1427	.00090	3.81	0.118	24.7
3600	371.81	3329.0	1.297	.4841	1315	.00082	1.01	.635	132.5
3200	223.04	3136.7	1.302	.4777	1199	.00074	1.07	.887	185.2
2800	126.01	2947.1	1.308	.4701	1079	.00066	1.37	1.080	225.4
2400	65.947	2760.8	1.317	.4609	955	.00057	1.95	1.240	258.8
2000	31.201	2578.7	1.328	.4490	826	.00049	3.09	1.379	287.8
1600	12.835	2402.1	1.344	.4333	690	.00039	5.51	1.501	313.4
1200	4.279	2232.6	1.366	.4135	546	.00030	11.57	1.610	336.1
900	1.494	2111.0	1.386	.3977	431	.00023	23.75	1.684	351.5
600	.358	1993.7	1.404	.3850	306	.00016	63.51	1.752	365.7

TABLE III. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion or compression from combustion-chamber pressure of 600 lb/sq in. abs.]

(f) Percent fluorine in oxidant by weight, 78.08

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(cm)(sec)(°K)}$	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r, 1.55; percent fuel, 17.55; O/F, 4.697									
4400	641.13	3348.4	1.302	0.4606	1658	0.00099	-------	-------	-------
4000	426.10	3165.1	1.306	.4560	1536	.00091	1.07	0.542	115.1
3600	278.54	2983.7	1.311	.4510	1411	.00083	1.02	.802	170.4
3200	166.34	2804.4	1.316	.4453	1283	.00074	1.20	.995	211.3
2800	95.771	2627.6	1.322	.4386	1152	.00066	1.57	1.154	245.0
2400	51.182	2453.7	1.331	.4304	1016	.00057	2.25	1.291	274.1
2000	24.789	2283.6	1.342	.4197	875	.00048	3.53	1.412	299.9
1600	10.473	2118.4	1.358	.4058	727	.00039	6.21	1.521	323.0
1200	3.600	1959.5	1.380	.3882	572	.00030	12.74	1.618	343.7
900	1.291	1845.1	1.399	.3745	449	.00023	25.59	1.685	357.9
r, 1.60; percent fuel, 18.02; O/F, 4.551									
4400	663.55	3419.7	1.302	0.4661	1650	0.00099	-------	-------	-------
4000	440.71	3234.2	1.306	.4613	1529	.00091	1.10	0.516	109.7
3600	288.70	3050.7	1.310	.4562	1405	.00083	1.01	.787	167.3
3200	171.81	2869.3	1.315	.4505	1278	.00075	1.18	.984	209.8
2800	98.847	2690.4	1.322	.4437	1147	.00066	1.54	1.146	243.6
2400	52.784	2514.6	1.330	.4353	1011	.00058	2.21	1.285	273.2
2000	25.543	2342.5	1.341	.4245	871	.00049	3.47	1.408	299.3
1600	10.782	2175.5	1.357	.4107	725	.00040	6.10	1.518	322.7
1200	3.702	2014.8	1.380	.3926	570	.00030	12.50	1.616	343.7
900	1.327	1899.1	1.399	.3787	447	.00023	25.12	1.684	358.0
r, 1.65; percent fuel, 18.48; O/F, 4.615									
4400	713.18	3507.6	1.298	0.4723	1632	0.00099	-------	-------	-------
4000	472.09	3319.6	1.303	.4673	1512	.00091	1.18	0.486	96.5
3600	300.70	3133.8	1.307	.4621	1390	.00083	1.00	.755	159.7
3200	188.72	2950.3	1.312	.4561	1264	.00075	1.15	.963	203.6
2800	104.70	2769.0	1.319	.4491	1135	.00066	1.50	1.131	239.2
2400	55.660	2591.0	1.327	.4405	1001	.00058	2.14	1.275	269.7
2000	26.809	2416.9	1.338	.4298	863	.00049	3.37	1.401	296.4
1600	11.250	2247.9	1.354	.4150	716	.00040	5.98	1.514	320.3
1200	3.838	2085.4	1.376	.3969	565	.00030	12.26	1.615	341.6
900	1.367	1968.5	1.396	.3827	444	.00023	24.75	1.684	356.8
600	.336	1855.4	1.418	.3719	313	.00016	64.89	1.748	369.8

(g) Percent fluorine in oxidant by weight, 79.67

r, 1.48; percent fuel, 16.88; O/F, 5.005									
4800	857.06	3404.8	1.301	0.4544	1808	0.00106	-------	-------	-------
4400	589.77	3224.1	1.306	.4495	1686	.00098	3.66	0.184	26.3
4000	393.28	3045.8	1.310	.4450	1562	.00090	1.03	.000	127.5
3600	252.48	2868.8	1.314	.4401	1434	.00082	1.04	.837	177.9
3200	154.68	2693.2	1.319	.4347	1304	.00074	1.23	1.019	216.5
2800	89.437	2520.5	1.326	.4283	1169	.00065	1.63	1.170	248.8
2400	48.021	2350.7	1.334	.4203	1031	.00057	2.33	1.303	276.9
2000	23.379	2184.6	1.345	.4100	887	.00048	3.66	1.420	301.9
1600	9.936	2023.1	1.361	.3966	737	.00039	6.41	1.526	324.3
1200	3.439	1867.8	1.383	.3797	579	.00030	13.08	1.621	344.5
900	1.241	1756.9	1.402	.3668	454	.00023	26.15	1.686	358.4
600	.309	1647.5	1.418	.3567	320	.00016	67.64	1.747	371.3
r, 1.51; percent fuel, 16.94; O/F, 4.904									
4800	870.94	3446.5	1.301	0.4577	1803	0.00106	-------	-------	-------
4400	599.02	3264.4	1.305	.4527	1681	.00098	11.69	0.038	0.2
4000	399.84	3084.2	1.309	.4482	1557	.00090	1.04	.590	125.5
3600	256.14	2905.9	1.314	.4433	1430	.00082	1.03	.831	176.6
3200	156.85	2729.7	1.319	.4378	1300	.00074	1.23	1.014	216.9
2800	90.689	2555.8	1.325	.4313	1166	.00066	1.61	1.167	248.4
2400	48.686	2384.8	1.333	.4233	1028	.00057	2.31	1.300	276.8
2000	23.696	2217.5	1.345	.4129	885	.00048	3.63	1.419	301.9
1600	10.045	2054.9	1.360	.3993	735	.00039	6.37	1.525	324.5
1200	3.473	1898.5	1.383	.3823	578	.00030	13.00	1.620	344.8
900	1.252	1785.9	1.402	.3690	453	.00023	26.00	1.686	358.8
r, 1.55; percent fuel, 17.31; O/F, 4.777									
4400	629.32	3331.2	1.302	0.4575	1669	0.00099	-------	-------	-------
4000	418.37	3149.1	1.307	.4529	1548	.00091	1.06	0.556	118.0
3600	267.69	2968.9	1.311	.4479	1420	.00082	1.02	.811	172.0
3200	163.44	2790.8	1.316	.4423	1291	.00074	1.21	1.001	212.3
2800	94.144	2615.2	1.323	.4356	1158	.00066	1.58	1.158	245.7
2400	50.338	2442.6	1.331	.4274	1021	.00057	2.27	1.294	274.6
2000	24.395	2273.6	1.342	.4168	879	.00048	3.57	1.414	300.2
1600	10.314	2109.5	1.358	.4030	730	.00039	6.28	1.522	323.1
1200	3.548	1951.7	1.380	.3857	574	.00030	12.86	1.620	343.7
900	1.273	1838.0	1.400	.3728	450	.00023	25.83	1.686	357.8

(h) Percent fluorine in oxidant by weight, 80.15

r, 1.46; percent fuel, 16.40; O/F, 5.098									
4800	838.04	3369.8	1.302	0.4511	1817	0.00106	-------	-------	-------
4400	577.23	3189.8	1.307	.4462	1694	.00098	2.48	0.186	39.5
4000	385.31	3012.2	1.311	.4418	1569	.00090	1.02	.614	130.4
3600	247.60	2836.4	1.316	.4370	1441	.00082	1.04	.846	179.7
3200	151.89	2662.6	1.320	.4317	1309	.00074	1.24	1.025	217.8
2800	87.934	2491.2	1.327	.4253	1174	.00066	1.64	1.175	249.7
2400	47.280	2322.6	1.335	.4174	1038	.00057	2.35	1.305	277.5
2000	23.055	2157.6	1.346	.4078	890	.00048	3.69	1.422	302.3
1600	9.816	1997.3	1.362	.3939	740	.00039	6.46	1.527	324.5
1200	3.404	1842.9	1.384	.3772	581	.00030	13.15	1.621	344.6
900	1.230	1731.7	1.403	.3648	456	.00023	26.25	1.686	358.4
600	.307	1624.0	1.419	.3546	321	.00016	67.77	1.746	371.2
r, 1.48; percent fuel, 16.89; O/F, 5.029									
4800	845.74	3396.2	1.308	0.4533	1813	0.00106	-------	-------	-------
4400	582.33	3215.9	1.306	.4484	1691	.00098	2.80	0.163	34.7
4000	388.57	3037.5	1.310	.4439	1565	.00090	1.03	.808	129.4
3600	249.60	2860.8	1.315	.4391	1438	.00082	1.04	.842	179.2
3200	153.05	2686.2	1.320	.4337	1307	.00074	1.24	1.022	217.5
2800	88.567	2514.0	1.326	.4273	1172	.00065	1.63	1.173	249.6
2400	47.597	2344.6	1.334	.4194	1033	.00057	2.34	1.304	277.5
2000	23.197	2178.6	1.346	.4098	889	.00048	3.68	1.421	302.4
1600	9.870	2017.7	1.362	.3957	739	.00039	6.44	1.526	324.5
1200	3.420	1862.7	1.384	.3789	580	.00030	13.12	1.621	344.6
900	1.235	1751.0	1.403	.3659	455	.00023	26.19	1.686	358.7
600	.308	1642.8	1.419	.3561	321	.00016	67.65	1.746	371.6
r, 1.50; percent fuel, 16.77; O/F, 4.962									
4800	865.64	3429.5	1.301	0.4557	1808	0.00106	-------	-------	-------
4400	595.41	3248.2	1.305	.4507	1686	.00098	9.43	0.083	17.6
4000	396.86	3068.9	1.309	.4462	1562	.00090	1.03	.594	126.2
3600	254.63	2891.3	1.314	.4413	1434	.00082	1.03	.833	177.1
3200	155.94	2715.9	1.319	.4359	1303	.00074	1.23	1.016	215.9
2800	90.114	2542.8	1.325	.4294	1169	.00066	1.62	1.169	248.4
2400	48.386	2372.6	1.333	.4214	1030	.00057	2.32	1.301	276.6
2000	23.528	2206.0	1.345	.4111	886	.00048	3.65	1.419	301.7
1600	9.998	2044.2	1.361	.3975	737	.00039	6.39	1.525	324.2
1800	3.455	1888.4	1.383	.3806	579	.00030	13.05	1.681	344.4
900	1.246	1776.3	1.402	.3674	454	.00023	26.09	1.686	358.3
600	.310	1667.6	1.418	.3575	320	.00016	67.56	1.747	371.3

TABLE III. - Concluded. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion or compression from combustion-chamber pressure of 600 lb/sq in. abs.]

(i) Percent fluorine in oxidant weight, 81.46

Temperature, T, $^{\circ}R$	Static pressure, P, lb/sq in. abs	Enthalpy h, cal/g	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(cm)(sec)(^{\circ}K)}$	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r, 1.38; percent fuel, 15.45; O/F, 5.471									
4800	791.22	3245.5	1.306	0.4394	1843	0.00105	------	------	------
4400	546.69	3070.7	1.310	.4347	1718	.00097	1.68	0.287	60.9
4000	366.16	2897.7	1.314	.4304	1591	.00089	1.01	.646	137.0
3600	236.15	2726.4	1.318	.4259	1461	.00081	1.05	.866	183.5
3200	145.43	2557.1	1.384	.4207	1327	.00073	1.27	1.038	220.0
2800	84.553	2390.0	1.330	.4146	1190	.00065	1.67	1.194	250.9
2400	45.677	2225.6	1.338	.4070	1049	.00056	2.40	1.312	277.9
2000	22.391	2064.7	1.349	.3972	903	.00047	3.75	1.426	302.1
1600	9.588	1908.1	1.365	.3844	749	.00038	6.53	1.528	323.8
1200	3.345	1757.5	1.387	.3683	589	.00029	13.44	1.621	343.4
900	1.215	1648.9	1.406	.3559	461	.00022	26.28	1.685	357.0
600	0.305	1543.6	1.422	.3468	325	.00015	67.68	1.744	369.6
r, 1.40; percent fuel, 15.64; O/F, 5.393									
4800	794.70	3270.3	1.305	0.4416	1839	0.00105	------	------	------
4400	548.87	3094.7	1.309	.4369	1715	.00097	1.71	0.281	59.6
4000	367.45	2920.8	1.314	.4326	1588	.00089	1.01	.644	136.7
3600	236.87	2748.7	1.318	.4280	1458	.00081	1.05	.865	183.5
3200	145.80	2578.5	1.323	.4228	1325	.00073	1.27	1.037	220.2
2800	84.720	2410.6	1.329	.4166	1188	.00065	1.67	1.193	251.2
2400	45.739	2245.4	1.338	.4090	1047	.00056	2.39	1.311	278.3
2000	22.406	2083.7	1.349	.3991	900	.00048	3.75	1.426	302.5
1600	9.588	1926.5	1.365	.3862	748	.00039	6.53	1.528	324.4
1200	3.345	1775.2	1.387	.3701	587	.00029	13.84	1.621	344.1
900	1.215	1666.0	1.406	.3575	460	.00022	26.31	1.685	357.6
600	.305	1560.3	1.421	.3484	324	.00015	67.57	1.745	370.2
r, 1.42; percent fuel, 15.83; O/F, 5.317									
4800	808.31	3300.7	1.304	0.4440	1835	0.00105	------	------	------
4400	557.70	3124.1	1.308	.4391	1711	.00097	1.86	0.255	54.1
4000	372.96	2949.3	1.312	.4348	1584	.00089	1.01	.635	134.7
3600	240.14	2776.3	1.317	.4302	1455	.00081	1.05	.859	182.2
3200	147.63	2605.3	1.322	.4249	1322	.00073	1.26	1.033	219.2
2800	85.667	2436.5	1.328	.4187	1185	.00065	1.66	1.181	250.5
2400	46.182	2270.5	1.337	.4110	1044	.00056	2.38	1.310	277.8
2000	22.585	2108.1	1.348	.4010	898	.00048	3.73	1.425	302.2
1600	9.647	1950.1	1.364	.3880	746	.00039	6.58	1.528	324.2
1200	3.358	1798.1	1.386	.3717	586	.00029	13.23	1.681	344.0
900	1.217	1688.5	1.405	.3591	459	.00022	26.33	1.685	357.5
600	.305	1582.3	1.420	.3498	323	.00015	67.78	1.745	370.2

(j) Percent fluorine in oxidant by weight, 82.61

r, 1.30; percent fuel, 14.53; O/F, 5.882									
4800	767.76	3136.1	1.309	0.4282	1865	0.00103	------	------	------
4400	532.84	2965.8	1.314	.4236	1739	.00096	1.51	0.326	68.6
4000	357.73	2797.2	1.318	.4195	1610	.00088	1.01	.661	139.2
3600	231.59	2630.2	1.322	.4151	1478	.00080	1.06	.874	184.1
3200	143.21	2465.1	1.327	.4102	1343	.00072	1.27	1.043	219.7
2800	83.639	2302.2	1.334	.4043	1204	.00064	1.68	1.187	249.9
2400	45.409	2141.9	1.342	.3970	1061	.00056	2.40	1.312	276.4
2000	22.383	1984.9	1.353	.3876	913	.00047	3.73	1.425	300.1
1600	9.646	1832.3	1.369	.3752	758	.00038	6.47	1.526	321.5
1200	3.398	1685.2	1.391	.3598	596	.00029	13.01	1.618	340.8
900	1.241	1579.0	1.410	.3480	466	.00022	25.68	1.681	354.1
600	.313	1476.0	1.424	.3395	329	.00015	65.47	1.740	366.5
r, 1.333; percent fuel, 14.85; O/F, 5.735									
4800	768.12	3174.3	1.308	0.4318	1860	0.00104	------	------	------
4400	532.01	3002.6	1.313	.4272	1734	.00096	1.51	0.326	68.9
4000	357.25	2832.5	1.317	.4231	1606	.00088	1.01	.662	139.8
3600	231.04	2664.2	1.321	.4186	1474	.00080	1.06	.875	184.9
3200	148.71	2497.7	1.326	.4136	1339	.00072	1.28	1.044	220.6
2800	83.250	2333.4	1.333	.4077	1201	.00064	1.68	1.188	251.0
2400	45.137	2171.7	1.341	.4003	1058	.00056	2.41	1.314	277.6
2000	22.216	2013.5	1.352	.3907	910	.00047	3.75	1.426	301.4
1600	9.559	1859.6	1.368	.3783	756	.00038	6.52	1.528	322.8
1200	3.355	1711.3	1.390	.3627	594	.00029	13.14	1.619	342.2
900	1.225	1604.3	1.409	.3506	465	.00022	25.97	1.683	355.6
600	.309	1500.6	1.423	.3420	328	.00015	66.33	1.742	368.0
r, 1.40; percent fuel, 15.48; O/F, 5.482									
4800	806.40	3271.4	1.303	0.4401	1839	0.00104	------	------	------
4400	555.98	3096.3	1.308	.4353	1714	.00097	1.82	0.260	54.9
4000	371.52	2923.1	1.312	.4309	1587	.00089	1.01	.637	134.5
3600	239.03	2751.6	1.316	.4263	1457	.00081	1.05	.861	181.7
3200	146.82	2582.1	1.321	.4211	1324	.00073	1.26	1.035	218.5
2800	85.119	2414.9	1.328	.4149	1187	.00064	1.67	1.192	249.6
2400	45.840	2250.4	1.336	.4072	1046	.00056	2.39	1.311	276.8
2000	22.393	2089.4	1.347	.3974	899	.00047	3.76	1.426	301.0
1600	9.552	1932.9	1.363	.3845	747	.00038	6.57	1.529	322.9
1200	3.319	1782.3	1.385	.3683	586	.00029	13.36	1.623	342.6
900	1.201	1673.7	1.404	.3559	459	.00022	26.64	1.687	356.1
600	.300	1568.4	1.419	.3468	323	.00015	68.75	1.747	368.7
r, 1.50; percent fuel, 16.40; O/F, 5.098									
4400	602.71	3241.7	1.300	0.4481	1671	0.00096	------	------	------
4000	399.54	3063.4	1.304	.4434	1547	.00089	1.04	0.588	123.8
3600	254.86	2887.0	1.308	.4384	1421	.00081	1.03	.832	175.2
3200	155.10	2712.8	1.314	.4329	1291	.00073	1.23	1.017	214.1
2800	89.020	2540.9	1.320	.4263	1158	.00064	1.63	1.172	246.6
2400	47.411	2371.9	1.328	.4182	1021	.00056	2.36	1.306	274.8
2000	22.873	2206.6	1.339	.4078	878	.00047	3.74	1.424	299.8
1600	9.620	2046.1	1.355	.3943	730	.00038	6.61	1.531	322.3
1200	3.287	1891.7	1.377	.3774	573	.00029	13.66	1.627	342.5
900	1.172	1780.4	1.396	.3643	449	.00022	27.62	1.693	356.3

TABLE IV. - THEORETICAL ROCKET PERFORMANCE FOR PRESSURE RATIOS FROM 1 TO 300 FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion from combustion-chamber pressure of 600 lb/sq in. abs.]

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

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °R	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Isentropic exponent, γ	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r, 1.00; percent fuel, 20.04; O/F, 3.990								
1.000	600.00	3497	2645.8	0.519	1.201	-------	-------	-------
1.040	576.92	3474	2633.9	.519	1.201	2.395	0.181	32.4
1.478	405.84	3275	2530.8	.515	1.203	1.033	.565	100.0
1.774	338.20	3175	2479.7	.513	1.204	1.000	.679	120.2
2.218	270.56	3057	2419.3	.511	1.205	1.031	.792	140.4
10.000	60.00	2355	2066.8	.492	1.215	2.84	1.267	224.4
20.000	30.00	2081	1933.4	.482	1.220	3.57	1.405	249.0
20.414	29.392	2073	1929.7	.481	1.220	3.68	1.409	249.6
40.000	15.00	1834	1815.6	.471	1.226	5.82	1.517	268.8
40.827	14.696	1827	1812.3	.470	1.227	5.91	1.520	269.3
60.000	10.00	1700	1753.4	.464	1.231	7.81	1.573	278.7
100.000	6.00	1544	1681.4	.454	1.237	11.37	1.635	289.7
300.000	2.00	1245	1548.7	.433	1.251	25.79	1.744	309.0
r, 1.30; percent fuel, 24.58; O/F, 3.069								
1.000	600.00	3444	3237.1	0.565	1.207	-------	-------	-------
1.040	576.92	3421	3224.1	.564	1.207	2.408	0.182	33.7
1.481	405.00	3219	3110.5	.560	1.209	1.033	.567	105.0
1.778	337.50	3119	3054.6	.558	1.210	1.000	.681	126.0
2.222	270.00	3000	2988.5	.555	1.211	1.030	.794	147.1
10.000	60.00	2296	2605.1	.533	1.228	2.23	1.266	234.5
20.000	30.00	2023	2460.4	.522	1.238	3.54	1.404	260.0
20.414	29.392	2014	2456.4	.521	1.238	3.59	1.407	260.6
40.000	15.00	1775	2333.2	.509	1.235	5.76	1.514	280.5
40.827	14.696	1768	2329.7	.508	1.235	5.84	1.517	281.0
60.000	10.00	1643	2266.2	.501	1.240	7.71	1.570	290.7
100.000	6.00	1487	2188.9	.490	1.246	11.19	1.631	302.0
300.000	2.00	1190	2047.1	.465	1.263	25.21	1.738	321.8
r, 1.40; percent fuel, 25.98; O/F, 2.850								
1.000	600.00	3372	3419.6	0.578	1.210	-------	-------	-------
1.040	576.92	3349	3406.4	.577	1.210	2.405	0.182	33.9
1.483	404.48	3148	3290.7	.573	1.213	1.032	.568	105.9
1.780	337.07	3049	3234.0	.571	1.214	1.000	.682	127.1
2.225	269.66	2931	3167.0	.568	1.215	1.030	.795	148.3
10.000	60.00	2235	2779.5	.544	1.226	2.22	1.266	236.0
20.000	30.00	1964	2633.6	.538	1.233	3.52	1.403	261.5
20.414	29.392	1956	2629.5	.532	1.233	3.57	1.406	262.2
40.000	15.00	1720	2505.6	.518	1.240	5.71	1.513	282.0
40.827	14.696	1713	2502.0	.518	1.240	5.80	1.516	282.6
60.000	10.00	1589	2438.3	.510	1.245	7.64	1.567	292.2
100.000	6.00	1435	2360.8	.498	1.252	11.08	1.628	303.5
300.000	2.00	1144	2219.1	.472	1.270	24.86	1.734	323.2
r, 1.50; percent fuel, 27.32; O/F, 2.660								
1.000	600.00	3272	3595.5	0.590	1.215	-------	-------	-------
1.040	576.92	3249	3582.2	.589	1.215	2.407	0.182	34.0
1.486	403.85	3050	3465.2	.584	1.217	1.032	.570	106.5
1.783	336.54	2952	3408.2	.582	1.218	1.000	.683	127.6
2.229	269.23	2836	3341.0	.578	1.219	1.030	.797	148.8
10.000	60.00	2152	2953.1	.554	1.232	2.21	1.265	236.4
20.000	30.00	1886	2807.5	.541	1.239	3.49	1.402	261.8
20.414	29.392	1879	2803.5	.540	1.239	3.54	1.405	262.5
40.000	15.00	1647	2680.1	.526	1.247	5.66	1.511	282.2
40.827	14.696	1641	2676.6	.525	1.247	5.75	1.514	282.8
60.000	10.00	1519	2613.3	.517	1.252	7.56	1.565	292.3
100.000	6.00	1369	2536.5	.505	1.260	10.94	1.625	303.5
300.000	2.00	1084	2396.7	.478	1.279	24.43	1.729	323.0
r, 1.60; percent fuel, 28.82; O/F, 2.493								
1.000	600.00	3147	3765.0	0.600	1.220	-------	-------	-------
1.040	576.92	3125	3751.7	.600	1.220	2.411	0.182	34.0
1.488	403.10	2929	3634.5	.594	1.222	1.032	.572	106.6
1.786	335.91	2833	3577.7	.592	1.223	1.000	.685	127.7
2.233	268.73	2719	3510.8	.588	1.225	1.030	.798	148.7
10.000	60.00	2052	3126.3	.562	1.238	2.20	1.265	235.8
20.000	30.00	1793	2982.4	.548	1.246	3.47	1.400	261.0
20.414	29.392	1785	2978.5	.547	1.246	3.52	1.404	261.6
40.000	15.00	1560	2857.0	.532	1.255	5.60	1.508	281.1
40.827	14.696	1554	2853.5	.531	1.255	5.68	1.511	281.6
60.000	10.00	1436	2791.4	.522	1.261	7.47	1.562	291.1
100.000	6.00	1290	2716.2	.509	1.269	10.77	1.621	302.1
300.000	2.00	1015	2579.8	.488	1.289	23.93	1.723	321.1
r, 1.80; percent fuel, 31.09; O/F, 2.216								
1.000	600.00	2855	4086.6	0.618	1.231	-------	-------	-------
1.040	576.92	2834	4073.6	.618	1.232	2.419	0.183	33.6
1.495	401.35	2646	3958.1	.611	1.235	1.031	.576	105.7
1.794	334.46	2556	3903.0	.608	1.236	1.000	.689	126.4
2.242	267.57	2449	3838.1	.604	1.238	1.029	.802	147.0
10.000	60.00	1824	3469.2	.574	1.254	2.17	1.264	231.8
20.000	30.00	1582	3332.2	.557	1.264	3.40	1.397	256.2
20.414	29.392	1575	3328.4	.557	1.264	3.45	1.400	256.8
40.000	15.00	1366	3213.7	.540	1.275	5.46	1.503	275.6
40.827	14.696	1360	3210.4	.539	1.275	5.54	1.505	276.1
60.000	10.00	1250	3152.1	.529	1.281	7.25	1.555	285.2
100.000	6.00	1116	3081.9	.516	1.291	10.40	1.612	295.7
300.000	2.00	865	2956.0	.489	1.312	22.82	1.710	313.6

TABLE IV. - Continued. THEORETICAL ROCKET PERFORMANCE FOR PRESSURE RATIOS FROM 1 TO 300 FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion from combustion-chamber pressure of 600 lb/sq in. abs.]

(b) Percent fluorine in oxidant by weight, 19.19

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(^\circ K)}$	Isentropic exponent, γ	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r, 1.20; percent fuel, 21.10; O/F, 3.740								
1.000	600.00	3622	3017.6	0.521	1.224	---	---	---
1.040	576.92	3596	3004.1	.521	1.224	2.414	0.183	34.3
1.490	402.55	3366	2884.6	.517	1.226	1.032	.573	107.6
1.789	335.46	3254	2827.1	.515	1.228	1.000	.686	128.8
2.236	268.37	3122	2759.2	.512	1.229	1.030	.799	149.9
10.000	60.00	2349	2370.5	.492	1.241	2.19	1.265	237.3
20.000	30.00	2050	2225.3	.481	1.247	3.46	1.400	262.6
20.414	29.392	2042	2221.3	.481	1.248	3.50	1.403	263.2
40.000	15.00	1784	2098.7	.469	1.255	5.58	1.507	282.8
40.827	14.696	1777	2095.2	.469	1.256	5.66	1.510	283.3
60.000	10.00	1642	2032.4	.462	1.261	7.44	1.561	292.8
100.000	6.00	1476	1956.5	.452	1.268	10.74	1.620	303.9
300.000	2.00	1163	1818.8	.429	1.286	23.90	1.722	323.0
r, 1.40; percent fuel, 23.78; O/F, 3.206								
1.000	600.00	3536	3359.2	0.548	1.227	---	---	---
1.040	576.92	3511	3345.1	.548	1.227	2.416	0.183	34.9
1.492	402.09	3283	3220.8	.543	1.230	1.032	.575	109.7
1.791	335.07	3173	3161.1	.541	1.231	1.000	.687	131.3
2.238	268.06	3042	3090.7	.538	1.232	1.030	.800	152.8
10.000	60.00	2281	2688.9	.516	1.245	2.18	1.264	241.5
20.000	30.00	1987	2539.0	.504	1.252	3.44	1.399	267.1
20.414	29.392	1979	2534.9	.504	1.252	3.49	1.402	267.8
40.000	15.00	1725	2408.7	.491	1.261	5.55	1.506	287.6
40.827	14.696	1718	2405.1	.490	1.261	5.63	1.509	288.1
60.000	10.00	1586	2340.6	.483	1.266	7.38	1.559	297.7
100.000	6.00	1422	2262.7	.472	1.274	10.64	1.617	308.9
300.000	2.00	1116	2121.8	.447	1.293	23.58	1.718	328.1
r, 1.50; percent fuel, 25.05; O/F, 2.992								
1.000	600.00	3460	3521.4	0.560	1.230	---	---	---
1.040	576.92	3435	3507.2	.560	1.230	2.418	0.183	35.1
1.494	401.70	3209	3381.4	.555	1.232	1.031	.576	110.4
1.792	334.75	3100	3321.2	.553	1.234	1.000	.688	132.0
2.240	267.80	2971	3250.3	.549	1.235	1.030	.801	153.6
10.000	60.00	2221	2846.2	.526	1.248	2.18	1.264	242.4
20.000	30.00	1932	2695.7	.514	1.256	3.42	1.398	268.0
20.414	29.392	1924	2691.6	.513	1.256	3.47	1.401	268.7
40.000	15.00	1674	2565.1	.500	1.265	5.51	1.505	288.5
40.827	14.696	1667	2561.5	.499	1.265	5.59	1.507	289.0
60.000	10.00	1537	2496.9	.491	1.271	7.34	1.557	298.6
100.000	6.00	1377	2419.1	.480	1.279	10.56	1.615	309.7
300.000	2.00	1076	2278.6	.455	1.299	23.32	1.715	328.8
r, 1.60; percent fuel, 26.28; O/F, 2.805								
1.000	600.00	3362	3678.2	0.571	1.233	---	---	---
1.040	576.92	3337	3664.1	.571	1.233	2.420	0.183	35.1
1.495	401.21	3115	3537.5	.566	1.236	1.031	.577	110.7
1.795	334.34	3008	3477.2	.563	1.237	1.000	.689	132.3
2.243	267.47	2882	3406.3	.560	1.239	1.029	.802	153.8
10.000	60.00	2146	3002.8	.536	1.253	2.17	1.264	242.4
20.000	30.00	1863	2852.9	.522	1.261	3.41	1.397	268.0
20.414	29.392	1855	2848.8	.522	1.261	3.45	1.401	268.6
40.000	15.00	1611	2723.1	.507	1.270	5.48	1.503	288.3
40.827	14.696	1604	2719.5	.507	1.271	5.55	1.506	288.8
60.000	10.00	1477	2655.5	.498	1.277	7.28	1.555	298.3
100.000	6.00	1320	2578.4	.487	1.285	10.45	1.613	309.4
300.000	2.00	1028	2439.7	.461	1.306	23.00	1.711	328.3
r, 1.80; percent fuel, 28.62; O/F, 2.493								
1.000	600.00	3119	3977.0	0.591	1.242	---	---	---
1.040	576.92	3096	3963.0	.590	1.242	2.426	0.184	34.9
1.500	399.98	2882	3837.2	.585	1.245	1.031	.580	110.3
1.800	333.31	2780	3777.8	.582	1.246	1.000	.692	131.7
2.250	266.65	2659	3708.1	.578	1.248	1.029	.805	153.0
10.000	60.00	1963	3314.2	.550	1.264	2.15	1.263	240.2
20.000	30.00	1695	3168.6	.535	1.274	3.36	1.395	265.2
20.414	29.392	1687	3164.6	.535	1.274	3.41	1.398	265.9
40.000	15.00	1457	3043.2	.519	1.285	5.38	1.499	285.1
40.827	14.696	1450	3039.8	.519	1.285	5.46	1.502	285.6
60.000	10.00	1331	2978.2	.509	1.292	7.13	1.550	294.8
100.000	6.00	1184	2904.4	.497	1.301	10.20	1.607	305.5
300.000	2.00	912	2772.7	.472	1.322	22.24	1.702	323.7

TABLE IV. - Continued. THEORETICAL ROCKET PERFORMANCE FOR PRESSURE RATIOS FROM 1 TO 300 FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion from combustion-chamber pressure of 600 lb/sq in. abs.]

(c) Percent fluorine in oxidant by weight, 37.25

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(^oK)}$	Isentropic exponent, γ	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r, 1.30; percent fuel, 20.36; O/F, 3.915								
1.000	600.00	3753	3145.8	0.505	1.247	--------	--------	-------
1.040	576.92	3724	3131.2	.505	1.247	2.429	0.184	35.7
1.502	399.38	3461	2999.1	.501	1.249	1.031	.582	113.0
1.803	332.81	3337	2937.2	.498	1.251	1.000	.694	134.7
2.254	266.25	3191	2864.4	.496	1.253	1.029	.806	156.5
10.000	60.00	2349	2454.6	.476	1.266	2.14	1.263	245.3
20.000	30.00	2087	2303.2	.465	1.274	3.35	1.394	270.8
20.414	29.392	2018	2299.1	.464	1.274	3.40	1.398	271.4
40.000	15.00	1743	2173.8	.453	1.283	5.37	1.498	291.0
40.827	14.696	1735	2169.2	.452	1.284	5.44	1.501	291.5
60.000	10.00	1592	2105.2	.445	1.290	7.11	1.549	300.9
100.000	6.00	1418	2028.5	.435	1.298	10.18	1.606	311.8
300.000	2.00	1095	1891.1	.414	1.319	22.26	1.701	330.4
r, 1.50; percent fuel, 22.77; O/F, 3.391								
1.000	600.00	3650	3447.2	0.530	1.248	--------	-------	-------
1.040	576.92	3621	3432.2	.530	1.248	2.430	0.184	36.2
1.503	399.14	3364	3296.7	.525	1.251	1.031	.582	114.5
1.804	332.61	3243	3233.2	.523	1.253	1.000	.694	136.5
2.255	266.09	3100	3158.6	.520	1.254	1.029	.806	158.5
10.000	60.00	2277	2739.4	.498	1.269	2.14	1.263	248.2
20.000	30.00	1963	2584.8	.486	1.277	3.34	1.394	273.9
20.414	29.392	1955	2580.5	.486	1.277	3.39	1.397	274.6
40.000	15.00	1686	2451.7	.473	1.287	5.34	1.498	294.3
40.827	14.696	1678	2448.1	.472	1.287	5.42	1.500	294.9
60.000	10.00	1539	2382.8	.465	1.293	7.08	1.548	304.3
100.000	6.00	1369	2304.7	.454	1.302	10.13	1.604	315.3
300.000	2.00	1053	2165.1	.431	1.323	22.07	1.699	334.0
r, 1.60; percent fuel, 23.93; O/F, 3.179								
1.000	600.00	3572	3591.2	0.541	1.250	--------	-------	-------
1.040	576.92	3544	3576.1	.541	1.250	2.431	0.184	36.3
1.504	398.88	3290	3439.6	.536	1.253	1.031	.583	114.8
1.805	332.40	3171	3375.9	.534	1.254	1.000	.695	136.9
2.256	265.92	3030	3301.0	.531	1.256	1.029	.807	158.9
10.000	60.00	2222	2880.7	.508	1.271	2.14	1.263	248.6
20.000	30.00	1913	2725.8	.495	1.280	3.33	1.393	274.4
20.414	29.392	1905	2721.5	.495	1.280	3.38	1.397	275.1
40.000	15.00	1641	2592.7	.481	1.290	5.32	1.497	294.8
40.827	14.696	1633	2589.0	.481	1.290	5.40	1.499	295.3
60.000	10.00	1496	2523.9	.473	1.297	7.04	1.547	304.7
100.000	6.00	1329	2445.8	.462	1.306	10.07	1.603	315.7
300.000	2.00	1021	2306.7	.439	1.328	21.90	1.698	334.3
r, 1.70; percent fuel, 25.05; O/F, 2.992								
1.000	600.00	3479	3730.9	0.552	1.252	--------	-------	-------
1.040	576.92	3451	3715.8	.551	1.253	2.433	0.184	36.3
1.506	398.53	3202	3579.0	.546	1.255	1.030	.584	115.0
1.807	332.11	3085	3515.3	.544	1.257	1.000	.696	137.0
2.258	265.69	2947	3440.5	.541	1.259	1.029	.808	159.0
10.000	60.00	2155	3021.3	.516	1.274	2.13	1.262	248.5
20.000	30.00	1853	2867.1	.503	1.284	3.32	1.393	274.2
20.414	29.392	1845	2862.9	.503	1.284	3.37	1.396	274.8
40.000	15.00	1586	2734.8	.489	1.294	5.30	1.496	294.4
40.827	14.696	1579	2731.2	.488	1.295	5.37	1.498	294.9
60.000	10.00	1446	2666.5	.480	1.301	7.00	1.546	304.3
100.000	6.00	1282	2589.1	.469	1.311	10.00	1.601	315.2
300.000	2.00	982	2451.5	.446	1.332	21.69	1.695	333.6
r, 1.90; percent fuel, 27.19; O/F, 2.677								
1.000	600.00	3258	3998.3	0.571	1.258	--------	-------	-------
1.040	576.92	3231	3983.4	.570	1.259	2.437	0.185	36.0
1.509	397.64	2992	3847.7	.565	1.262	1.030	.586	114.5
1.811	331.37	2881	3784.9	.562	1.264	1.000	.698	136.3
2.263	265.09	2750	3711.3	.558	1.266	1.029	.809	158.0
10.000	60.00	1998	3300.8	.532	1.283	2.12	1.262	246.4
20.000	30.00	1711	3150.3	.517	1.293	3.29	1.391	271.6
20.414	29.392	1703	3146.2	.517	1.294	3.34	1.395	272.3
40.000	15.00	1459	3021.8	.501	1.305	5.23	1.493	291.5
40.827	14.696	1452	3018.3	.501	1.306	5.30	1.496	292.0
60.000	10.00	1325	2955.6	.492	1.313	6.90	1.543	301.2
100.000	6.00	1172	2880.9	.481	1.323	9.82	1.597	311.8
300.000	2.00	890	2748.8	.458	1.344	21.16	1.689	329.7

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TABLE IV. - Continued. THEORETICAL ROCKET PERFORMANCE FOR PRESSURE RATIOS FROM 1 TO 300 FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion from combustion-chamber pressure of 600 lb/sq in. abs.]

(d) Percent fluorine in oxidant by weight, 54.29

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, cal/(g)(°K)	Isentropic exponent, γ	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, lb-sec/lb
r, 1.30; percent fuel, 18.26; O/F, 4.475								
1.000	600.00	3957	3100.6	0.476	1.271	----------	------	------
1.040	576.92	3924	3084.9	.475	1.271	2.444	0.185	36.9
1.515	396.05	3620	2941.1	.471	1.274	1.030	.591	117.8
1.818	330.04	3481	2875.5	.469	1.276	1.000	.702	139.9
2.272	264.03	3316	2798.7	.467	1.278	1.028	.813	162.1
10.000	60.00	2388	2373.6	.448	1.293	2.10	1.261	251.5
20.000	30.00	2037	2218.4	.437	1.302	3.25	1.389	277.1
20.414	29.392	2028	2214.2	.437	1.302	3.30	1.393	277.7
40.000	15.00	1731	2086.2	.426	1.313	5.15	1.490	297.1
40.827	14.696	1723	2082.6	.425	1.313	5.23	1.492	297.6
60.000	10.00	1571	2018.4	.419	1.320	6.79	1.539	306.9
100.000	6.00	1386	1942.0	.409	1.329	9.65	1.592	317.5
300.000	2.00	1049	1807.1	.390	1.351	20.74	1.682	335.5
r, 1.40; percent fuel, 19.40; O/F, 4.156								
1.000	600.00	3917	3238.7	0.488	1.270	----------	------	------
1.040	576.92	3885	3232.9	.487	1.270	2.444	0.185	37.2
1.515	396.15	3585	3077.3	.483	1.273	1.030	.590	118.5
1.817	330.13	3447	3010.9	.481	1.275	1.000	.701	140.8
2.272	264.10	3285	2933.0	.478	1.277	1.028	.813	163.1
10.000	60.00	2366	2502.1	.459	1.292	2.10	1.261	253.2
20.000	30.00	2019	2344.7	.448	1.301	3.25	1.389	278.9
20.414	29.392	2010	2340.5	.448	1.302	3.30	1.393	279.6
40.000	15.00	1716	2210.7	.436	1.312	5.16	1.490	299.1
40.827	14.696	1708	2207.1	.436	1.313	5.23	1.493	299.6
60.000	10.00	1557	2141.9	.429	1.319	6.80	1.539	308.9
100.000	6.00	1374	2064.4	.419	1.329	9.66	1.592	319.7
300.000	2.00	1040	1927.6	.400	1.351	20.76	1.683	337.8
r, 1.50; percent fuel, 20.50; O/F, 3.879								
1.000	600.00	3864	3373.1	0.499	1.270	----------	------	------
1.040	576.92	3832	3357.1	.499	1.270	2.444	0.185	37.3
1.515	396.17	3536	3210.2	.495	1.273	1.030	.590	119.1
1.817	330.14	3400	3143.1	.492	1.275	1.000	.701	141.5
2.272	264.11	3240	3064.5	.490	1.277	1.028	.812	163.9
10.000	60.00	2334	2629.6	.469	1.292	2.10	1.261	254.4
20.000	30.00	1992	2470.8	.458	1.302	3.25	1.389	280.2
20.414	29.392	1982	2466.4	.458	1.302	3.30	1.393	280.9
40.000	15.00	1693	2335.5	.446	1.313	5.16	1.490	300.5
40.827	14.696	1684	2331.8	.445	1.313	5.23	1.493	301.0
60.000	10.00	1536	2266.1	.438	1.320	6.80	1.539	310.4
100.000	6.00	1355	2187.8	.428	1.330	9.66	1.592	321.1
300.000	2.00	1025	2049.9	.408	1.351	20.74	1.682	339.3
r, 1.60; percent fuel, 21.57; O/F, 3.636								
1.000	600.00	3798	3503.9	0.511	1.270	----------	------	------
1.040	576.92	3766	3487.8	.510	1.270	2.444	0.185	37.4
1.515	396.11	3475	3340.0	.505	1.274	1.030	.590	119.4
1.818	330.09	3341	3272.6	.503	1.275	1.000	.702	141.9
2.272	264.07	3184	3193.5	.500	1.277	1.028	.813	164.3
10.000	60.00	2293	2756.4	.479	1.293	2.10	1.261	255.0
20.000	30.00	1955	2596.8	.467	1.303	3.25	1.389	280.9
20.414	29.392	1946	2592.5	.467	1.303	3.30	1.393	281.6
40.000	15.00	1661	2461.0	.454	1.314	5.15	1.490	301.2
40.827	14.696	1653	2457.3	.454	1.314	5.22	1.492	301.8
60.000	10.00	1506	2391.3	.447	1.321	6.78	1.539	311.1
100.000	6.00	1328	2312.8	.436	1.331	9.64	1.592	321.9
300.000	2.00	1004	2174.5	.416	1.353	20.68	1.682	340.1
r, 1.80; percent fuel, 23.63; O/F, 3.232								
1.000	600.00	3628	3755.1	0.531	1.272	----------	------	------
1.040	576.92	3598	3739.0	.531	1.273	2.446	0.185	37.4
1.516	395.76	3317	3590.9	.525	1.276	1.030	.591	119.5
1.819	329.80	3189	3523.5	.523	1.278	1.000	.702	142.0
2.274	263.84	3037	3444.6	.520	1.280	1.028	.813	164.4
10.000	60.00	2181	3008.7	.496	1.297	2.09	1.261	254.8
20.000	30.00	1857	2849.9	.484	1.307	3.24	1.389	280.6
20.414	29.392	1848	2845.6	.483	1.308	3.28	1.392	281.3
40.000	15.00	1574	2715.0	.470	1.319	5.12	1.489	300.8
40.827	14.696	1567	2711.3	.470	1.319	5.19	1.491	301.4
60.000	10.00	1426	2645.9	.462	1.327	6.74	1.537	310.7
100.000	6.00	1256	2568.1	.451	1.337	9.56	1.590	321.4
300.000	2.00	946	2431.4	.431	1.359	20.46	1.679	339.4

TABLE IV. - Continued. THEORETICAL ROCKET PERFORMANCE FOR PRESSURE RATIOS FROM 1 TO 300 FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion from combustion-chamber pressure of 600 lb/sq in. abs.]

(e) Percent fluorine in oxidant by weight, 70.37

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(^oK)}$	Isentropic exponent, γ	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r, 1.40; percent fuel, 17.22; O/F, 4.809								
1.000	600.00	4209	3178.8	0.458	1.294	-------	-------	-------
1.040	576.92	4171	3161.7	.458	1.294	2.459	0.186	38.6
1.527	392.88	3821	3001.9	.454	1.298	1.029	.599	124.1
1.833	327.40	3664	2930.8	.452	1.300	1.000	.709	146.9
2.291	261.92	3480	2847.8	.449	1.302	1.028	.819	169.7
10.000	60.00	2456	2396.3	.431	1.319	2.06	1.260	260.9
20.000	30.00	2073	2233.2	.421	1.329	3.16	1.385	286.8
20.414	29.392	2062	2228.8	.421	1.329	3.20	1.388	287.5
40.000	15.00	1742	2095.8	.410	1.340	4.97	1.482	307.0
40.827	14.696	1733	2092.1	.410	1.341	5.04	1.485	307.5
60.000	10.00	1571	2025.9	.403	1.348	6.51	1.529	316.7
100.000	6.00	1375	1947.6	.395	1.358	9.19	1.580	327.3
300.000	2.00	1022	1811.4	.378	1.381	19.45	1.665	344.9
r, 1.50; percent fuel, 18.22; O/F, 4.488								
1.000	600.00	4157	3299.0	0.469	1.293	-------	-------	-------
1.040	576.92	4120	3281.7	.469	1.293	2.459	0.186	38.8
1.527	393.02	3775	3120.7	.464	1.297	1.029	.599	124.6
1.832	327.52	3620	3049.0	.462	1.299	1.000	.709	147.5
2.290	262.01	3438	2965.3	.460	1.301	1.028	.819	170.4
10.000	60.00	2428	2509.5	.441	1.318	2.06	1.260	262.1
20.000	30.00	2051	2344.8	.431	1.328	3.17	1.385	288.2
20.414	29.392	2040	2340.3	.430	1.328	3.21	1.388	288.8
40.000	15.00	1724	2205.9	.419	1.340	4.97	1.482	308.4
40.827	14.696	1715	2202.2	.419	1.340	5.04	1.485	308.9
60.000	10.00	1554	2135.3	.412	1.347	6.52	1.530	318.2
100.000	6.00	1361	2056.2	.404	1.358	9.20	1.581	328.8
300.000	2.00	1012	1918.5	.386	1.380	19.48	1.666	346.6
r, 1.60; percent fuel, 19.20; O/F, 4.208								
1.000	600.00	4091	3416.3	0.480	1.292	-------	-------	-------
1.040	576.92	4055	3398.9	.479	1.293	2.458	0.186	38.8
1.526	393.08	3716	3237.2	.475	1.296	1.029	.599	124.8
1.832	327.57	3564	3165.1	.473	1.298	1.000	.709	147.8
2.290	262.05	3386	3080.9	.470	1.300	1.028	.819	170.8
10.000	60.00	2392	2622.7	.451	1.317	2.06	1.260	262.8
20.000	30.00	2020	2457.0	.440	1.328	3.17	1.385	288.9
20.414	29.392	2010	2452.5	.439	1.328	3.21	1.388	289.6
40.000	15.00	1698	2317.4	.428	1.340	4.97	1.482	309.2
40.827	14.696	1689	2313.6	.428	1.340	5.04	1.485	309.8
60.000	10.00	1531	2246.4	.421	1.348	6.52	1.530	319.1
100.000	6.00	1340	2166.9	.412	1.358	9.20	1.581	329.7
300.000	2.00	996	2028.4	.394	1.380	19.48	1.666	347.5
r, 1.70; percent fuel, 20.16; O/F, 3.960								
1.000	600.00	4014	3530.8	0.490	1.292	-------	-------	-------
1.040	576.92	3979	3513.4	.489	1.293	2.458	0.186	38.9
1.526	393.07	3646	3351.4	.485	1.296	1.029	.599	124.9
1.832	327.56	3497	3279.2	.482	1.298	1.000	.709	148.0
2.290	262.05	3322	3194.9	.480	1.300	1.028	.819	171.0
10.000	60.00	2346	2735.9	.459	1.318	2.06	1.260	263.0
20.000	30.00	1981	2570.1	.448	1.328	3.16	1.385	289.1
20.414	29.392	1971	2565.6	.448	1.329	3.21	1.388	289.8
40.000	15.00	1665	2430.3	.436	1.341	4.97	1.482	309.4
40.827	14.696	1656	2426.6	.436	1.341	5.04	1.485	310.0
60.000	10.00	1501	2359.2	.429	1.349	6.51	1.529	319.3
100.000	6.00	1313	2279.7	.419	1.359	9.19	1.581	329.9
300.000	2.00	976	2141.2	.402	1.381	19.45	1.666	347.7

TABLE IV. - Continued. THEORETICAL ROCKET PERFORMANCE FOR PRESSURE RATIOS FROM 1 TO 300 FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion from combustion-chamber pressure of 600 lb/sq in. abs.]

(f) Percent fluorine in oxidant by weight, 78.08

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(^\circ K)}$	Isentropic exponent, γ	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r, 1.55; percent fuel, 17.55; O/F, 4.697								
1.000	600.00	4333	3317.5	0.460	1.303	-------	-------	-------
1.040	576.92	4293	3299.4	.459	1.303	2.465	0.187	39.7
1.532	391.68	3922	3129.4	.455	1.307	1.029	.602	127.9
1.838	326.40	3757	3054.6	.453	1.309	1.000	.712	151.2
2.298	261.12	3564	2967.3	.450	1.311	1.027	.822	174.6
10.000	60.00	2496	2495.3	.433	1.328	2.04	1.259	267.5
20.000	30.00	2099	2325.4	.423	1.339	3.13	1.383	293.8
20.414	29.392	2088	2320.8	.422	1.339	3.17	1.387	294.5
40.000	15.00	1758	2182.8	.412	1.351	4.90	1.479	314.2
40.827	14.696	1748	2179.0	.411	1.351	4.97	1.482	314.7
60.000	10.00	1581	2110.6	.405	1.359	6.41	1.526	324.1
100.000	6.00	1379	2029.8	.396	1.369	9.02	1.576	334.7
300.000	2.00	1019	1889.9	.380	1.392	18.99	1.659	352.4
r, 1.60; percent fuel, 18.02; O/F, 4.551								
1.000	600.00	4298	3372.4	0.465	1.303	-------	-------	-------
1.040	576.92	4259	3354.3	.464	1.303	2.465	0.187	39.7
1.532	391.72	3891	3184.0	.460	1.307	1.029	.602	128.0
1.838	326.43	3728	3109.0	.458	1.309	1.000	.712	151.4
2.298	261.15	3536	3021.5	.455	1.311	1.027	.822	174.7
10.000	60.00	2477	2548.3	.437	1.328	2.04	1.259	267.8
20.000	30.00	2083	2378.0	.427	1.339	3.13	1.383	294.2
20.414	29.392	2073	2373.4	.427	1.339	3.17	1.387	294.8
40.000	15.00	1744	2235.1	.416	1.351	4.90	1.479	314.6
40.827	14.696	1735	2231.2	.415	1.351	4.97	1.482	315.1
60.000	10.00	1569	2162.6	.409	1.359	6.41	1.526	324.5
100.000	6.00	1369	2081.7	.400	1.369	9.02	1.576	335.1
300.000	2.00	1011	1941.4	.384	1.392	18.99	1.659	352.9
r, 1.65; percent fuel, 18.48; O/F, 4.413								
1.000	600.00	4228	3426.7	0.470	1.300	-------	-------	-------
1.040	576.92	4190	3408.8	.470	1.301	2.463	0.187	39.5
1.530	392.03	3831	3240.7	.465	1.304	1.029	.601	127.2
1.837	326.69	3671	3166.5	.463	1.306	1.000	.711	150.5
2.296	261.36	3483	3079.9	.460	1.308	1.027	.821	173.7
10.000	60.00	2445	2610.7	.442	1.326	2.05	1.259	266.5
20.000	30.00	2058	2441.7	.431	1.336	3.14	1.384	292.8
20.414	29.392	2047	2437.2	.431	1.337	3.18	1.387	293.4
40.000	15.00	1724	2299.8	.420	1.349	4.92	1.480	313.1
40.827	14.696	1715	2295.9	.420	1.349	4.98	1.483	313.7
60.000	10.00	1551	2227.7	.413	1.357	6.43	1.527	323.0
100.000	6.00	1354	2147.3	.404	1.367	9.06	1.577	333.7
300.000	2.00	1002	2007.7	.387	1.389	19.09	1.661	351.4

(g) Percent fluorine in oxidant by weight, 79.87

r, 1.48; percent fuel, 16.66; O/F, 5.003								
1.000	600.00	4418	3232.1	0.450	1.305	-------	-------	-------
1.040	576.92	4377	3213.9	.449	1.306	2.467	0.187	39.7
1.533	391.36	3995	3043.1	.445	1.310	1.028	.603	128.2
1.840	326.13	3826	2968.2	.443	1.311	1.000	.713	151.5
2.300	260.91	3628	2880.7	.441	1.314	1.027	.823	174.9
10.000	60.00	2537	2408.6	.423	1.331	2.04	1.259	267.7
20.000	30.00	2131	2238.7	.414	1.341	3.12	1.383	294.0
20.414	29.392	2120	2234.2	.413	1.341	3.16	1.386	294.7
40.000	15.00	1783	2096.4	.403	1.353	4.88	1.479	314.4
40.827	14.696	1774	2092.5	.403	1.353	4.95	1.481	314.9
60.000	10.00	1603	2024.2	.397	1.361	6.39	1.525	324.2
100.000	6.00	1398	1943.7	.388	1.371	8.99	1.575	334.8
300.000	2.00	1031	1804.3	.372	1.394	18.89	1.658	352.5
r, 1.51; percent fuel, 16.94; O/F, 4.904								
1.000	600.00	4402	3265.2	0.453	1.305	-------	-------	-------
1.040	576.92	4362	3247.0	.452	1.305	2.466	0.187	39.8
1.533	391.41	3981	3075.9	.448	1.309	1.028	.603	128.3
1.840	326.17	3813	3000.7	.446	1.311	1.000	.713	151.7
2.300	260.94	3616	2913.0	.444	1.313	1.027	.822	175.1
10.000	60.00	2529	2439.6	.426	1.330	2.04	1.259	268.0
20.000	30.00	2125	2269.3	.416	1.341	3.12	1.383	294.4
20.414	29.392	2114	2264.7	.416	1.341	3.16	1.386	295.0
40.000	15.00	1778	2126.5	.406	1.353	4.89	1.479	314.8
40.827	14.696	1768	2122.7	.405	1.353	4.95	1.481	315.3
60.000	10.00	1598	2054.2	.399	1.361	6.39	1.525	324.6
100.000	6.00	1394	1973.4	.391	1.371	8.99	1.575	335.3
300.000	2.00	1028	1833.6	.375	1.394	18.90	1.688	352.9
r, 1.55; percent fuel, 17.31; O/F, 4.777								
1.000	600.00	4351	3309.0	0.457	1.303	-------	-------	-------
1.040	576.92	4312	3290.9	.457	1.303	2.465	0.187	39.6
1.532	391.67	3939	3121.3	.452	1.307	1.028	.602	127.8
1.838	326.39	3773	3046.6	.450	1.309	1.000	.712	151.1
2.298	261.11	3579	2959.4	.448	1.311	1.027	.822	174.4
10.000	60.00	2507	2488.3	.430	1.328	2.04	1.259	267.2
20.000	30.00	2108	2318.7	.420	1.339	3.13	1.383	293.5
20.414	29.392	2097	2314.2	.420	1.339	3.17	1.387	294.2
40.000	15.00	1765	2176.4	.409	1.351	4.90	1.479	313.9
40.827	14.696	1755	2172.6	.409	1.351	4.97	1.482	314.4
60.000	10.00	1587	2104.3	.402	1.359	6.41	1.526	323.8
100.000	6.00	1385	2023.7	.394	1.369	9.02	1.576	334.4
300.000	2.00	1023	1884.1	.378	1.392	18.99	1.659	352.1

TABLE IV. - Continued. THEORETICAL ROCKET PERFORMANCE FOR PRESSURE RATIOS FROM 1 TO 300 FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion from combustion-chamber pressure of 600 lb/sq in. abs.]

(h) Percent fluorine in oxidant by weight, 80.15

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(^\circ K)}$	Isentropic exponent, γ	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{lb\text{-}sec}{lb}$
r, 1.46; percent fuel, 16.40; O/F, 5.098								
1.000	600.00	4440	3207.7	0.447	1.306	-------	-------	-------
1.040	576.92	4399	3189.5	.446	1.307	2.467	0.187	39.7
1.534	391.25	4015	3018.6	.442	1.310	1.028	.603	128.3
1.840	326.05	3844	2943.6	.440	1.312	1.000	.713	151.6
2.300	260.84	3645	2856.2	.438	1.314	1.027	.823	174.9
10.000	60.00	2547	2384.3	.421	1.331	2.04	1.259	267.7
20.000	30.00	2139	2214.6	.411	1.342	3.12	1.383	294.0
20.414	29.392	2128	2210.1	.411	1.342	3.16	1.386	294.6
40.000	15.00	1789	2072.4	.401	1.354	4.88	1.479	314.5
40.827	14.696	1780	2068.6	.400	1.354	4.94	1.481	314.8
60.000	10.00	1608	2000.4	.394	1.362	6.38	1.525	324.1
100.000	6.00	1402	1920.0	.386	1.372	8.97	1.575	334.7
300.000	2.00	1034	1780.9	.370	1.395	18.86	1.658	352.4
r, 1.48; percent fuel, 16.59; O/F, 5.029								
1.000	600.00	4431	3229.8	0.449	1.306	-------	-------	-------
1.040	576.92	4390	3211.6	.448	1.306	2.467	0.187	39.8
1.533	391.29	4007	3040.4	.444	1.310	1.028	.603	128.4
1.840	326.08	3837	2965.3	.442	1.312	1.000	.713	151.7
2.300	260.86	3638	2877.6	.440	1.314	1.027	.823	175.1
10.000	60.00	2543	2404.7	.428	1.331	2.04	1.259	267.9
20.000	30.00	2136	2234.7	.413	1.341	3.12	1.383	294.3
20.414	29.392	2125	2230.1	.413	1.342	3.16	1.386	294.9
40.000	15.00	1786	2092.1	.402	1.354	4.88	1.479	314.6
40.827	14.696	1777	2088.3	.402	1.354	4.95	1.481	315.2
60.000	10.00	1606	2019.9	.396	1.361	6.38	1.525	324.5
100.000	6.00	1400	1939.3	.388	1.372	8.98	1.575	335.1
300.000	2.00	1033	1799.8	.372	1.394	18.87	1.658	352.7
r, 1.50; percent fuel, 16.77; O/F, 4.982								
1.000	600.00	4408	3251.8	0.451	1.305	-------	-------	-------
1.040	576.92	4368	3233.7	.450	1.305	2.466	0.187	39.7
1.533	391.40	3987	3063.0	.446	1.309	1.028	.603	128.2
1.840	326.17	3819	2988.1	.444	1.311	1.000	.713	151.5
2.299	260.94	3621	2900.7	.442	1.313	1.027	.822	174.8
10.000	60.00	2533	2428.6	.424	1.330	2.04	1.259	267.6
20.000	30.00	2128	2258.8	.415	1.341	3.12	1.383	293.9
20.414	29.392	2117	2254.2	.414	1.341	3.16	1.386	294.6
40.000	15.00	1780	2116.4	.404	1.353	4.89	1.479	314.5
40.827	14.696	1771	2112.6	.404	1.353	4.95	1.481	314.8
60.000	10.00	1600	2044.3	.398	1.361	6.39	1.525	324.1
100.000	6.00	1396	1963.8	.389	1.371	8.99	1.575	334.8
300.000	2.00	1030	1824.3	.373	1.394	18.91	1.658	352.4

(i) Percent fluorine in oxidant by weight, 81.46

r, 1.38; percent fuel, 15.45; O/F, 5.471								
1.000	600.00	4498	3113.3	0.436	1.309	-------	-------	-------
1.040	576.92	4456	3095.2	.435	1.309	2.469	0.187	39.6
1.535	390.88	4063	2924.8	.431	1.313	1.028	.604	128.1
1.842	325.74	3890	2850.3	.429	1.315	1.000	.714	151.3
2.302	260.59	3687	2763.3	.427	1.317	1.027	.824	174.5
10.000	60.00	2570	2295.3	.410	1.334	2.03	1.259	266.8
20.000	30.00	2157	2127.2	.401	1.345	3.11	1.382	292.9
20.414	29.392	2148	2122.7	.401	1.345	3.15	1.386	293.6
40.000	15.00	1809	1990.1	.392	1.356	4.87	1.475	312.6
40.827	14.696	1800	1986.3	.391	1.356	4.95	1.478	313.2
60.000	10.00	1622	1917.8	.385	1.364	6.37	1.522	322.5
100.000	6.00	1413	1836.5	.377	1.375	8.95	1.573	333.3
300.000	2.00	1041	1698.8	.362	1.397	18.99	1.656	350.8
r, 1.40; percent fuel, 15.64; O/F, 5.393								
1.000	600.00	4493	3135.6	0.438	1.308	-------	-------	-------
1.040	576.92	4452	3117.4	.437	1.309	2.469	0.187	39.7
1.535	390.93	4060	2946.6	.433	1.313	1.028	.604	128.2
1.842	325.78	3887	2871.8	.431	1.315	1.000	.714	151.5
2.302	260.62	3684	2784.6	.429	1.317	1.027	.823	174.8
10.000	60.00	2569	2315.0	.418	1.334	2.04	1.259	267.2
20.000	30.00	2156	2146.3	.403	1.344	3.11	1.382	293.4
20.414	29.392	2145	2141.7	.403	1.344	3.15	1.386	294.1
40.000	15.00	1801	2005.0	.393	1.356	4.86	1.478	313.6
40.827	14.696	1792	2001.2	.393	1.357	4.93	1.480	314.2
60.000	10.00	1618	1933.5	.387	1.364	6.35	1.524	323.4
100.000	6.00	1410	1883.7	.379	1.375	8.93	1.574	334.0
300.000	2.00	1038	1715.8	.363	1.397	18.76	1.656	351.5
r, 1.42; percent fuel, 15.83; O/F, 5.317								
1.000	600.00	4476	3157.7	0.440	1.308	-------	-------	-------
1.040	576.92	4435	3139.6	.440	1.308	2.468	0.187	39.7
1.534	391.06	4045	2969.1	.435	1.312	1.028	.604	128.1
1.841	325.88	3873	2894.4	.433	1.314	1.000	.714	151.4
2.301	260.71	3672	2807.3	.431	1.316	1.027	.823	174.6
10.000	60.00	2563	2337.8	.414	1.333	2.04	1.259	267.1
20.000	30.00	2151	2169.0	.405	1.343	3.11	1.383	293.3
20.414	29.392	2140	2164.5	.405	1.344	3.15	1.386	294.0
40.000	15.00	1798	2027.7	.395	1.355	4.87	1.478	313.6
40.827	14.696	1788	2023.9	.395	1.356	4.93	1.481	314.1
60.000	10.00	1618	1956.1	.389	1.363	6.36	1.524	323.3
100.000	6.00	1408	1876.3	.380	1.374	8.95	1.574	333.9
300.000	2.00	1037	1738.8	.365	1.396	18.80	1.657	351.4

TABLE IV. - Concluded. THEORETICAL ROCKET PERFORMANCE FOR PRESSURE RATIOS FROM 1 TO 300 FOR LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES

[Frozen composition assumed during isentropic expansion from combustion-chamber pressure of 600 lb/sq in. abs.]

(j) Percent fluorine in oxidant by weight, 82.61

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, cal/(g)(°K)	Isentropic exponent, γ	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, lb-sec/lb
r, 1.30; percent fuel, 14.53; O/F, 5.882								
1.000	600.00	4527	3019.9	0.425	1.312	---	---	---
1.040	576.92	4485	3002.0	.425	1.313	2.471	0.187	39.4
1.537	390.44	4085	2832.9	.420	1.317	1.028	.606	127.5
1.844	325.37	3910	2759.2	.419	1.319	1.000	.715	150.6
2.305	260.29	3704	2673.4	.416	1.321	1.027	.824	173.6
10.000	60.00	2576	2212.0	.400	1.338	8.03	1.259	265.1
20.000	30.00	2158	2046.5	.392	1.348	3.10	1.382	291.0
20.414	29.392	2147	2042.0	.391	1.348	3.14	1.385	291.7
40.000	15.00	1800	1908.1	.382	1.360	4.84	1.477	311.0
40.827	14.696	1791	1904.4	.381	1.361	4.90	1.479	311.5
60.000	10.00	1616	1838.1	.376	1.368	6.31	1.523	320.7
100.000	6.00	1406	1760.2	.368	1.379	8.87	1.572	331.1
300.000	2.00	1033	1625.6	.353	1.401	18.58	1.654	348.3
r, 1.333; percent fuel, 14.85; O/F, 5.735								
1.000	600.00	4528	3057.2	0.429	1.311	---	---	---
1.040	576.92	4486	3039.2	.428	1.312	2.470	0.187	39.6
1.536	390.57	4087	2869.2	.424	1.316	1.028	.605	127.9
1.843	325.47	3911	2795.0	.422	1.318	1.000	.715	151.0
2.304	260.38	3706	2708.6	.420	1.320	1.027	.824	174.2
10.000	60.00	2579	2243.8	.404	1.337	8.03	1.259	266.0
20.000	30.00	2162	2077.0	.395	1.347	3.10	1.382	292.0
20.414	29.392	2150	2072.5	.395	1.347	3.14	1.385	292.7
40.000	15.00	1804	1937.5	.385	1.359	4.84	1.477	312.1
40.827	14.696	1794	1933.8	.385	1.360	4.91	1.480	312.7
60.000	10.00	1620	1867.0	.379	1.367	6.32	1.523	321.8
100.000	6.00	1410	1788.3	.371	1.378	8.89	1.572	332.3
300.000	2.00	1036	1652.6	.356	1.400	18.63	1.654	349.6
r, 1.40; percent fuel, 15.48; O/F, 5.462								
1.000	600.00	4480	3131.0	0.436	1.307	---	---	---
1.040	576.92	4438	3113.1	.436	1.307	2.467	0.187	39.5
1.534	391.16	4049	2944.3	.431	1.311	1.028	.604	127.4
1.841	325.97	3877	2870.3	.430	1.313	1.000	.713	150.6
2.301	260.77	3676	2784.1	.427	1.315	1.027	.823	173.7
10.000	60.00	2567	2318.9	.411	1.332	2.04	1.259	265.8
20.000	30.00	2156	2151.6	.402	1.342	3.12	1.383	291.9
20.414	29.392	2144	2147.1	.401	1.343	3.16	1.386	292.6
40.000	15.00	1802	2011.5	.391	1.354	4.87	1.478	312.1
40.827	14.696	1793	2007.7	.391	1.355	4.94	1.481	312.6
60.000	10.00	1620	1940.5	.385	1.362	6.37	1.525	321.9
100.000	6.00	1412	1861.3	.377	1.373	8.96	1.574	332.4
300.000	2.00	1041	1724.3	.362	1.395	18.83	1.657	349.9
r, 1.50; percent fuel, 16.40; O/F, 5.098								
1.000	600.00	4395	3239.7	0.448	1.300	---	---	---
1.040	576.92	4356	3221.9	.448	1.300	2.463	0.187	39.3
1.530	392.08	3982	3055.7	.443	1.304	1.029	.601	126.5
1.836	326.74	3816	2982.2	.441	1.306	1.000	.711	149.7
2.295	261.39	3622	2896.5	.439	1.308	1.027	.821	172.8
10.000	60.00	2543	2432.0	.421	1.325	2.05	1.259	265.1
20.000	30.00	2142	2264.6	.412	1.335	3.14	1.384	291.3
20.414	29.392	2131	2260.1	.412	1.335	3.18	1.387	291.9
40.000	15.00	1796	2124.0	.401	1.347	4.92	1.480	311.6
40.827	14.696	1786	2120.2	.401	1.347	4.99	1.483	312.1
60.000	10.00	1616	2052.5	.395	1.354	6.44	1.527	321.4
100.000	6.00	1412	1972.7	.387	1.365	9.08	1.577	332.0
300.000	2.00	1046	1834.1	.371	1.387	19.16	1.662	349.7

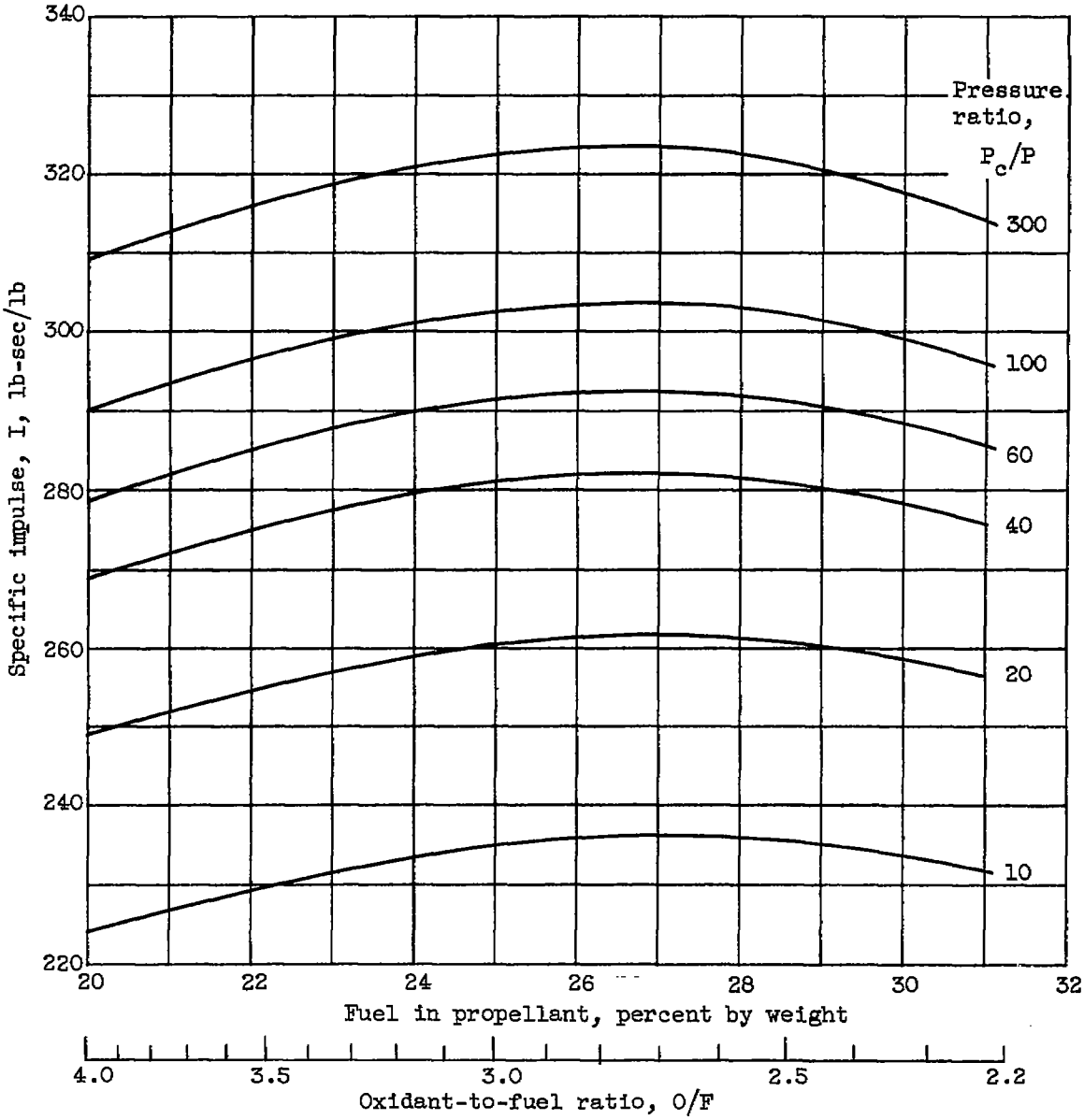
TABLE V. - EQUILIBRIUM COMPOSITION IN COMBUSTION CHAMBER FOR LIQUID METHANE WITH SEVERAL MIXTURES OF FLUORINE AND OXYGEN

Equivalence ratio, r, $\frac{4(C)+(H)}{2(O)+(F)}$	Fuel, percent by weight	Oxidant-to-fuel weight ratio, O/F	Equilibrium composition (mole fraction[a])															
			C	CF	CF_2	CF_3	C_2F_2	CO	CO_2	F	F_2	H	H_2	HF	H_2O	O	O_2	OH
Percent fluorine in oxidant, 0 (100 percent oxygen)																		
1.00	20.04	3.990						0.13640	0.14731			0.02123	0.05398		0.46666	0.02138	0.07074	0.08027
1.50	24.58	3.069						.21085	.10377			.02790	.11914		.47275	.00747	.01153	.04680
1.40	25.98	2.850						.23183	.08878			.02648	.15088		.46075	.00385	.00482	.03270
1.50	27.32	2.660						.24986	.07514			.02292	.18712		.44122	.00174	.00158	.02041
1.60	28.62	2.493						.26451	.06355			.01799	.22588		.41557	.00065	.00046	.01141
1.80	31.09	2.216						.28462	.04692			.00849	.30191		.35538	.00006	.00005	.00269
Percent fluorine in oxidant by weight, 19.19																		
1.20	21.10	5.740						0.18552	0.08841	0.00134		0.03490	0.08425	0.18468	0.33151	0.01786	0.02688	0.06454
1.40	25.78	3.208						.22241	.06792	.00072		.03650	.13566	.15009	.33333	.00749	.00714	.04074
1.50	28.05	2.992						.23827	.05818	.00048		.03410	.16475	.14526	.32607	.00405	.00305	.02878
1.60	28.28	2.805						.25190	.04948	.00029		.02970	.19900	.13670	.31122	.00192	.00115	.01865
1.80	28.82	2.493						.27257	.03598	.00008		.01821	.27038	.12460	.27190	.00050	.00012	.00618
Percent fluorine in oxidant by weight, 37.25																		
1.30	20.35	5.913						0.19828	0.06397	0.00364		0.04755	0.09144	0.30680	0.20844	0.01874	0.01634	0.06482
1.50	22.77	5.391						.22865	.04105	.00195		.04784	.14104	.28358	.21148	.00775	.00445	.03427
1.60	23.93	3.179						.23877	.03508	.00132		.04464	.17091	.27252	.20588	.00431	.00199	.02480
1.70	25.05	2.992						.24934	.02974	.00084		.03951	.20304	.26183	.19821	.00218	.00081	.01851
1.90	27.19	2.677						.26603	.02130	.00029		.02849	.26902	.24168	.18848	.00043	.00010	.00620
Percent fluorine in oxidant by weight, 54.29																		
1.30	18.26	4.475						0.19147	0.03170	0.01100		0.06088	0.08984	0.44878	0.09860	0.02700	0.01459	0.04615
1.40	19.40	4.156						.20375	.02795	.00841		.06490	.08988	.43266	.10456	.01902	.00848	.04112
1.50	20.50	3.879						.21512	.02418	.00624		.06529	.11264	.41915	.10709	.01252	.00456	.03525
1.60	21.57	3.638						.22556	.02053	.00447		.06386	.13862	.40567	.10613	.00762	.00225	.02651
1.80	23.63	3.252						.24537	.01411	.00205		.05410	.19751	.37940	.09458	.00223	.00041	.01225
Percent fluorine in oxidant by weight, 70.37																		
1.40	17.22	4.809						0.19458	0.01018	0.02882		0.08194	0.05458	0.55515	0.02473	0.02197	0.00382	0.02525
1.50	18.22	4.488						.20396	.00826	.02211		.08759	.07558	.54388	.02577	.01414	.00160	.01878
1.60	19.20	4.208						.21271	.00638	.01603		.08982	.09579	.53169	.02475	.00825	.00061	.01381
1.70	20.16	3.960						.22076	.00496	.01134		.08856	.12104	.51882	.02143	.00422	.00029	.00901
Percent fluorine in oxidant by weight, 78.08																		
1.55	17.55	4.887						0.20269	0.00068	0.04108		0.10250	0.05844	0.58573	0.00171	0.00216	0.00002	0.00197
1.60	18.02	4.551	0.00011	0.00006				.20643	.00002	.05490		.10818	.06815	.58496	.00006	.00006		.00005
1.65	18.48	4.415	.00186	.00154	0.00003		0.00157	.20444		.02712		.10215	.07975	.58170				
Percent fluorine in oxidant by weight, 78.67																		
1.48	18.88	5.005	0.00001	0.00001				0.19577	0.00038	0.06005		0.09820	0.04187	0.60618	0.00071	0.00186	0.00001	0.00114
1.51	18.84	4.904	.00015	.00012			0.00001	.19799	.00002	.05492		.10108	.04844	.58907	.00004	.00009		.00006
1.55	17.31	4.777	.00178	.00141	0.00004		.00103	.19648		.04566		.10087	.05351	.59818		.00001		
Percent fluorine in oxidant by weight, 80.15																		
1.48	18.40	5.068	0.00001	0.00002				0.19373	0.00028	0.06874		0.09823	0.03774	0.60266	0.00047	0.00130	0.00001	0.00082
1.48	18.59	5.029	.00009	.00008				.19526	.00004	.06305		.09845	.04054	.60215	.00007	.00017		.00011
1.50	18.77	4.982	.00101	.00065	0.00003		0.00029	.19473		.05785		.09878	.04357	.60286	.00001	.00001		.00001
Percent fluorine in oxidant by weight, 81.46																		
1.38	15.45	5.471	0.00001	0.00001				0.18580	0.00029	0.09326		0.08535	0.02526	0.60710	0.00035	0.00172	0.00001	0.00062
1.40	15.64	5.393	.00007	.00007				.18747	.00006	.08877		.08835	.02758	.60727	.00007	.00032		.00016
1.42	15.83	5.317	.00059	.00046	0.00003		0.00023	.18721		.08252		.08970	.02959	.60691	.00001	.00002		.00001
Percent fluorine in oxidant by weight, 82.81																		
1.30	14.53	5.882	0.00001	0.00001				0.17758	0.00041	0.12373	0.00001	0.07130	0.01628	0.60854	0.00033	0.00277	0.00002	0.00103
1.333	14.85	5.735	.00014	.00016	0.00001		0.00001	.18043	.00003	.11488	.00001	.07703	.01898	.60805	.00003	.00019		.00008
1.40	15.48	5.482	.00238	.00253	.00010	0.00001	.00196	.17829		.09102		.08504	.02518	.61530		.00001		
1.50	16.40	5.098	.00484	.00397	.00013	.00001	.00875	.17476		.06181		.09075	.02811	.61948				

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

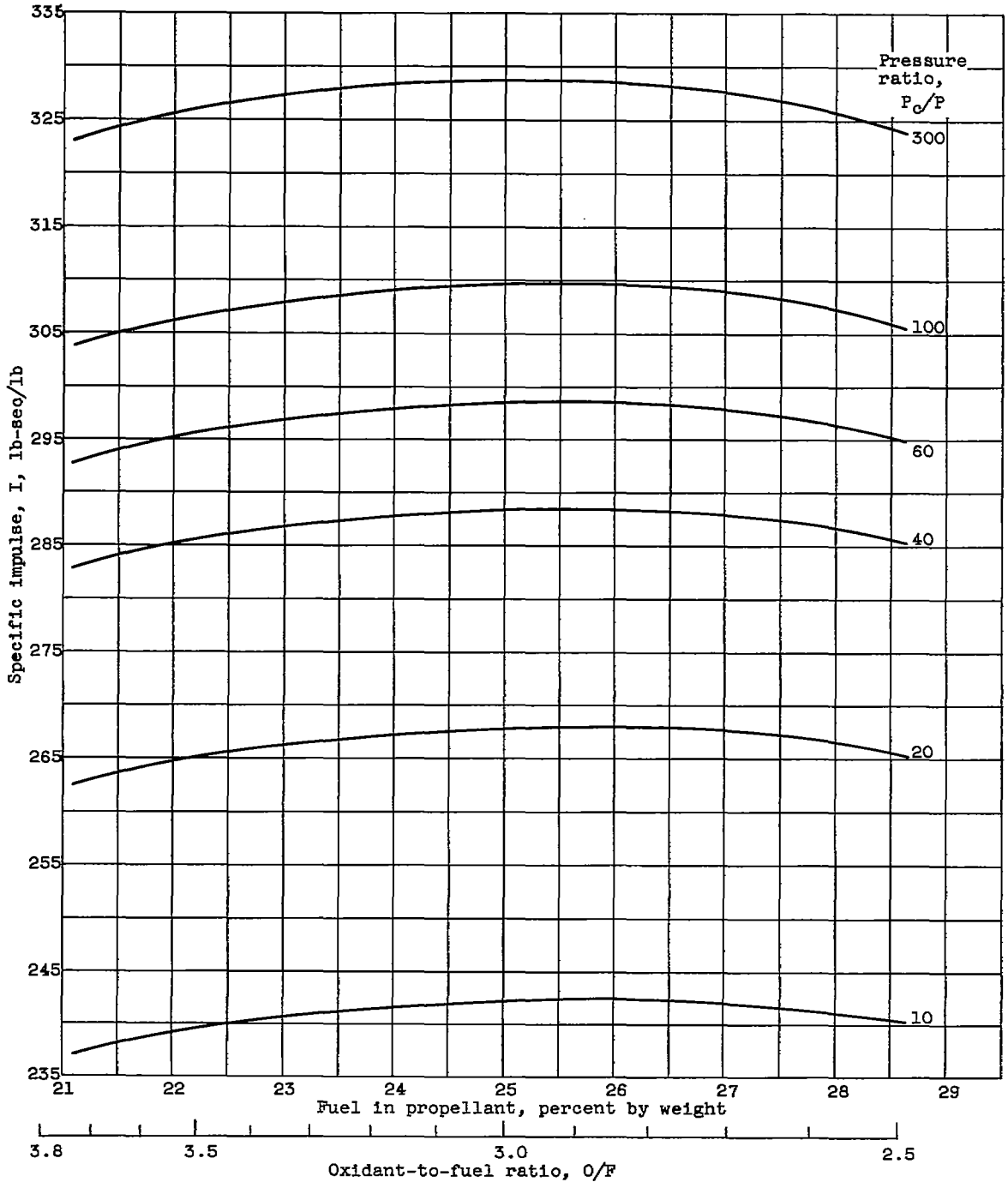
TABLE VI. - THEORETICAL ROCKET PERFORMANCE FOR EXPANSION TO EXIT PRESSURE OF 1 ATMOSPHERE FOR LIQUID METHANE WITH SEVERAL MIXTURES OF FLUORINE AND OXYGEN

Equivalence ratio, $r_a = \frac{4(C) + (H)}{2(O) + (F)}$	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	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, lb-sec/lb
Percent fluorine in oxidant, O (100 percent oxygen)								
1.00	20.04	3.990	3497	1827	5700	5.91	1.520	269.3
1.30	24.58	3.069	3444	1768	5959	5.84	1.517	281.0
1.40	25.98	2.850	3372	1713	5998	5.80	1.516	282.6
1.50	27.32	2.660	3272	1641	6011	5.75	1.514	282.8
1.60	28.62	2.493	3147	1554	5996	5.68	1.511	281.6
1.80	31.09	2.216	2855	1360	5901	5.54	1.505	276.1
Percent fluorine in oxidant by weight, 19.19								
1.20	21.10	3.740	3622	1777	6036	5.66	1.510	283.3
1.40	23.78	3.206	3536	1718	6145	5.63	1.509	288.1
1.50	25.05	2.992	3460	1667	6169	5.59	1.507	289.0
1.60	26.28	2.805	3362	1604	6172	5.55	1.506	288.8
1.80	28.62	2.493	3119	1450	6118	5.46	1.502	285.6
Percent fluorine in oxidant by weight, 37.25								
1.30	20.35	3.913	3753	1735	6248	5.44	1.501	291.5
1.50	22.77	3.391	3650	1678	6324	5.42	1.500	294.9
1.60	23.93	3.179	3572	1633	6336	5.40	1.499	295.3
1.70	25.05	2.992	3479	1579	6333	5.37	1.498	294.9
1.90	27.19	2.677	3258	1452	6282	5.30	1.496	292.0
Percent fluorine in oxidant by weight, 54.29								
1.30	18.26	4.475	3957	1723	6416	5.23	1.492	297.6
1.40	19.40	4.156	3917	1708	6459	5.23	1.493	299.6
1.50	20.50	3.879	3864	1684	6489	5.23	1.493	301.0
1.60	21.57	3.636	3798	1653	6506	5.22	1.492	301.8
1.80	23.63	3.232	3628	1567	6503	5.19	1.491	301.4
Percent fluorine in oxidant by weight, 70.37								
1.40	17.22	4.809	4209	1733	6664	5.04	1.485	307.5
1.50	18.22	4.488	4157	1715	6694	5.04	1.485	308.9
1.60	19.20	4.208	4091	1689	6711	5.04	1.485	309.8
1.70	20.16	3.960	4014	1656	6717	5.04	1.485	310.0
Percent fluorine in oxidant by weight, 78.08								
1.55	17.55	4.697	4333	1748	6833	4.97	1.482	314.7
1.60	18.02	4.551	4298	1735	6841	4.97	1.482	315.1
1.65	18.48	4.413	4228	1715	6807	4.98	1.483	313.7
Percent fluorine in oxidant by weight, 79.67								
1.48	16.66	5.003	4418	1774	6840	4.95	1.481	314.9
1.51	16.94	4.904	4402	1768	6848	4.95	1.481	315.3
1.55	17.31	4.777	4351	1755	6827	4.97	1.482	314.4
Percent fluorine in oxidant by weight, 80.15								
1.46	16.40	5.098	4440	1780	6839	4.94	1.481	314.8
1.48	16.59	5.029	4431	1777	6846	4.95	1.481	315.2
1.50	16.77	4.962	4408	1771	6838	4.95	1.481	314.8
Percent fluorine in oxidant by weight, 81.46								
1.38	15.45	5.471	4498	1803	6817	4.96	1.479	313.5
1.40	15.64	5.393	4493	1792	6828	4.93	1.480	314.2
1.42	15.83	5.317	4476	1788	6825	4.93	1.481	314.1
Percent fluorine in oxidant by weight, 82.61								
1.30	14.53	5.882	4527	1791	6776	4.90	1.479	311.5
1.333	14.85	5.735	4528	1794	6799	4.91	1.480	312.7
1.40	15.48	5.462	4480	1793	6793	4.94	1.481	312.6
1.50	16.40	5.098	4395	1786	6772	4.99	1.483	312.1



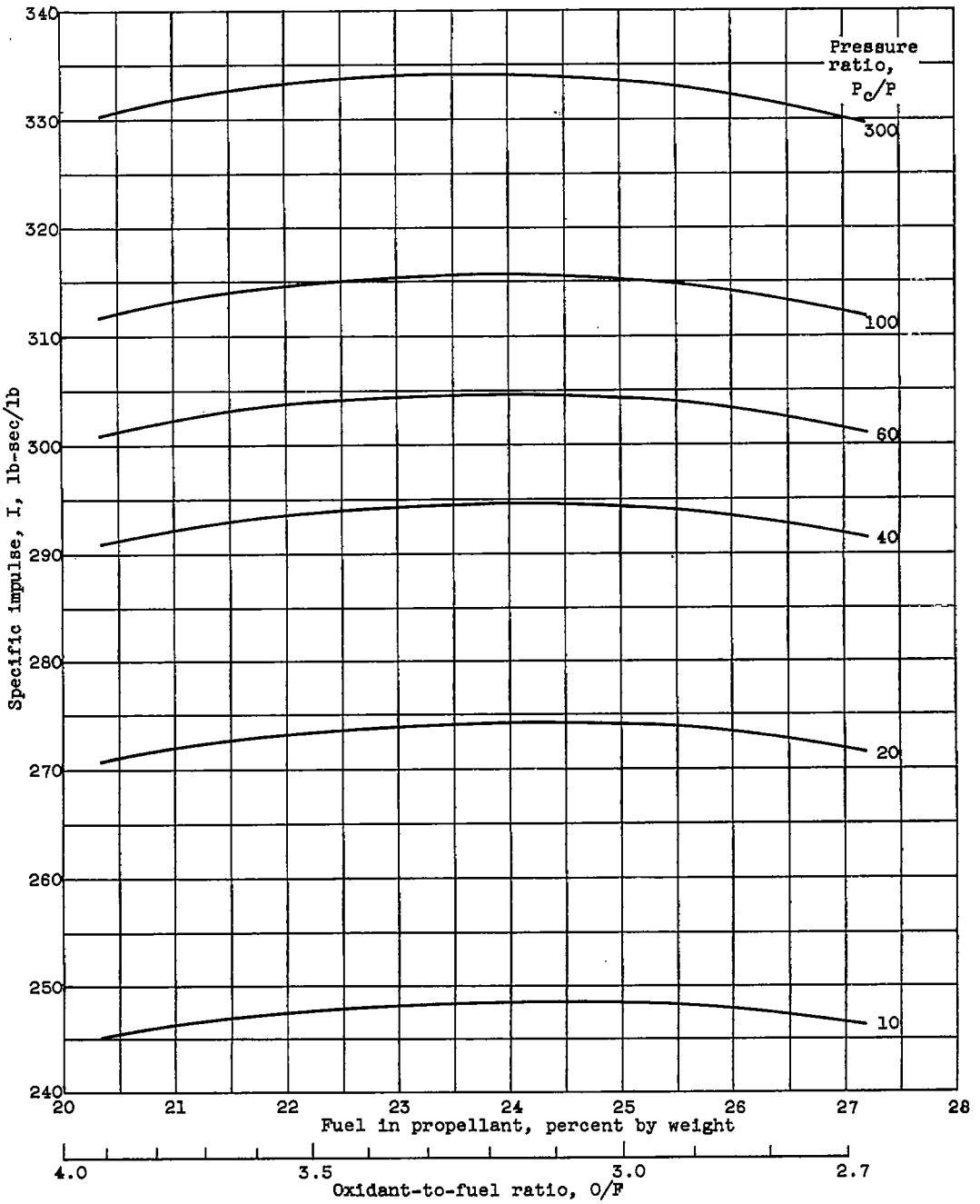
(a) Percent fluorine in oxidant by weight, O (100 percent oxygen).

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



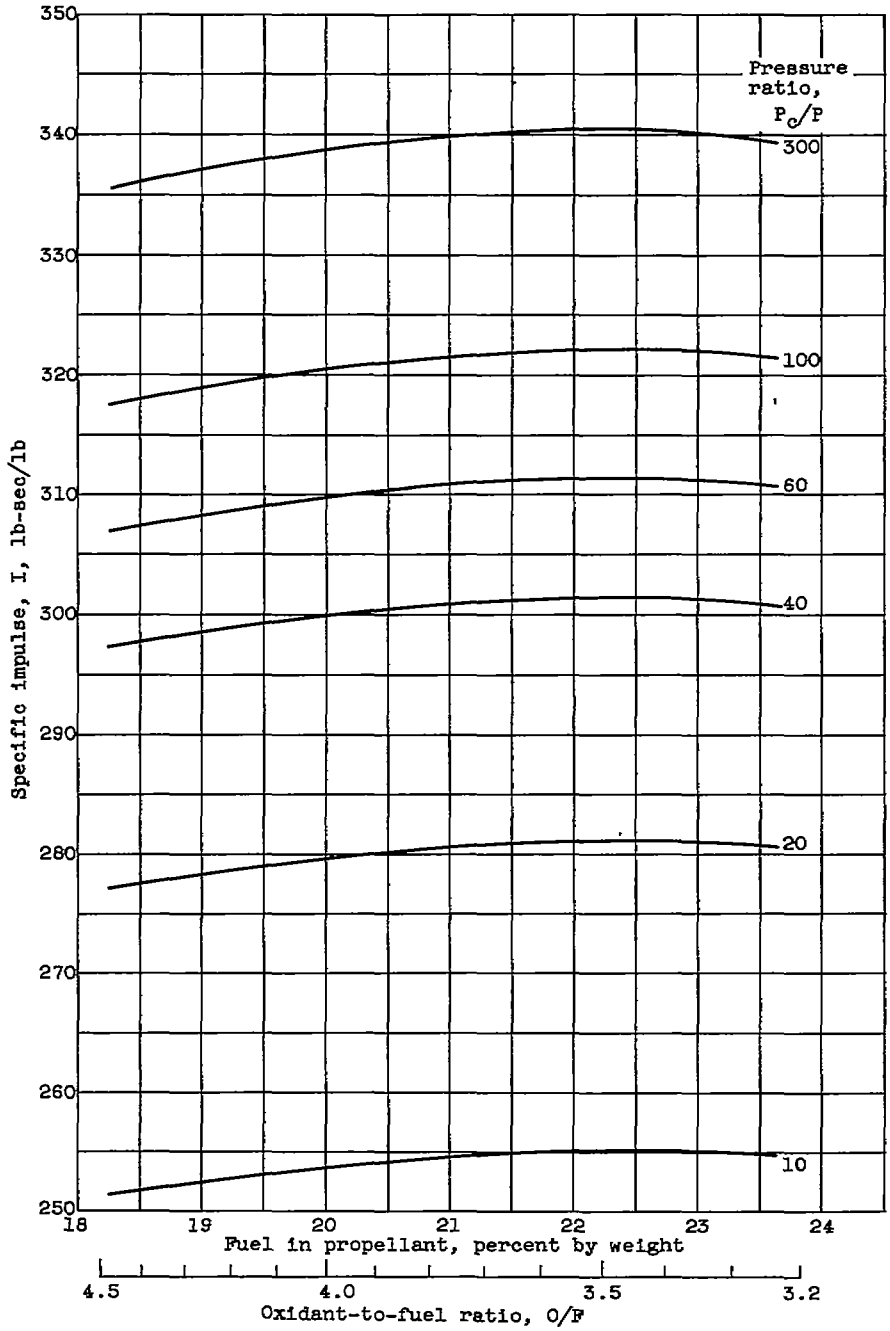
(b) Percent fluorine in oxidant by weight, 19.19.

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



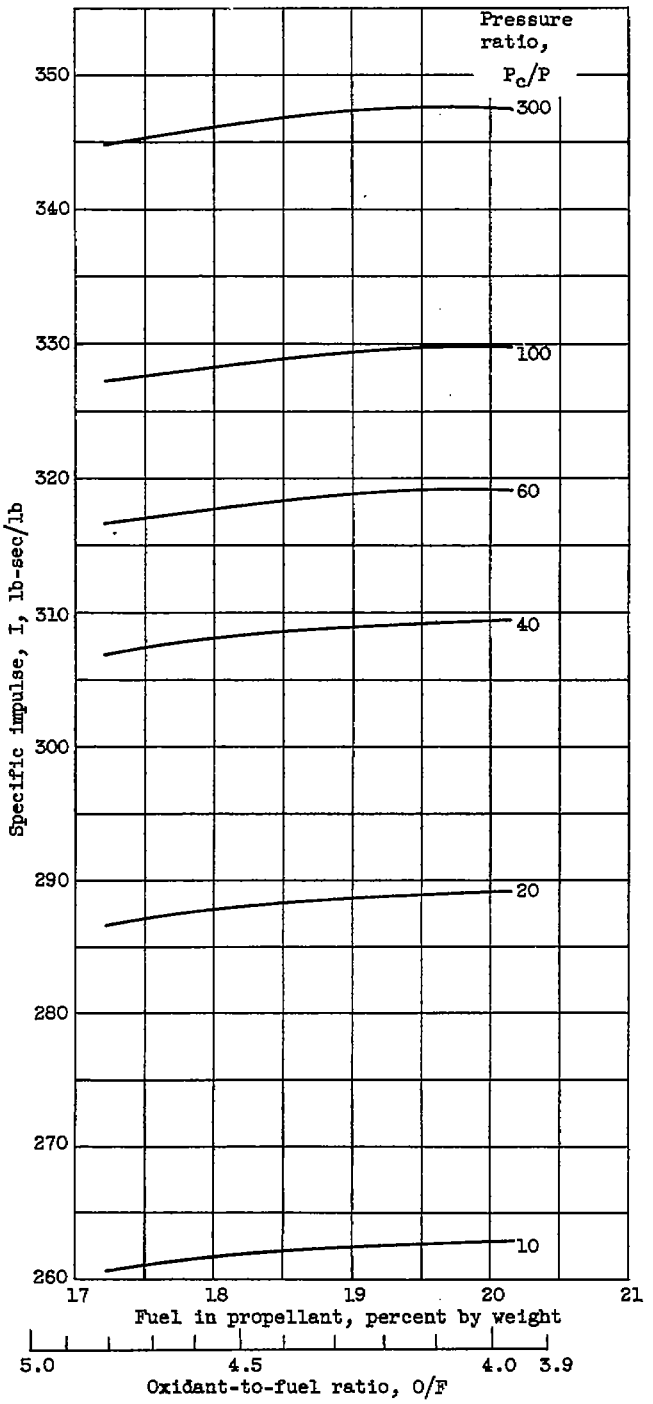
(c) Percent fluorine in oxidant by weight, 37.25.

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



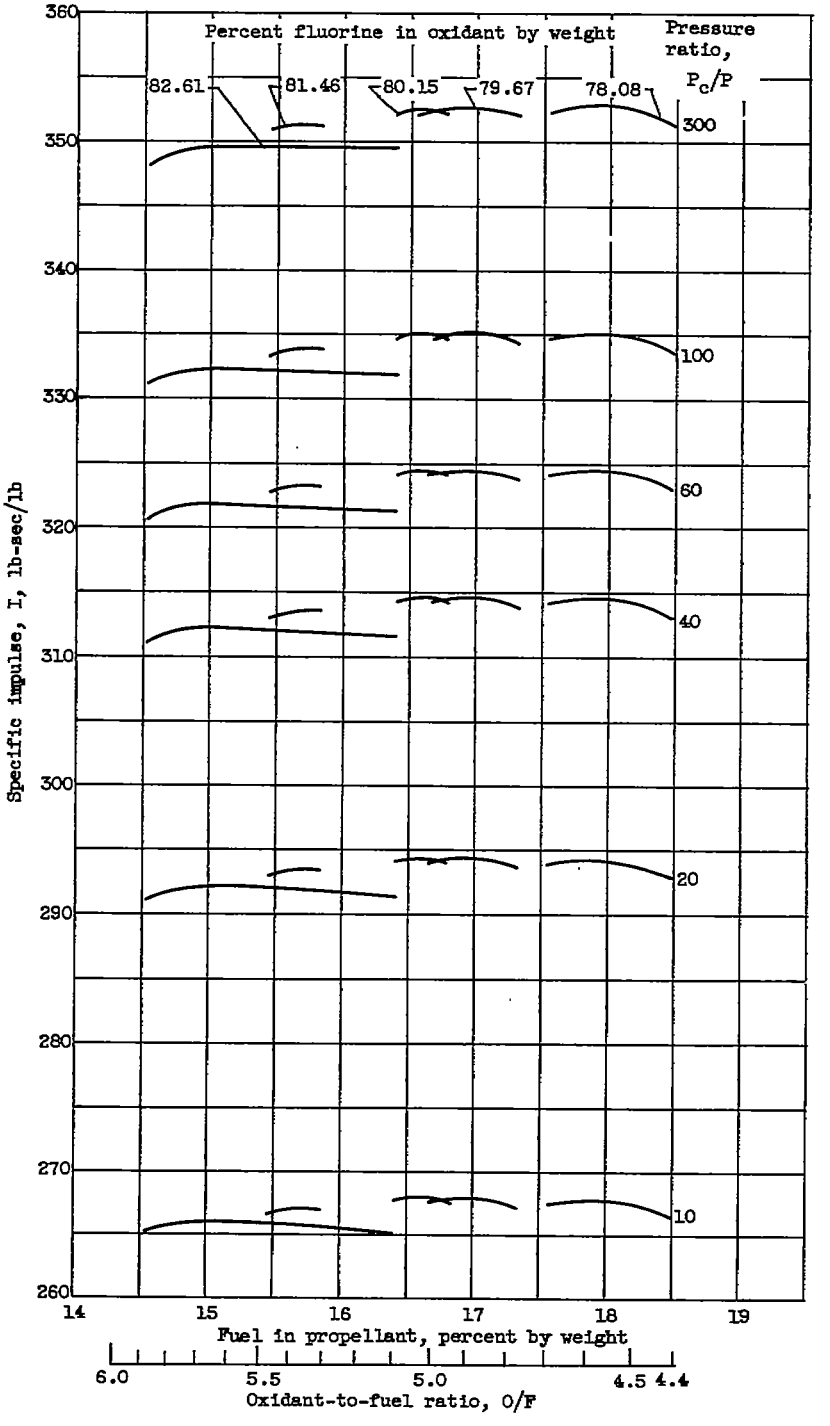
(d) Percent fluorine in oxidant by weight, 54.29.

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



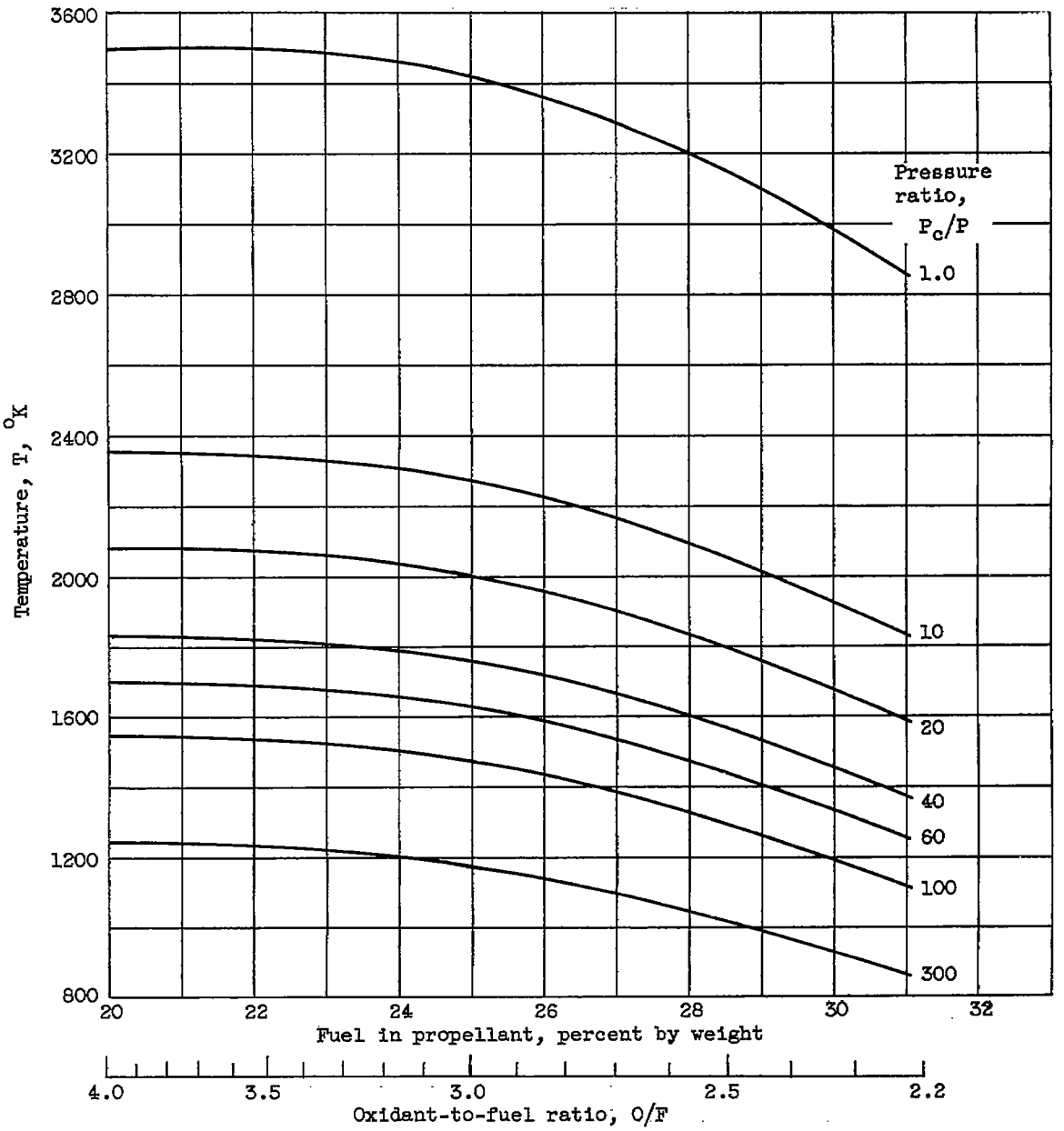
(e) Percent fluorine in oxidant by weight, 70.37.

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



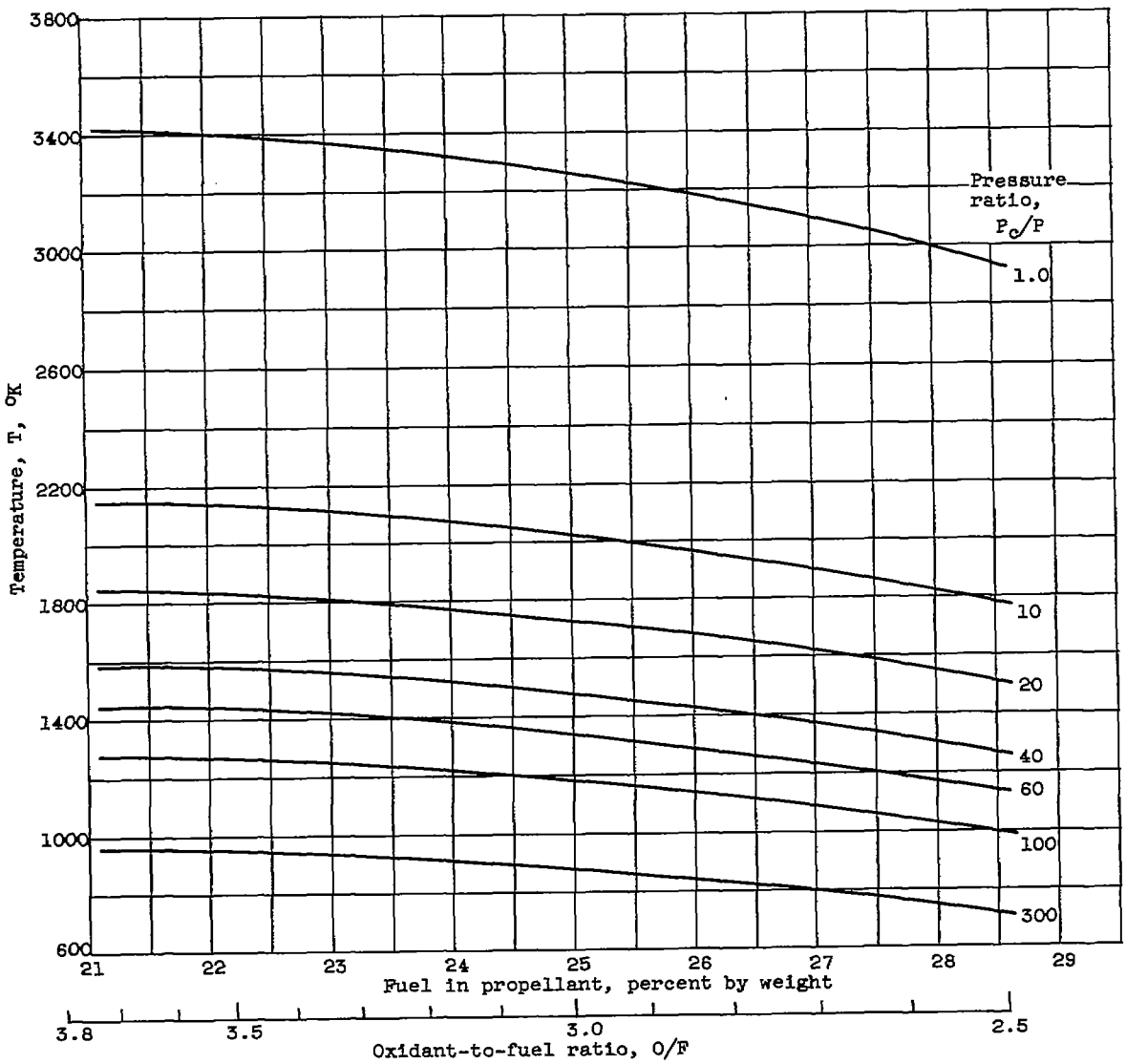
(f) Percent fluorine in oxidant by weight, 78.08 to 82.61.

Figure 1. - Concluded. Theoretical specific impulse of liquid methane with several fluorine-oxygen mixtures. Frozen composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratios indicated.



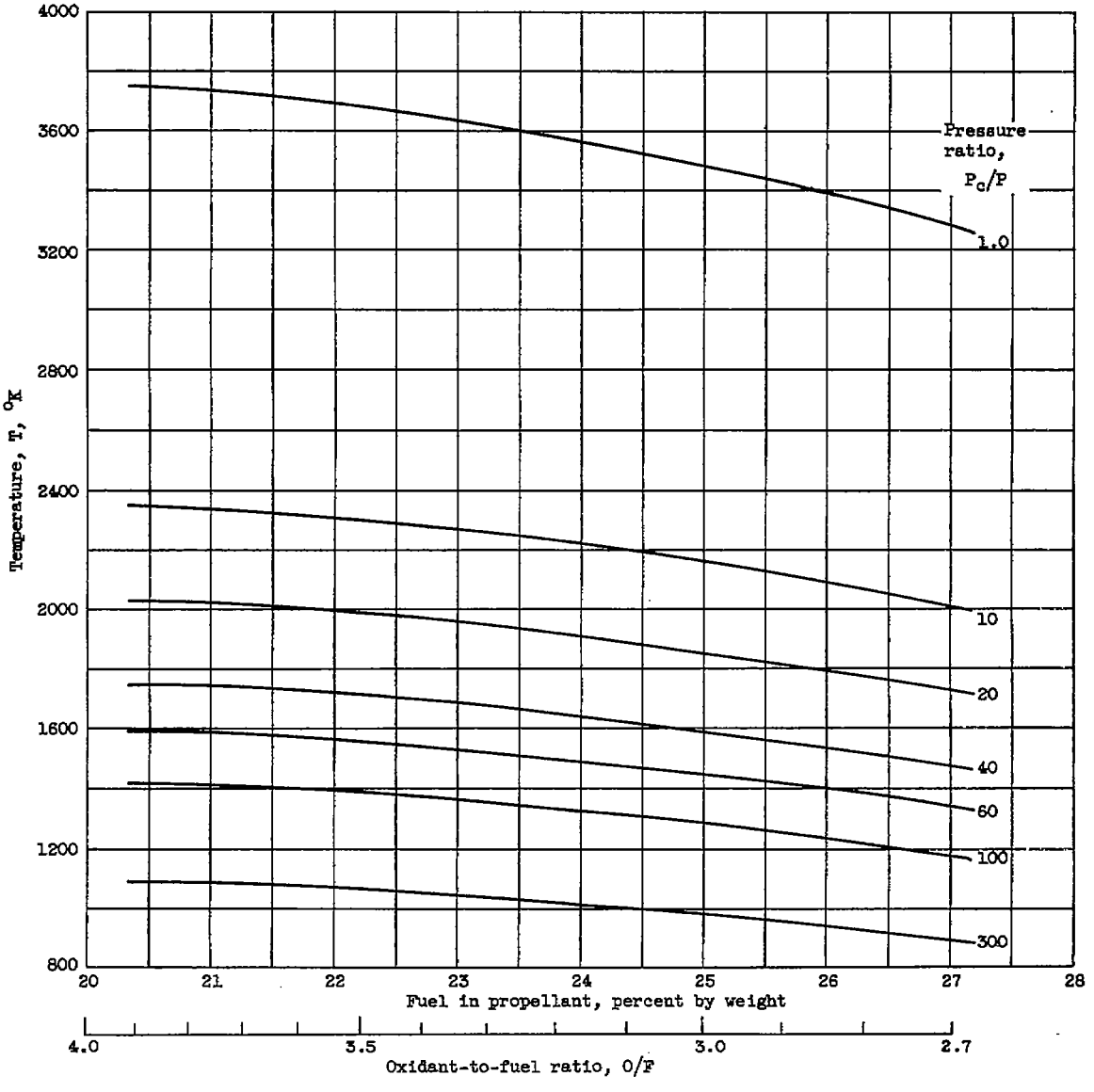
(a) Percent fluorine in oxidant by weight, 0 (100 percent oxygen).

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



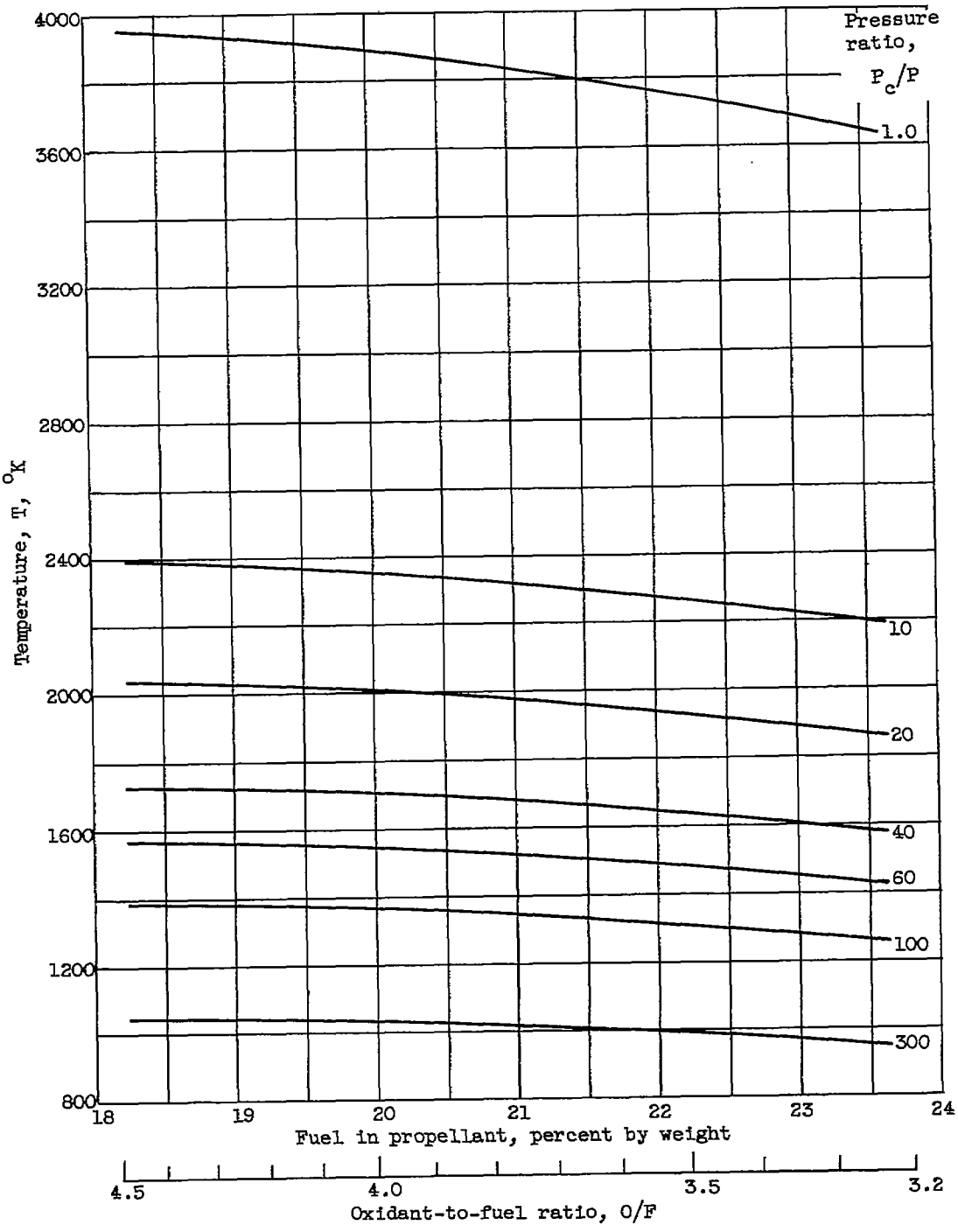
(b) Percent fluorine in oxidant by weight, 19.19.

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



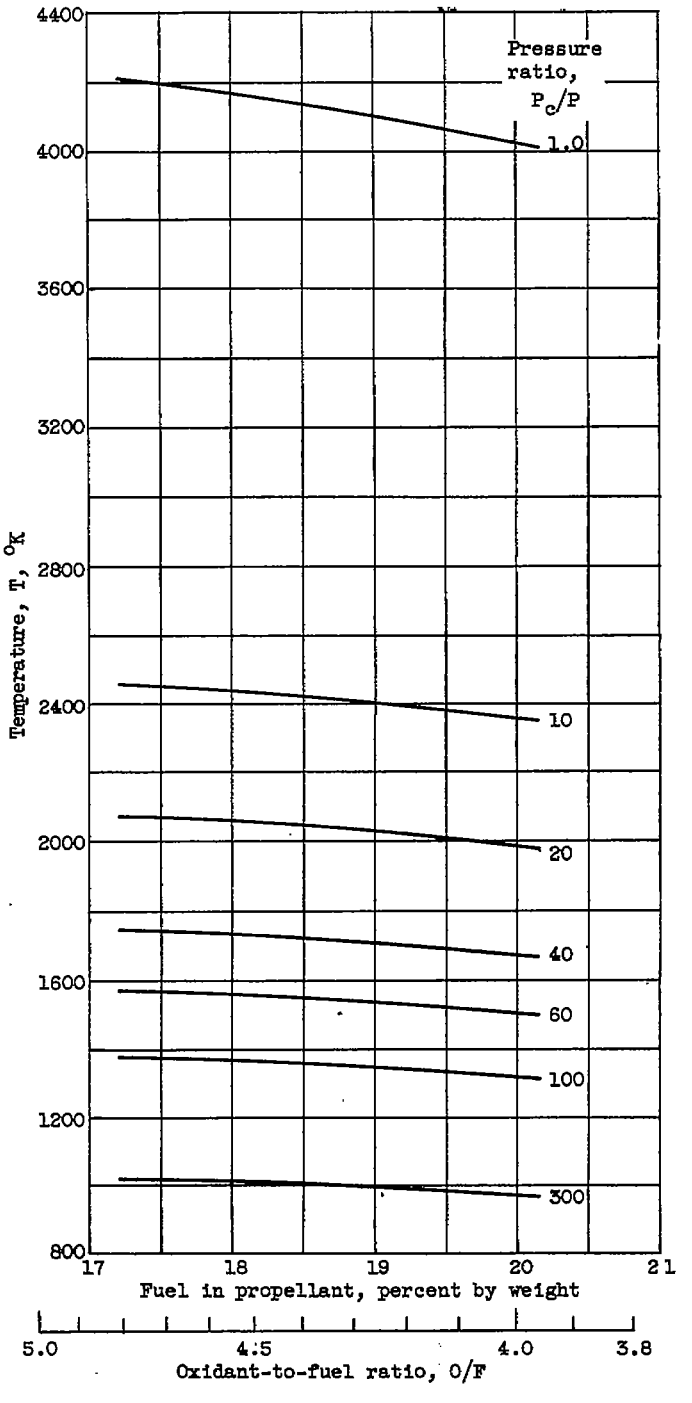
(c) Percent fluorine in oxidant by weight, 37.25.

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



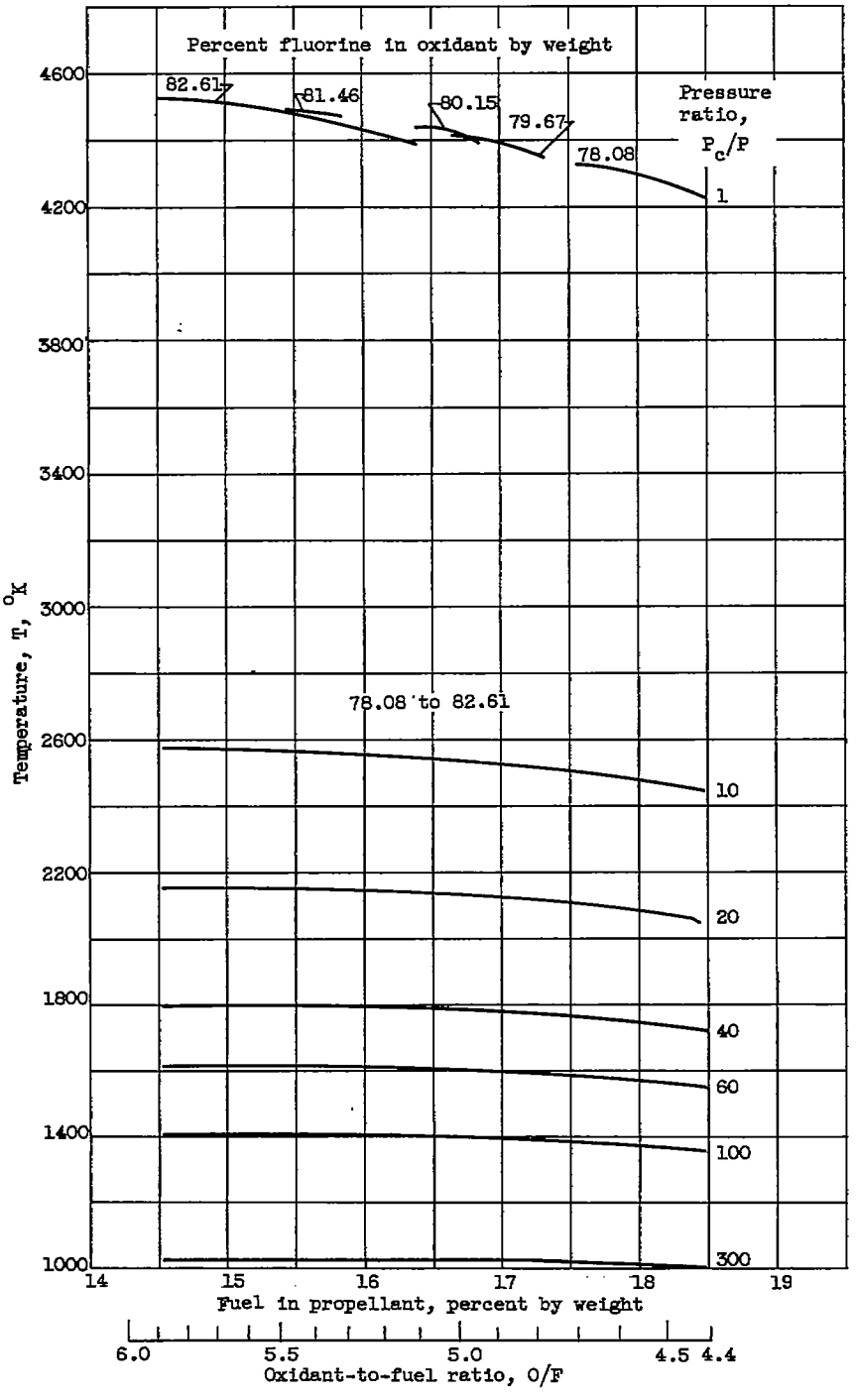
(d) Percent fluorine in oxidant by weight, 54.29.

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



(f) Percent fluorine in oxidant by weight, 78.08 to 82.61.

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

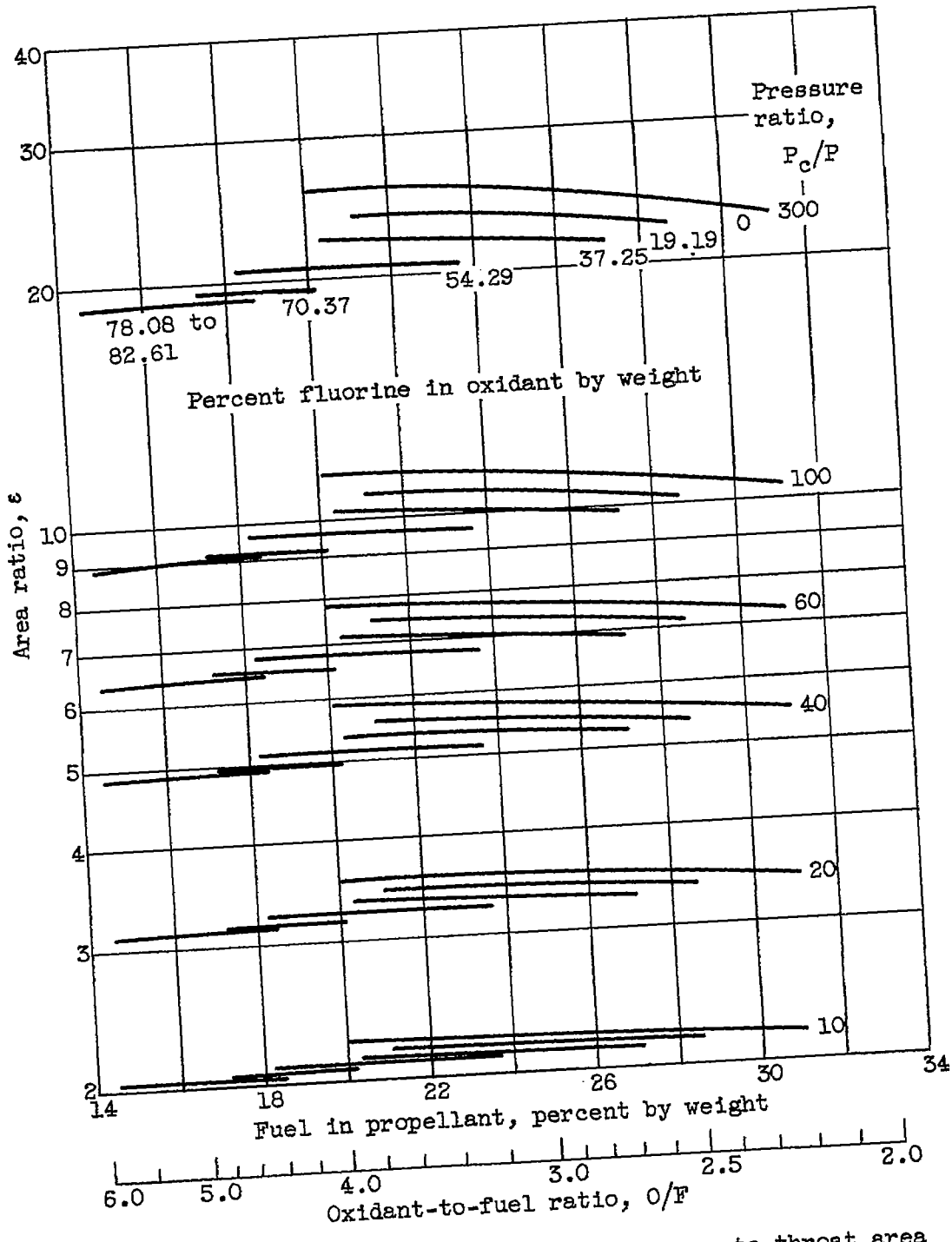


Figure 3. - Theoretical ratio of nozzle area to throat area for liquid methane with several fluorine-oxygen mixtures. Frozen composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.

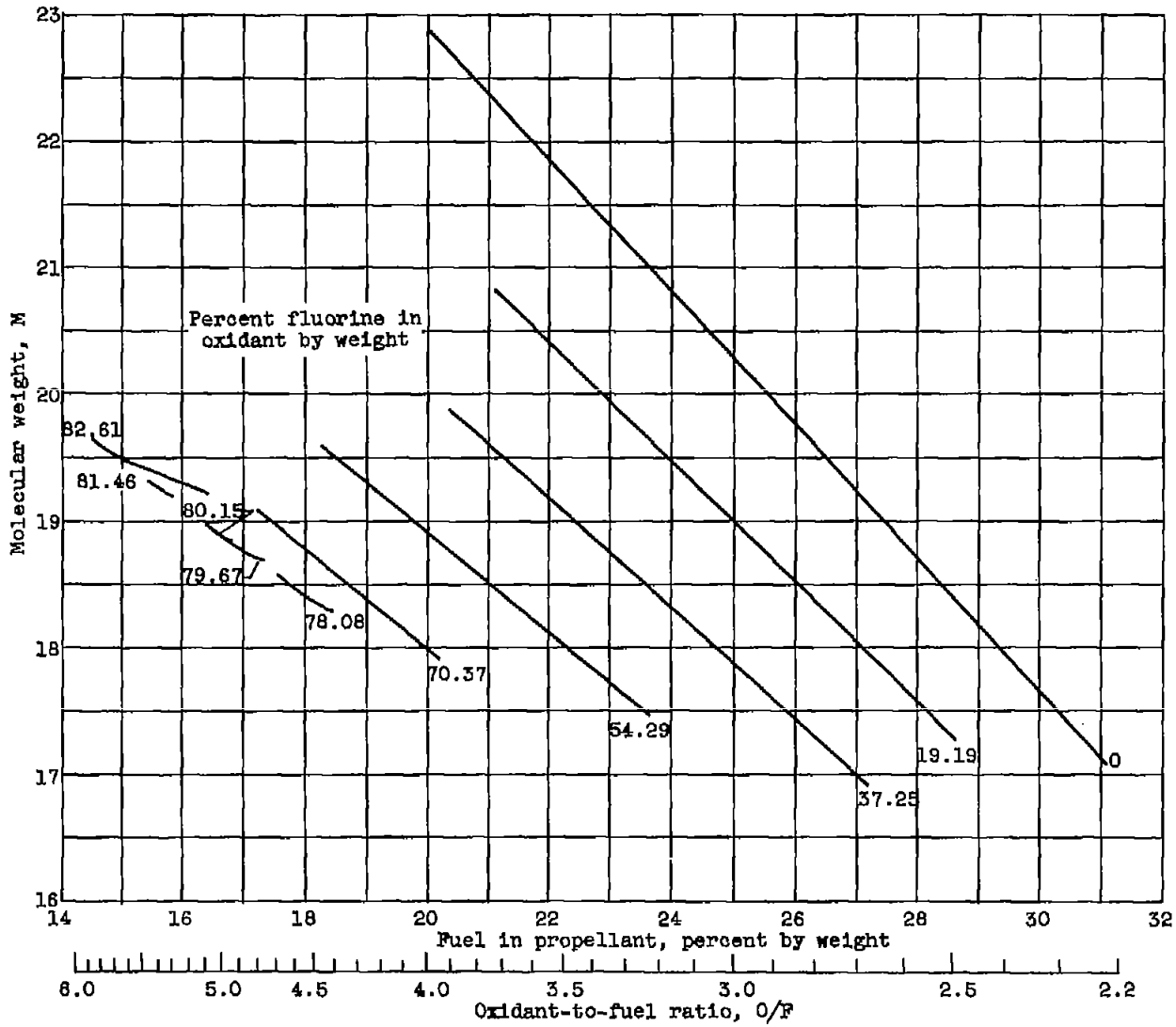


Figure 4. - Theoretical combustion-chamber molecular weight for liquid methane with several fluorine-oxygen mixtures. Combustion-chamber pressure, 600 pounds per square inch absolute.

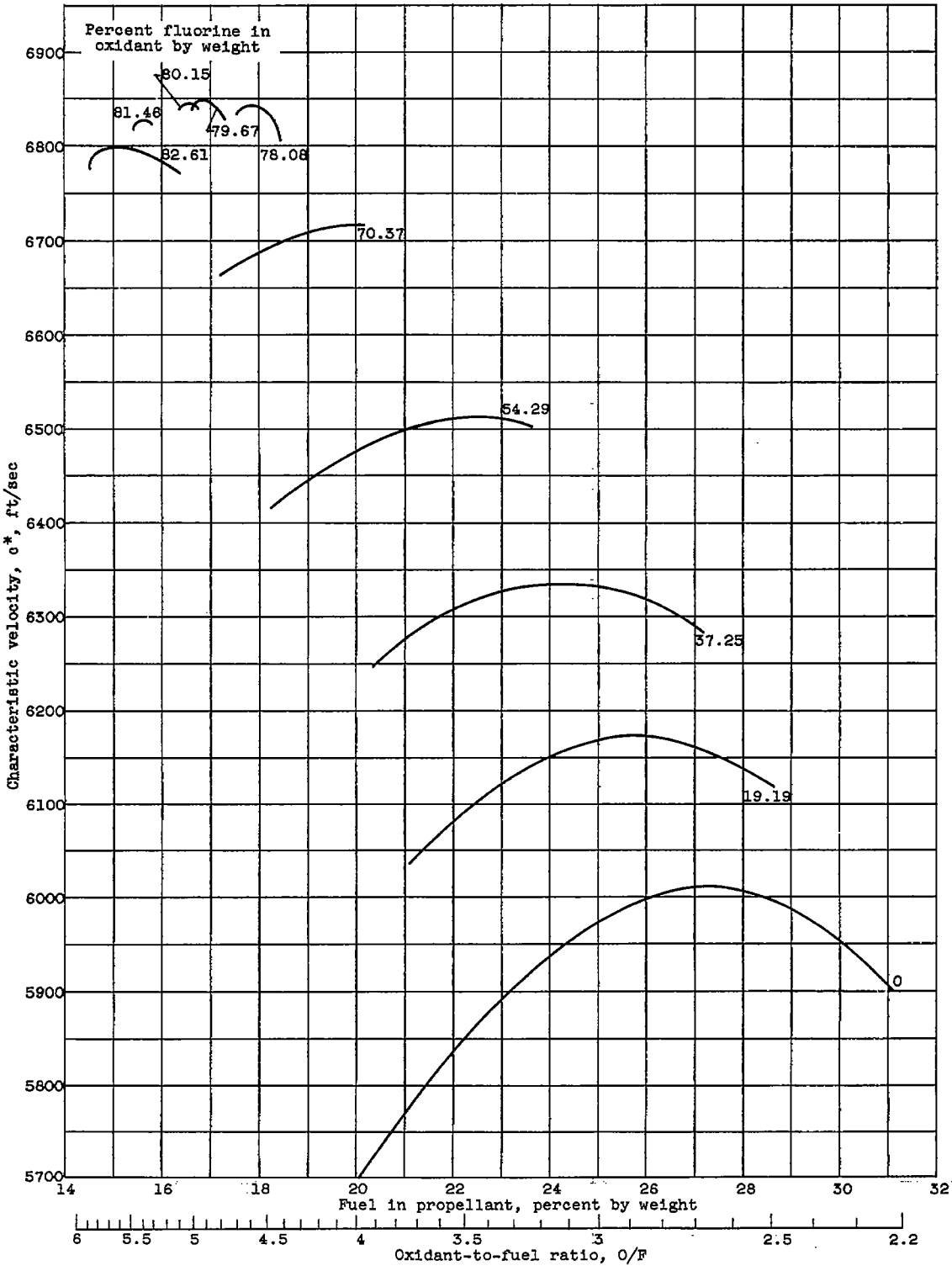


Figure 5. - Theoretical characteristic velocity for liquid methane with several fluorine-oxygen mixtures. Isentropic expansion assuming frozen composition from combustion-chamber pressure of 600 pounds per square inch absolute.

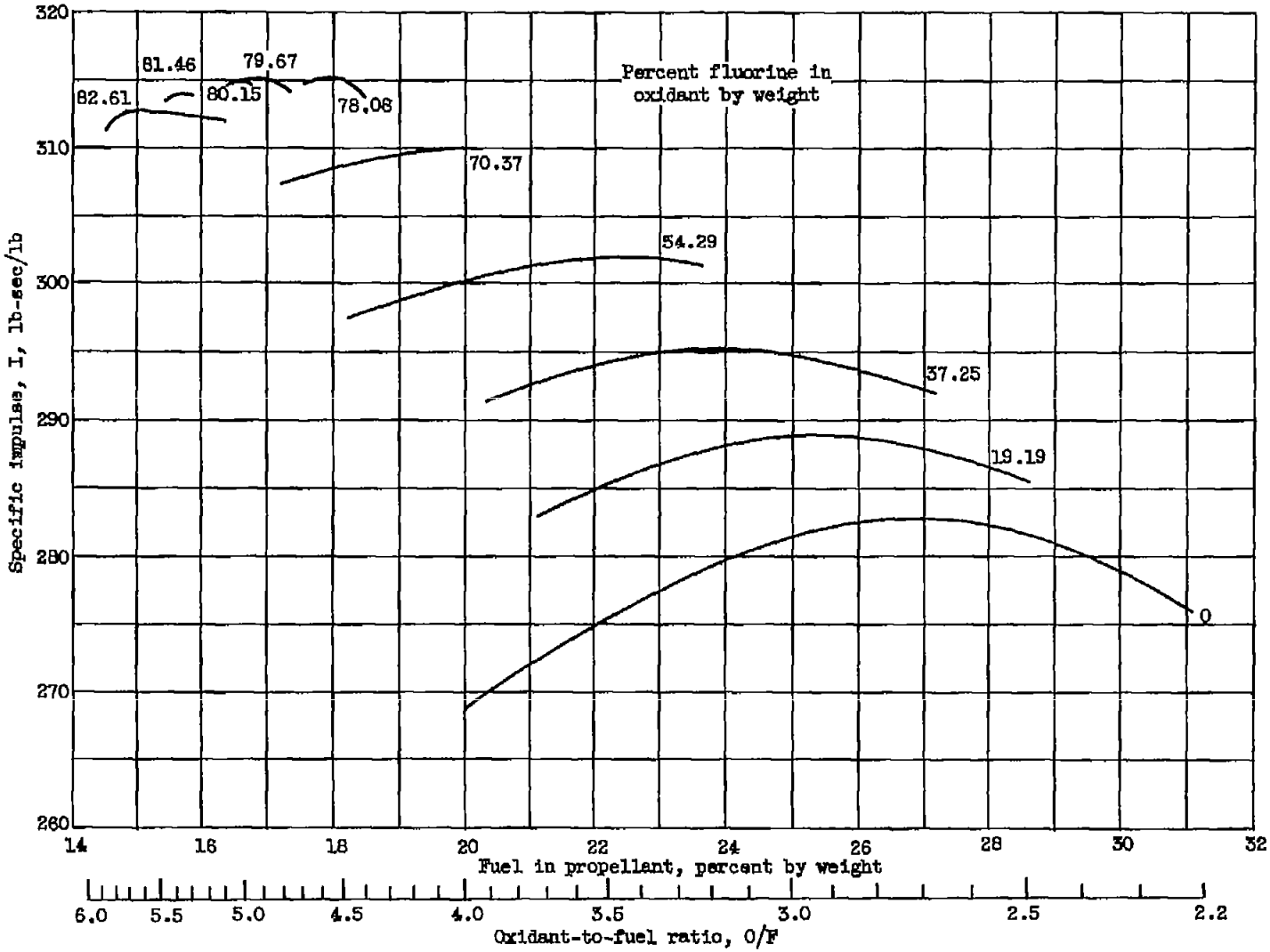


Figure 6. - Theoretical specific impulse for liquid methane with several fluorine-oxygen mixtures. Isentropic expansion assuming frozen composition from combustion-chamber pressure of 600 pounds per square inch absolute to exit pressure of 1 atmosphere.

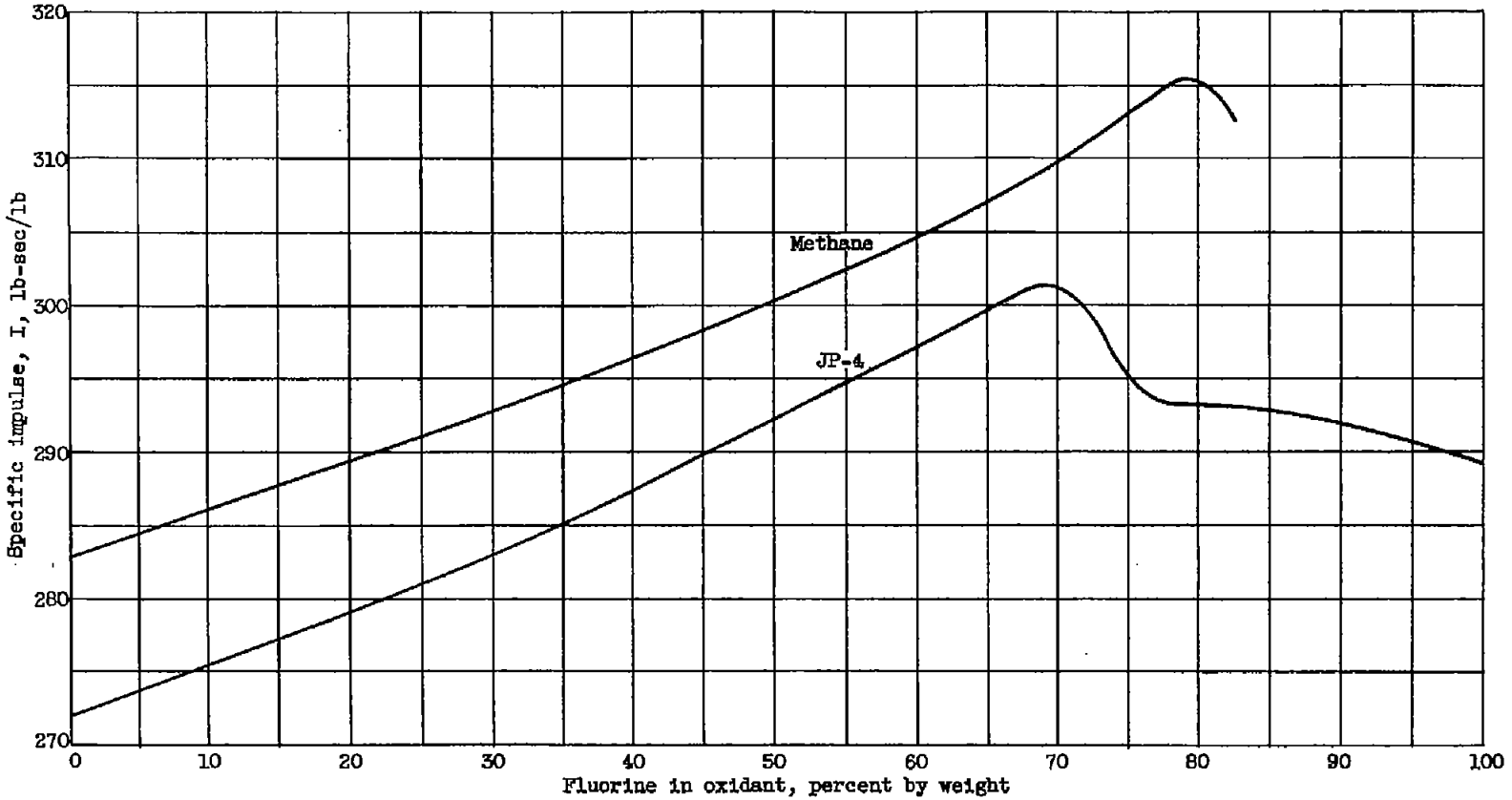


Figure 7. - Comparison of theoretical specific impulse of liquid methane with that of JP-4 fuel both with fluorine-oxygen mixtures at equivalence ratios for which specific impulse is maximum. Frozen composition assumed during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to 1 atmosphere.