NACA

RESEARCH MEMORANDUM

AN INVESTIGATION AT TRANSONIC SPEEDS OF THE EFFECTS OF CONTROL CHORD AND SPAN ON THE CONTROL CHARACTERISTICS OF A TAPERED WEDGE-TYPE WING OF ASPECT RATIO 2.5

TRANSONIC-BUMP METHOD

By Raymond D. Vogler, Vernard E. Lockwood,
and Thomas R. Turner

Langley Aeronautical Laboratory
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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
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SUMMARY

An investigation has been made in the Langley high-speed 7- by 10-foot tunnel to determine the control characteristics of flap-type controls of various chords and spans on an unswept wing having a 6-percent-thick modified double-wedge section, an aspect ratio of 2.5, and a taper ratio of 0.625. The control chords investigated were 25, 35, and 45 percent of the wing chord, and the control spans were 25, 50, and 75 percent of the wing semispan.

Lift, rolling-, and pitching-moment data were obtained through a range of control deflections up to 15°, at angles of attack of -4°, 0°, and 4°, through a Mach range of 0.6 to 1.18 obtained by use of the transonic bump. In general, the control-effectiveness-parameter values were approximately proportional to the control chord and to the control span for chords from 25 to 45 percent of the wing chord and for spans from 25 to 75 percent of the wing semispan.

INTRODUCTION

Wings designed for high-speed flight generally differ in geometric characteristics (aspect ratio, sweep, and airfoil section) from those used for low-speed flight. Because of the change in wing design pronounced differences are likely to occur in the control characteristics, and the problem of control in the subsonic range must be reexamined and its study extended to include the transonic and supersonic range. The primary purpose of this investigation was to obtain high subsonic and transonic control-surface data on a low-aspect-ratio wedge-type wing with particular emphasis on the effect of control chord and span.

This paper presents the results of an investigation made in the Langley high-speed 7- by 10-foot tunnel using the transonic-bump technique (reference 1). The wing had an unswept 50-percent-chord line, a modified 6-percent-thick double-wedge section, an aspect ratio of 2.5, a taper ratio of 0.625, and flap-type controls of 25, 35, and 45 percent of the wing chord. Each control was investigated with three different spans - 25, 50, and 75 percent of the wing semispan. Lift, rolling-, and pitching-moment data were obtained through a range of control deflections up to 15° and at angles of attack of -4°, 0°, and 4°. The Mach range was approximately 0.6 to 1.18 and the Reynolds number varied from 10^6 to 1.24×10^6.

Additional information at a Mach number of 1.9 obtained with this wing having similar control configurations may be found in reference 2.

MODEL AND APPARATUS

The 4.063-inch semispan steel wing used in this investigation (fig. 1) had an aspect ratio of 2.5, a taper ratio of 0.625, and a 6-percent-thick modified double-wedge airfoil section with the 50-percent-chord line unswept. The wing was mounted in the midwing position and had no incidence or dihedral. The brass fuselage was a modified half-body revolution composed of a $\frac{1}{8}$-inch-thick strip attached to a body of semicircular cross section as shown in figure 2.

The controls (fig. 2) were made integral with the wing by cutting grooves 0.031 inch wide on the upper wing surface along the 55-, 65-, and 75-percent-chord lines. The various control deflections were set by bending the wing along the proper groove and then filling the grooves with wax. The controls extended spanwise from 95 percent to 20 percent of the wing semispan and each of the 25-, 35-, and 45-percent-chord controls was divided into three equal spanwise segments as shown in figure 2.

The relative size and position of the model and balance with respect to the transonic bump is shown in figure 3.

COEFFICIENTS AND SYMBOLS

C_L lift coefficient $\left(\frac{\text{Twice lift of semispan model}}{qS}\right)$

C_{l_a} rolling-moment coefficient produced by the control (rolling-moment coefficient with control deflected minus rolling-moment coefficient without deflection; rolling-moment coefficient at plane of symmetry equals $\left.\frac{\text{Rolling moment of semispan model}}{qSb}\right)$

C_m pitching-moment coefficient about $0.50\bar{c}$ $\left(\frac{\text{Twice pitching moment of semispan model}}{qS\bar{c}}\right)$

q effective dynamic pressure over span of model, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$

S twice wing area of semispan model, 0.1834 square foot

b twice span of semispan model, 0.677 foot

b_a control span, measured perpendicular to plane of symmetry, feet

$\bar{c}$ mean aerodynamic chord of wing, 0.276 foot $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$

c local wing chord parallel to plane of symmetry, feet

y spanwise distance from plane of symmetry, feet

y_i spanwise distance from plane of symmetry to inboard end of control, feet

y_o spanwise distance from plane of symmetry to outboard end of control, feet

ρ mass density of air, slugs per cubic foot

V air stream velocity, feet per second

M effective Mach number over span of model $\left(\frac{2}{S}\int_0^{b/2} cM_a\, dy\right)$

M_a — average chordwise local Mach number

M_l — local Mach number over the bump

R — Reynolds number of model based on $\bar{c}$

α — angle of attack of wing-root-chord line, degrees

δ — control deflection relative to wing-chord plane, measured in a plane perpendicular to control hinge axis (positive when trailing edge is down), degrees

k — reflection-plane correction factor

C_{L_δ} — lift effectiveness parameter $\left(\frac{\partial C_L}{\partial \delta}\right)_\alpha$

C_{l_δ} — aileron effectiveness parameter $\left(\frac{\partial C_{l_a}}{\partial \delta}\right)_\alpha$

C_{m_δ} — pitching effectiveness parameter $\left(\frac{\partial C_m}{\partial \delta}\right)_\alpha$

The subscript α indicates the factor held constant.

CORRECTIONS

The rolling-moment coefficients presented herein represent the aerodynamic effects on a complete wing produced by the deflection of the control on only one semispan of the complete wing. Reflection-plane correction factors (fig. 4) have been applied to the rolling-moment coefficients throughout the Mach range of the investigation. The values of the correction factors were obtained from unpublished low-speed data and theoretical considerations. Although the corrections are based on low-speed considerations and hence are valid for low Mach numbers only, it is believed that the results obtained by applying the corrections give better representation of true conditions than uncorrected data. No attempt has been made to correct the rolling-moment data for increments of rolling moment caused by asymmetrical pressure distribution on the surface of the fuselage as a result of control deflection. However, this effect is believed to be small.

TEST TECHNIQUE

The investigation was made in the Langley high-speed 7- by 10-foot tunnel. The high-velocity flow field generated over the curved surface of a bump on the tunnel floor was utilized in obtaining a Mach number range of 0.6 to 1.18. Typical contours of local Mach number in the vicinity of the model location on the bump with model removed are shown in figure 5. The effective test Mach number was obtained from contour charts similar to those presented in figure 5 by using the relationship

$$M = \frac{2}{S}\int_0^{b/2} cM_a \, dy$$

The model was mounted on an electrical strain-gage balance wired to a calibrated potentiometer. Force and moment data were obtained with 25-, 35-, and 45-percent-chord and 25-, 50-, and 75-percent-semispan controls at angles of attack of -4°, 0°, and 4°, with control deflections of 0°, 2°, 5°, 10°, and 15°, through a Mach number range from 0.6 to 1.18.

The variation of mean test Reynolds number with Mach number is shown in figure 6.

RESULTS AND DISCUSSION

Typical curves of lift, rolling-, and pitching-moment coefficients plotted against control deflection for the 25-, 35-, and 45-percent-chord, 50-percent-span outboard control at three angles of attack through a Mach range from 0.60 to 1.18 are given in figures 7 to 9. In general, the forces and moments vary linearly with control deflection. The curves presented in figures 7 to 9 are typical of the curves of the other configurations.

The data for the various configurations are presented in figures 10 to 12 as variations of control effectiveness parameters with Mach number. The parameters were obtained from figures 7 to 9 and similar plots of data for the other configurations. The slopes were measured between 0° and 10° control deflection. Although the variations of lift and aileron effectiveness with Mach number are rather nonuniform above a Mach number of 0.80, there is a general loss in effectiveness through the transonic range. As expected, the data indicate that the 50-percent-span inboard control is more effective in producing lift but much less effective in producing roll than the 50-percent-span outboard control. The pitching effectiveness parameters based on pitching moments of the model mounted at the 50-percent-chord line vary only slightly with Mach number except near a Mach number of 1.0 where the parameters increase negatively and then decrease as the Mach number increases.

The variation of the control-parameter values with control span is given in figures 13 and 14 for each of the three control chords at several Mach numbers. The values of the parameters are approximately proportional to the control span. The experimental values of C_{l_δ}, except for the 25-percent-chord control, agree very well with the estimated values for a Mach number of 0.60 as shown in figure 15. The estimated values were obtained by modifying the method of reference 3 for compressibility effects. The estimated C_{l_δ} is represented by the following equation:

$$C_{l_\delta} = \frac{C_{l_\delta}'}{\sqrt{1 - M^2}}$$

where C_{l_δ}' is the aileron effectiveness parameter estimated by the method of reference 3 after modifying the wing geometric characteristics by the Glauert-Prandtl transformations (reference 4).

Figures 16 and 17 show the relationship between the control-parameter values and the chord magnitude. The data indicate that the control-parameter values are approximately proportional to control chord up to 45 percent of the wing chord for control deflections up to 15°.

CONCLUDING REMARKS

An investigation was made at subsonic and transonic speeds to determine the effect of control chord and span on the control characteristics of a wing having a 6-percent-thick modified double-wedge section, an aspect ratio of 2.5, a taper ratio of 0.625, an unswept 50-percent-chord line, and control surfaces of various chords and spans. The data resulting from this investigation indicate that the control-parameter values are approximately proportional to control chord or span for chords from 25 to 45 percent of the wing chord and for spans from 25 to 75 percent of the wing semispan.

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1. Schneiter, Leslie E., and Ziff, Howard L.: Preliminary Investigation of Spoiler Lateral Control on a 42° Sweptback Wing at Transonic Speeds. NACA RM L7F19, 1947.

2. Mitchell, Meade H., Jr.: Effects of Varying the Size and Location of Trailing-edge Flap-Type Controls on the Aerodynamic Characteristics of an Unswept Wing at a Mach Number of 1.9. NACA RM L50F08, 1950.

3. Lowry, John G., and Schneiter, Leslie E.: Estimation of Effectiveness of Flap-Type Controls on Sweptback Wings. NACA TN 1674, 1948.

4. DeYoung, John: Theoretical Additional Span Loading Characteristics of Wings with Arbitrary Sweep, Aspect Ratio, and Taper Ratio. NACA TN 1491, 1947.

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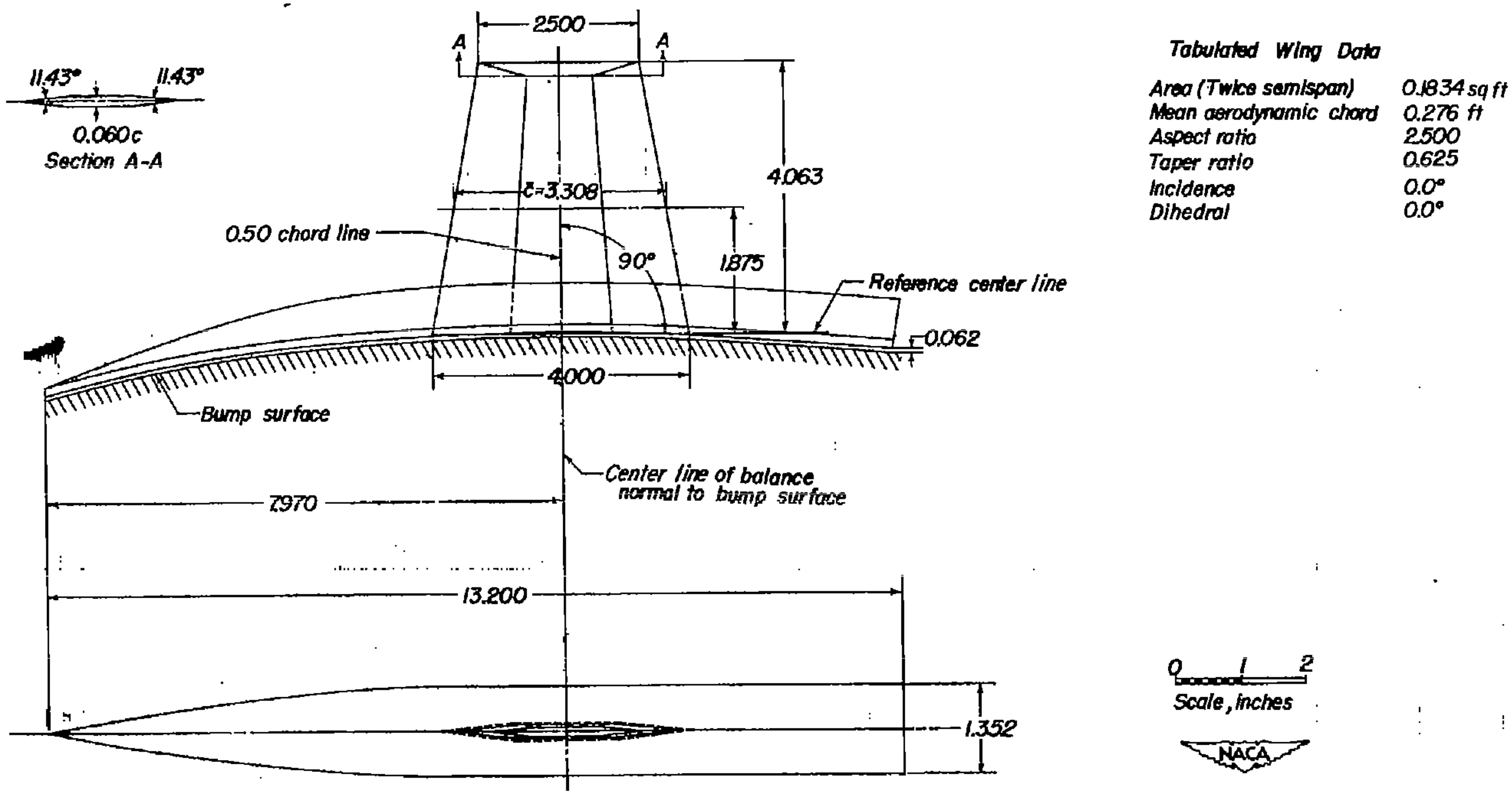

Figure 1.- Model and dimensions.

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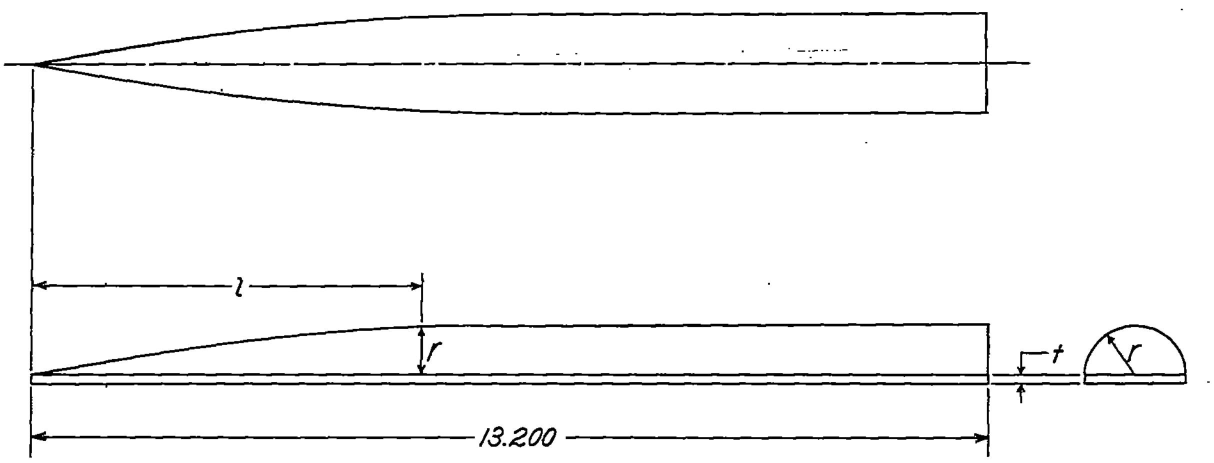

Fuselage ordinates, inches	
l	r
0	0
0.676	0.117
1.353	.225
2.029	.325
2.706	.413
3.382	.489
4.059	.555
4.735	.613
5.412	.649
6.088	.672
6.765	.676
13.200	.676
t = 1/8	

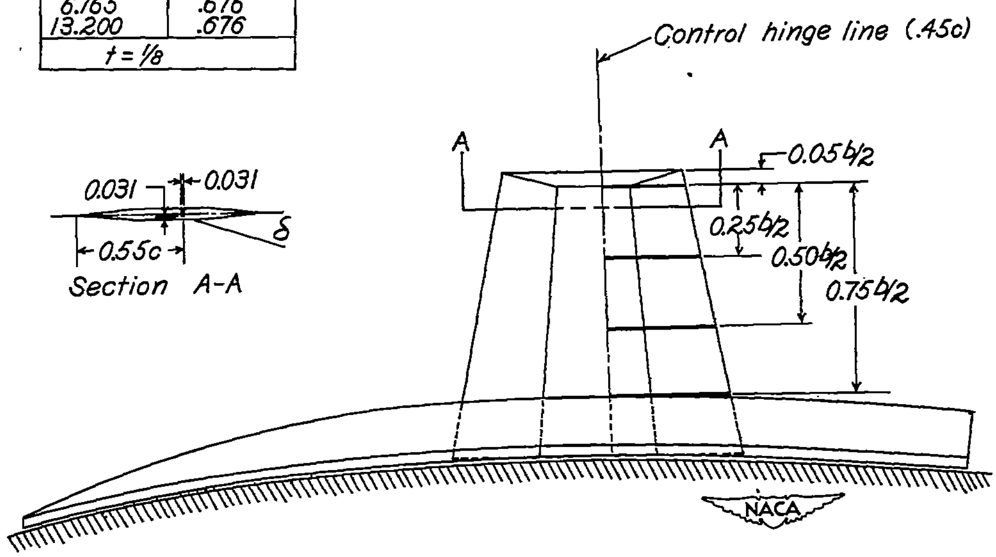

Figure 2.- Details of typical controls and fuselage.

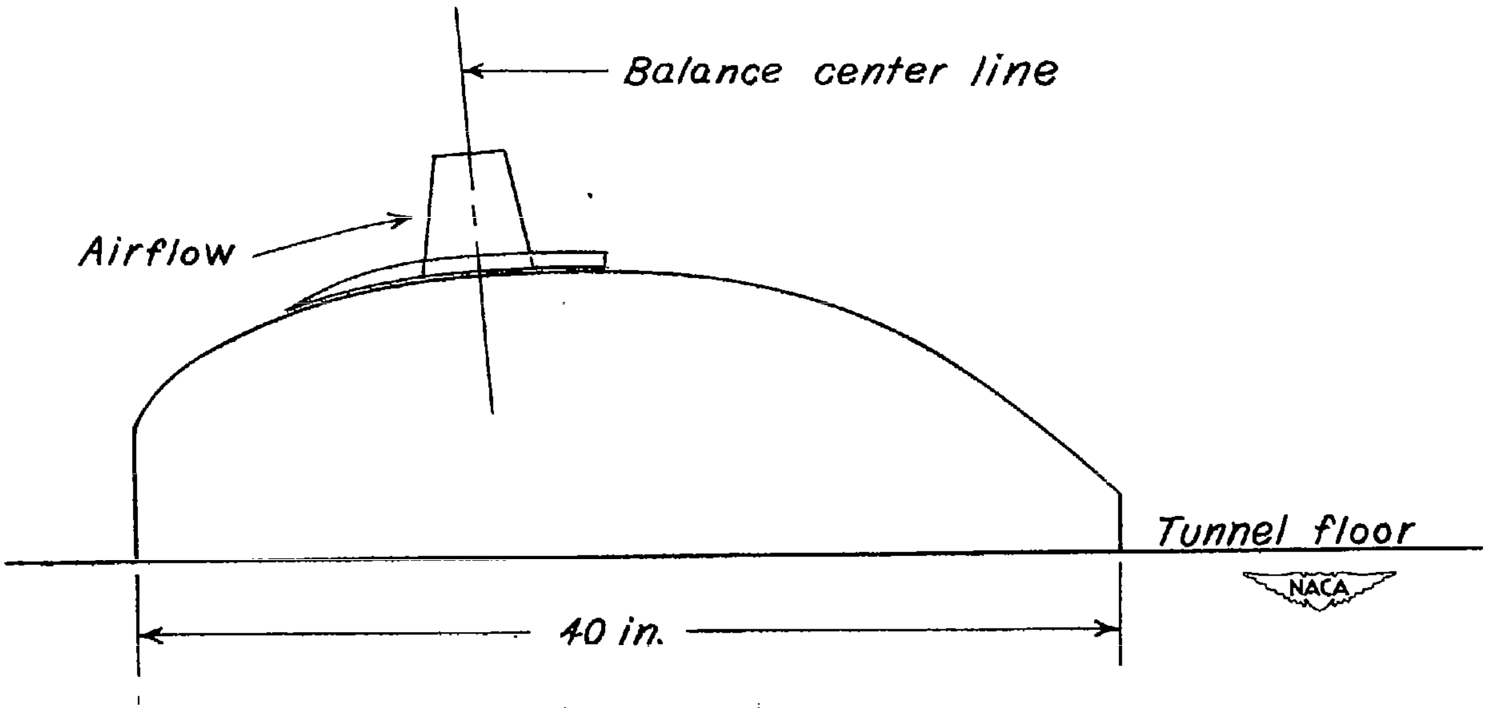

Figure 3.- Schematic sketch of relative size and position of model, balance, and transonic bump as mounted in the Langley high-speed 7- by 10-foot tunnel.

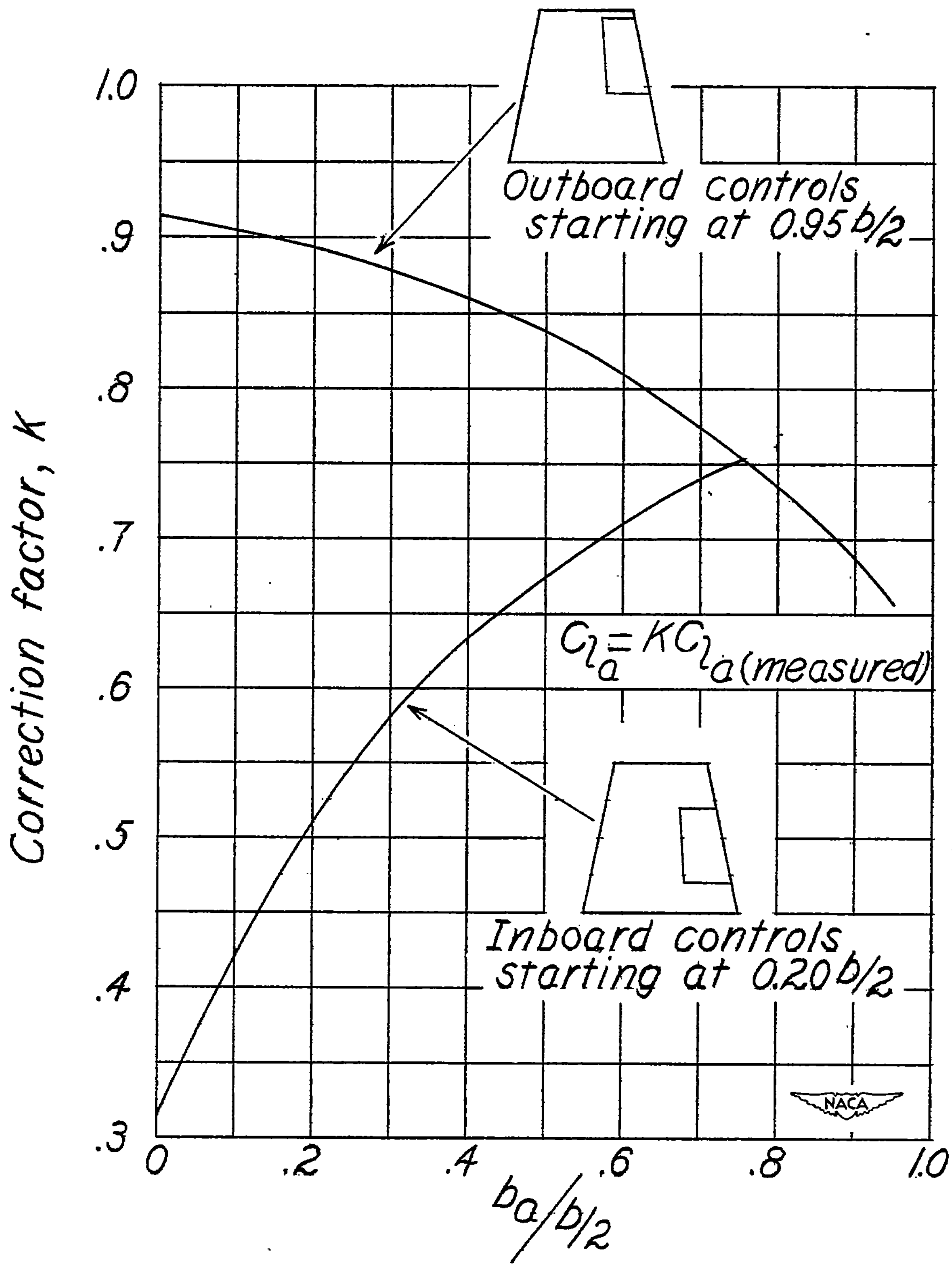

Figure 4.- Reflection-plane correction factors for controls of various spans for an unswept wing, aspect ratio 2.5, and taper ratio 0.625.

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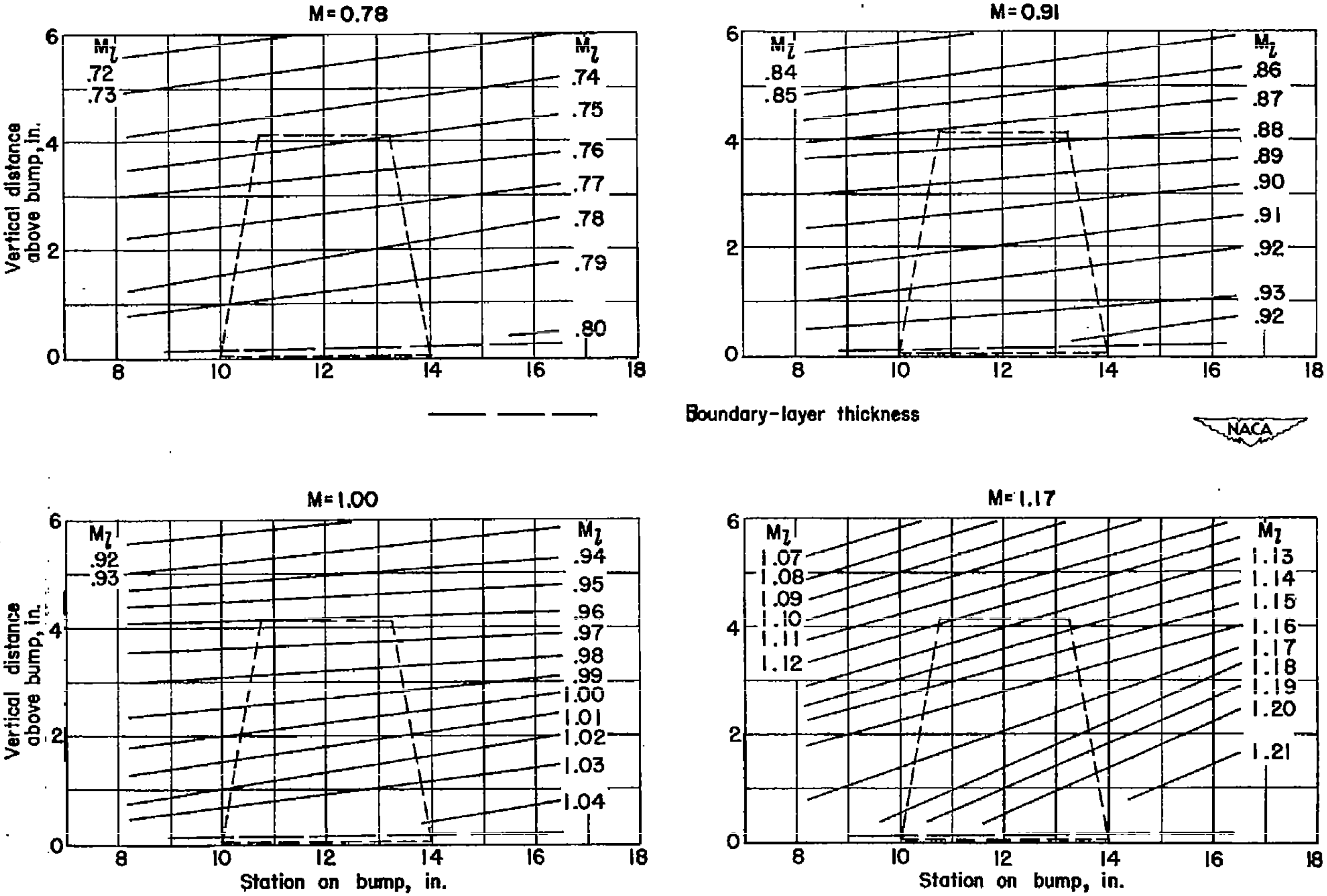

Figure 5.- Typical Mach number contours over transonic bump in region of model location.

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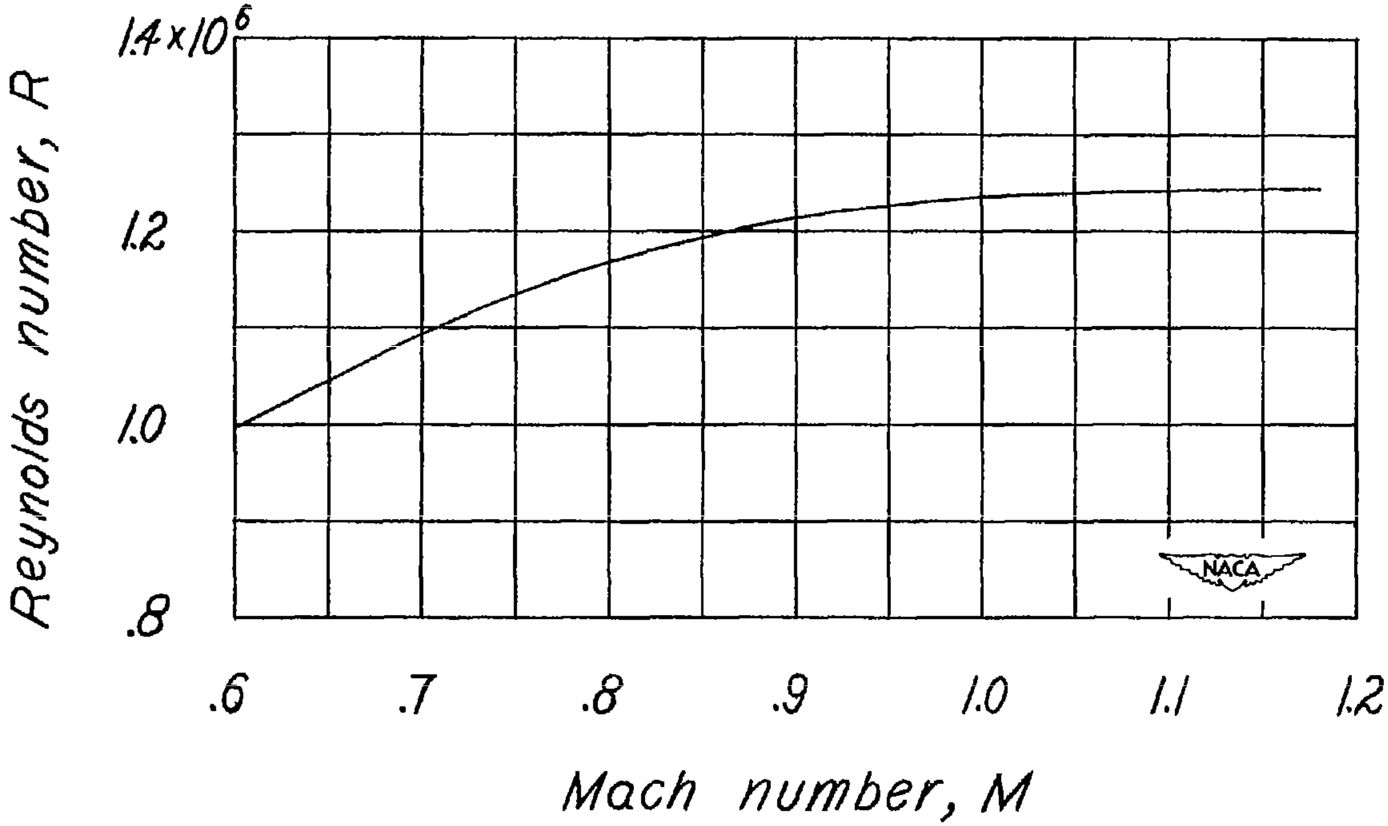

Figure 6.- Variation of mean Reynolds number with Mach number.

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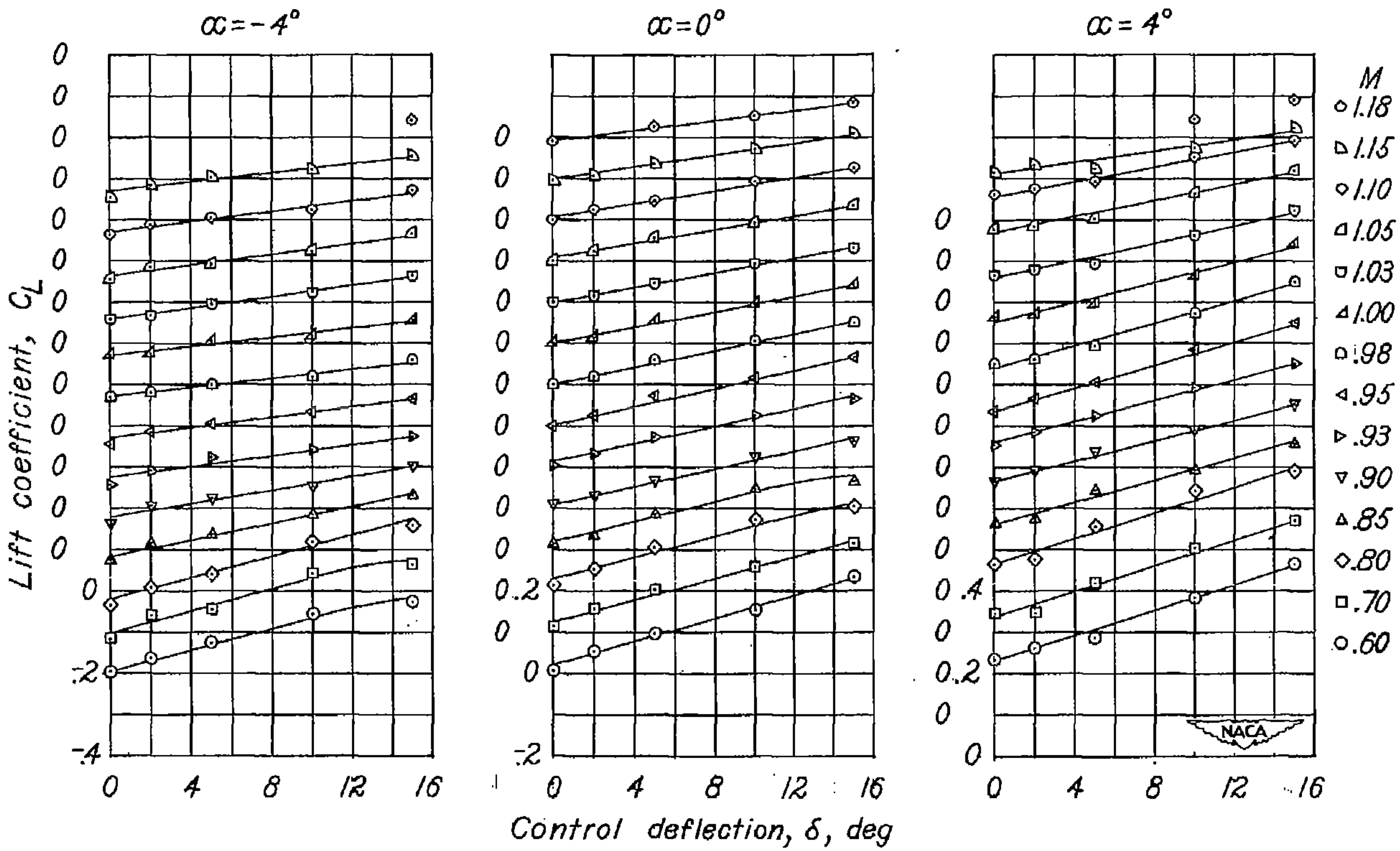
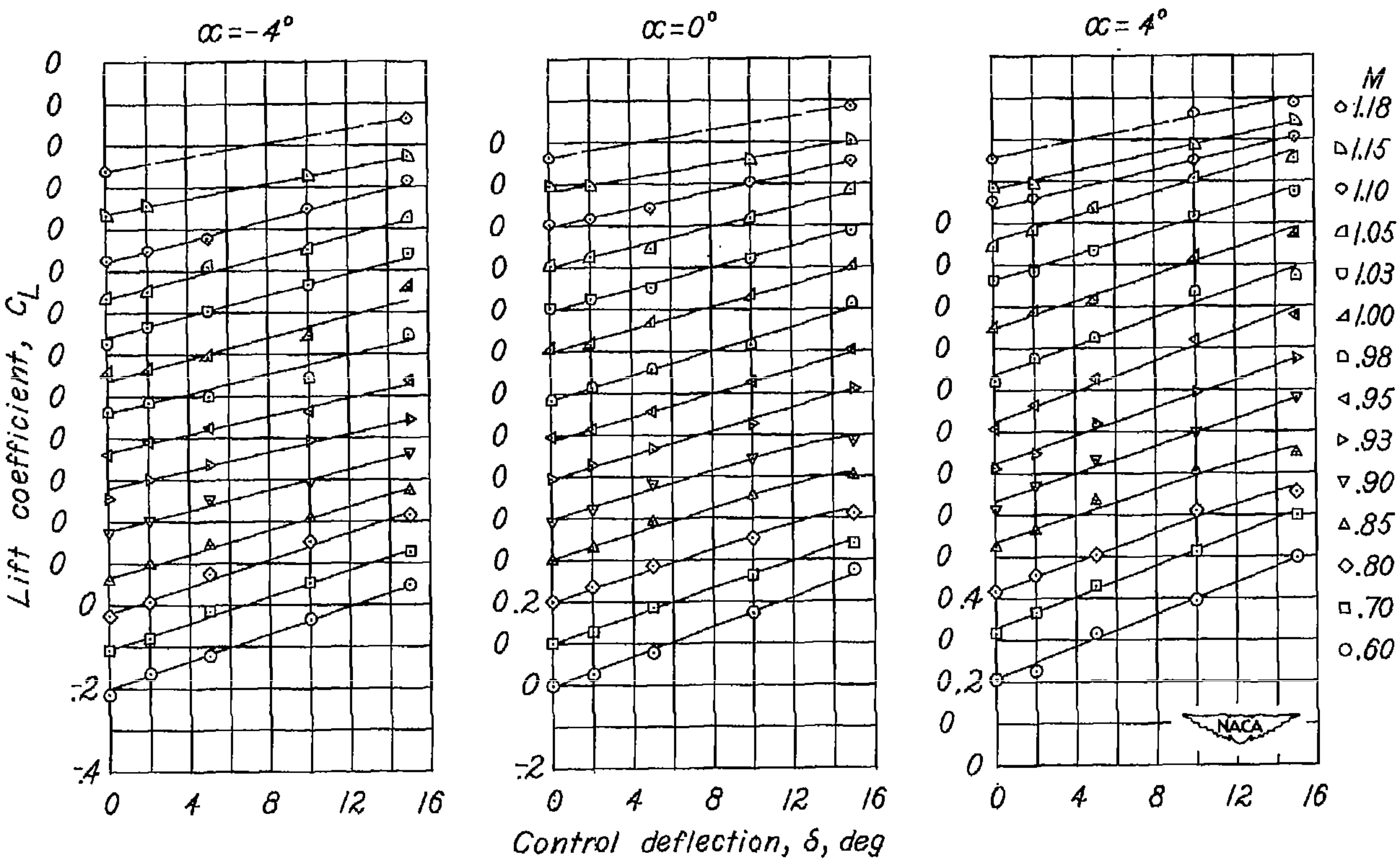


(a) 0.25c control.

Figure 7.- Variation of lift coefficient with control deflection at three angles of attack for various Mach numbers. $y_i = 0.45\frac{b}{2}$, $y_o = 0.95\frac{b}{2}$.



(b) 0.35c control.

Figure 7.- Continued.

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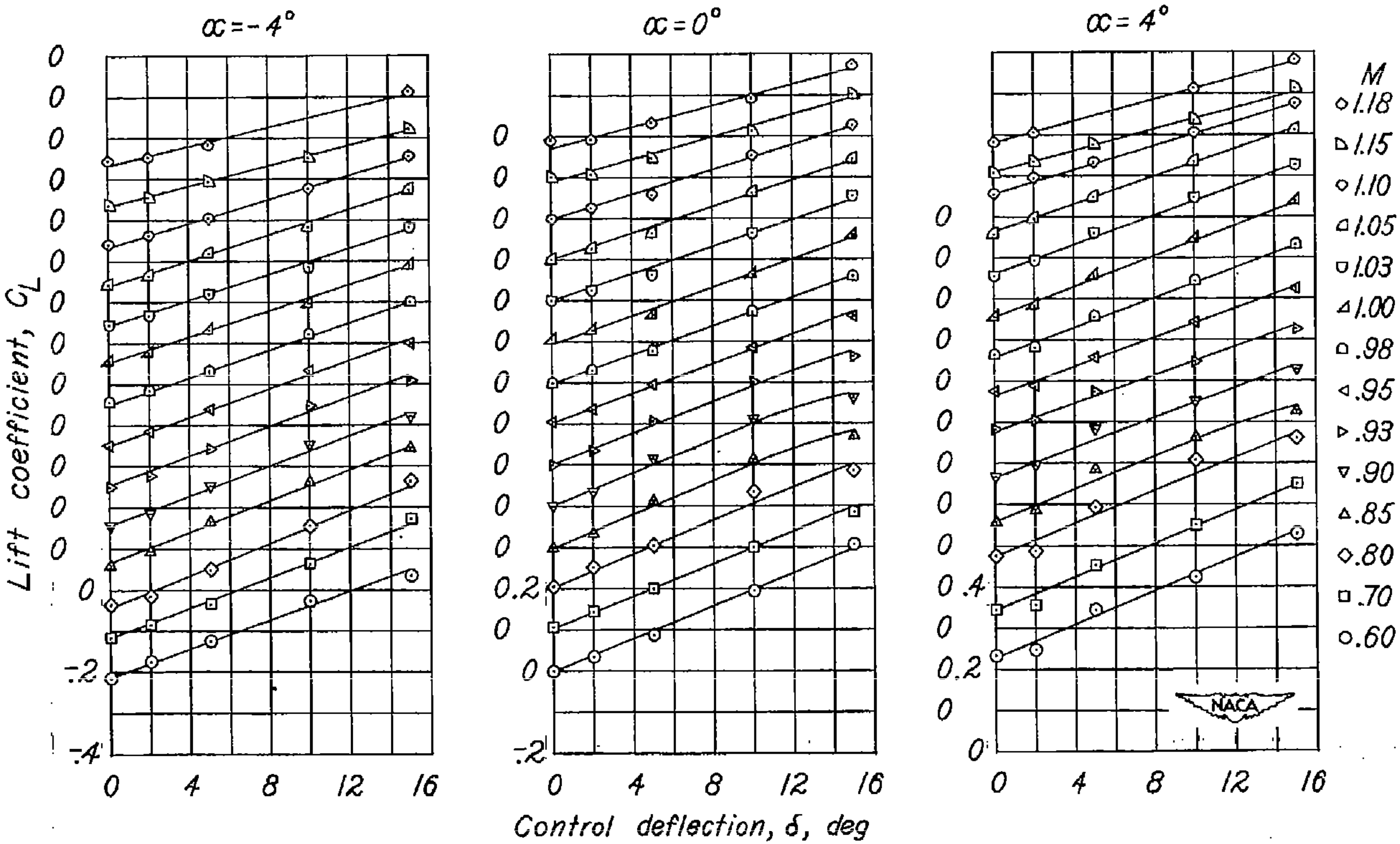
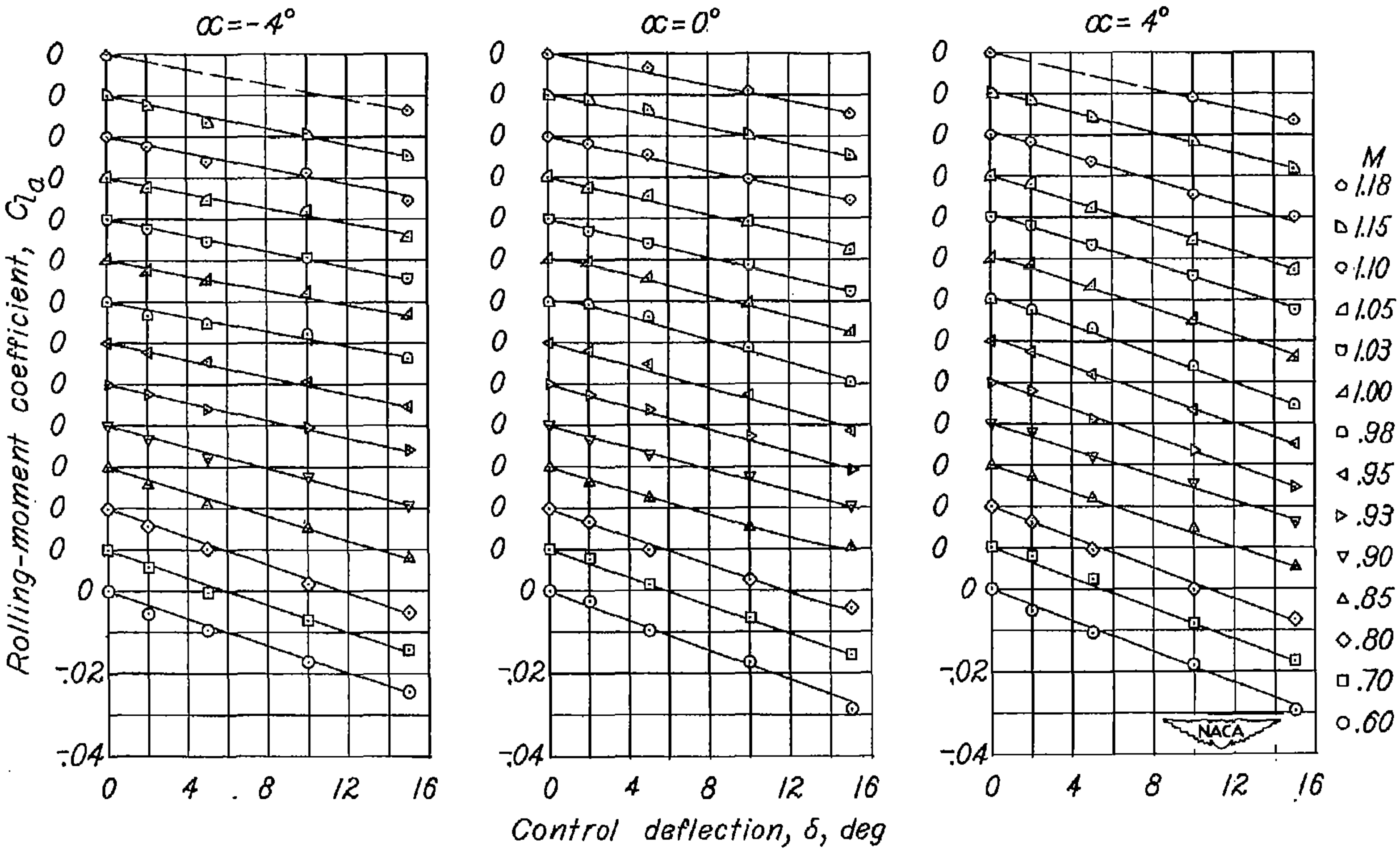


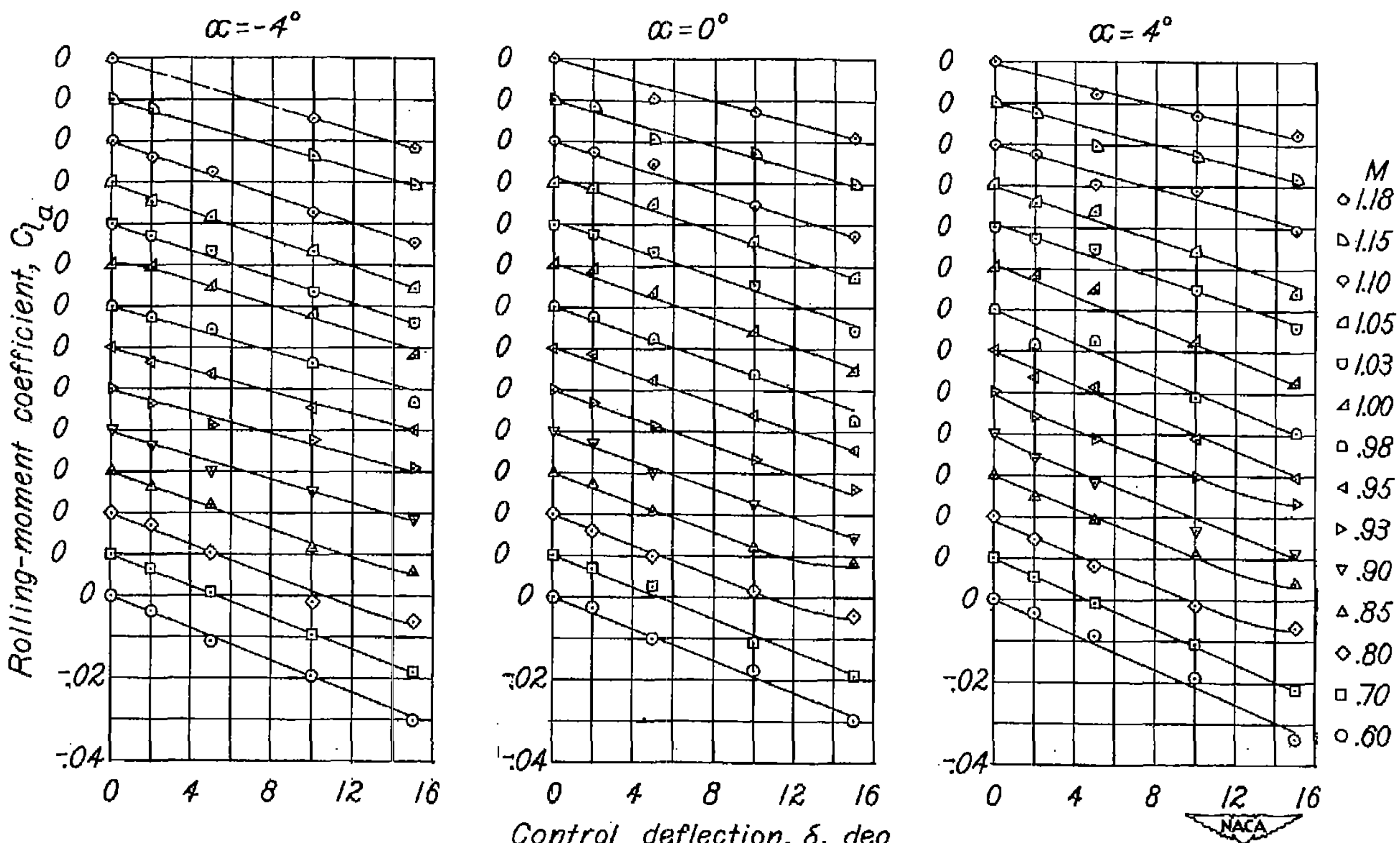
(c) 0.45c control.

Figure 7.- Concluded.



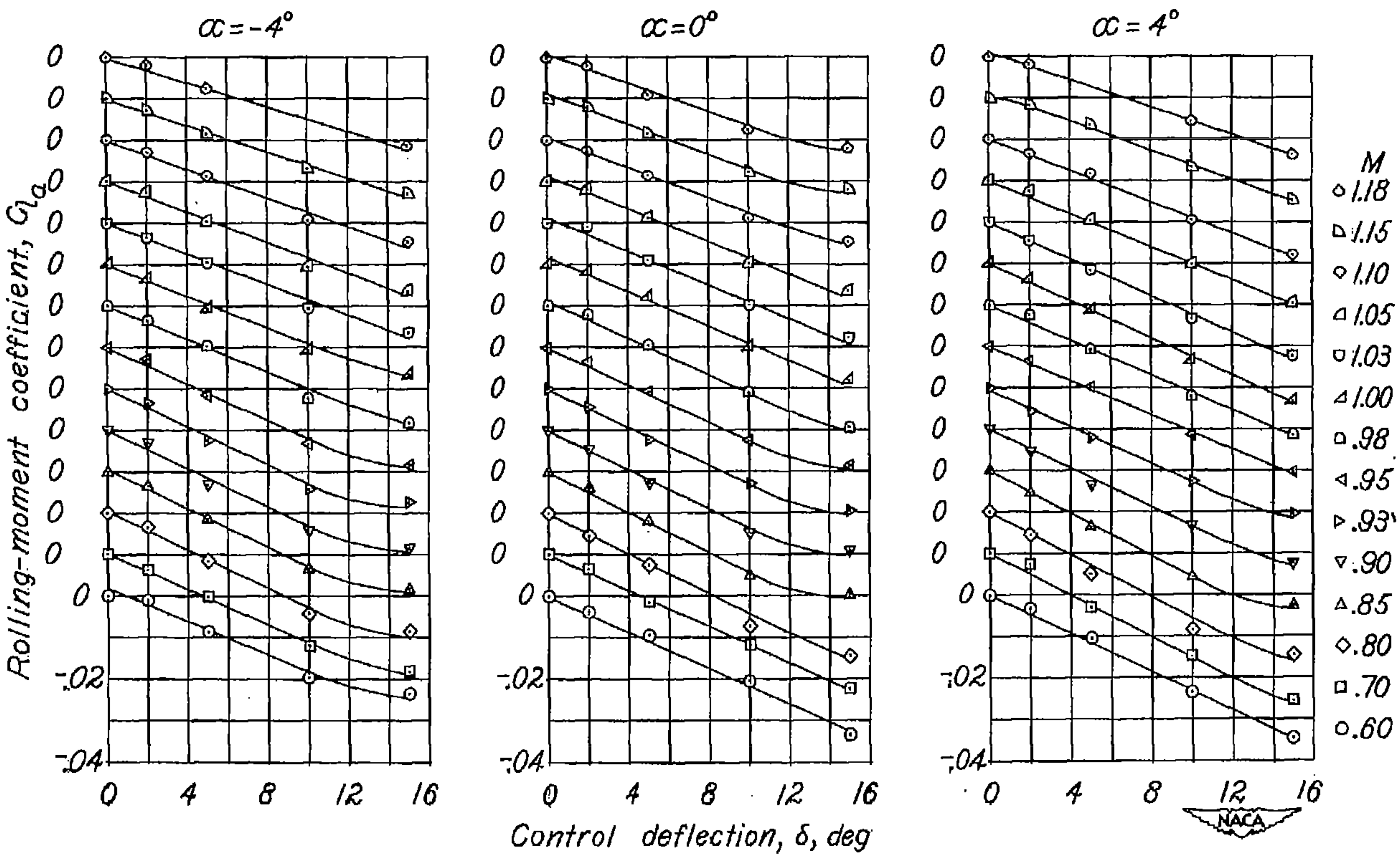
(a) 0.25c control.

Figure 8.- Variation of rolling-moment coefficient with control deflection at three angles of attack for various Mach numbers. $y_i = 0.45\frac{b}{2}$, $y_o = 0.95\frac{b}{2}$.



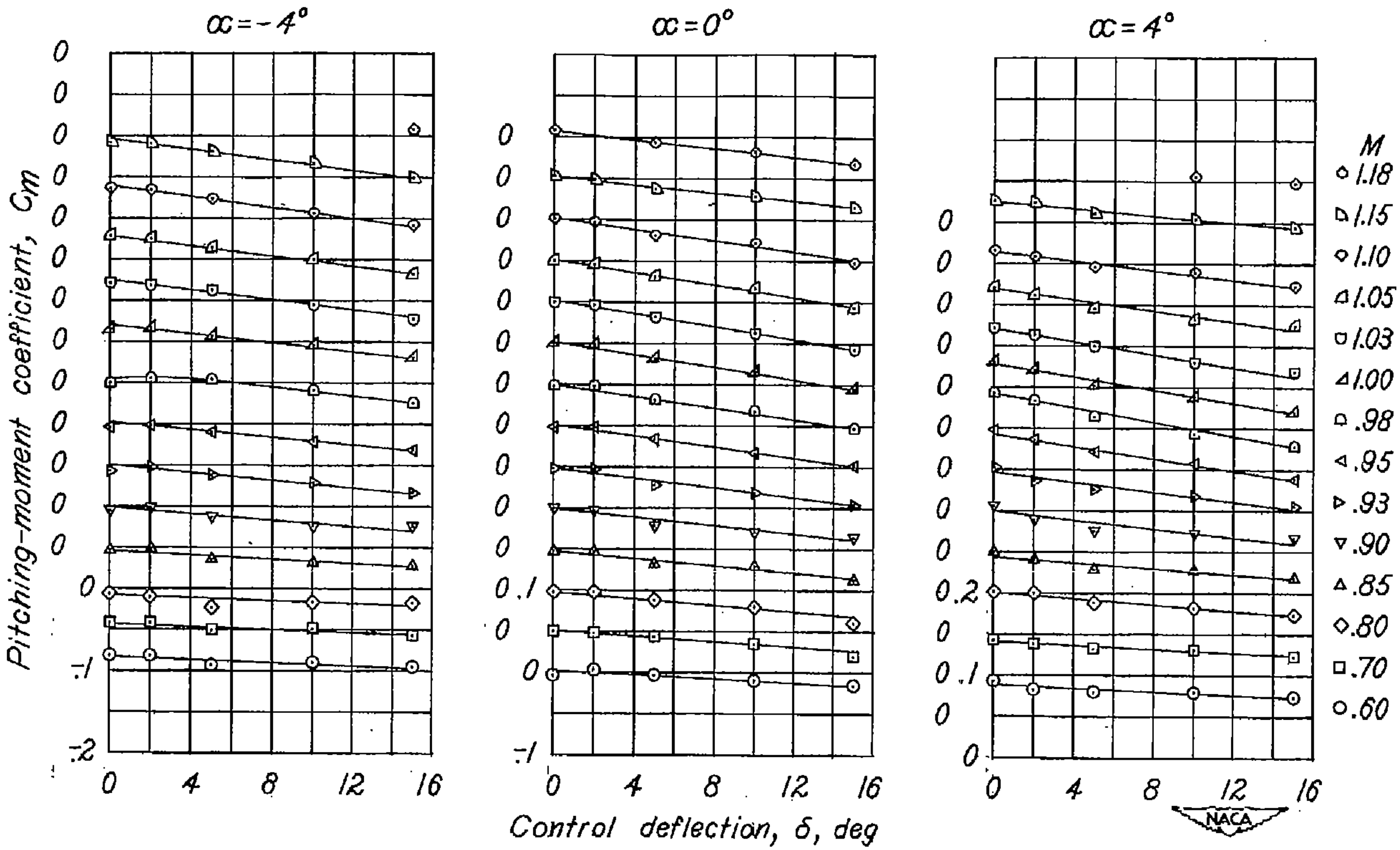
(b) 0.35c control.

Figure 8.- Continued.



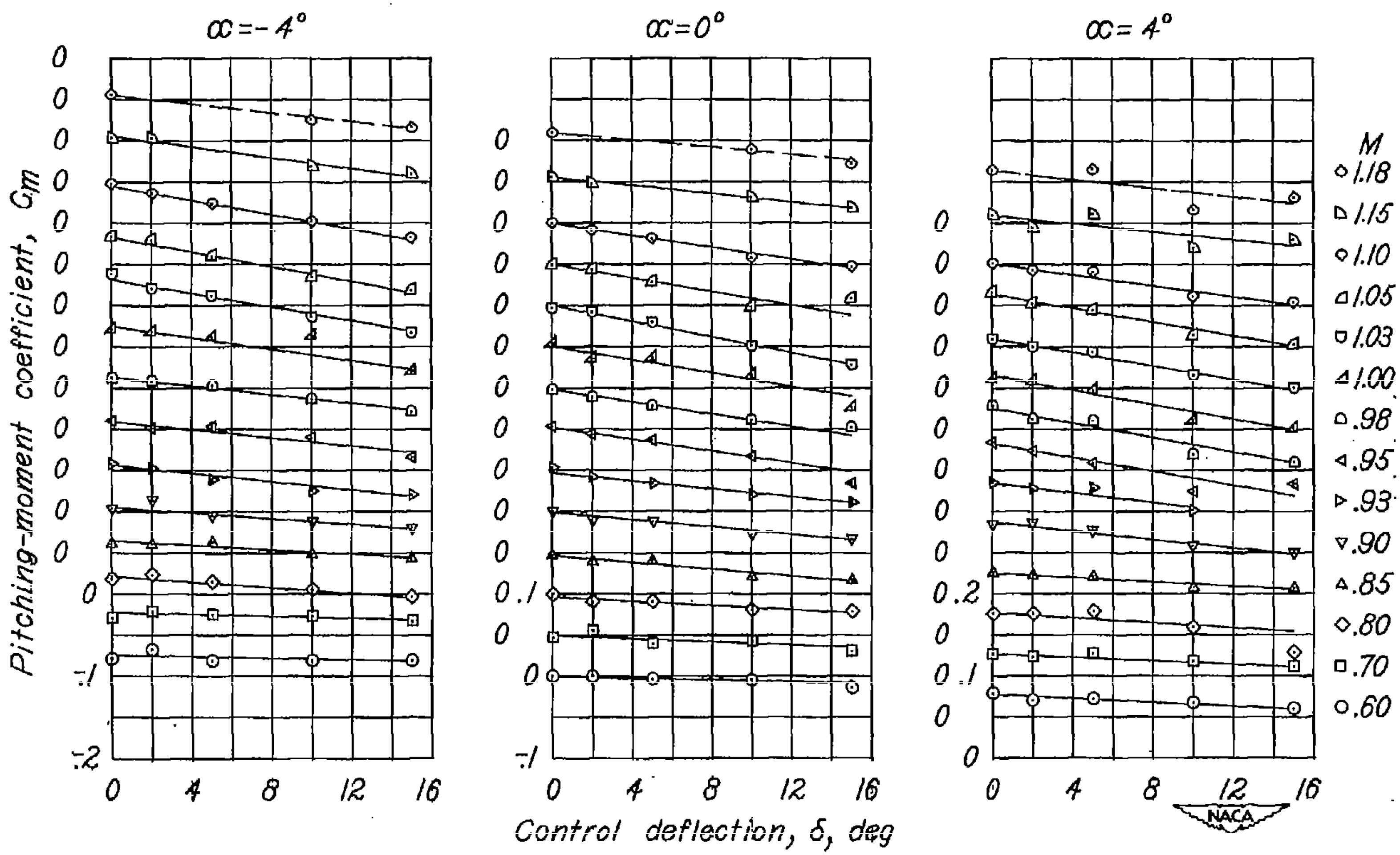
(c) 0.45c control.

Figure 8.- Concluded.



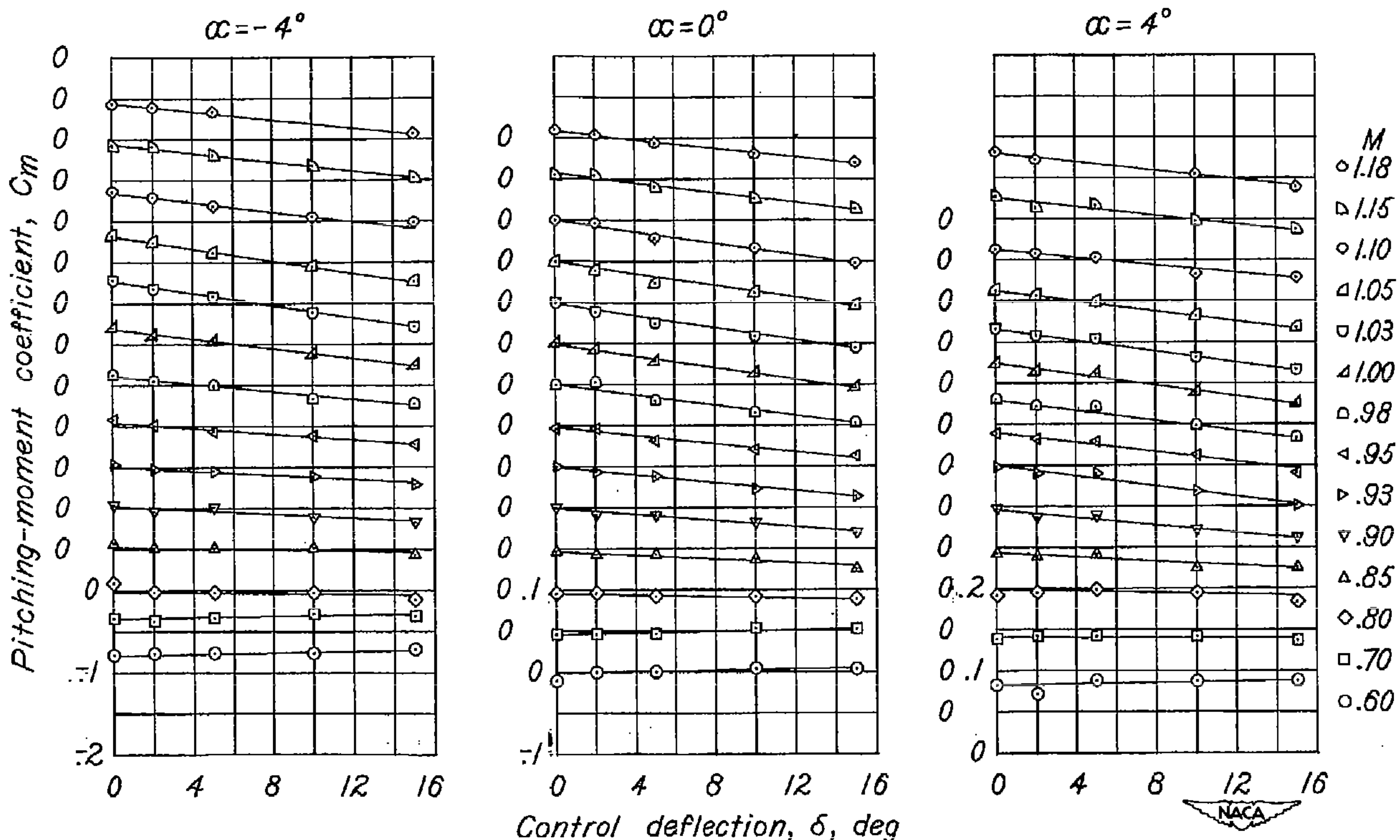
(a) 0.25c control.

Figure 9.- Variation of pitching-moment coefficient with control deflection at three angles of attack for various Mach numbers. $y_i = 0.45\frac{b}{2}$, $y_o = 0.95\frac{b}{2}$.



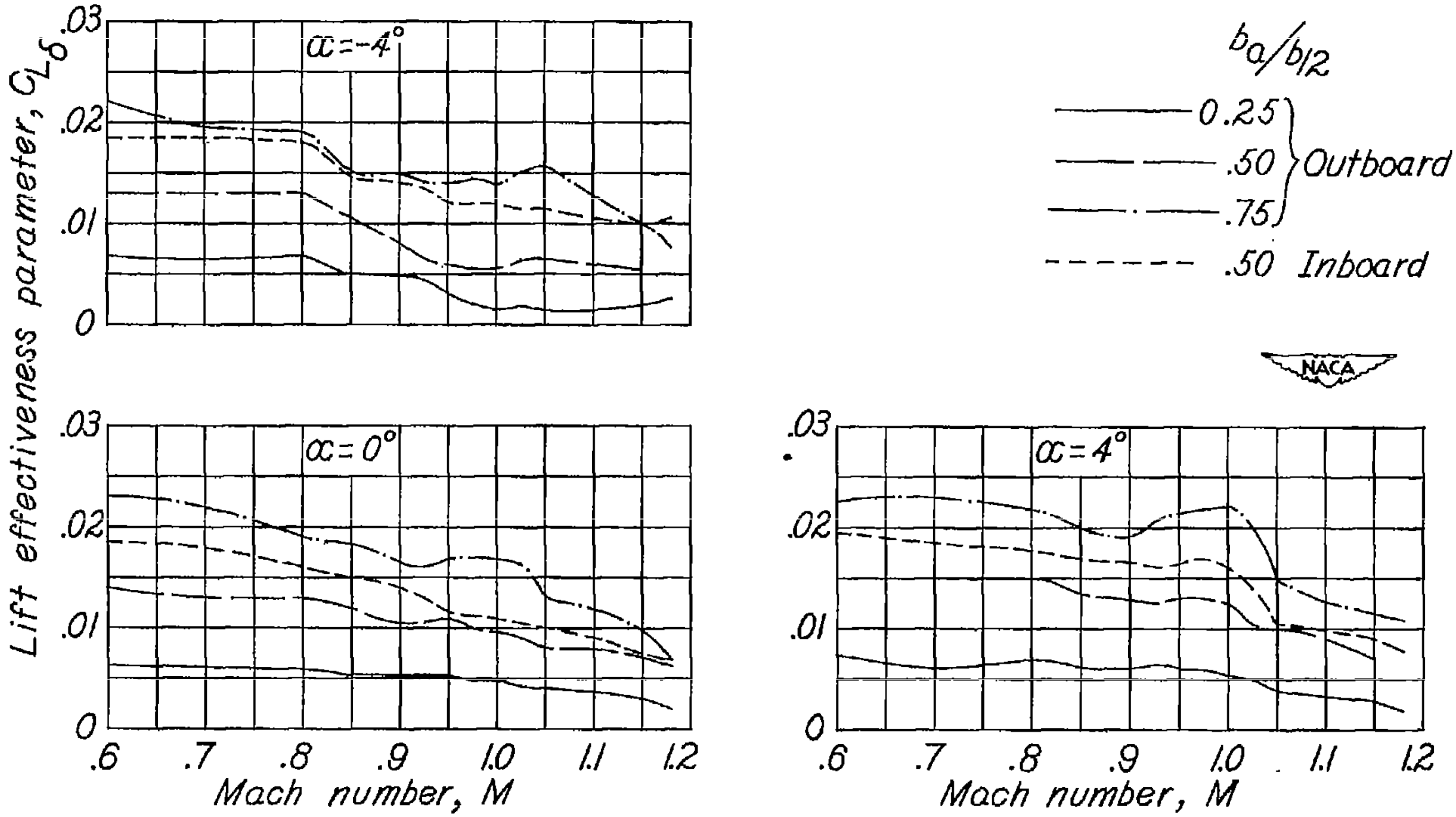
(b) 0.35c control.

Figure 9.- Continued.



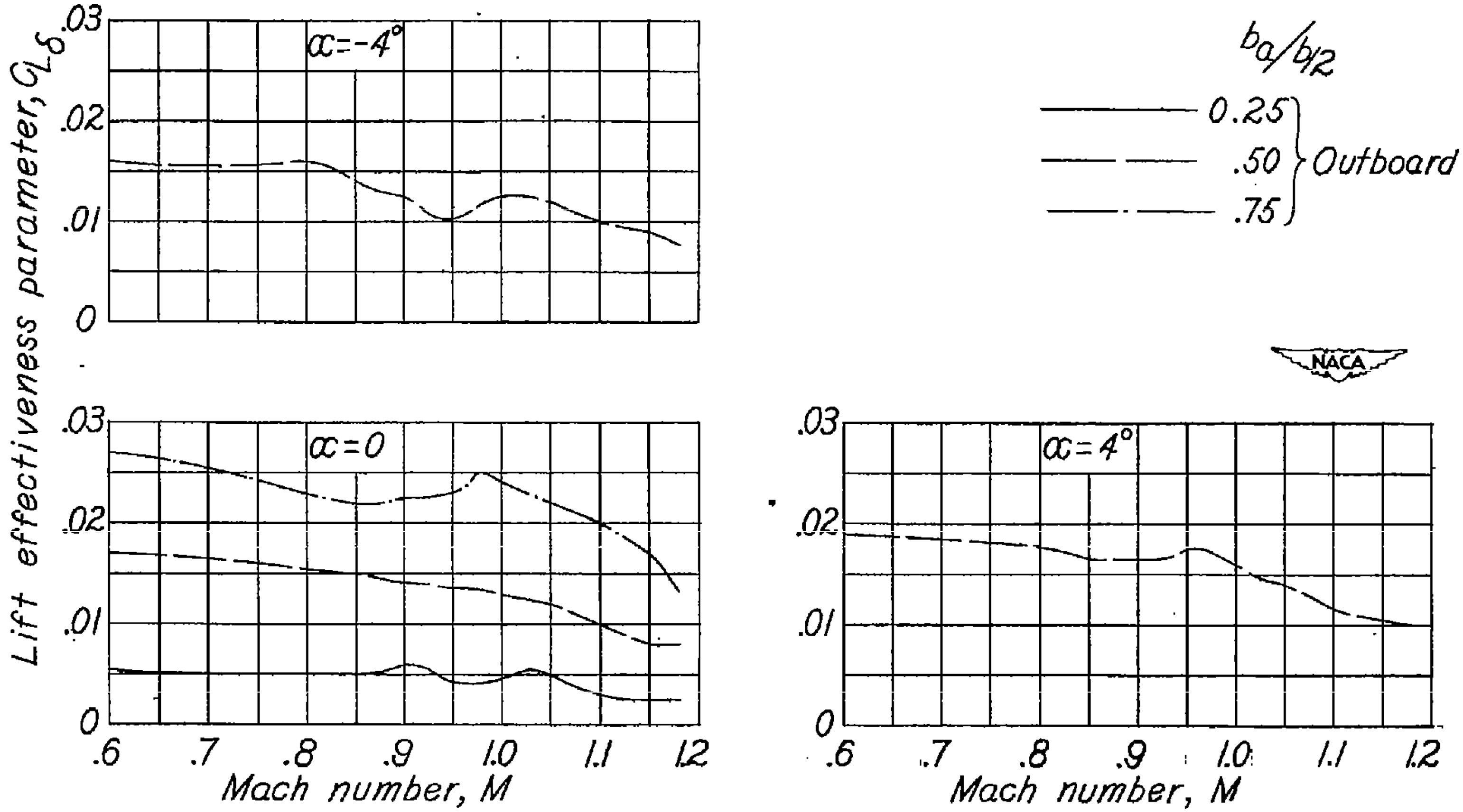
(c) 0.45c control.

Figure 9.- Concluded.



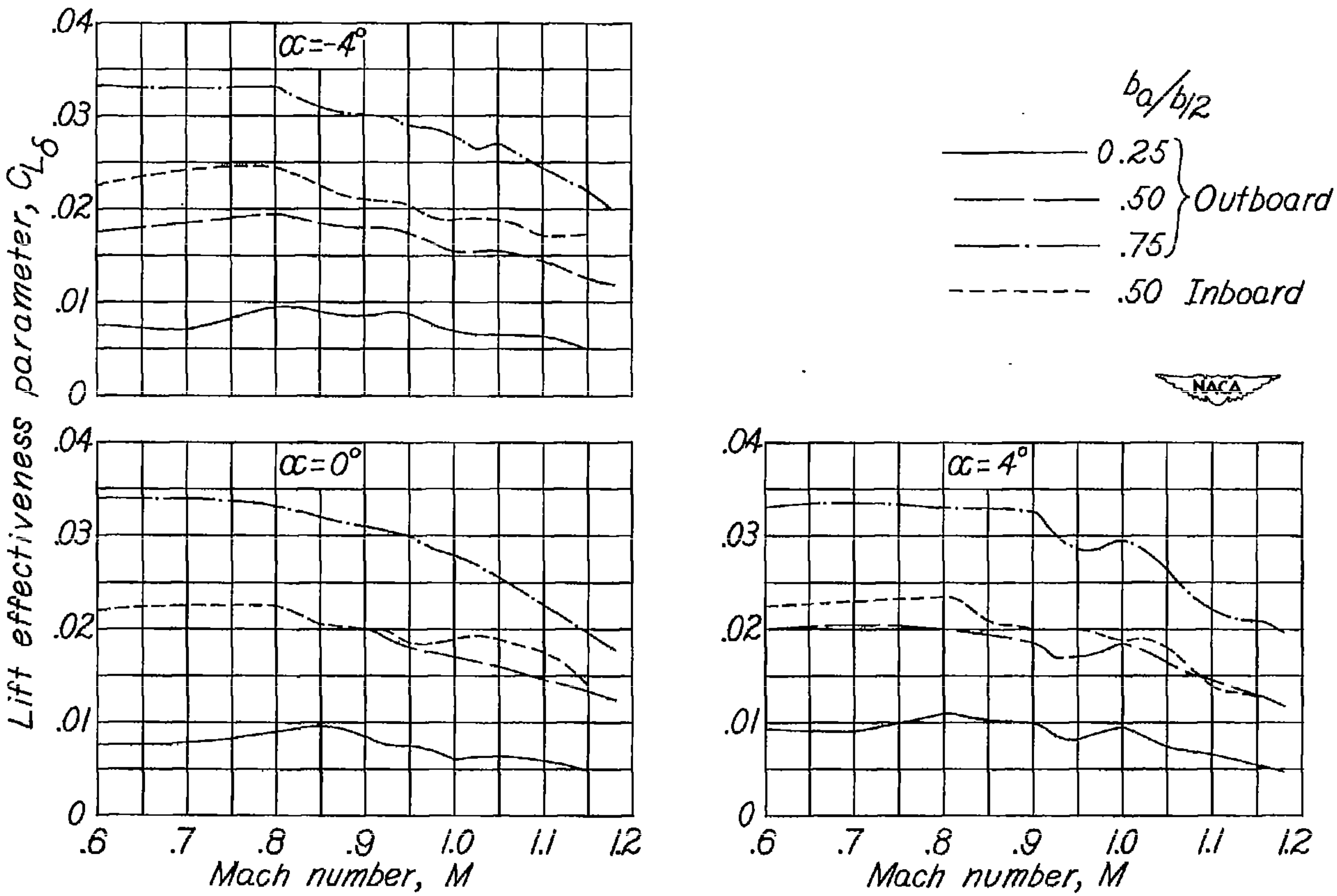
(a) 0.25c control.

Figure 10.- Variation of lift effectiveness parameter with Mach number.



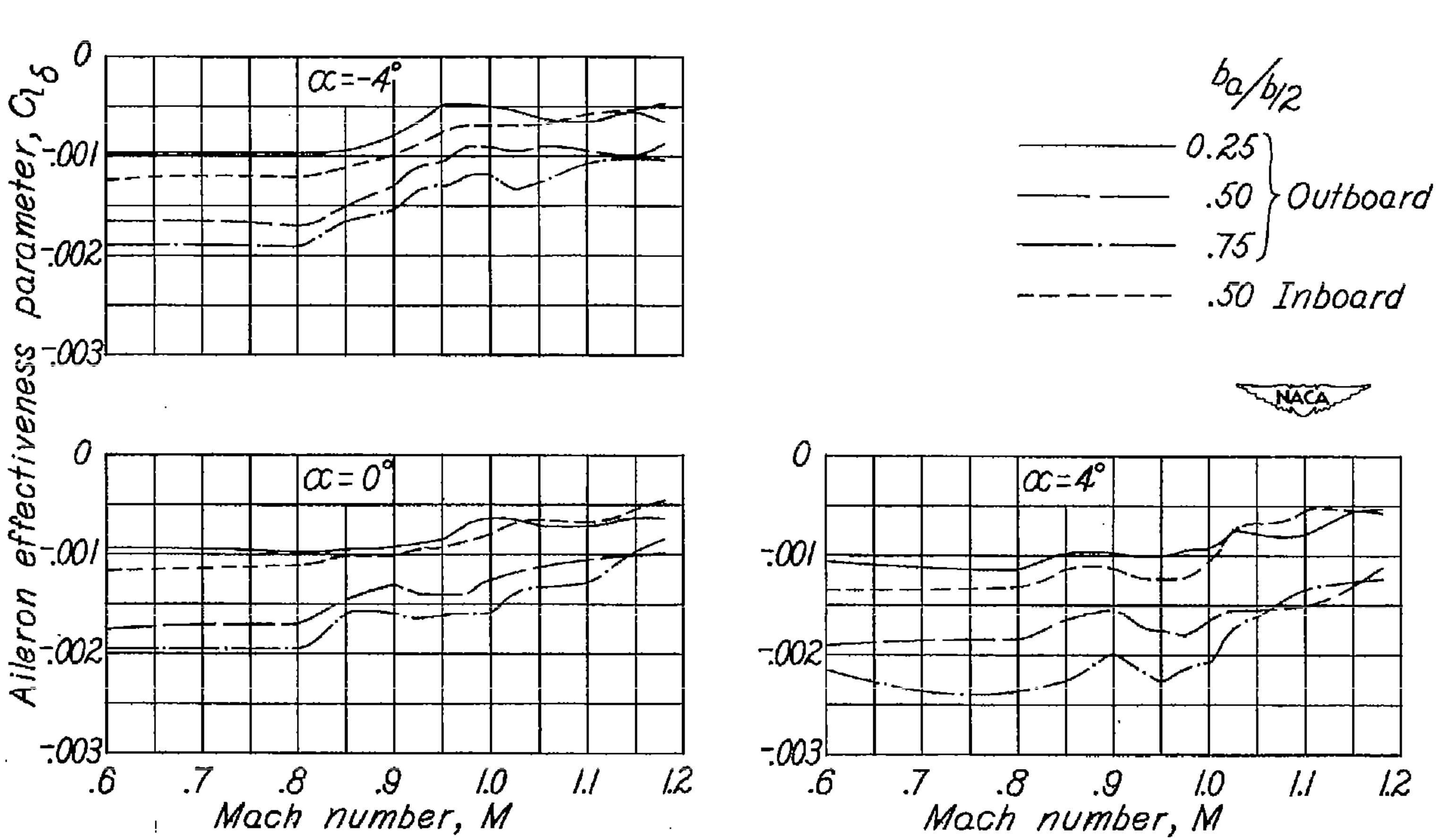
(b) 0.35c control.

Figure 10.- Continued.



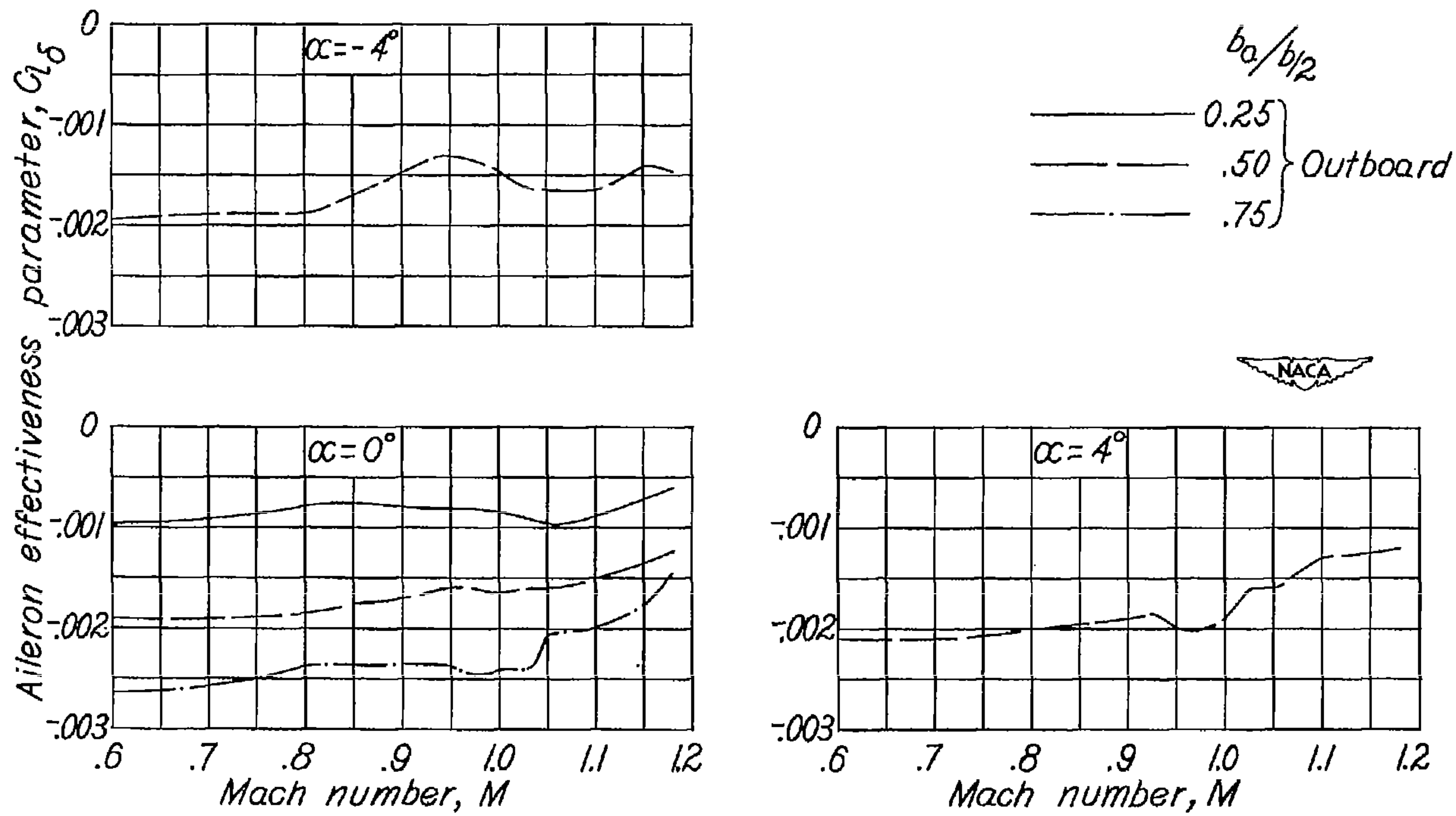
(c) 0.45c control.

Figure 10.- Concluded.



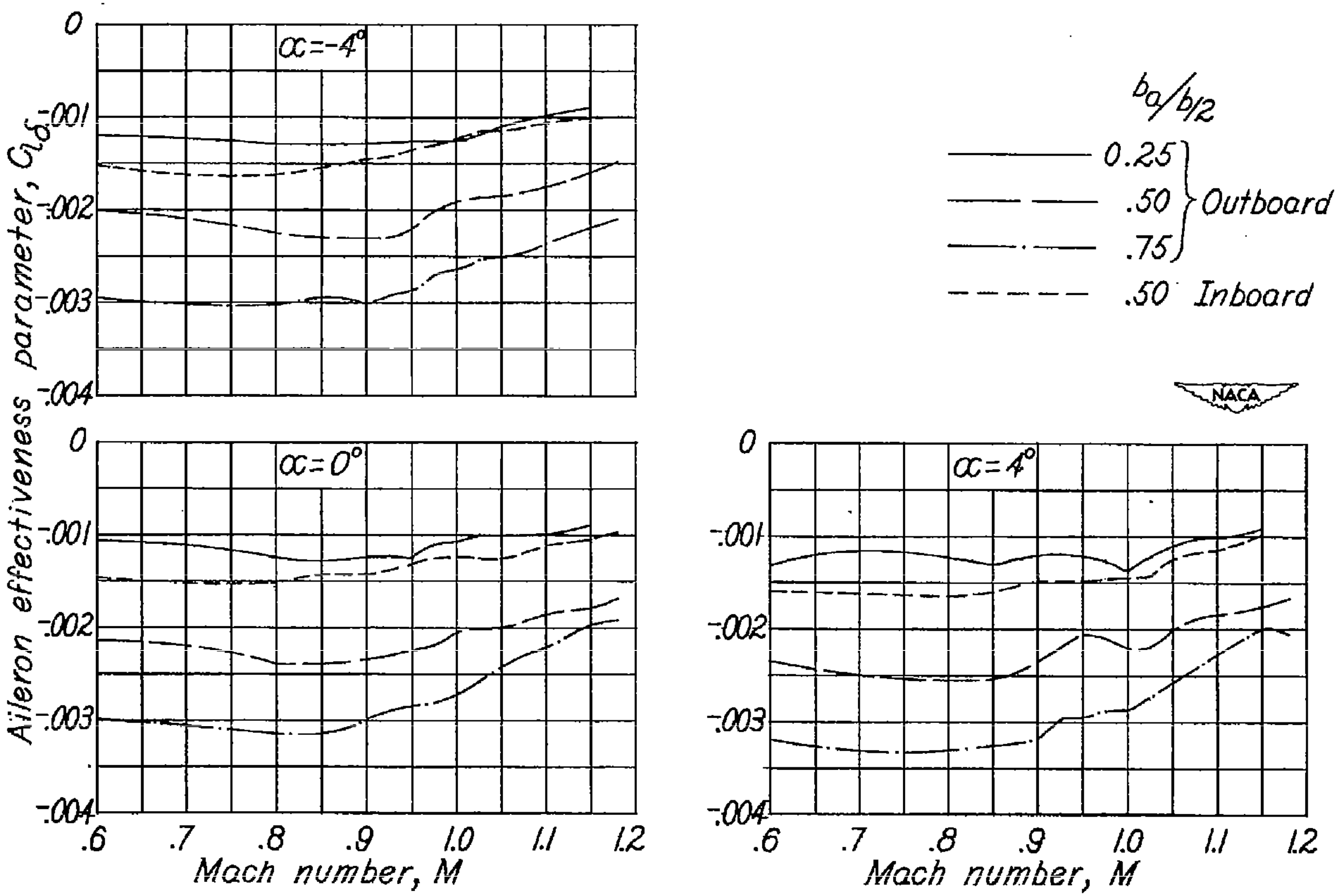
(a) 0.25c control.

Figure 11.- Variation of aileron effectiveness parameter with Mach number.



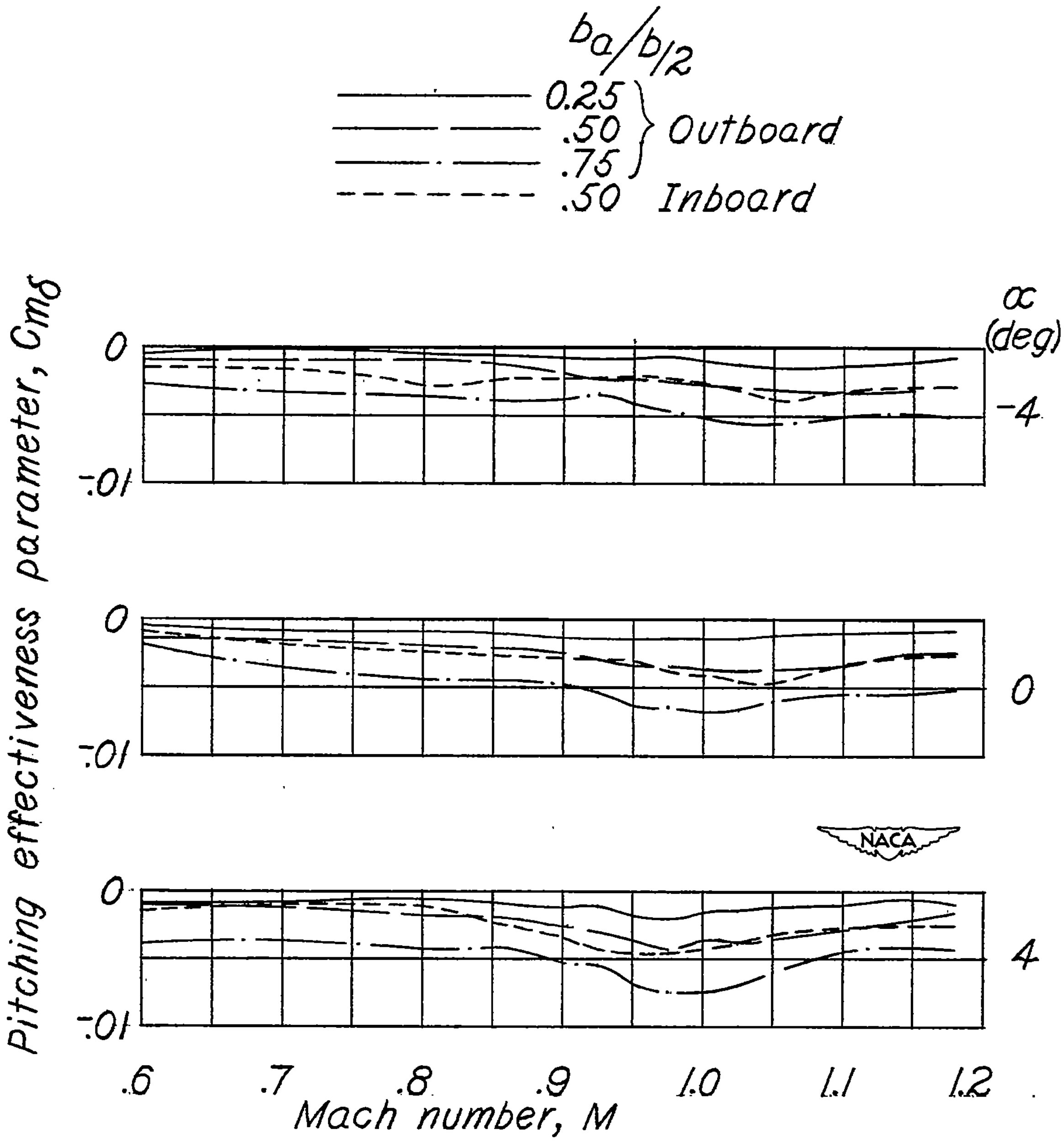
(b) 0.35c control.

Figure 11.- Continued.



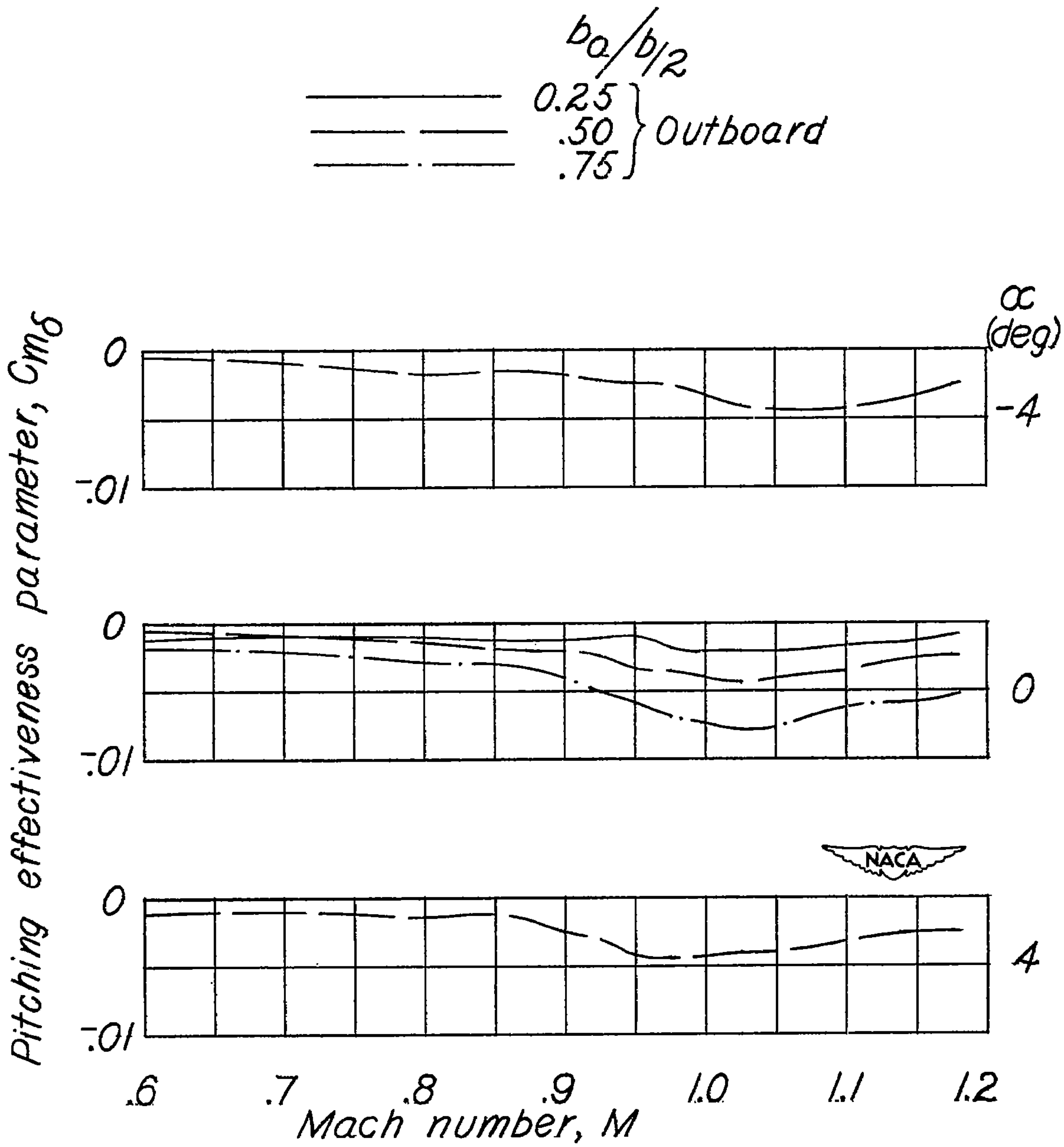
(c) 0.45c control.

Figure 11.- Concluded.



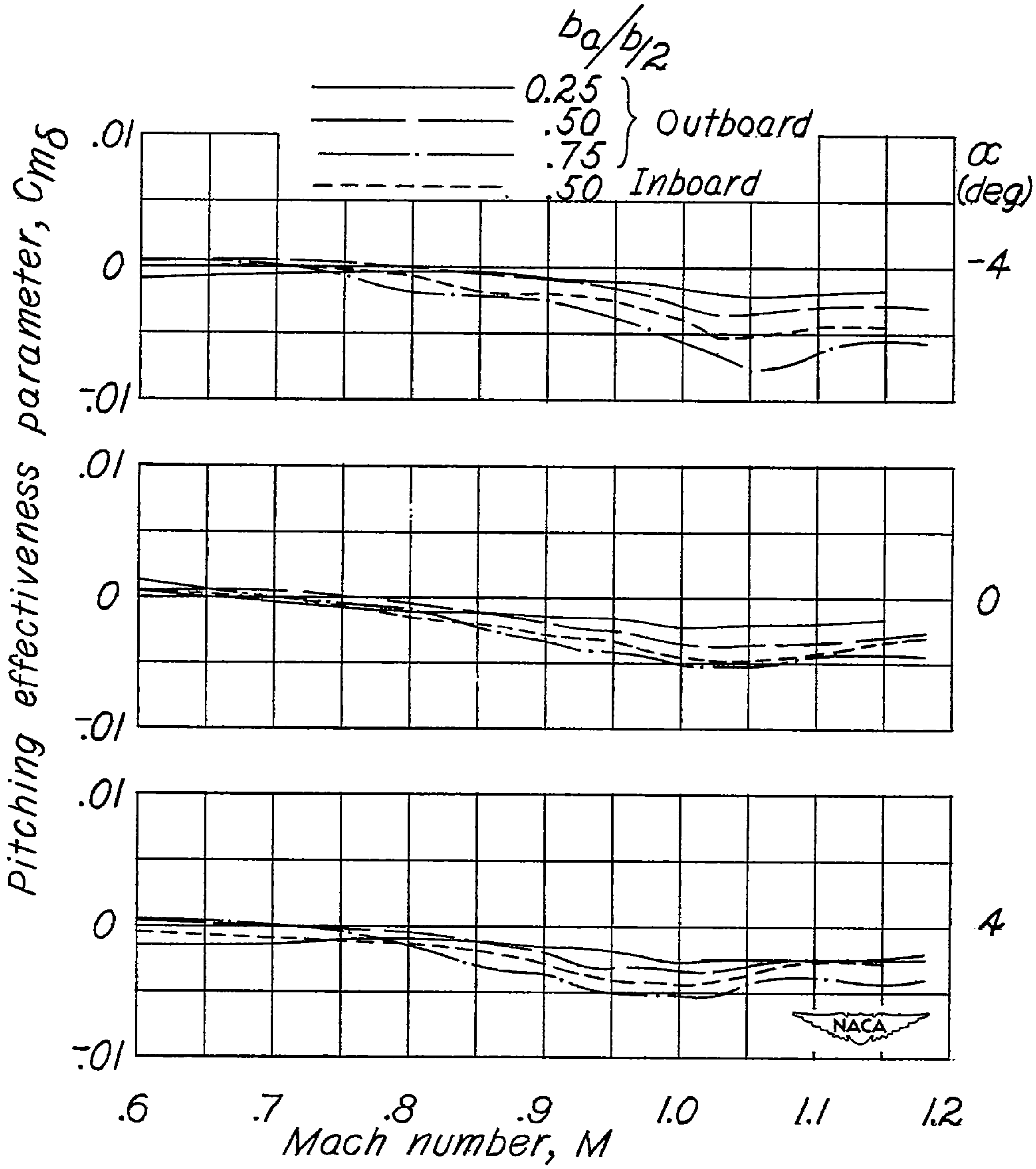
(a) 0.25c control.

Figure 12.- Variation of pitching effectiveness parameter with Mach number.



(b) 0.35c control.

Figure 12.- Continued.



(c) 0.45c control.

Figure 12.- Concluded.

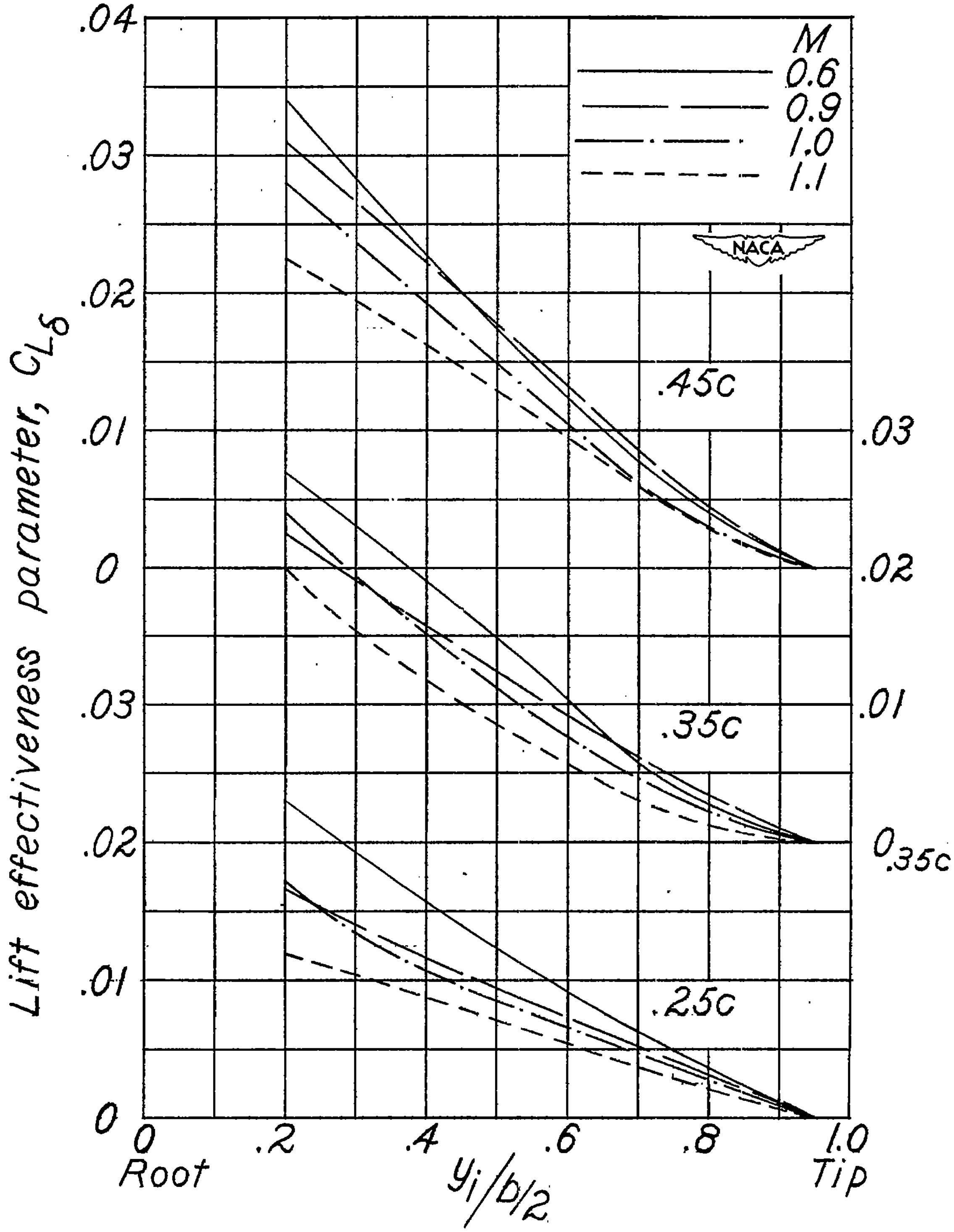


Figure 13.- Effect of control span on the lift effectiveness parameter for controls starting at $0.95\frac{b}{2}$. $\alpha = 0^{\circ}$.

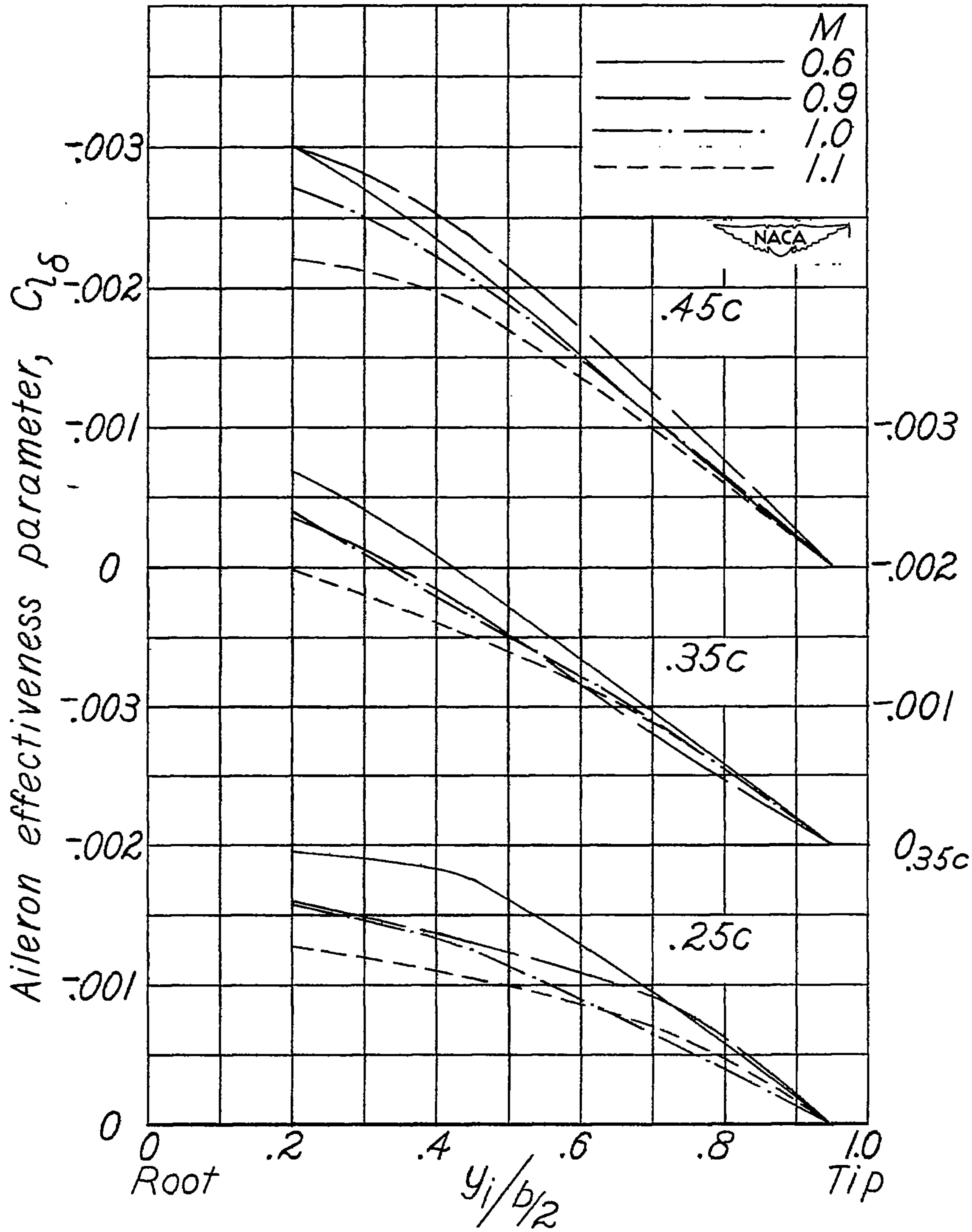


Figure 14.- Effect of control span on the aileron effectiveness parameter for controls starting at $0.95\frac{b}{2}$. $\alpha = 0^{\circ}$.

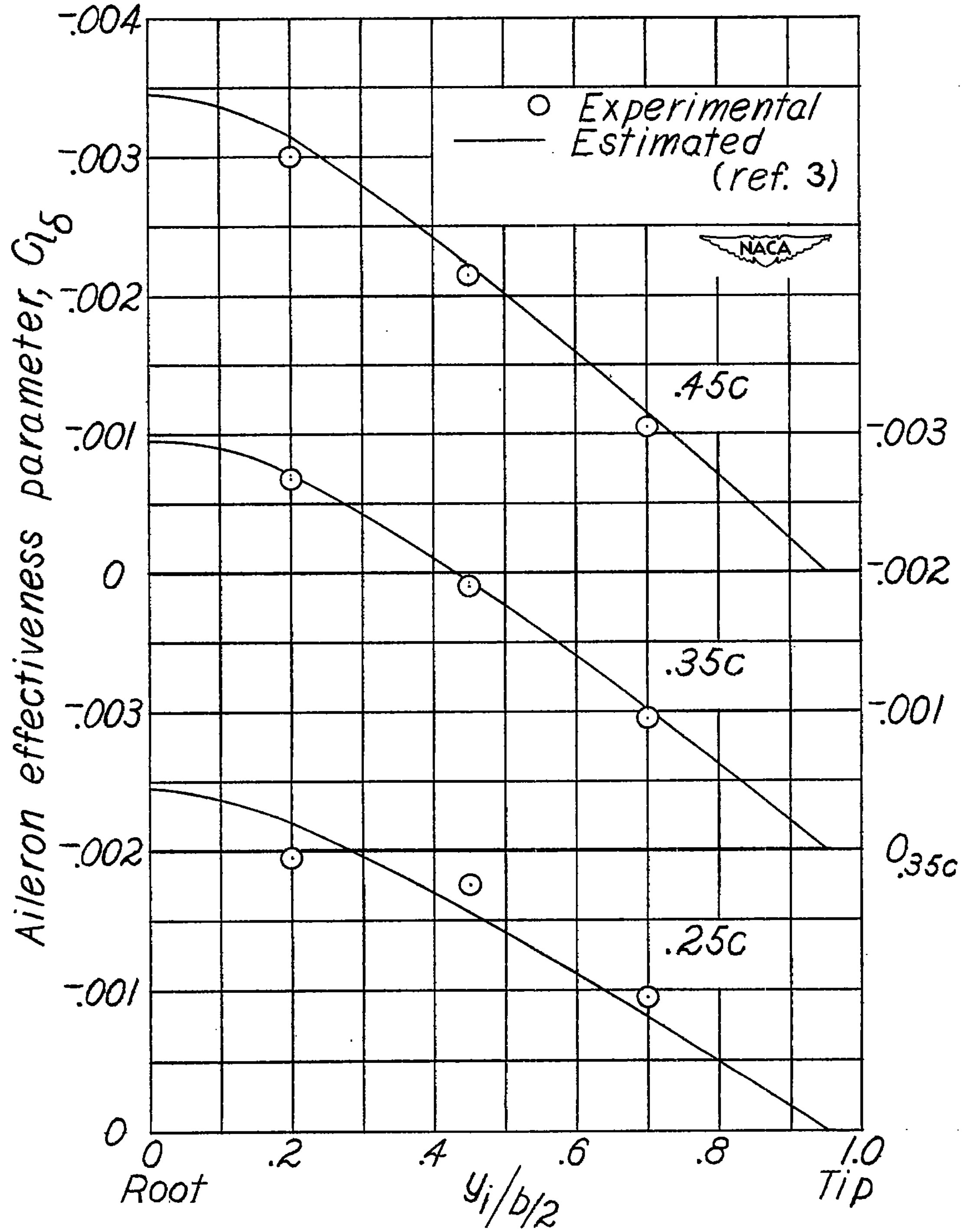


Figure 15.- Comparison of the experimental and the estimated effect of control span on the aileron effectiveness parameter for controls starting at $0.95\frac{b}{2}$. $M = 0.60$; $\alpha = 0^\circ$.

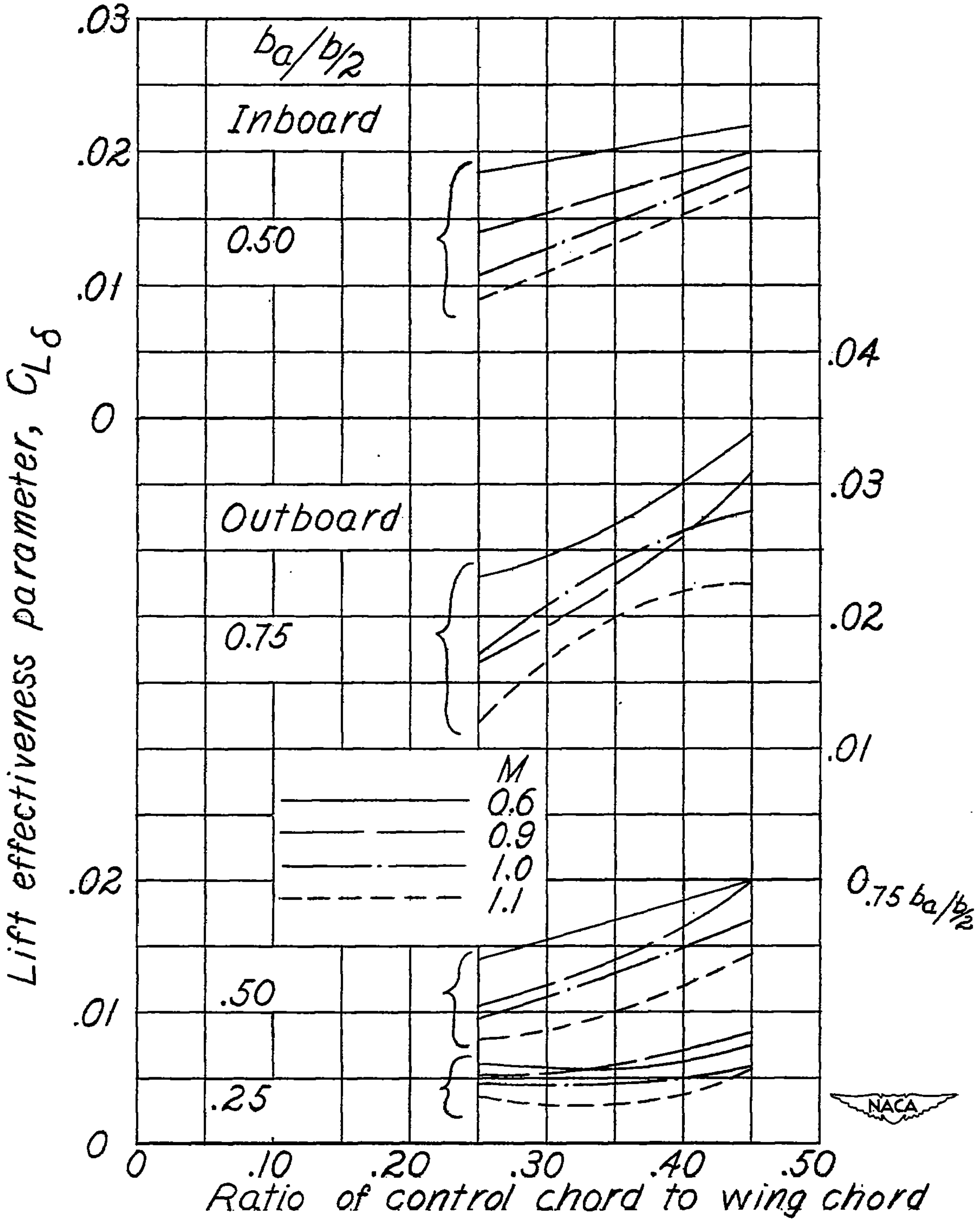


Figure 16.- Variation of lift effectiveness parameter with control-chord magnitude. $\alpha = 0^{\circ}$.

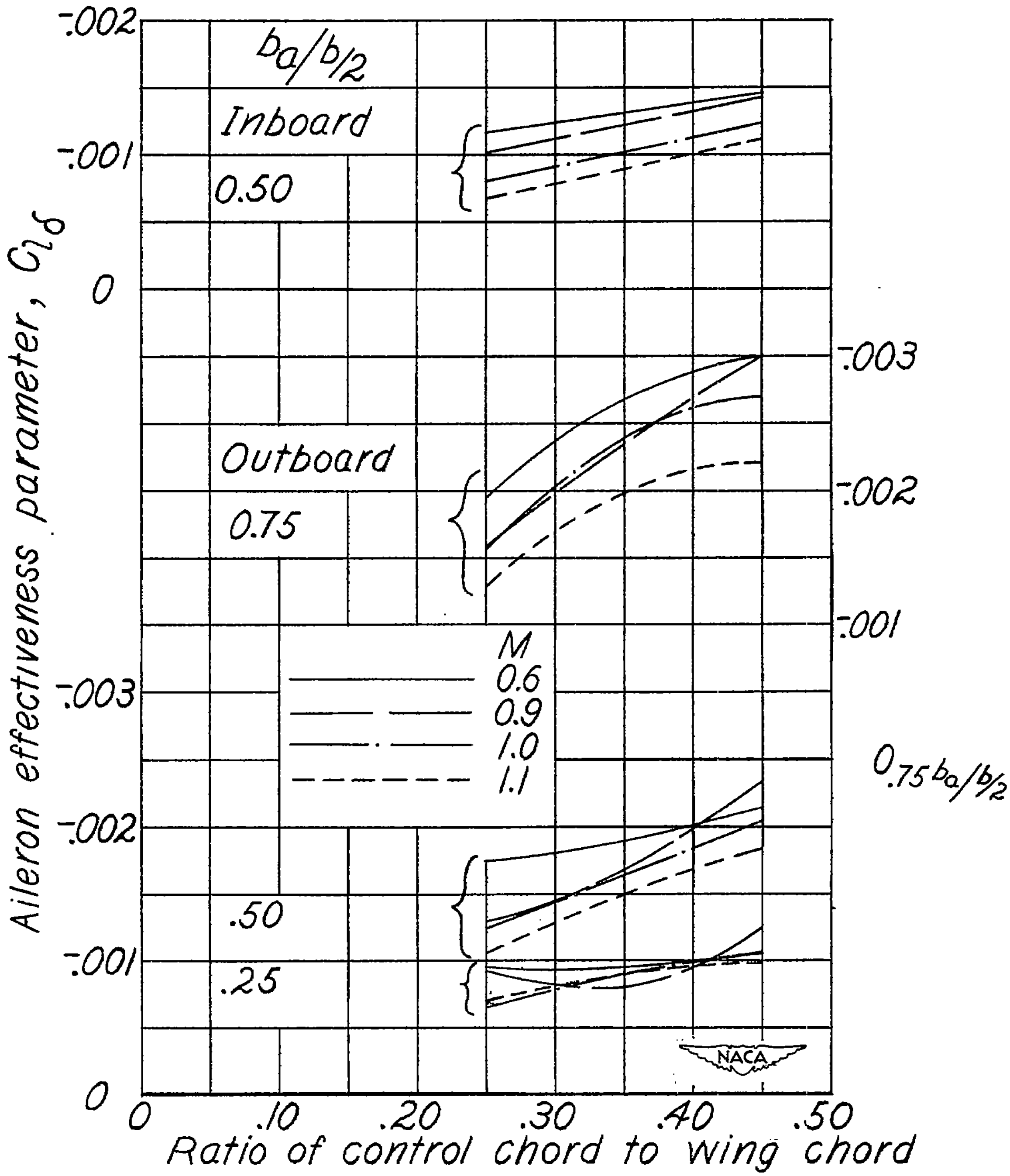
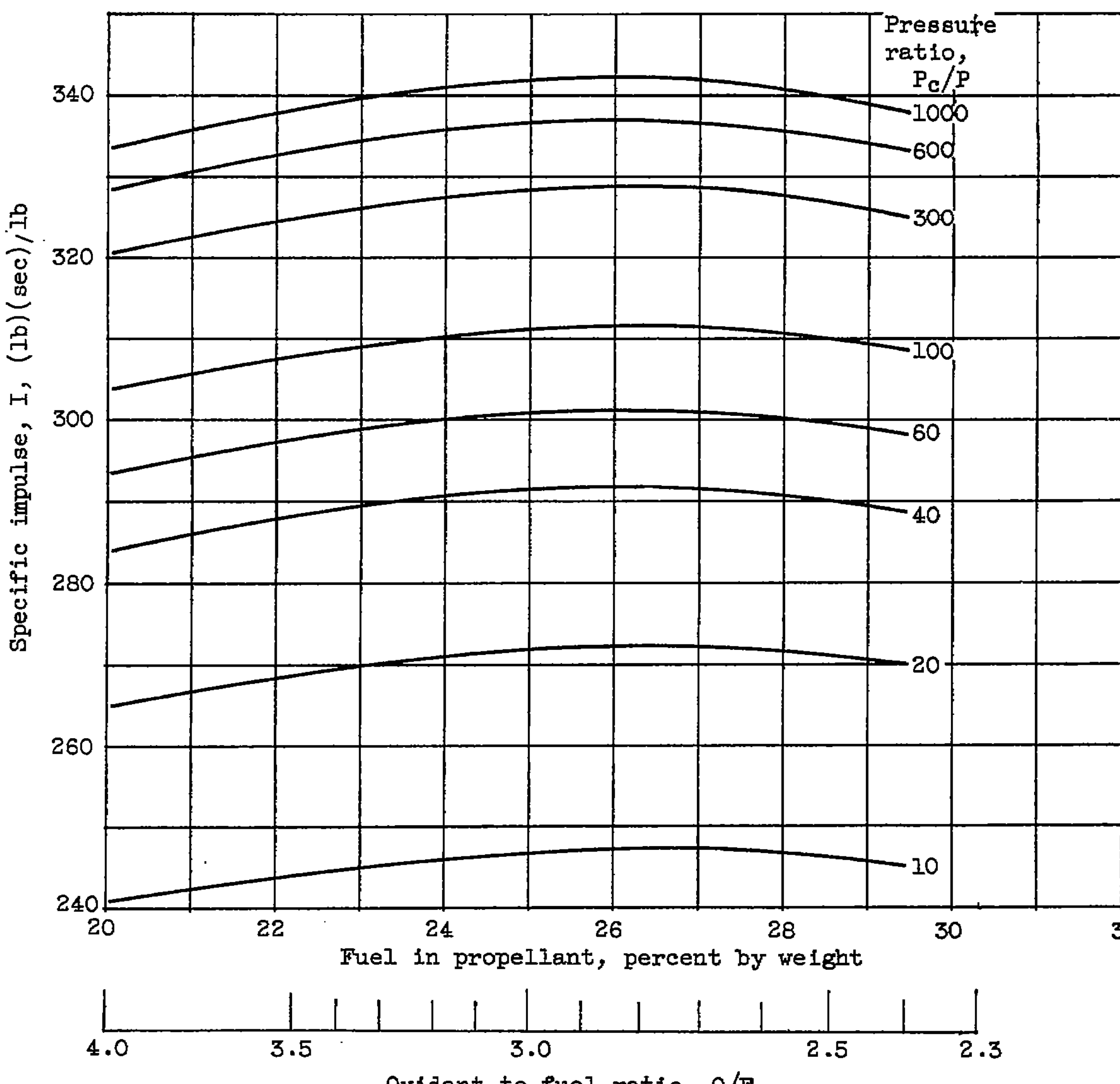


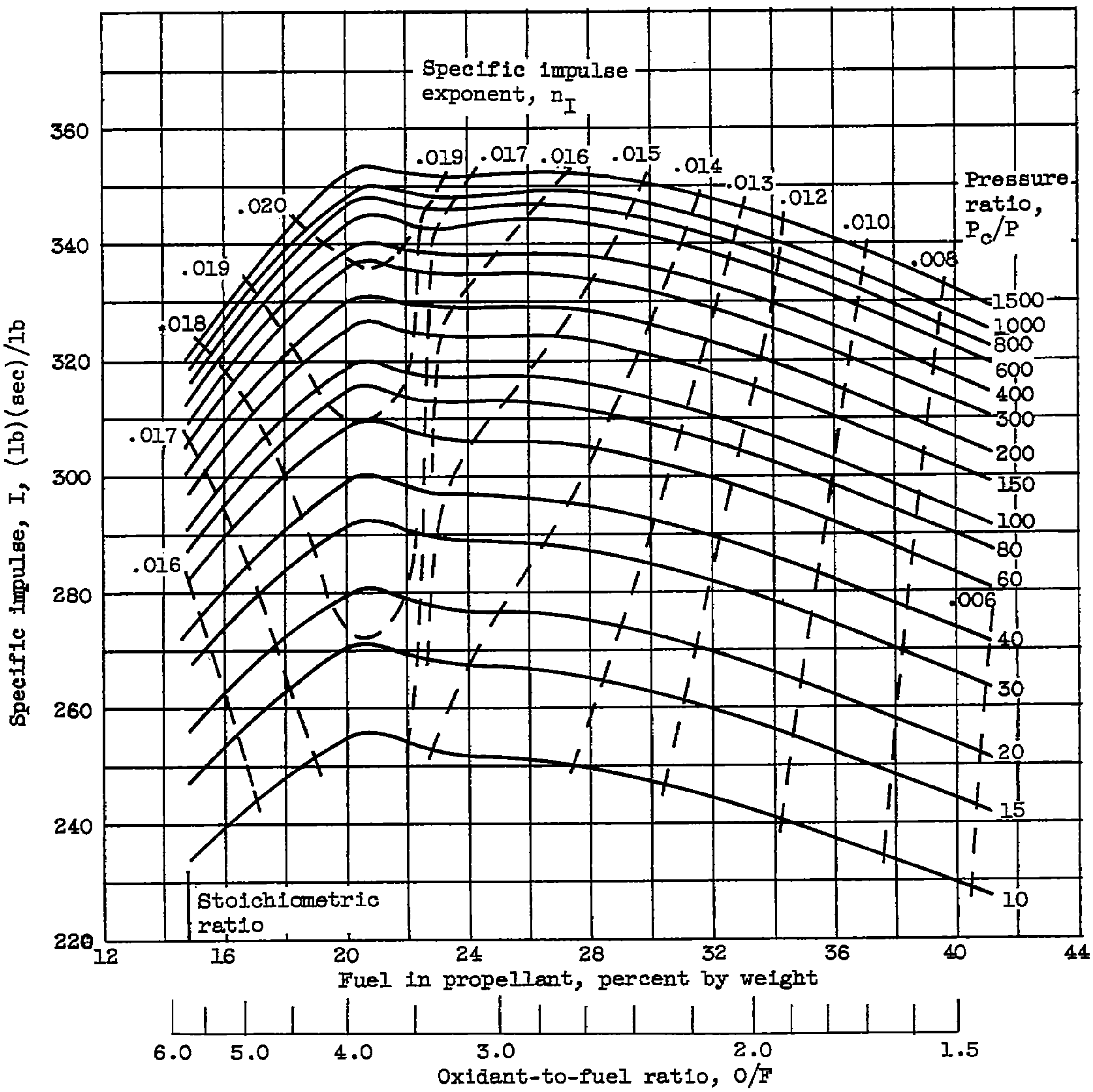
Figure 17.- Variation of aileron effectiveness parameter with control-chord magnitude. $\alpha = 0^{\circ}$.

NACA-Langley - 9-20-51 - 325



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

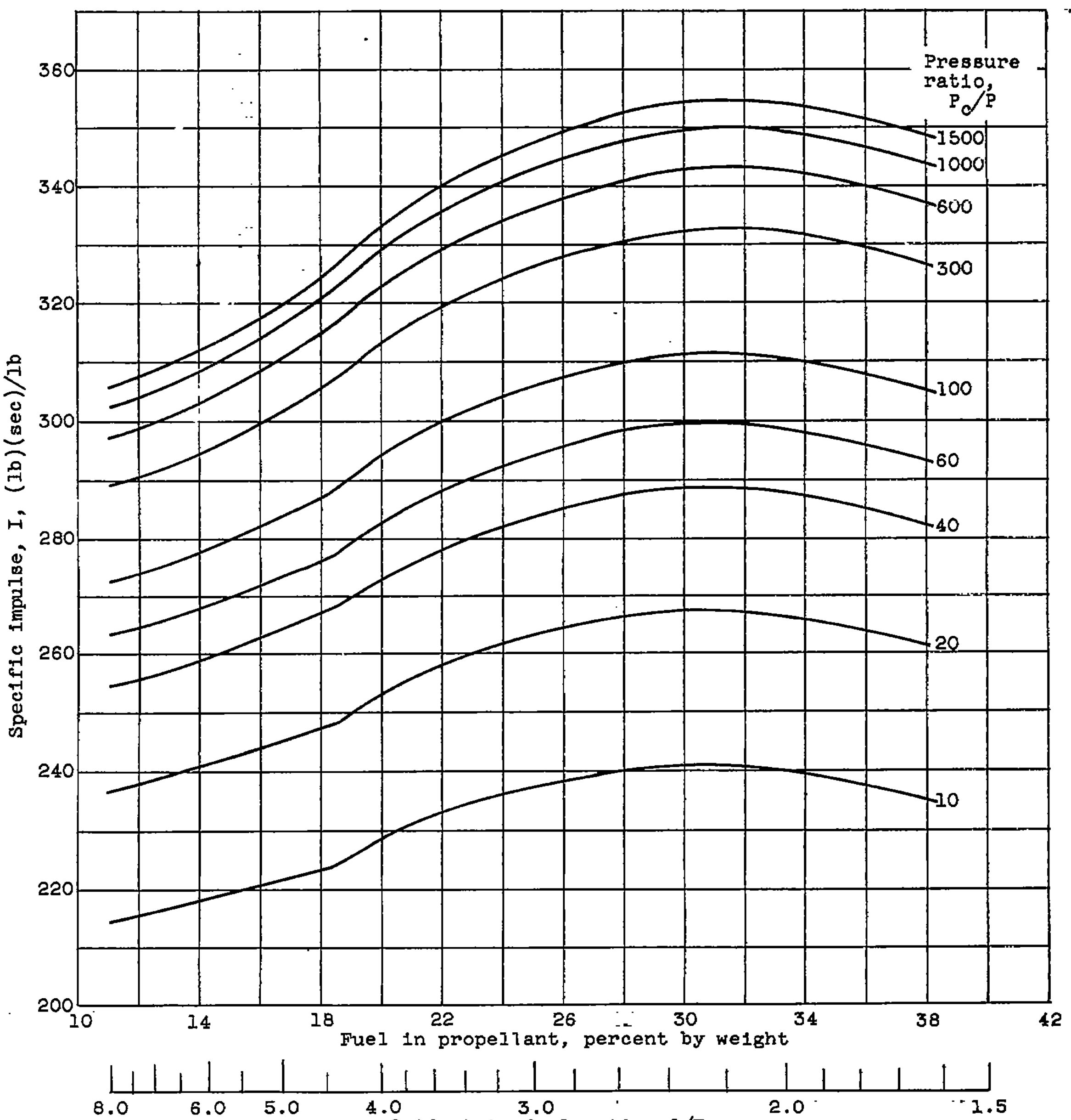
Figure 1. - Continued. Theoretical specific impulse of JP-4 fuel with several fluorine-oxygen mixtures. Frozen composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



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

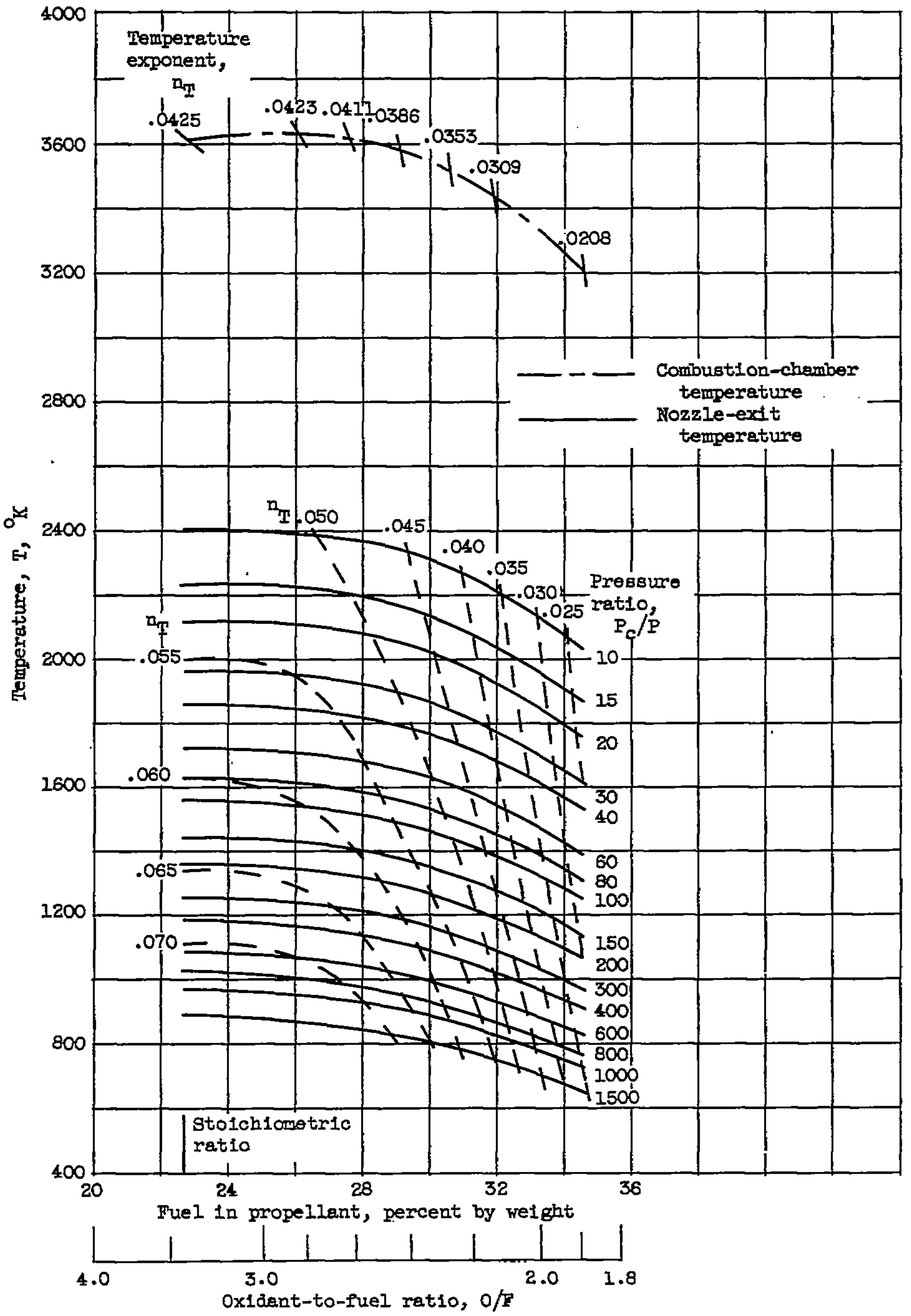
Exponent n_I for use in equation $I = I_{600}\left(\frac{P_c}{600}\right)^{n_I}$.

Figure 1. - Continued. Theoretical specific impulse of JP-4 fuel 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, 100 (zero percent oxygen).

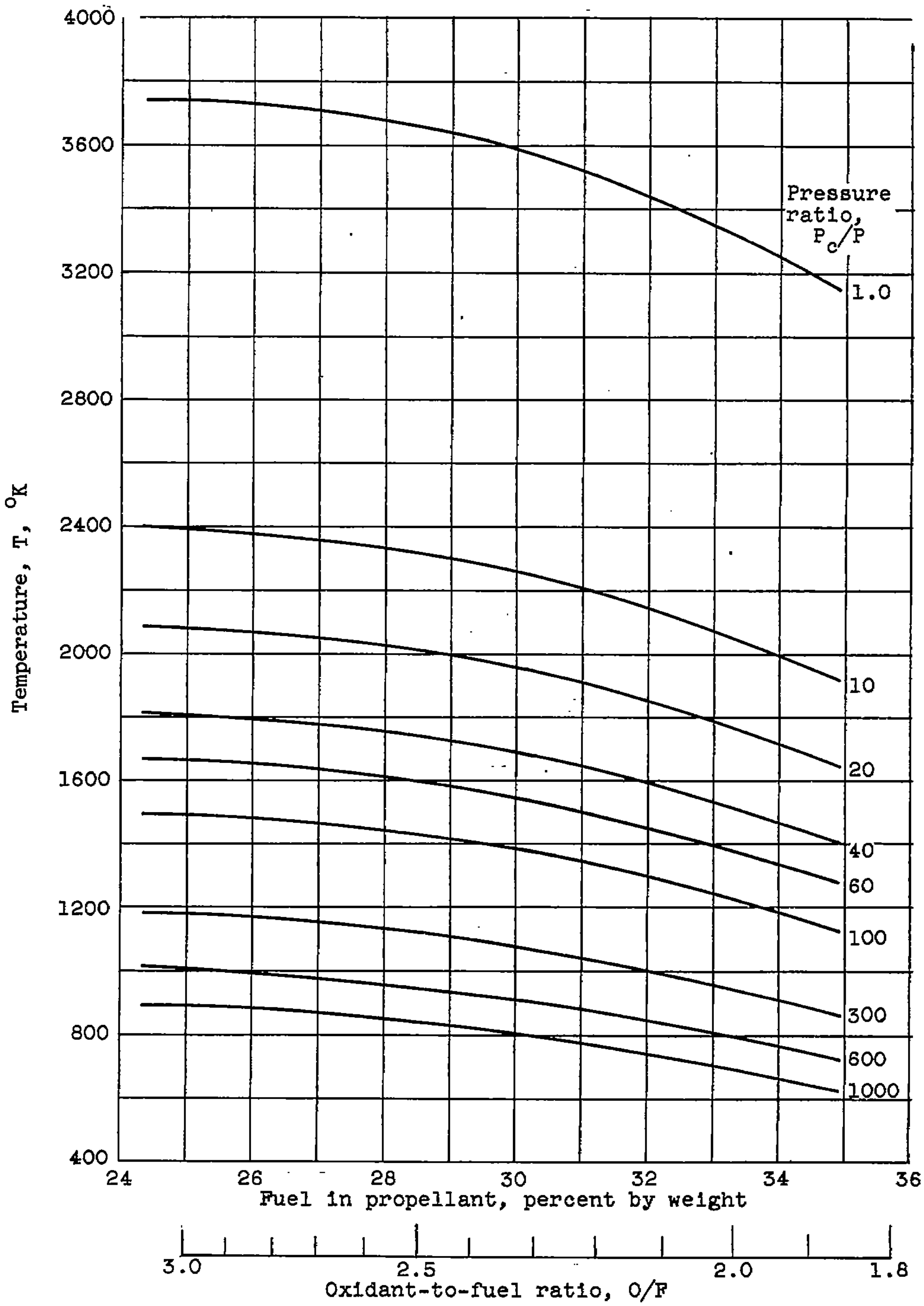
Figure 1. - Concluded. Theoretical specific impulse of JP-4 fuel with several fluorine-oxygen mixtures. Frozen composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



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

Exponent n_T for use in equation $T = T_{600} \left(\frac{P_c}{600}\right)^{n_T}$.

Figure 2. - Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel 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, 15.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel 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.

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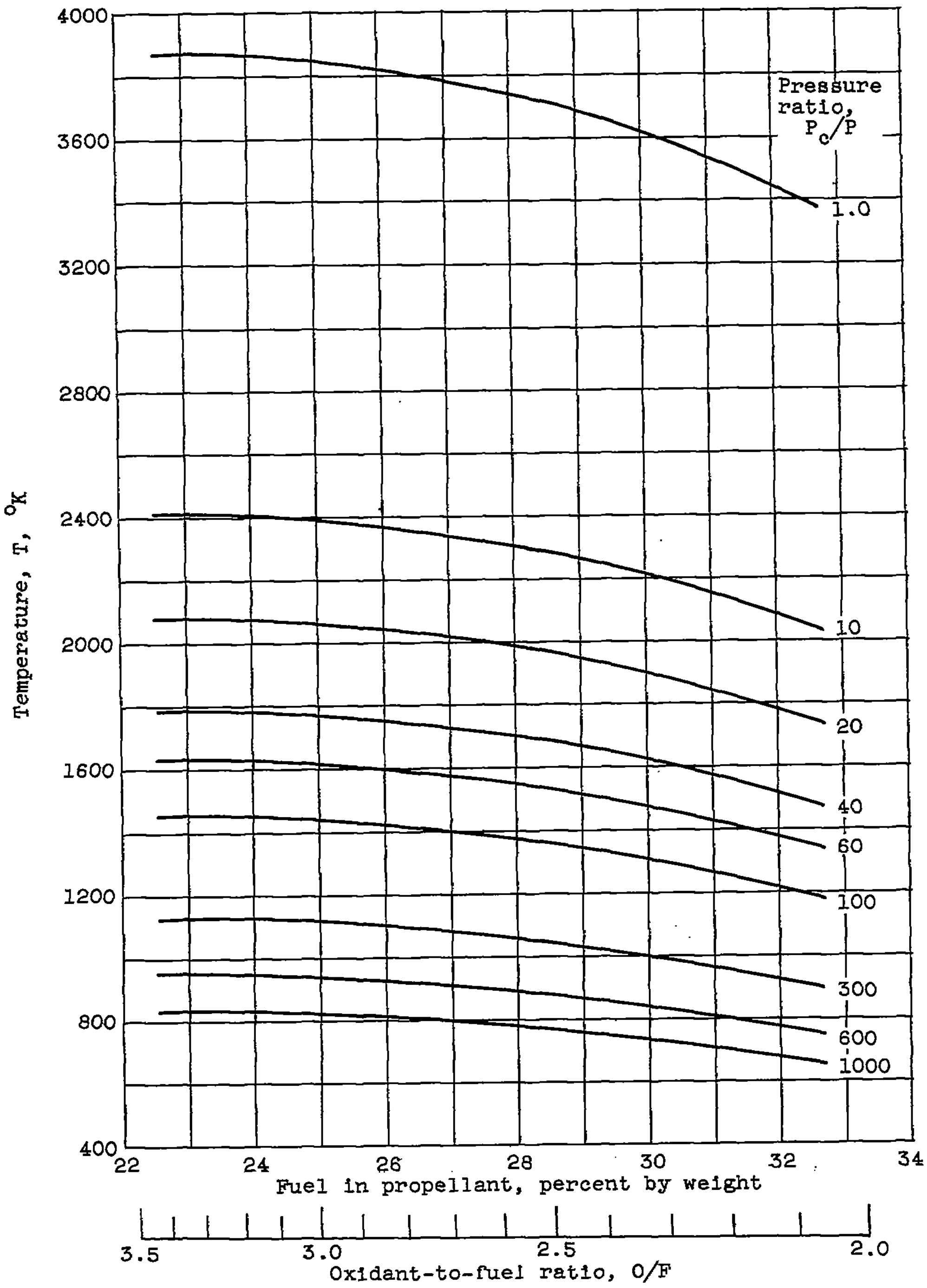
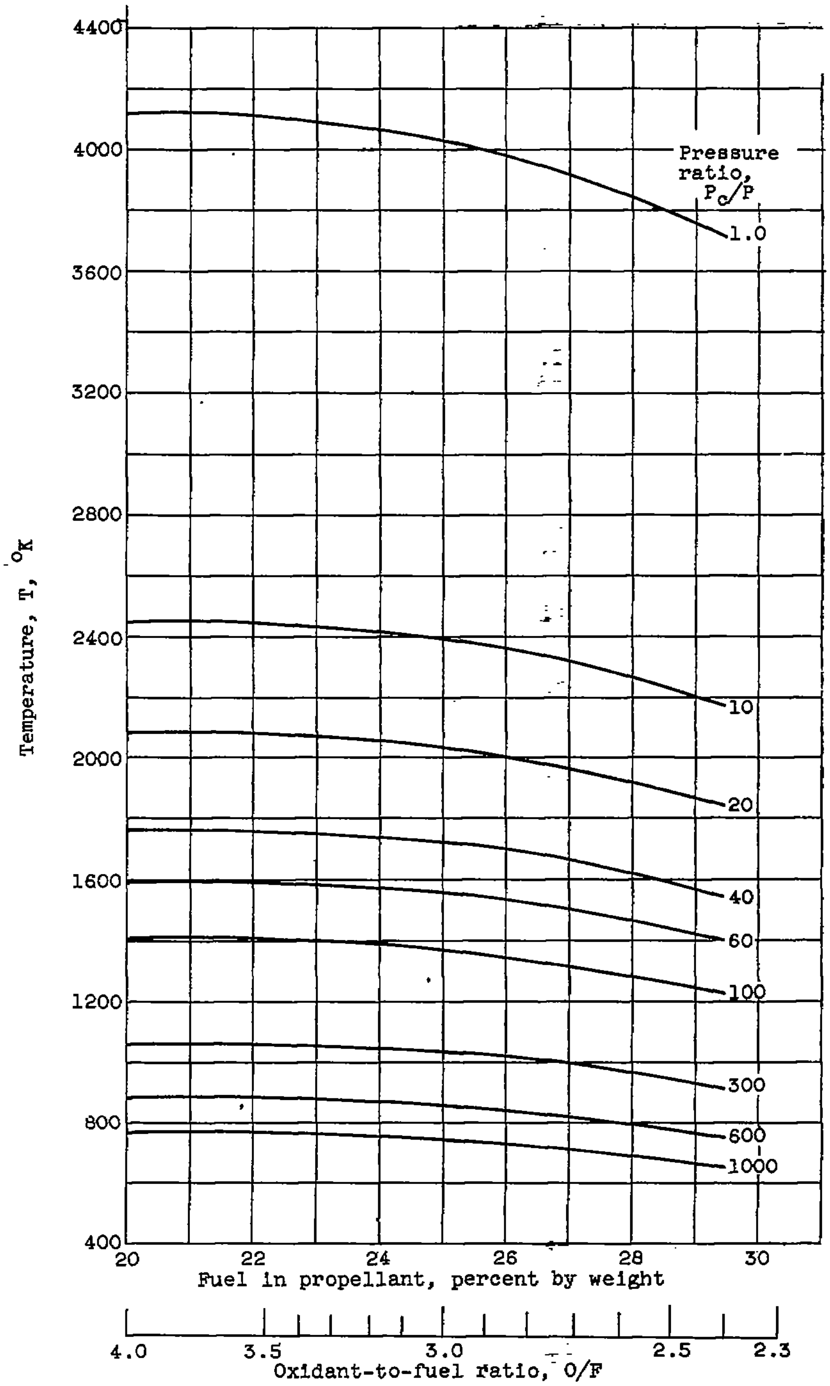
CB-6 back



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

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel 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, 50.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel 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.

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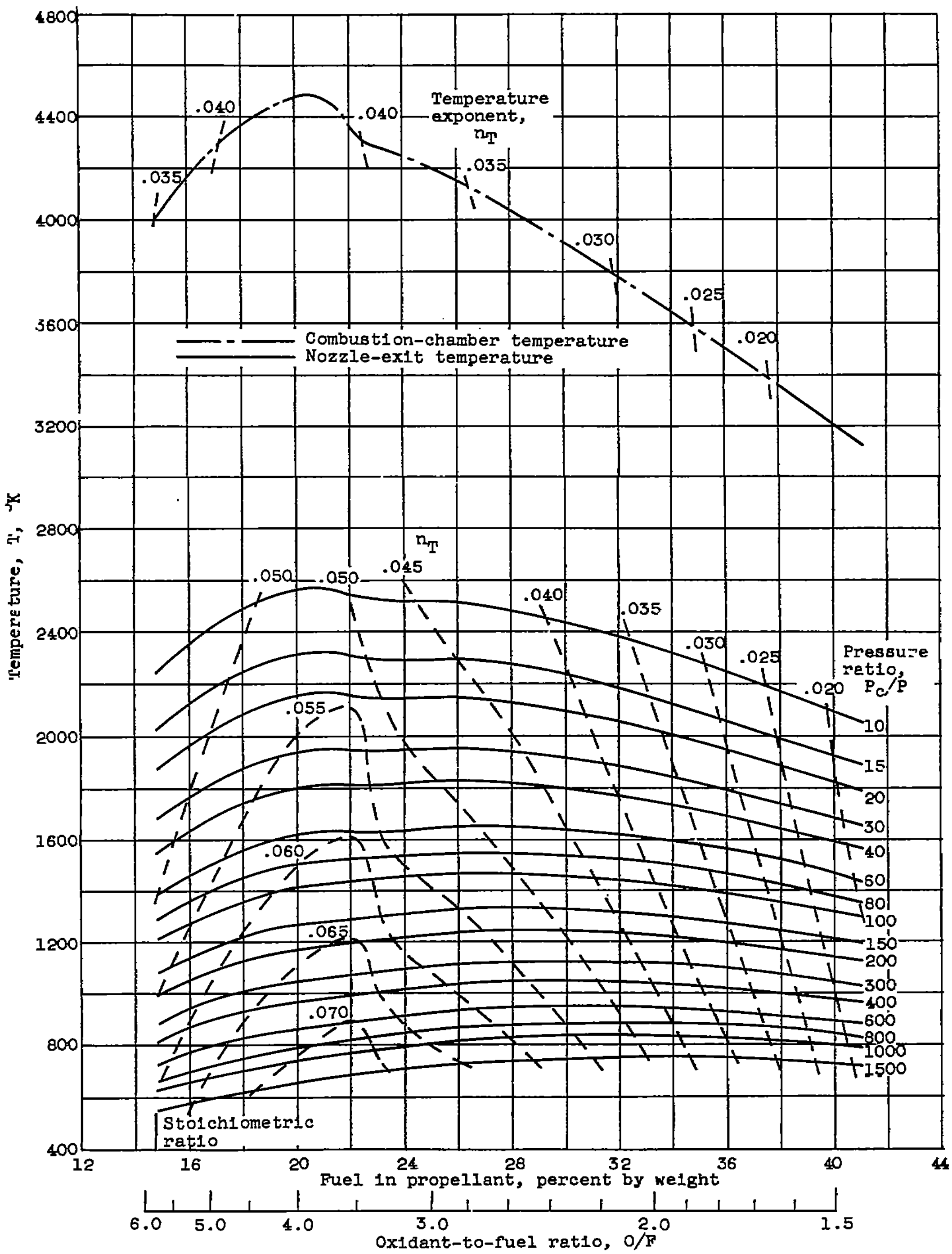
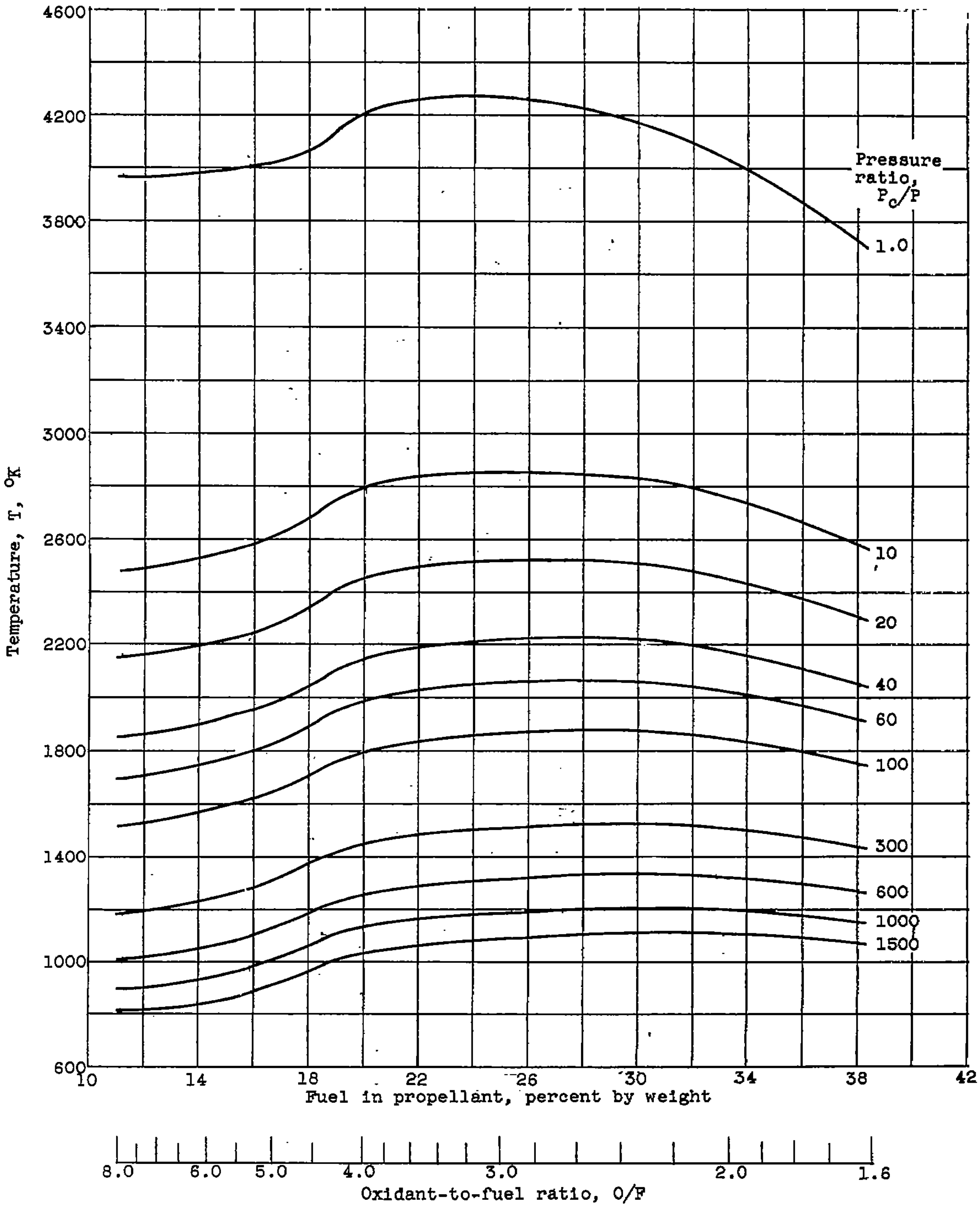


(e) Percent fluorine in oxidant by weight, 70.37.

Exponent n_T for use in equation $T = T_{600}\left(\frac{P_c}{600}\right)^{n_T}$.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel 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, 100 (zero percent oxygen).

Figure 2. - Concluded. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel 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.

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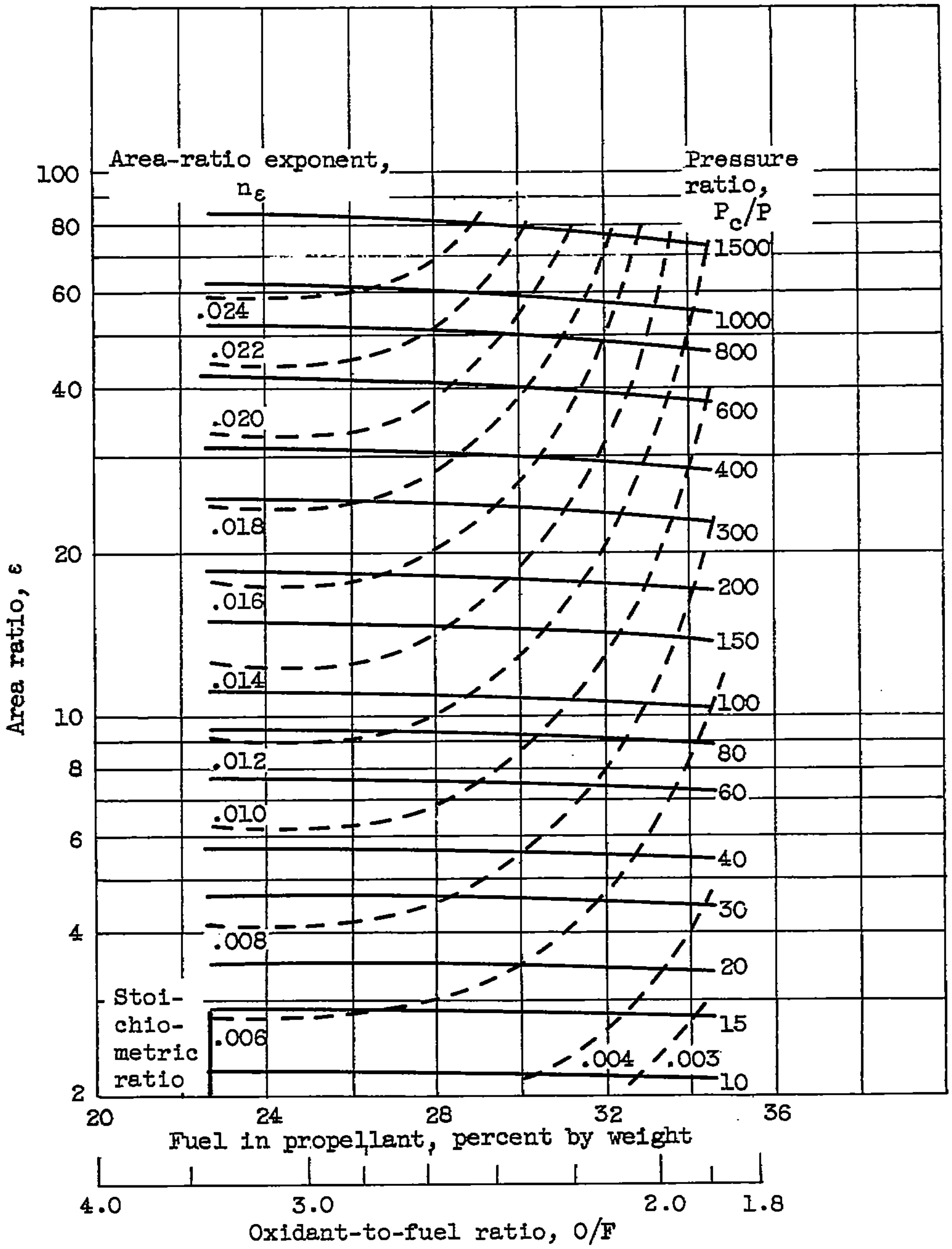
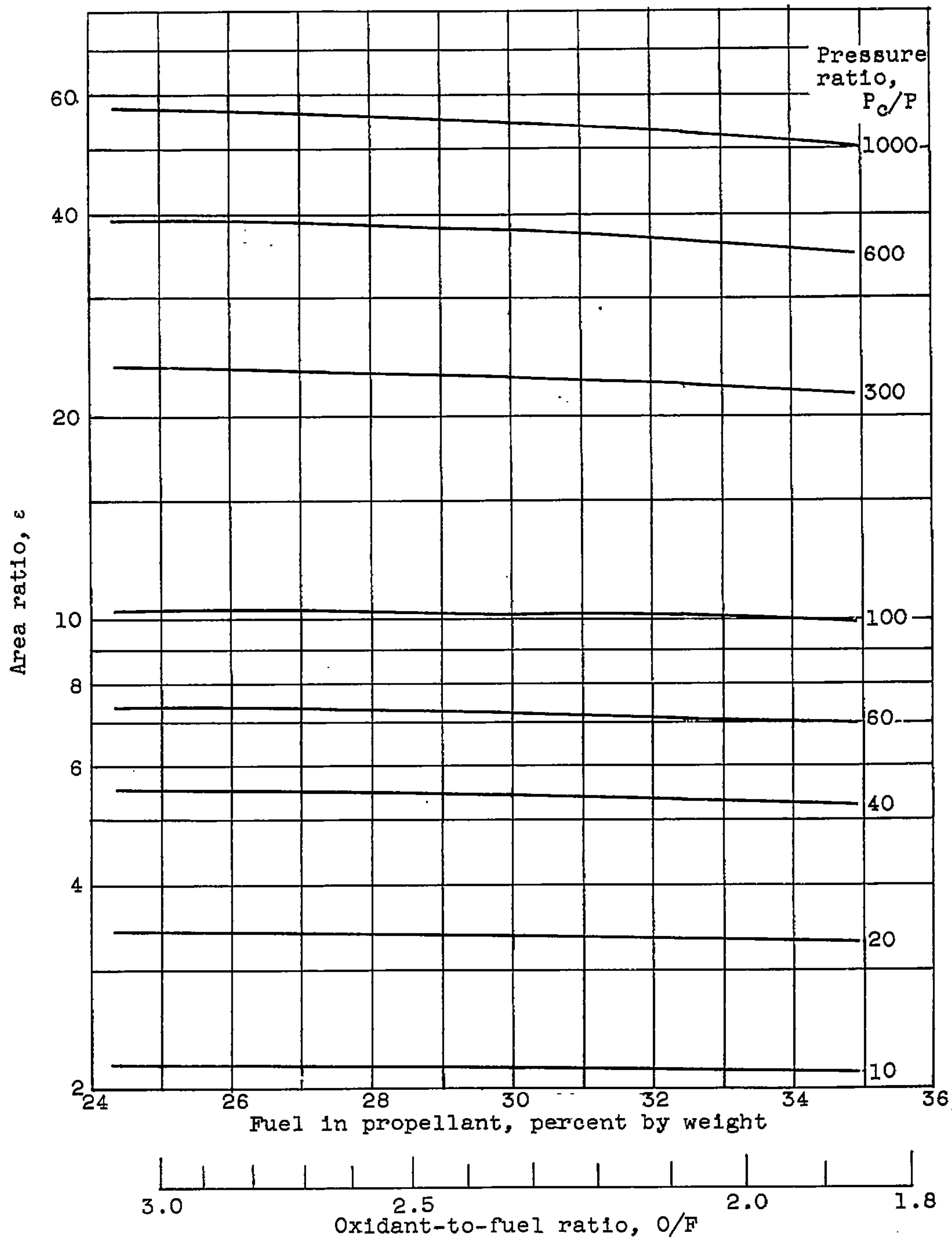


(a) Percent fluorine in oxidant, 0 (100 percent oxygen).

Exponent n_ε for use in equation $\varepsilon = \varepsilon_{600}\left(\frac{P_c}{600}\right)^{n_\varepsilon}$.

Figure 3. - Theoretical ratio of nozzle area to throat area for JP-4 fuel 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, 15.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel 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.

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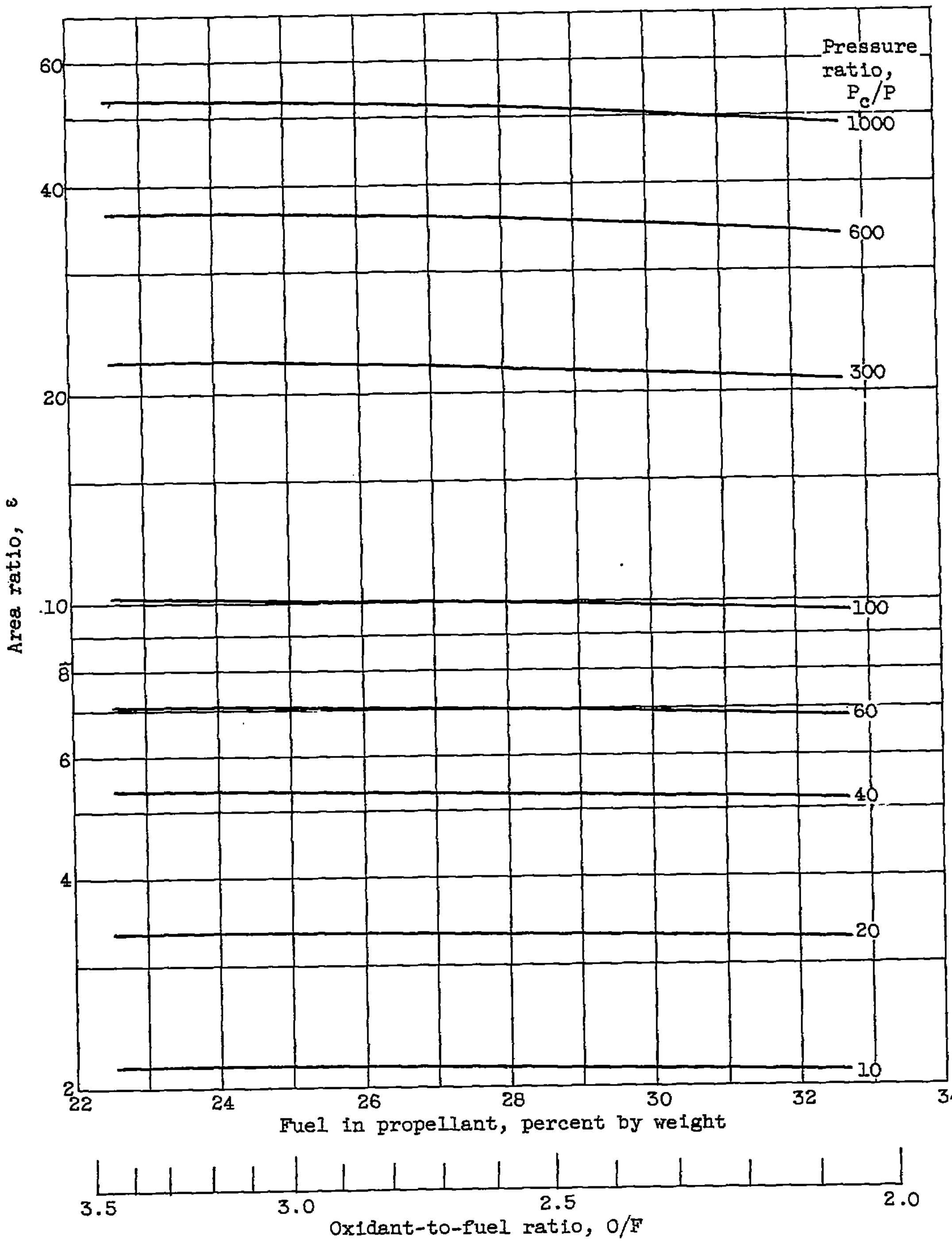

(c) Percent fluorine in oxidant by weight, 30.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel 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.

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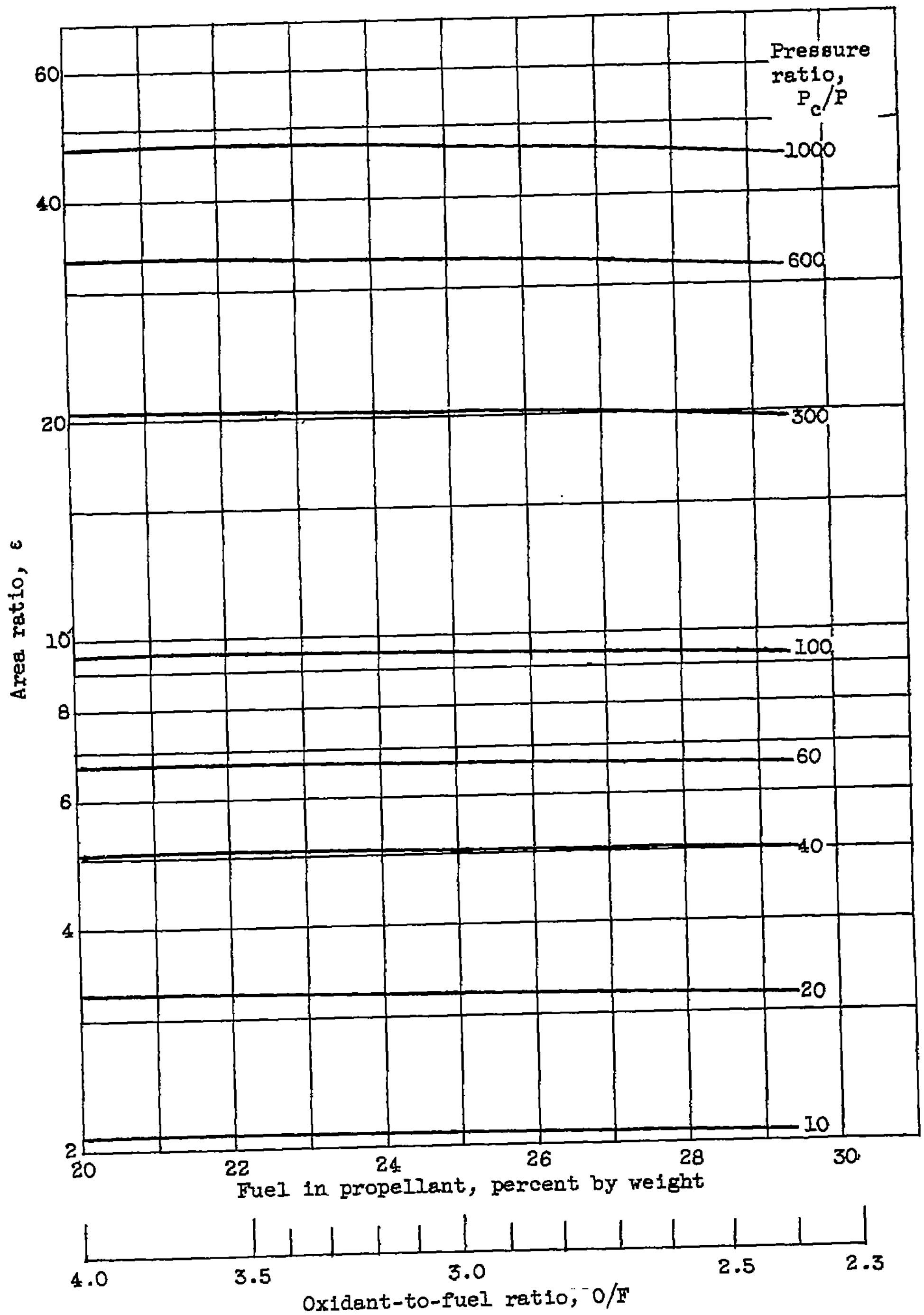

(d) Percent fluorine in oxidant by weight, 50.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel 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.

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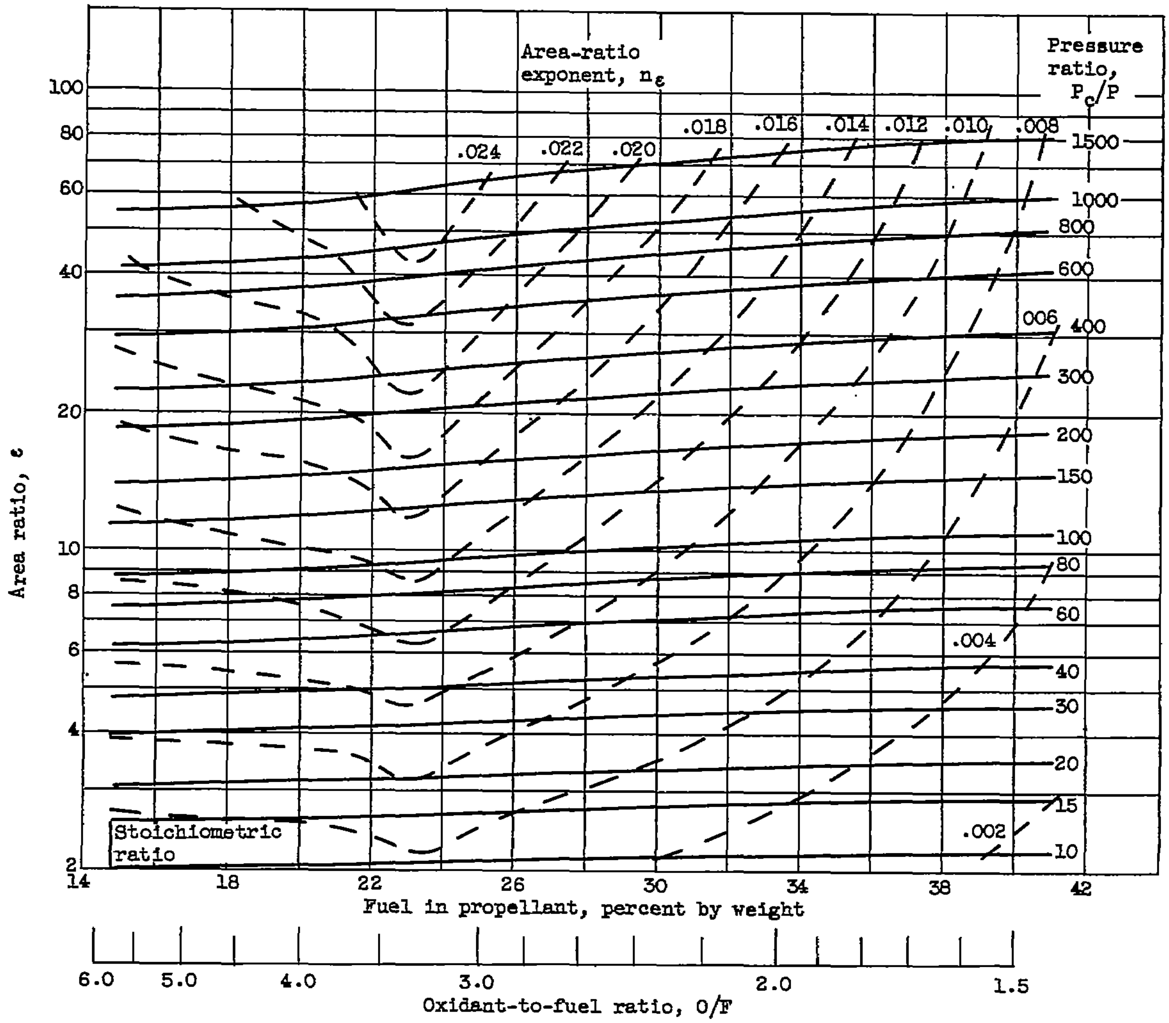
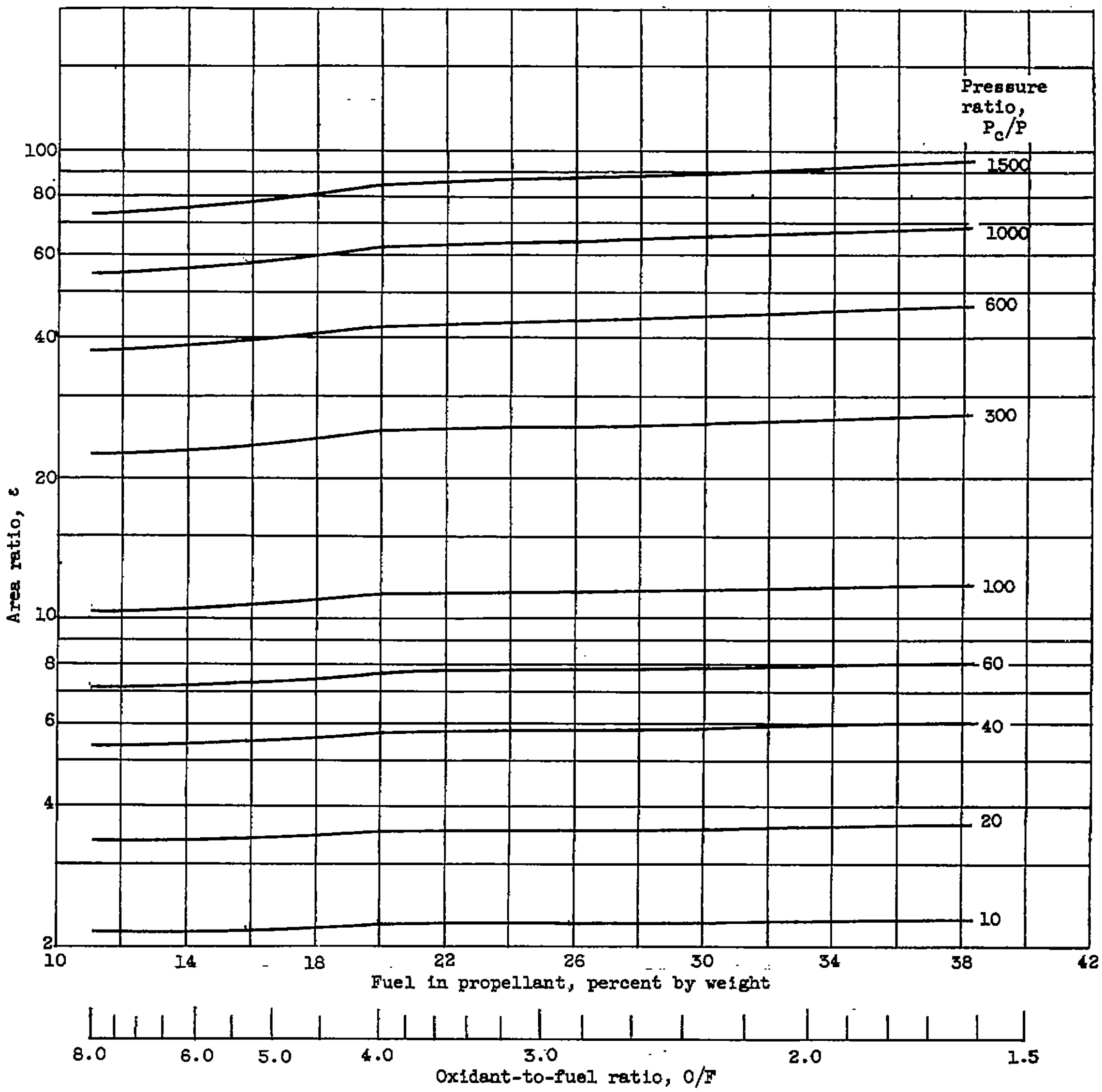


(e) Percent fluorine in oxidant by weight, 70.37.

Exponent n_ε for use in equation $\varepsilon = \varepsilon_{600}\left(\frac{P_c}{600}\right)^{n_\varepsilon}$.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel 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, 100 (zero percent oxygen).

Figure 3. - Concluded. Theoretical ratio of nozzle area to throat area for JP-4 fuel 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.

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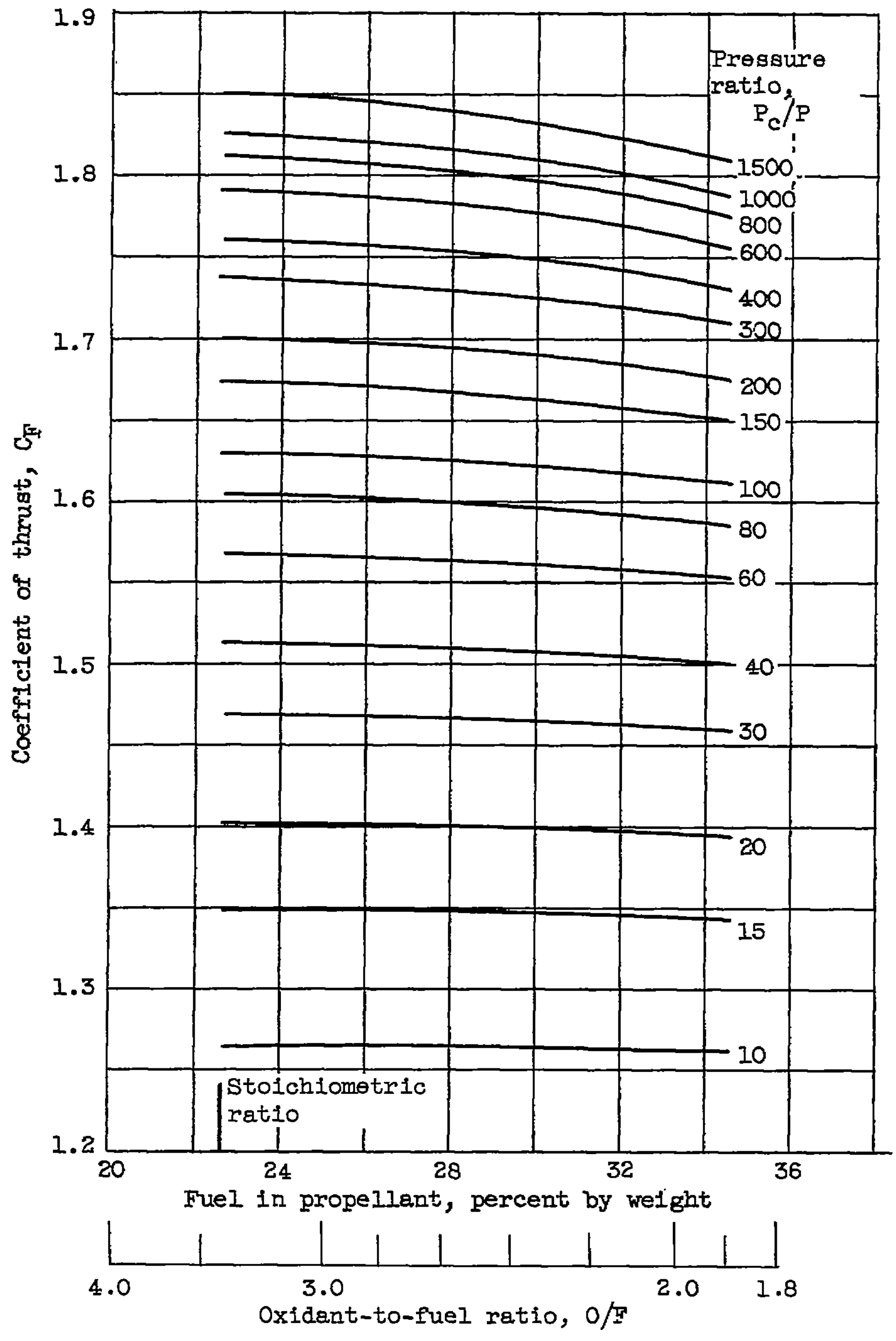
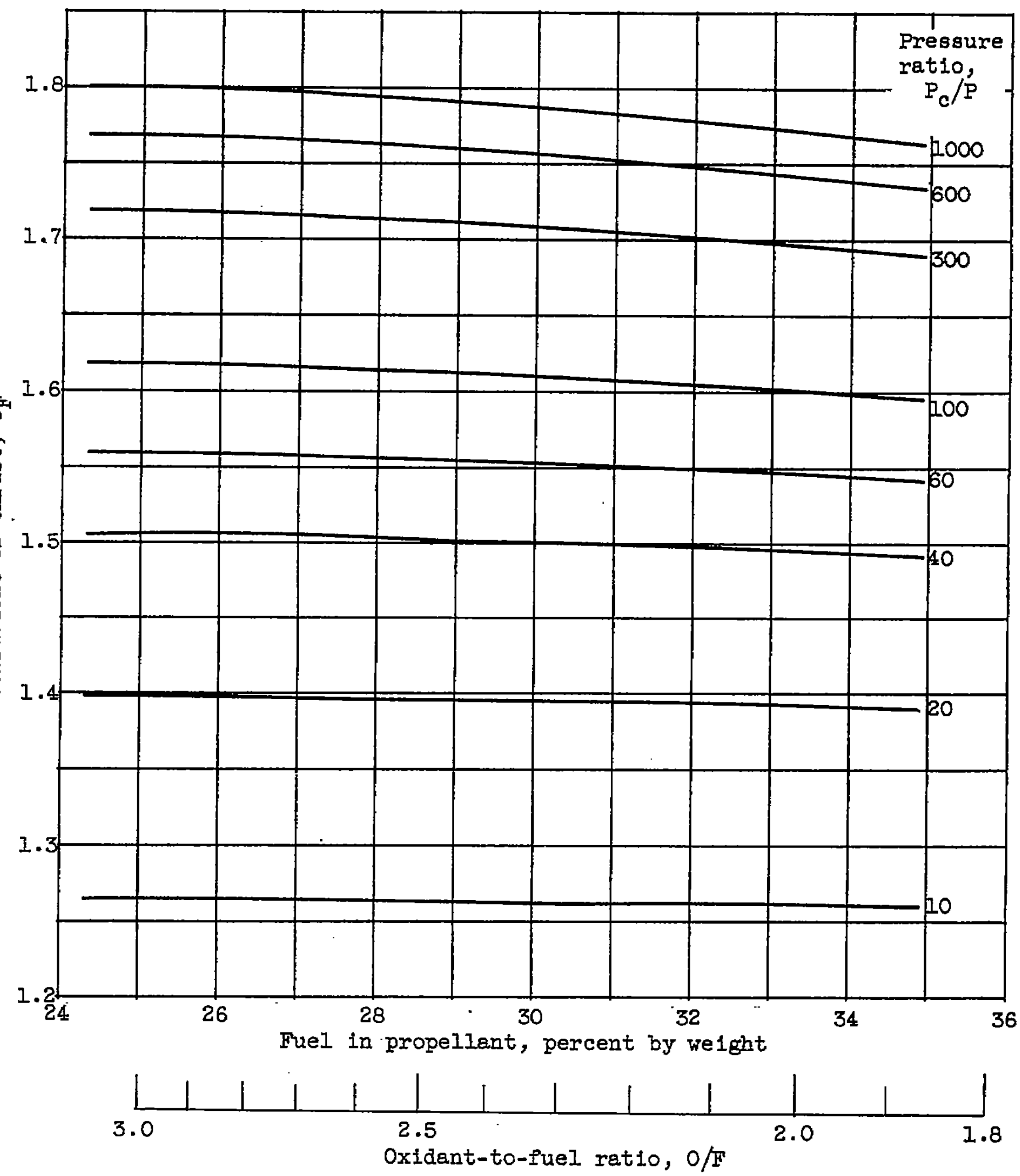


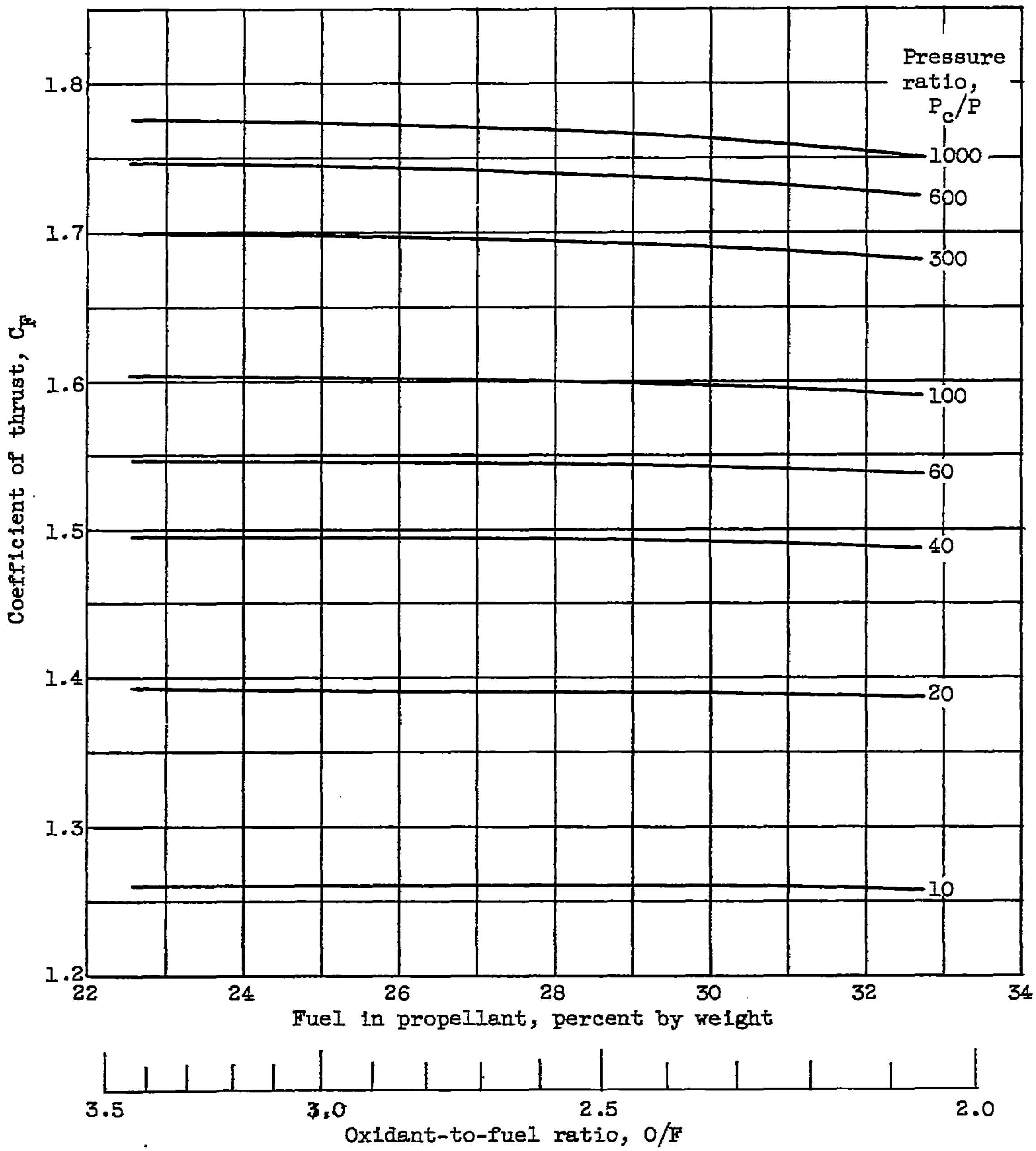
(a) Percent fluorine in oxidant, 0 (100 percent oxygen).

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



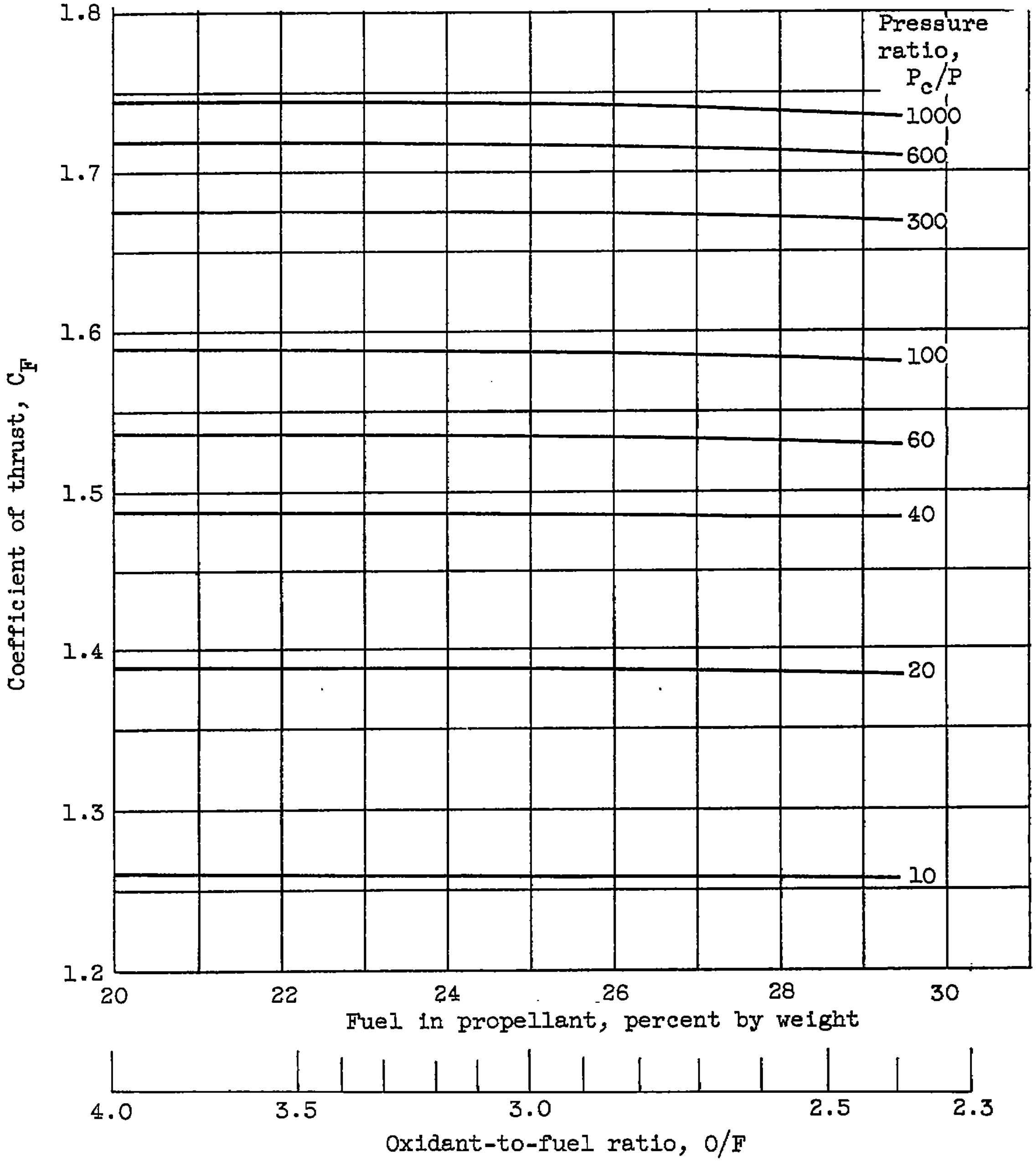
(b) Percent fluorine in oxidant by weight, 15.

Figure 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel 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.



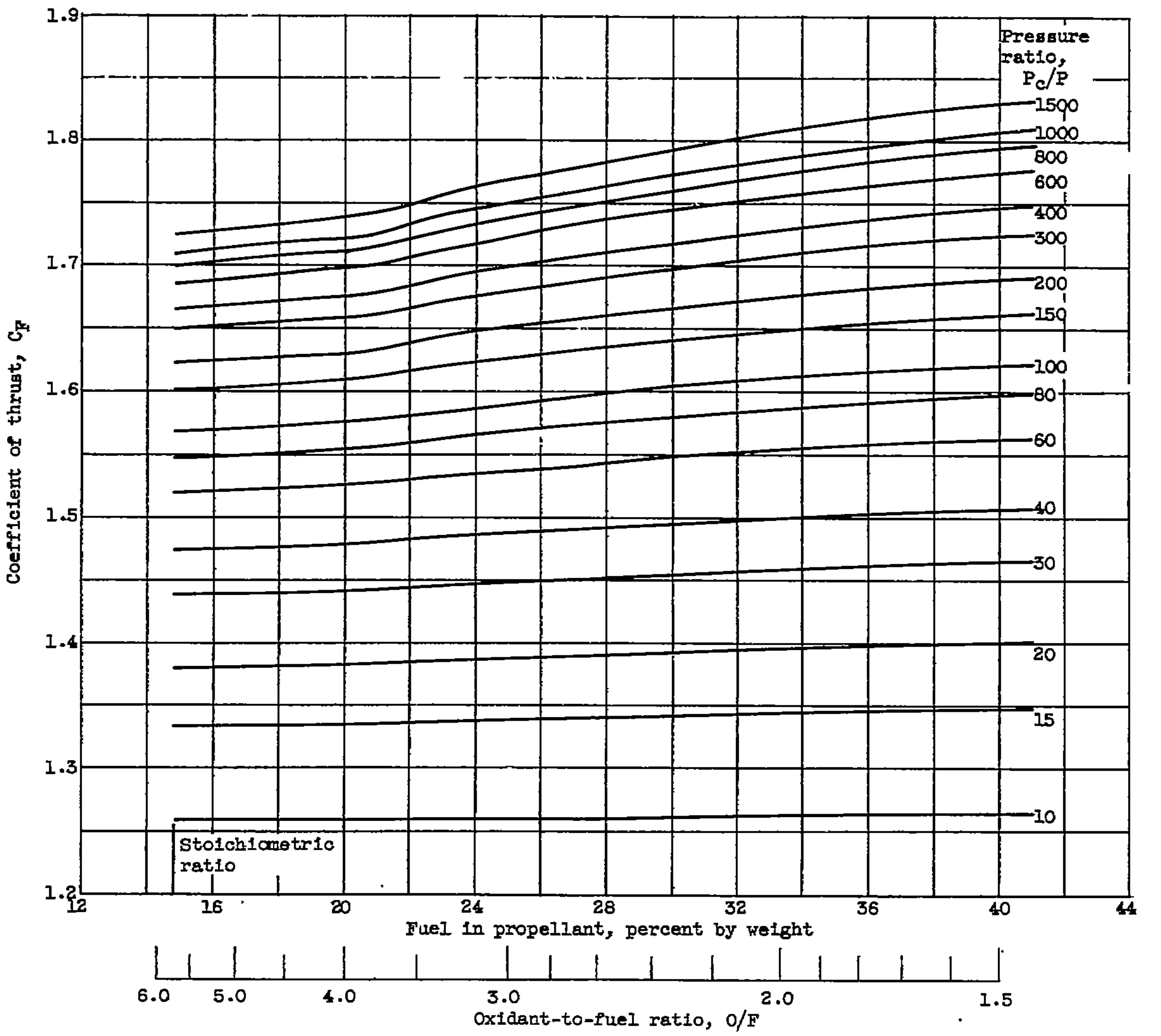
(c) Percent fluorine in oxidant by weight, 30.

Figure 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel 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.



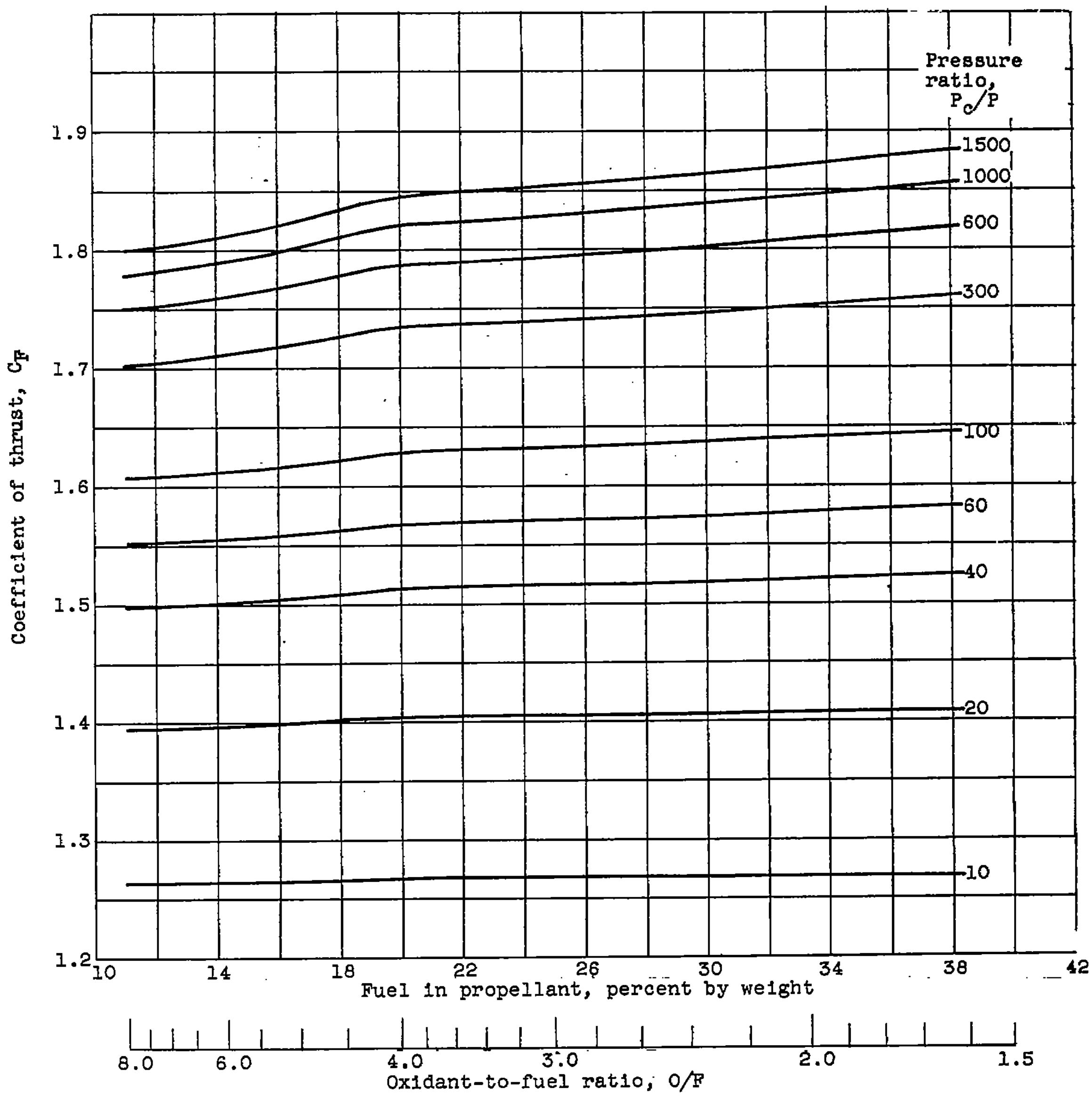
(d) Percent fluorine in oxidant by weight, 50.

Figure 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel 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 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel 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, 100 (zero percent oxygen).

Figure 4. - Concluded. Theoretical coefficient of thrust for JP-4 fuel 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.

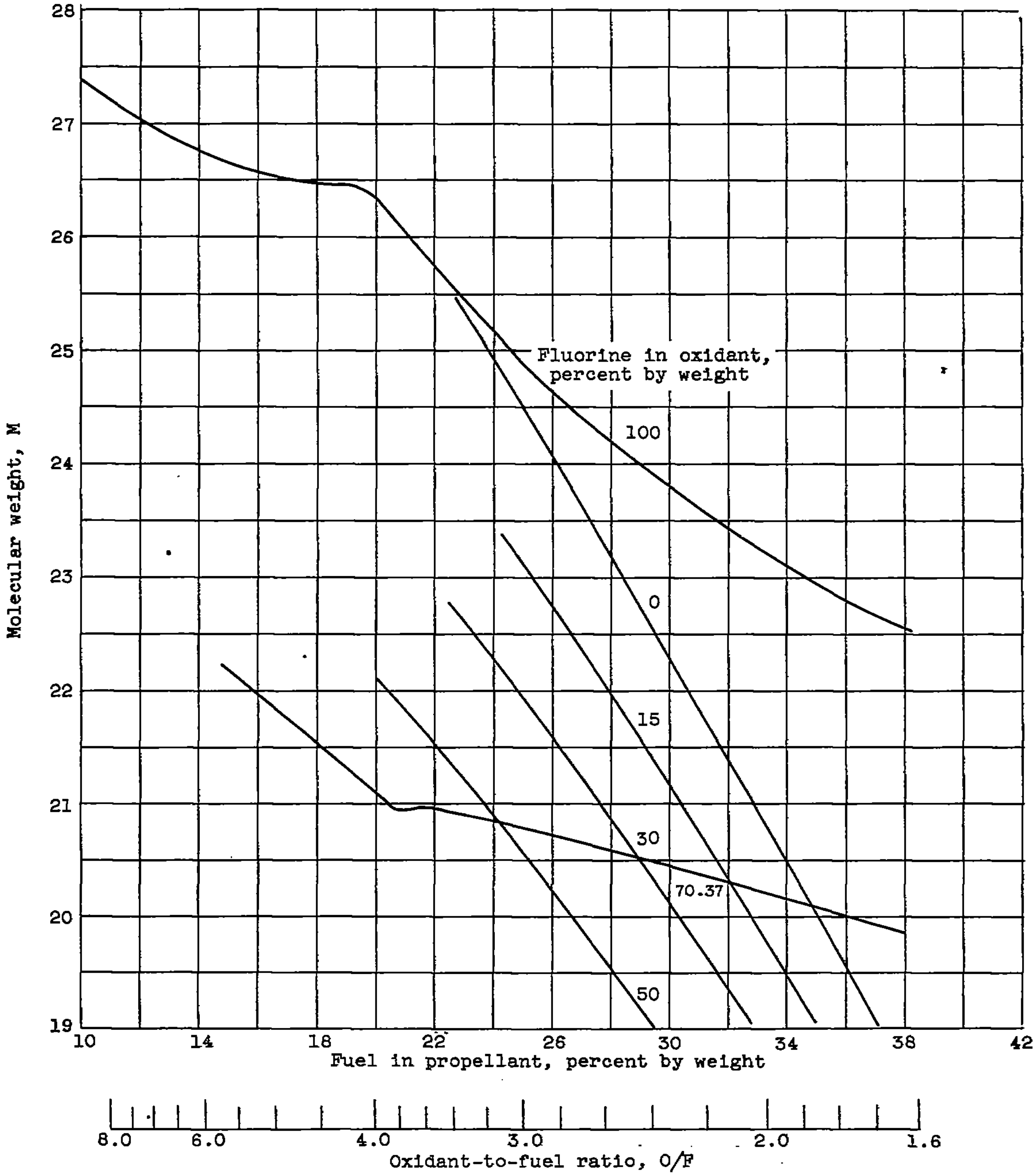


Figure 5. - Theoretical combustion-chamber molecular weight for JP-4 fuel with several fluorine-oxygen mixtures. Combustion-chamber pressure, 600 pounds per square inch absolute.

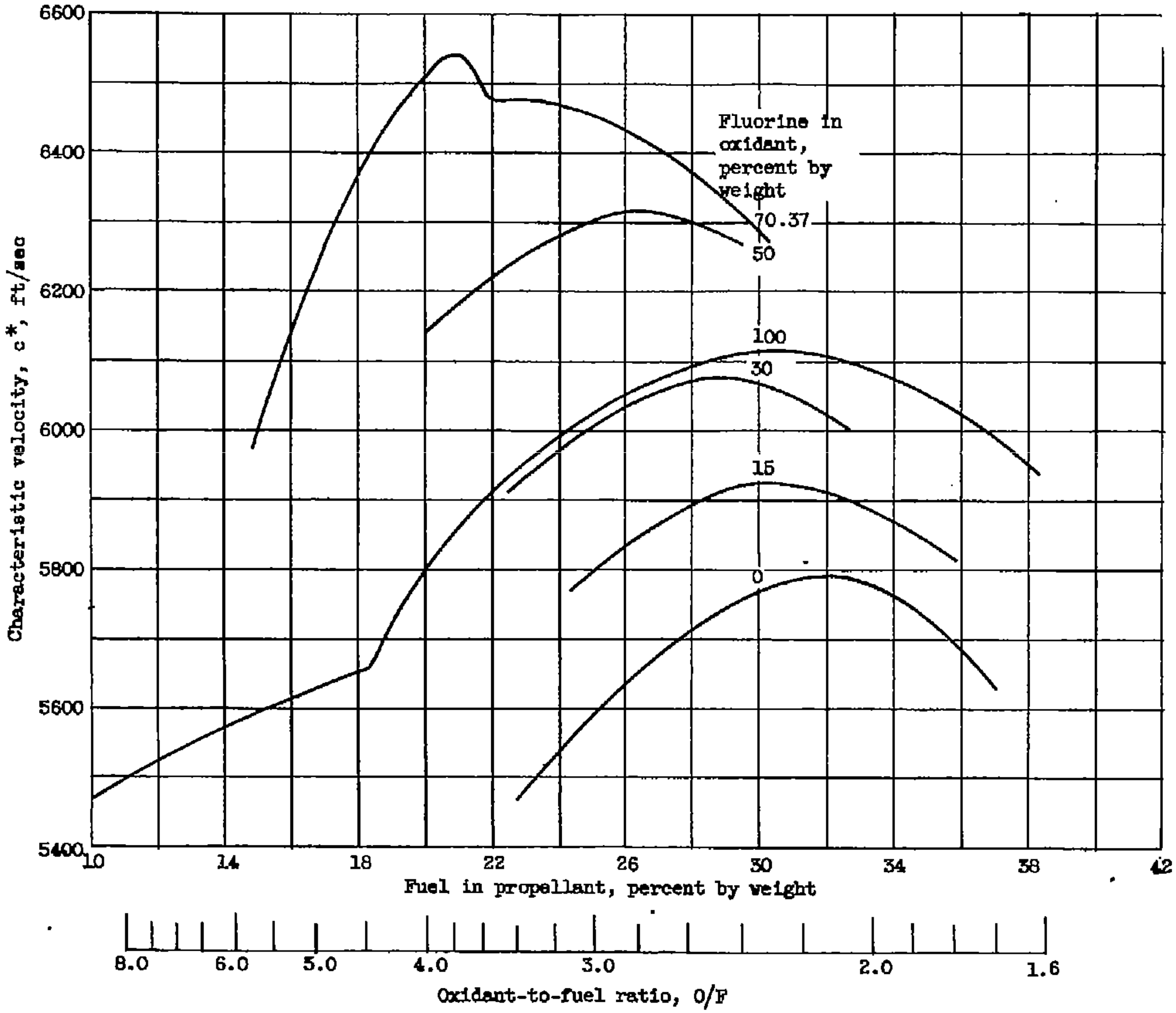


Figure 6. - Theoretical characteristic velocity for JP-4 fuel with several fluorine-oxygen mixtures. Isentropic expansion assuming frozen composition from combustion-chamber pressure, 600 pounds per square inch absolute.

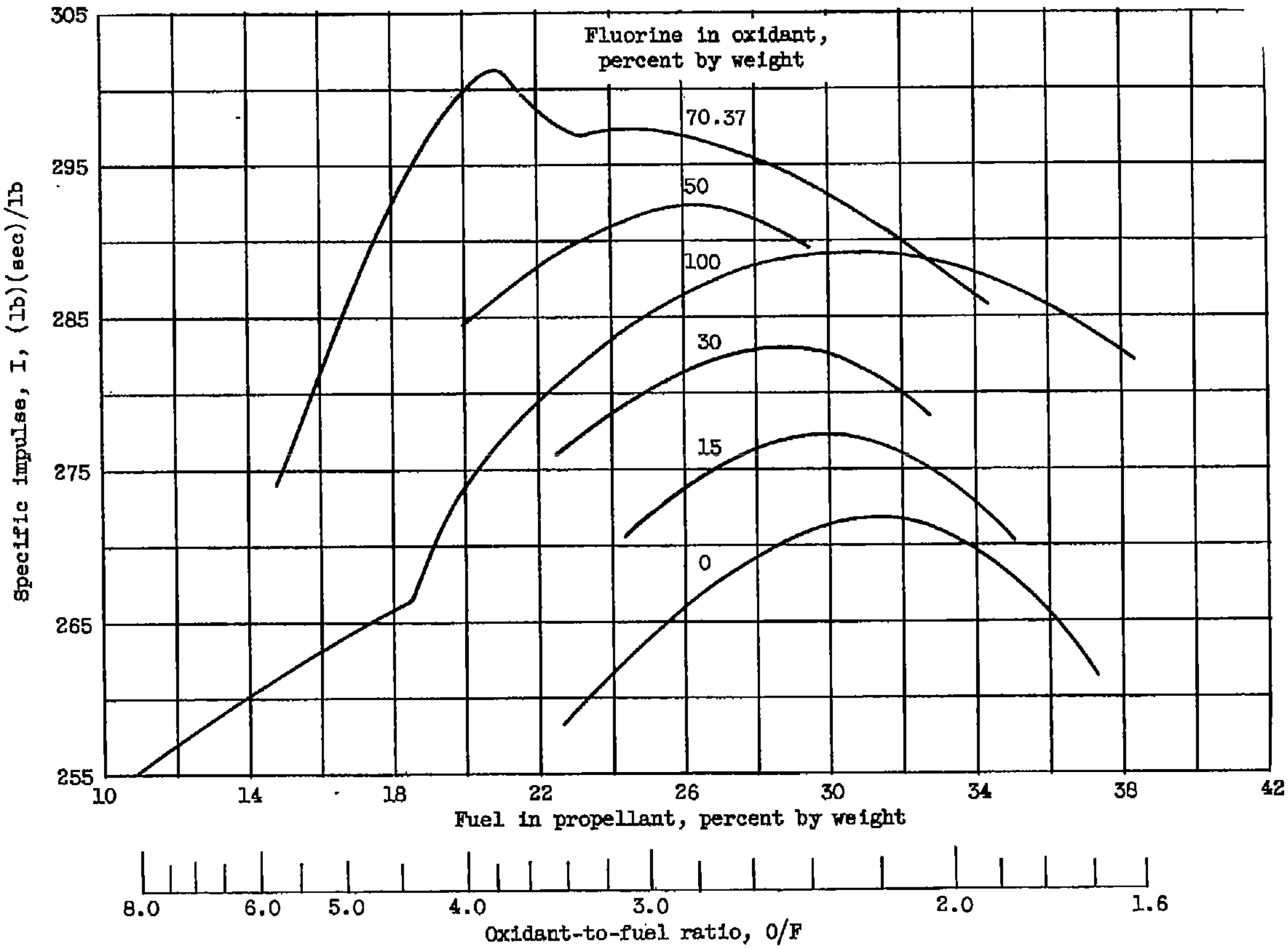


Figure 7. - Theoretical specific impulse for JP-4 fuel with several fluorine-oxygen mixtures. Isentropic expansion assuming frozen composition from combustion-chamber pressure of 600 pounds per square inch absolute to exit pressure of 1 atmosphere.

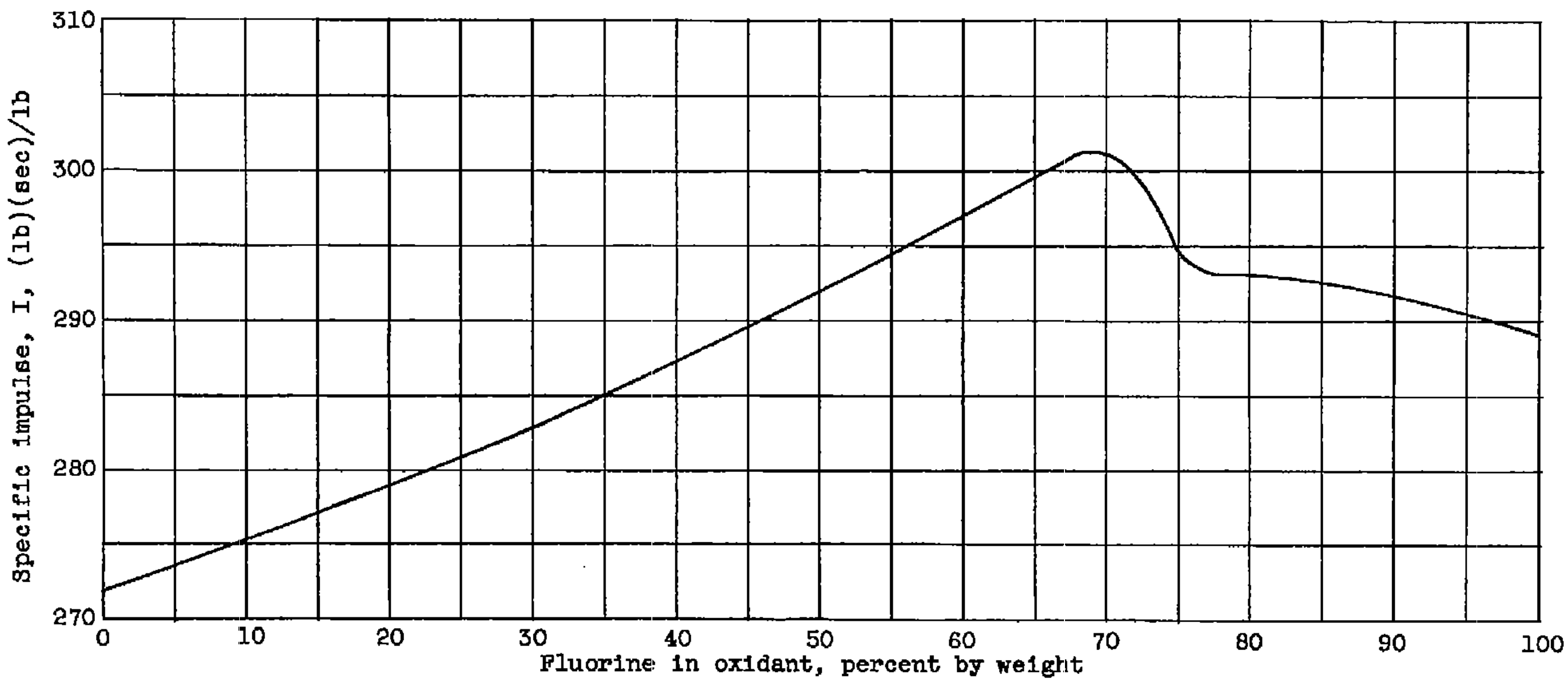


Figure 8. - Theoretical specific impulse of JP-4 fuel with fluorine-oxygen mixtures at equivalence ratios for which specific impulse is maximum. Frozen composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to 1 atmosphere.

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RESEARCH MEMORANDUM

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

By Sanford Gordon and Kenneth S. Drellishak

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

November 13, 1957

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

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

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SUMMARY

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

The maximum value of specific impulse for a chamber pressure of 600 pounds per square inch absolute (40.827 atm) and an exit pressure of 1 atmosphere is 301.1 for 70.37 percent fluorine in the oxidant as compared with 271.8 and 289.3 for 100 percent oxygen and 100 percent fluorine, respectively.

INTRODUCTION

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

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

SYMBOLS

The following symbols are used in this report:

A nozzle area, sq in.

a local velocity of sound (velocity of flow at throat), ft/sec

C_F coefficient of thrust; $C_F = g_c I/c^* = F/P_c A_t$ 4576

C_p^o molar specific heat at constant pressure, cal/(mole)(°K)

c_p specific heat at constant pressure, $\frac{\sum_i x_i (C_p^o)_i}{M(1 - x_k)}$, cal/(g)(°K)

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/sec²)

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,

$$\frac{\sum_i x_i (H_T^o)_i}{M(1 - x_k)}, \text{ cal/g}$$

I specific impulse, (lb force)(sec)/lb mass

k coefficient of thermal conductivity, cal/(sec)(cm)(°K)

M molecular weight, $\frac{\sum_i x_i M_i}{1 - x_k}$, g/g-mole or lb/lb-mole

n_c^* characteristic-velocity exponent, $\left(\frac{\Delta \log c^*}{\Delta \log P_c}\right)$

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

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

n_ε area-ratio exponent for fixed pressure ratio, $\left(\frac{\Delta \log \varepsilon}{\Delta \log P_c}\right)_{P_c/P}$

O/F oxidant-fuel weight ratio

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

p partial pressure, lb/sq in.

R universal gas constant (consistent units)

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

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

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

T temperature, °K

w mass-flow rate, lb/sec

x mole fraction

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

ε ratio of nozzle area to throat area, A/A_t

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_c/P constant pressure ratio

s constant entropy

t nozzle throat

Superscript:

o thermodynamic standard reference state

4576

CALCULATION OF PERFORMANCE DATA

Performance data were obtained for JP-4 fuel with several fluorine-oxygen mixtures for a range of equivalence ratios and pressure ratios. 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 2 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 2. Data for graphite were taken from reference 3, for carbon monofluoride from reference 4, for the remainder of the fluorocarbons from reference 5, and for water from reference 6. Data for methane were determined by the rigid-rotator - harmonic-oscillator approximation using spectroscopic data from reference 7. The base used in this report for assigning absolute values to enthalpy is the same as in reference 2.

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. 8). The heat of solution of oxygen and fluorine was assumed to be zero.

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

Several properties of the oxidants taken from references 2, 8, 10, and 11 are listed in table I.

Viscosity data. - The viscosity data for the individual combustion products were either taken from the literature when available, or estimated. The viscosities of F, H, H_2, and HF are given in reference 12. 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. 13).

Formulas

Interpolation formulas and accuracy of results are discussed in reference 14. The formulas used in computing the various performance parameters are as follows:

Specific impulse, (lb force)(sec)/lb mass 4576

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

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

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

Characteristic velocity, ft/sec

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

Coefficient of thrust

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

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

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

Ratio of nozzle area to throat area

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

Specific heat at constant pressure, cal/(g)($^{\circ}$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, poise

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

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

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

THEORETICAL PERFORMANCE DATA

Tables

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

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

Curves

The performance parameters are plotted in figures 1 to 6.

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

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

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

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

Figures 5 and 6 present curves of molecular weight and characteristic velocity, respectively, as functions of percent by weight of fuel.

Effect of fluorine-oxygen ratio. - The specific-impulse data for expansion from chamber pressure to 1 atmosphere (table VII) are plotted in figure 7 to show the effect of fluorine-oxygen ratio on performance. Specific impulse increases with increasing percentages of fluorine to about 70 percent fluorine in the oxidant. Increasing the amount of fluorine in the oxidant from about 70 to 100 percent results in a decrease in specific impulse. Maximum values of specific impulse calculated for a chamber pressure of 600 pounds per square inch absolute (40.827 atm) and an exit pressure of 1 atmosphere are shown in the following table:

Fluorine in oxidant, percent by weight	Maximum specific impulse, $\frac{(lb)(sec)}{lb}$
0	271.8
15	277.1
30	282.8
50	292.0
70.37	301.1
100	289.3

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

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

Chamber-pressure effect. - The use of the chamber-pressure exponents (n_I, n_T, n_ε, and n_{c*}) to obtain performance data for chamber pressure other than 600 pounds per square inch absolute is explained in reference 14.

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

SUMMARY OF RESULTS

A theoretical investigation of the performance of JP-4 fuel with fluorine-oxygen mixtures was made for the following conditions: Fluorine in oxidant by weight from 0 to 100 percent for various equivalence ratios, pressure ratios from 1 to 1000 (or 1 to 1500), and frozen composition during expansion from chamber pressure of 600 pounds per square inch absolute. The maximum values of specific impulse calculated for a chamber pressure of 600 pounds per square inch absolute (40.827 atm) and an exit pressure of 1 atmosphere ranged from 271.8 to 301.1 for 0 to 70.37 percent fluorine in the oxidant and from 301.1 to 289.3 for 70.37 to 100 percent fluorine in the oxidant.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, August 12, 1957

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4576

TABLE I. - PROPERTIES OF LIQUID OXIDANTS

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

[a]At -182.0° C; ref. 10.
[b]At -196° C; ref. 11.
[c]Ref. 8.
[d]Ref. 2.
[e]At -182.97° C.
[f]At -187.92° C.
[g]At -218.76° C.
[h]At -217.96° C.

TABLE II. - THERMODYNAMIC PROPERTIES OF COMBUSTION GASES FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

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

Equivalence ratio, r, $\frac{4(C)+(H)}{2(O)+F}$	Fuel, percent by weight	Oxidant-to-fuel weight ratio, O/F	Temperature, T, $^{\circ}K$	Molecular weight, M	Enthalpy, h, cal/g (a)	Entropy, s, $\frac{cal}{(g)(^{\circ}K)}$	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$ (b)	Isentropic exponent, γ (b)	Characteristic-velocity exponent, n_{c*} (b)	Characteristic velocity, c*, ft/sec (b)
Percent fluorine in oxidant, 0 (100 percent oxygen)										
1.0	22.71	3.403	3612	25.48	2531.6	2.5729	0.451	1.209	0.0157	5475
1.2	26.07	2.836	3628	24.03	2901.1	2.6815	.470	1.213	.0157	5643
1.3	27.64	2.618	3612	23.36	3074.1	2.7297	.479	1.216	.0153	5707
1.4	29.15	2.431	3576	22.70	3239.9	2.7740	.487	1.219	.0146	5755
1.5	30.59	2.269	3518	22.05	3399.0	2.8146	.494	1.223	.0133	5785
1.6	31.98	2.127	3436	21.41	3551.6	2.8515	.501	1.227	.0119	5794
1.8	34.59	1.891	3205	20.17	3839.4	2.9142	.513	1.238	.0080	5747
2.0	37.01	1.702	2923	19.03	4105.8	2.9627	.522	1.250	.0045	5630
3.0	46.85	1.134	1657	15.49	5188.4	3.0102	.542	1.310	------	4618
Percent fluorine in oxidant by weight, 15										
1.2	24.36	3.106	3735	23.39	2888.3	2.7033	0.453	1.231	------	5773
1.4	27.31	2.662	3694	22.25	3206.2	2.7907	.469	1.235	------	5880
1.6	30.04	2.329	3583	21.15	3500.2	2.8650	.484	1.241	------	5929
1.8	32.57	2.071	3391	20.08	3773.0	2.9264	.497	1.249	------	5906
2.0	34.92	1.864	3142	19.06	4026.7	2.9753	.507	1.259	------	5818
Percent fluorine in oxidant by weight, 30										
1.2	22.56	3.432	3868	22.78	2874.8	----	0.434	1.252	------	5918
1.4	25.37	2.942	3836	21.81	3170.7	2.7867	.451	1.253	------	6019
1.6	27.98	2.574	3745	20.87	3445.8	2.8580	.466	1.267	------	6074
1.8	30.41	2.288	3586	19.95	3702.3	2.9180	.479	1.263	------	6068
2.0	32.69	2.057	3369	19.06	3942.1	2.9667	.490	1.284	------	6005
Percent fluorihe in oxidant by weight, 50										
1.2	20.03	3.992	4120	22.10	2855.9	2.6800	0.409	1.288	------	6147
1.4	22.62	3.421	4100	21.31	3120.2	2.7582	.425	1.281	------	6245
1.6	25.04	2.994	4030	20.54	3368.1	2.8257	.439	1.282	------	6305
1.8	27.31	2.661	3898	19.78	3600.8	2.8826	.453	1.285	------	6314
2.0	29.46	2.395	3708	19.03	3819.9	2.9282	.465	1.290	------	6270
Percent fluorine in oxidant by weight, 70.37										
1.0	14.83	5.743	4007	22.24	2592.0	2.5230	0.365	1.324	0.0147	5974
1.4	19.60	4.102	4464	21.20	3064.9	2.6853	.397	1.309	.0174	6484
1.5	20.71	3.829	4479	20.95	3175.0	2.7138	.404	1.307	.0174	6539
1.6	21.79	3.589	4396	20.97	3282.1	2.7302	.414	1.397	.0172	6491
2.5	30.33	2.297	3898	20.41	4128.8	2.8100	.485	1.251	.0118	6277
Percent fluorine in oxidant, 100 (zero percent oxygen)										
1.0	11.01	8.083	3962	27.41	2621.2	2.1971	0.366	1.247	------	5466
1.5	15.65	5.389	4008	26.63	3060.4	2.3189	.399	1.230	------	5605
2.0	19.84	4.041	4206	26.42	3456.0	2.4039	.432	1.211	0.0014	5799
2.8	25.73	2.887	4262	24.72	4013.3	2.5000	.475	1.204	------	6047
3.0	27.07	2.694	4249	24.41	4140.1	2.5199	.485	1.202	.0098	6080
3.5	30.22	2.309	4172	23.76	4437.8	2.5634	.453	1.226	.0099	6116
4.0	33.10	2.021	4041	23.26	4710.9	2.5991	.531	1.192	.0099	6092
5.0	38.22	1.617	3708	22.53	5194.5	2.6512	.569	1.184	.0085	5945

[a]The base used for enthalpy is given in ref. 2.

[b]Parameter based on frozen composition.

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

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

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

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	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, $\frac{(lb)(sec)}{lb}$
r, 1.00; percent fuel, 22.71; O/F, 3.403									
4000	1085.000	2707.3	1.207	0.4554	986	0.00055	-------	-------	-------
3600	588.250	2526.0	1.209	.4507	922	.00051	3.33	0.129	22.0
3200	299.050	2346.8	1.212	.4450	854	.00046	1.01	.745	126.0
2800	140.380	2170.2	1.217	.4381	783	.00042	1.35	1.042	177.5
2400	59.544	1996.6	1.222	.4295	708	.00037	2.23	1.268	215.6
2000	22.098	1826.9	1.229	.4182	627	.00032	4.37	1.455	247.6
1600	6.824	1662.6	1.240	.4027	540	.00027	10.20	1.616	275.0
1200	1.609	1505.7	1.258	.3804	443	.00021	29.87	1.756	298.3
900	.412	1394.8	1.279	.3577	361	.00016	83.01	1.848	314.5
600	.069	1291.7	1.310	.3293	265	.00011	315.28	1.930	328.5
r, 1.20; percent fuel, 26.07; O/F, 2.836									
4000	1047.500	3076.8	1.211	0.4748	971	0.00056	-------	-------	-------
3600	573.730	2887.8	1.213	.4700	907	.00052	2.26	0.195	34.1
3200	294.950	2700.9	1.217	.4641	841	.00048	1.01	.753	132.0
2800	140.180	2516.7	1.221	.4570	771	.00043	1.34	1.043	182.9
2400	60.293	2335.6	1.226	.4480	697	.00038	2.21	1.265	221.0
2000	22.739	2158.6	1.234	.4362	618	.00033	4.26	1.449	254.2
1600	7.161	1987.3	1.245	.4198	532	.00028	9.75	1.608	282.0
1200	1.731	1823.8	1.264	.3961	436	.00022	27.86	1.746	306.8
900	.455	1708.4	1.286	.3722	355	.00017	75.57	1.837	322.5
600	.079	1601.0	1.317	.3434	262	.00012	278.10	1.918	336.5
r, 1.30; percent fuel, 27.64; O/F, 2.618									
4000	1068.800	3261.0	1.213	0.4839	965	0.00057	-------	-------	-------
3600	588.850	3068.4	1.216	.4789	902	.00053	3.42	0.126	22.4
3200	304.680	2878.0	1.219	.4730	836	.00048	1.01	.737	130.6
2800	145.860	2690.2	1.224	.4657	766	.00044	1.32	1.031	182.6
2400	63.247	2505.7	1.229	.4566	693	.00039	2.14	1.254	222.4
2000	24.081	2325.3	1.237	.4445	614	.00034	4.07	1.439	255.3
1600	7.669	2150.7	1.248	.4277	529	.00028	9.22	1.598	283.5
1200	1.881	1984.2	1.267	.4035	434	.00022	25.94	1.736	308.0
900	.501	1866.7	1.289	.3791	353	.00017	69.39	1.827	324.1
600	.088	1757.2	1.321	.3502	260	.00012	251.02	1.909	338.5
r, 1.40; percent fuel, 29.15; O/F, 2.431									
3600	622.770	3251.6	1.219	0.4875	897	0.00054	-------	-------	-------
3200	324.560	3057.8	1.222	.4814	831	.00049	1.00	0.704	125.9
2800	156.620	2866.7	1.227	.4740	763	.00044	1.27	1.008	180.2
2400	68.535	2678.8	1.232	.4648	690	.00040	2.03	1.235	221.0
2000	26.369	2495.3	1.240	.4524	611	.00034	3.81	1.423	254.5
1600	8.504	2317.5	1.252	.4353	527	.00029	8.49	1.584	283.3
1200	2.118	2148.1	1.271	.4106	432	.00022	23.49	1.723	308.2
900	.573	2028.5	1.293	.3860	352	.00017	61.87	1.815	324.7
r, 1.60; percent fuel, 31.98; O/F, 2.127									
3600	772.670	3634.2	1.226	0.5038	890	0.00055	-------	-------	-------
3200	409.370	3433.9	1.229	.4975	826	.00051	1.04	0.562	101.2
2800	201.230	3236.4	1.234	.4898	758	.00046	1.13	.920	165.6
2400	89.929	3042.4	1.240	.4802	685	.00041	1.71	1.169	210.5
2000	35.451	2852.7	1.248	.4675	608	.00035	3.08	1.369	246.6
1600	11.767	2669.1	1.260	.4497	524	.00031	6.60	1.539	277.1
1200	3.035	2494.0	1.280	.4245	431	.00023	17.54	1.685	303.4
900	.847	2370.2	1.303	.3995	351	.00018	44.60	1.780	320.6
600	.158	2254.6	1.334	.3709	260	.00013	152.15	1.866	335.9
r, 1.80; percent fuel, 34.59; O/F, 1.891									
3600	1102.400	4043.1	1.234	0.5192	888	0.00057	-------	-------	-------
3200	594.950	3836.7	1.238	.5126	824	.00052	5.09	0.085	15.2
2800	298.610	3633.2	1.243	.5047	756	.00047	1.01	.750	133.9
2400	136.620	3433.2	1.249	.4948	684	.00042	1.35	1.052	188.0
2000	55.344	3237.8	1.257	.4818	607	.00037	2.27	1.281	228.8
1600	18.965	3048.5	1.270	.4637	523	.00031	4.63	1.469	262.3
1200	5.082	2867.8	1.290	.4382	431	.00024	11.69	1.628	290.8
900	1.466	2740.0	1.313	.4135	352	.00019	28.58	1.731	309.3
600	.284	2620.0	1.343	.3857	261	.00013	93.35	1.823	325.7
r, 3.00; percent fuel, 46.85; O/F, 1.134									
1800	852.500	5266.2	1.305	0.5491	567	0.00040	-------	-------	-------
1600	517.330	5157.4	1.312	.5389	526	.00037	1.39	0.362	51.9
1400	297.010	5050.8	1.321	.5272	482	.00033	1.00	.762	109.4
1200	158.910	4946.6	1.333	.5137	436	.00029	1.21	1.010	145.0
1000	77.401	4845.4	1.346	.4987	387	.00025	1.74	1.204	172.6
900	51.524	4795.9	1.354	.4906	361	.00023	2.21	1.288	184.8
600	11.380	4652.3	1.379	.4666	275	.00017	5.70	1.505	216.0
400	2.662	4560.3	1.393	.4545	206	.00013	14.99	1.629	233.6

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

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

(b) Percent fluorine in oxidant by weight, 15

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(cm)(sec)(°K)	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/lb
r, 1.20; percent fuel, 24.36; O/F, 3.106									
4000	865.790	3008.7	1.229	0.4556	1054	0.00059	----------	-------	-------
3600	493.480	2827.4	1.232	.4509	982	.00055	1.239	0.406	72.8
3200	265.100	2648.1	1.236	.4454	908	.00050	1.032	0.806	144.6
2800	132.330	2471.2	1.240	.4387	830	.00045	1.373	1.062	190.5
2400	60.147	2297.4	1.246	.4303	748	.00040	2.175	1.264	226.8
2000	24.165	2127.3	1.254	.4193	660	.00035	3.976	1.434	257.3
1600	8.190	1962.5	1.266	.4042	565	.00029	8.507	1.582	283.8
1200	2.159	1804.8	1.285	.3830	461	.00023	22.370	1.711	307.1
900	.612	1692.9	1.307	.3620	374	.00017	56.360	1.797	322.5
600	.116	1587.9	1.336	.3376	274	.00012	190.700	1.875	336.4
r, 1.40; percent fuel, 27.51; O/F, 2.662									
4000	912.660	3350.2	1.233	0.4731	1037	0.00061	----------	-------	-------
3600	523.790	3162.0	1.236	.4682	967	.00056	1.413	0.340	62.0
3200	283.530	2975.8	1.239	.4625	894	.00051	1.017	0.775	141.6
2800	142.730	2792.1	1.244	.4556	818	.00046	1.318	1.039	189.8
2400	65.500	2611.6	1.250	.4469	737	.00041	2.055	1.245	227.5
2000	26.611	2435.0	1.258	.4354	651	.00036	3.701	1.417	259.0
1600	9.142	2263.8	1.270	.4196	558	.00030	7.797	1.567	286.4
1200	2.453	2100.2	1.290	.3972	455	.00023	20.120	1.697	310.2
900	.707	1984.3	1.312	.3754	369	.00018	49.800	1.784	326.1
600	.136	1875.3	1.342	.3506	271	.00013	164.800	1.862	340.3
r, 1.60; percent fuel, 30.04; O/F, 2.329									
3600	615.220	3508.7	1.241	0.4844	956	0.00058	----------	-------	-------
3200	336.450	3316.1	1.244	.4784	884	.00053	1.000	0.687	126.6
2800	171.330	3126.1	1.249	.4712	809	.00048	1.206	0.979	180.4
2400	79.663	2939.4	1.255	.4622	729	.00042	1.815	1.199	220.9
2000	32.861	2756.8	1.264	.4503	645	.00037	3.185	1.380	254.3
1600	11.496	2579.7	1.276	.4339	553	.00030	6.546	1.536	283.0
1200	3.154	2410.6	1.297	.4108	452	.00024	16.450	1.671	307.9
900	.928	2290.6	1.319	.3885	367	.00019	39.780	1.761	324.4
600	.184	2177.7	1.348	.3637	270	.00013	128.200	1.841	339.2
r, 1.80; percent fuel, 32.24; O/F, 2.071									
3600	810.870	3877.1	1.247	0.4997	949	0.00059	----------	-------	-------
3200	449.060	3678.5	1.251	.4935	878	.00054	1.106	0.494	90.7
2800	231.930	3482.6	1.256	.4860	804	.00049	1.069	0.866	159.0
2400	109.590	3290.0	1.262	.4766	725	.00044	1.504	1.117	205.0
2000	46.056	3101.6	1.271	.4644	641	.00038	2.529	1.317	241.7
1600	16.470	2919.1	1.284	.4476	551	.00031	5.016	1.485	272.6
1200	4.639	2744.5	1.304	.4241	451	.00025	12.170	1.630	299.2
900	1.397	2620.5	1.327	.4018	367	.00019	28.630	1.725	316.7
600	.284	2503.6	1.355	.3775	271	.00014	89.450	1.811	332.3
r, 2.00; percent fuel, 34.92; O/F, 1.864									
3200	655.370	4055.9	1.258	0.5079	876	0.00056	----------	-------	-------
2800	343.640	3854.2	1.263	.5001	801	.00051	1.001	0.677	122.5
2400	165.190	3656.0	1.270	.4905	723	.00045	1.217	0.993	179.6
2000	70.808	3462.2	1.279	.4780	640	.00039	1.918	1.226	221.6
1600	25.914	3274.3	1.292	.4609	550	.00033	3.631	1.415	255.9
1200	7.502	3094.4	1.313	.4374	451	.00026	8.452	1.575	284.8
900	2.313	2966.4	1.335	.4154	368	.00020	19.280	1.680	303.7
600	.483	2845.3	1.362	.3919	273	.00014	58.330	1.773	320.6

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

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

(c) Percent fluorine in oxidant by weight, 30

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	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, $\frac{(lb)(sec)}{lb}$
r, 1.20; percent fuel, 22.56; O/F, 3.432									
4000	709.280	2932.3	1.250	0.4355	1155	0.00063	----------	-------	-------
3600	420.290	2758.9	1.254	.4311	1073	.00058	1.056	0.546	100.4
3200	235.680	2587.5	1.258	.4259	989	.00053	1.063	0.860	158.1
2800	123.390	2418.4	1.262	.4196	900	.00048	1.410	1.084	199.3
2400	59.186	2252.0	1.269	.4119	808	.00042	2.157	1.266	232.8
2000	25.288	2089.2	1.277	.4018	709	.00036	3.745	1.421	261.5
1600	9.207	1931.1	1.290	.3881	604	.00030	7.508	1.558	286.6
1200	2.642	1779.4	1.309	.3692	489	.00023	18.220	1.678	308.7
900	.806	1671.3	1.330	.3512	394	.00018	42.730	1.759	323.6
600	.165	1568.9	1.357	.3313	287	.00013	133.200	1.833	337.1
r, 1.40; percent fuel, 25.37; O/F, 2.942									
4000	738.690	3244.9	1.252	0.4526	1131	0.00064	----------	-------	-------
3600	438.840	3064.7	1.255	.4480	1052	.00059	1.086	0.513	96.0
3200	246.760	2886.6	1.259	.4426	970	.00054	1.049	0.840	157.2
2800	129.590	2710.8	1.264	.4361	884	.00049	1.373	1.069	200.0
2400	62.377	2537.9	1.270	.4281	793	.00043	2.084	1.254	234.6
2000	26.762	2368.7	1.279	.4175	697	.00037	3.596	1.412	264.2
1600	9.795	2204.4	1.292	.4030	594	.00031	7.161	1.550	290.0
1200	2.831	2047.0	1.312	.3830	482	.00024	17.230	1.671	312.7
900	.871	1934.9	1.334	.3642	389	.00019	40.070	1.753	327.9
600	.181	1828.7	1.361	.3437	284	.00013	123.500	1.827	341.7
r, 1.60; percent fuel, 27.98; O/F, 2.574									
4000	828.380	3564.7	1.255	0.4687	1113	0.00065	----------	-------	-------
3600	494.410	3378.1	1.258	.4639	1036	.00060	1.249	0.406	76.7
3200	279.450	3193.7	1.262	.4583	955	.00055	1.018	0.785	148.1
2800	147.620	3011.6	1.267	.4516	871	.00050	1.285	1.030	194.4
2400	71.530	2832.6	1.274	.4432	782	.00044	1.912	1.224	231.0
2000	30.929	2657.5	1.282	.4322	688	.00038	3.259	1.387	261.9
1600	11.427	2487.4	1.296	.4171	587	.00031	6.382	1.530	288.8
1200	3.343	2324.6	1.316	.3963	477	.00025	15.130	1.655	312.4
900	1.040	2208.5	1.338	.3769	385	.00019	34.730	1.738	328.1
600	.219	2098.6	1.365	.3561	282	.00013	105.400	1.814	342.4
r, 1.80; percent fuel, 30.41; O/F, 2.288									
3600	611.690	3709.2	1.263	0.4790	1024	0.00062	----------	-------	-------
3200	348.360	3518.8	1.267	.4731	945	.00056	1.002	0.670	126.4
2800	185.590	3330.9	1.272	.4661	862	.00051	1.157	0.953	179.8
2400	90.812	3146.1	1.278	.4574	775	.00045	1.656	1.166	220.0
2000	39.715	2965.3	1.287	.4460	682	.00039	2.741	1.343	253.2
1600	14.872	2789.9	1.301	.4305	583	.00032	5.263	1.494	281.8
1200	4.422	2621.7	1.322	.4093	474	.00025	12.200	1.626	306.6
900	1.395	2501.8	1.343	.3896	384	.00020	27.510	1.714	323.2
600	.299	2388.0	1.370	.3690	282	.00014	81.830	1.793	338.2
r, 2.00; percent fuel, 32.69; O/F, 2.059									
3600	820.240	4055.6	1.268	0.4934	1018	0.00063	----------	-------	-------
3200	471.310	3859.5	1.272	.4873	939	.00058	1.167	0.454	84.8
2800	253.650	3666.0	1.277	.4800	857	.00052	1.038	0.831	155.0
2400	125.550	3475.7	1.284	.4710	770	.00046	1.383	1.079	201.5
2000	55.646	3289.6	1.294	.4593	679	.00040	2.199	1.277	238.3
1600	21.168	3108.8	1.307	.4435	581	.00033	4.093	1.443	269.3
1200	6.412	2935.5	1.328	.4220	473	.00026	9.280	1.586	296.0
900	2.056	2811.8	1.350	.4024	384	.00020	20.350	1.680	313.6
600	.448	2694.1	1.375	.3824	283	.00015	59.230	1.766	329.5

4576

CB-3

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

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

(d) Percent fluorine in oxidant by weight, 50

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{o}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(^{o}K)}$	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 1.20; percent fuel, 20.03; O/F, 3.992									
4400	809.530	2970.6	1.280	0.4111	1415	0.00074	---------	--------	--------
4000	524.630	2806.9	1.283	.4074	1320	.00069	1.434	0.342	65.3
3600	326.290	2644.7	1.287	.4033	1221	.00063	1.000	0.709	135.5
3200	192.980	2484.3	1.291	.3986	1120	.00057	1.133	0.941	179.8
2800	107.210	2326.0	1.297	.3930	1014	.00051	1.494	1.124	214.7
2400	54.973	2170.1	1.304	.3861	904	.00045	2.196	1.279	244.3
2000	25.350	2017.4	1.313	.3772	788	.00039	3.588	1.414	270.1
1600	10.086	1868.7	1.326	.3654	665	.00032	6.650	1.534	293.1
1200	3.215	1725.6	1.346	.3495	534	.00025	14.620	1.641	313.6
900	1.075	1622.8	1.366	.3354	426	.00019	31.390	1.714	327.6
600	.245	1524.3	1.389	.3213	308	.00013	88.320	1.782	340.4
r, 1.40; percent fuel, 22.62; O/F, 3.421									
4400	828.500	3248.1	1.279	0.4274	1382	0.00075	---------	--------	--------
4000	536.300	3077.9	1.282	.4236	1289	.00070	1.540	0.313	60.7
3600	333.110	2909.3	1.286	.4193	1194	.00064	1.000	0.698	135.5
3200	196.730	2742.5	1.290	.4145	1095	.00058	1.125	0.934	181.3
2800	109.110	2577.8	1.296	.4087	992	.00052	1.481	1.119	217.3
2400	55.842	2415.7	1.302	.4015	885	.00046	2.176	1.275	247.6
2000	25.698	2256.9	1.312	.3922	772	.00039	3.560	1.412	274.1
1600	10.204	2102.4	1.326	.3796	653	.00032	6.607	1.533	297.6
1200	3.247	1953.8	1.346	.3628	524	.00025	14.550	1.641	318.6
900	1.086	1847.2	1.366	.3477	419	.00019	31.230	1.715	332.8
600	.248	1745.1	1.389	.3329	303	.00014	87.740	1.782	345.9
r, 1.60; percent fuel, 25.04; O/F, 2.994									
4400	895.750	3531.3	1.279	0.4431	1353	0.00076	---------	--------	--------
4000	580.030	3354.9	1.283	.4391	1263	.00071	2.627	0.173	33.8
3600	360.410	3180.2	1.286	.4346	1170	.00065	1.006	0.652	127.9
3200	212.950	3007.3	1.291	.4296	1074	.00059	1.093	0.904	177.2
2800	118.170	2836.6	1.296	.4236	974	.00053	1.420	1.097	215.0
2400	60.517	2668.6	1.303	.4161	869	.00047	2.071	1.259	246.7
2000	27.873	2504.0	1.312	.4064	759	.00040	3.372	1.399	274.2
1600	11.081	2344.0	1.326	.3932	642	.00033	6.232	1.523	298.5
1200	3.533	2190.1	1.347	.3756	517	.00026	13.670	1.634	320.2
900	1.184	2079.7	1.368	.3599	414	.00020	29.250	1.708	334.8
600	.271	1974.1	1.390	.3445	300	.00014	81.800	1.777	348.3
r, 1.80; percent fuel, 27.31; O/F, 2.661									
4000	674.500	3647.3	1.284	0.4539	1243	0.00072	---------	--------	--------
3600	420.080	3466.6	1.288	.4493	1152	.00066	1.060	0.551	108.1
3200	248.860	3287.9	1.292	.4440	1058	.00060	1.041	0.841	165.0
2800	138.510	3111.6	1.298	.4377	960	.00054	1.309	1.051	206.3
2400	71.186	2938.0	1.305	.4300	857	.00048	1.876	1.224	240.2
2000	32.923	2767.9	1.315	.4198	750	.00041	3.016	1.372	269.2
1600	13.154	2602.6	1.329	.4062	635	.00034	5.515	1.502	294.7
1200	4.220	2443.6	1.349	.3880	512	.00026	11.980	1.617	317.3
900	1.422	2329.5	1.370	.3720	411	.00020	25.420	1.695	332.6
600	.328	2220.3	1.393	.3564	298	.00014	70.520	1.766	346.6
r, 2.00; percent fuel, 29.46; O/F, 2.395									
4000	842.100	3956.3	1.287	0.4682	1229	0.00074	---------	--------	--------
3600	526.430	3770.0	1.291	.4632	1139	.00068	1.452	0.338	65.9
3200	313.200	3585.8	1.296	.4577	1047	.00062	1.001	0.732	142.7
2800	175.190	3403.9	1.301	.4511	950	.00055	1.175	0.976	190.2
2400	90.549	3225.0	1.308	.4431	849	.00049	1.630	1.167	227.5
2000	42.159	3049.8	1.318	.4326	743	.00042	2.564	1.328	258.9
1600	16.978	2879.4	1.332	.4187	631	.00035	4.608	1.468	286.1
1200	5.498	2715.5	1.353	.4002	509	.00027	9.849	1.591	310.0
1000	2.760	2636.5	1.366	.3895	444	.00023	15.790	1.646	320.9
900	1.868	2597.8	1.374	.3840	409	.00021	20.670	1.673	326.1
600	.435	2485.0	1.395	.3687	299	.00015	56.680	1.749	340.8

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

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

(e) Percent fluorine in oxidant by weight, 70.37

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/lb
r, 1.00; percent fuel, 14.83; O/F, 5.743									
4400	880.19	2735.8	1.321	0.3678	1583	0.00076	------	--------	-------
4000	595.53	2589.3	1.324	.3648	1474	.00070	5.53	0.082	15.3
3600	388.09	2444.0	1.328	.3615	1361	.00064	1.03	.611	113.5
3200	241.56	2300.1	1.333	.3578	1246	.00058	1.04	.858	159.3
2800	141.97	2157.9	1.338	.3534	1126	.00052	1.27	1.047	194.3
2400	77.518	2017.5	1.345	.3480	1001	.00046	1.74	1.204	223.6
2000	38.374	1879.7	1.355	.3410	870	.00039	2.63	1.341	249.0
1600	16.561	1745.0	1.368	.3318	733	.00032	4.47	1.462	271.5
1200	5.801	1614.6	1.387	.3199	586	.00025	8.91	1.571	291.5
900	2.106	1520.1	1.405	.3099	466	.00020	17.58	1.645	305.4
600	.528	1428.5	1.422	.3010	336	.00014	44.90	1.714	318.2
r, 1.40; percent fuel, 19.60; O/F, 4.102									
4800	816.82	3198.8	1.306	0.3999	1664	0.00086	------	-------	-------
4400	564.56	3039.6	1.310	.3961	1557	.00080	2.02	0.233	46.9
4000	378.05	2881.9	1.314	.3927	1449	.00074	1.02	.626	126.2
3600	243.66	2725.5	1.317	.3890	1337	.00068	1.04	.853	171.8
3200	149.84	2570.8	1.322	.3848	1222	.00061	1.25	1.029	207.4
2800	86.912	2417.8	1.328	.3798	1102	.00055	1.65	1.178	237.3
2400	46.773	2267.1	1.335	.3736	979	.00048	2.36	1.307	263.5
2000	22.792	2119.2	1.345	.3655	849	.00041	3.71	1.424	286.9
1600	9.671	1975.1	1.359	.3546	713	.00034	6.52	1.528	307.9
1200	3.329	1835.9	1.380	.3405	568	.00026	13.38	1.623	327.0
900	1.193	1735.6	1.399	.3286	451	.00020	26.93	1.688	340.1
600	.295	1638.6	1.417	.3185	324	.00014	70.08	1.748	352.3
r, 1.50; percent fuel, 20.71; O/F, 3.829									
4800	806.49	3305.1	1.304	0.4074	1647	0.00087	------	--------	-------
4400	556.04	3142.9	1.307	.4035	1542	.00080	1.83	0.260	52.8
4000	371.36	2982.2	1.311	.4000	1434	.00074	1.01	.637	129.5
3600	238.65	2823.0	1.315	.3962	1324	.00068	1.05	.861	175.0
3200	146.31	2665.3	1.319	.3919	1209	.00062	1.27	1.036	210.6
2800	84.568	2509.6	1.325	.3868	1092	.00055	1.68	1.184	240.6
2400	45.339	2356.1	1.332	.3804	969	.00048	2.42	1.313	265.9
2000	21.998	2205.5	1.342	.3720	841	.00041	3.81	1.429	290.4
1600	9.289	2058.9	1.357	.3609	706	.00034	6.73	1.533	311.6
1200	3.180	1917.3	1.377	.3463	563	.00026	13.90	1.628	330.8
900	1.134	1815.3	1.397	.3340	447	.00020	28.11	1.693	344.0
600	.279	1716.7	1.415	.3234	321	.00014	73.57	1.753	356.2
r, 1.60; percent fuel, 21.79; O/F, 3.589									
4400	602.43	3283.7	1.297	0.4136	1497	0.00080	------	--------	-------
4000	398.17	3119.1	1.301	.4098	1393	.00074	1.03	0.590	119.1
3600	253.04	2955.9	1.305	.4057	1286	.00067	1.04	.835	168.5
3200	153.25	2794.6	1.309	.4011	1176	.00061	1.24	1.081	206.0
2800	87.418	2635.2	1.315	.3956	1061	.00055	1.66	1.176	237.3
2400	46.181	2478.2	1.322	.3889	943	.00048	2.41	1.311	264.5
2000	22.038	2324.4	1.332	.3800	818	.00041	3.85	1.431	288.7
1600	9.130	2174.6	1.346	.3683	688	.00033	6.92	1.539	310.4
1200	3.055	2030.2	1.367	.3531	548	.00026	14.59	1.636	330.0
900	1.067	1926.2	1.386	.3402	435	.00020	30.11	1.703	343.5
600	.256	1825.9	1.405	.3288	312	.00014	80.83	1.764	356.0
r, 2.50; percent fuel, 30.33; O/F, 2.297									
4000	682.17	4178.2	1.250	0.4868	1570	0.00096	-------	-------	-------
3600	404.11	3984.6	1.254	.4809	1447	.00087	1.04	0.574	112.0
3200	226.76	3793.6	1.258	.4743	1321	.00079	1.08	.876	170.8
2800	118.92	3605.3	1.264	.4668	1190	.00070	1.44	1.094	213.4
2400	57.201	3420.4	1.270	.4577	1055	.00061	2.20	1.273	248.3
2000	24.541	3239.5	1.279	.4460	913	.00052	3.82	1.426	278.2
1600	8.984	3064.1	1.292	.4307	765	.00042	7.62	1.560	304.4
1200	2.593	2895.7	1.311	.4102	607	.00032	18.40	1.679	327.6
900	.793	2775.2	1.330	.3927	480	.00025	43.10	1.759	343.2
600	.161	2660.2	1.353	.3734	343	.00017	135.7	1.832	357.5

4576

CB-3 back

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

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

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

Temperature, T, °K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity μ, micropoises	Thermal conductivity, k, $\frac{cal}{(cm)(sec)(^{\circ}K)}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 1.00; percent fuel, 11.01; O/F, 8.083									
4000	629.59	2635.1	1.246	0.3669	1107	0.00051	-----	-----	-----
3600	370.72	2489.4	1.250	.3619	1026	.00046	1.010	0.630	107.1
3200	206.77	2345.6	1.255	.3567	943	.00042	1.113	.911	154.9
2800	107.75	2204.1	1.260	.3510	857	.00038	1.519	1.121	190.5
2400	51.440	2065.0	1.267	.3445	767	.00033	2.362	1.295	220.0
2000	21.838	1928.7	1.274	.3368	671	.00029	4.155	1.445	245.5
1600	7.856	1795.7	1.284	.3274	570	.00024	8.463	1.577	268.0
1200	2.193	1667.0	1.298	.3158	461	.00019	21.153	1.696	288.2
900	.639	1573.8	1.311	.3055	371	.00015	51.925	1.777	301.9
r, 1.50; percent fuel, 15.65; O/F, 5.389									
4400	990.47	3217.5	1.227	0.4040	1222	0.00061	-----	-----	-----
4000	593.35	3057.1	1.230	.3984	1140	.00056	4.431	0.098	17.0
3600	339.46	3898.8	1.235	.3926	1055	.00051	1.000	.681	118.6
3200	183.55	2743.0	1.239	.3865	967	.00046	1.173	.954	166.2
2800	92.494	2589.8	1.245	.3796	876	.00041	1.673	1.162	202.4
2400	42.568	2439.5	1.251	.3717	781	.00036	2.712	1.334	232.4
2000	17.365	2292.6	1.259	.3623	682	.00031	4.983	1.484	258.5
1600	5.981	2150.0	1.270	.3506	576	.00026	10.627	1.616	281.5
1200	1.593	2012.5	1.285	.3362	462	.00020	27.904	1.733	302.0
900	.446	1913.5	1.299	.3241	369	.00015	71.384	1.813	315.9
r, 2.00; percent fuel, 19.84; O/F, 4.041									
4400	779.01	3540.4	1.208	0.4363	1274	0.00068	-----	-----	-----
4000	449.96	3367.2	1.212	.4300	1186	.00062	1.101	0.488	87.9
3600	247.51	3196.5	1.216	.4235	1096	.00057	1.054	.834	150.3
3200	128.23	3028.5	1.235	.4164	1003	.00049	1.410	1.070	192.9
2800	61.656	2863.4	1.226	.4086	907	.00046	2.179	1.260	227.1
2400	26.939	2701.8	1.232	.3994	807	.00040	3.789	1.421	256.2
2000	10.367	2544.1	1.240	.3884	702	.00034	7.461	1.563	281.7
1600	3.342	2391.4	1.251	.3747	591	.00028	17.135	1.689	304.4
1200	.824	2244.8	1.266	.3576	471	.00021	48.851	1.801	324.6
900	.216	2139.7	1.281	.3431	374	.00016	134.105	1.878	338.4
r, 2.80; percent fuel, 25.73; O/F, 2.887									
4400	724.75	4079.1	1.202	0.4776	1935	0.00112	-----	-----	-----
4000	413.02	3889.3	1.206	.4710	1788	.00102	1.040	0.553	103.9
3600	223.78	3702.3	1.209	.4642	1639	.00093	1.090	.875	164.5
3200	113.97	3518.1	1.214	.4567	1486	.00083	1.510	1.105	207.6
2800	53.745	3337.0	1.218	.4484	1329	.00073	2.400	1.291	242.6
2400	22.963	3159.6	1.224	.4385	1167	.00063	4.280	1.450	272.5
2000	8.612	2986.6	1.232	.4262	1001	.00053	8.670	1.590	298.9
1600	2.696	2819.1	1.243	.4106	828	.00042	20.560	1.715	322.4
1200	.643	2658.8	1.260	.3899	646	.00032	60.650	1.827	343.3
900	.165	2544.4	1.275	.3727	502	.00024	170.70	1.902	357.5

TABLE III. - Concluded. THEORETICAL PERFORMANCE AT ASSIGNED EXIT TEMPERATURES FOR JP-4

FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

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

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

Temperature, T, ^{o}K	Static pressure, P, lb/sq in. abs	Enthalpy, h, cal/g	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{o}K)}$	Absolute viscosity μ, micropoises	Thermal conductivity k, $\frac{cal}{(cm)(sec)(^{o}K)}$	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 3.00; percent fuel, 27.07; O/F, 2.694									
4400	739.12	4213.5	1.200	0.4879	2119	0.00127	-----	-----	-----
4000	419.19	4019.7	1.204	.4812	1955	.00116	1.050	0.542	102.4
3600	225.92	3828.6	1.207	.4742	1787	.00105	1.090	.871	164.6
3200	114.41	3640.4	1.211	.4666	1616	.00093	1.510	1.103	208.5
2800	53.598	3455.4	1.216	.4581	1441	.00082	2.410	1.292	244.1
2400	22.732	3274.2	1.222	.4479	1262	.00069	4.330	1.453	274.5
2000	84.54	3097.4	1.230	.4354	1078	.00059	8.830	1.594	301.2
1600	26.21	2926.3	1.241	.4193	887	.00046	21.130	1.720	325.0
1200	6.19	2762.7	1.257	.3979	689	.00035	63.030	1.832	346.2
900	1.57	2646.0	1.273	.3799	533	.00026	179.05	1.908	360.6
r, 3.50; percent fuel, 30.22; O/F, 2.309									
4400	830.78	4554.4	1.195	0.5133	2550	0.00158	-----	-----	-----
4000	464.76	4350.5	1.198	.5062	2341	.00143	1.130	0.458	87.1
3600	246.79	4149.5	1.201	.4989	2130	.00129	1.060	.833	158.4
3200	122.95	3951.5	1.205	.4909	1916	.00114	1.450	1.082	205.7
2800	56.562	3757.0	1.210	.4818	1698	.00100	2.340	1.280	243.4
2400	23.503	3566.3	1.216	.4711	1477	.00085	4.260	1.449	275.4
2000	8.539	3380.4	1.224	.4577	1251	.00070	8.870	1.596	303.3
1600	2.576	3200.6	1.234	.4406	1020	.00056	21.740	1.726	328.1
1200	.589	3028.8	1.251	.4173	783	.00041	66.830	1.842	350.1
900	.145	2906.5	1.266	.3978	600	.00030	194.93	1.920	365.0
r, 4.00; percent fuel, 33.10; O/F, 2.021									
4400	1022.20	4902.9	1.189	0.5381	3858	0.00184	-----	-----	-----
4000	563.19	4689.2	1.192	.5305	2617	.00167	1.920	0.230	43.5
3600	294.16	4478.5	1.195	.5227	2373	.00149	1.010	.751	142.2
3200	143.93	4271.1	1.199	.5142	2127	.00132	1.340	1.033	195.6
2800	64.911	4067.3	1.204	.5046	1878	.00115	2.150	1.250	236.6
2400	26.379	3867.7	1.209	.4933	1626	.00098	3.960	1.431	270.9
2000	9.345	3673.1	1.217	.4791	1371	.00080	8.390	1.587	300.5
1600	2.738	3485.0	1.228	.4608	1112	.00063	21.070	1.725	326.6
1200	.604	3305.3	1.244	.4359	848	.00046	66.850	1.847	349.7
900	.145	3177.7	1.259	.4149	646	.00034	200.73	1.929	365.2
r, 5.00; percent fuel, 38.22; O/F, 1.617									
4000	981.05	5361.6	1.181	0.5753	2835	0.00194	-----	-----	-----
3600	496.15	5133.2	1.184	.5664	2569	.00174	1.240	0.395	73.0
3200	234.40	4908.6	1.188	.5568	2300	.00153	1.080	.854	157.7
2800	101.73	4688.0	1.193	.5461	2029	.00133	1.630	1.136	209.9
2400	39.609	4472.0	1.198	.5334	1755	.00113	3.010	1.357	250.7
2000	13.366	4261.6	1.205	.5177	1477	.00093	6.550	1.542	284.9
1600	3.701	4058.4	1.216	.4974	1196	.00073	17.140	1.702	314.4
1200	.764	3864.7	1.231	.4697	910	.00053	57.530	1.841	340.2
900	.172	3727.4	1.246	.4461	692	.00039	182.48	1.934	357.3

4576

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

JP-4 FUEL WITH TWO FLUORINE-OXYGEN MIXTURES

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

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

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(^\circ K)}$	Isentropic exponent, γ	Thrust coefficient, C_F	Area ratio, ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 1.00; percent fuel, 22.71; O/F, 3.403								
1.000	600.00	3612	2531.6	0.451	1.209	-------	-------	-------
1.020	588.24	3600	2526.0	.451	1.209	0.129	3.326	22.0
1.040	576.92	3588	2520.6	.451	1.209	.182	2.404	31.0
1.200	500.00	3500	2481.0	.449	1.210	.390	1.263	66.3
1.480	404.73	3374	2424.4	.448	1.211	.568	1.032	96.6
1.779	337.27	3268	2377.2	.446	1.212	.681	1.000	115.9
2.220	269.82	3143	2321.4	.444	1.213	.795	1.030	135.2
4.000	150.00	2833	2184.7	.439	1.216	1.021	1.301	173.7
8.000	75.00	2502	2040.7	.432	1.220	1.215	1.931	206.7
r, 1.20; percent fuel, 26.07; O/F, 2.836								
1.000	600.00	3628	2901.1	0.470	1.213	-------	-------	-------
1.020	588.24	3616	2895.2	.470	1.213	0.130	3.330	22.7
1.040	576.92	3604	2889.4	.470	1.213	.182	2.406	31.9
1.200	500.00	3514	2847.3	.469	1.214	.390	1.264	68.4
1.485	404.14	3384	2786.6	.467	1.215	.569	1.032	99.8
1.782	336.79	3276	2736.4	.465	1.216	.683	1.000	119.7
2.226	269.42	3149	2677.2	.463	1.217	.796	1.030	139.6
4.000	150.00	2834	2532.4	.458	1.220	1.021	1.298	179.1
8.000	75.00	2498	2379.8	.450	1.225	1.214	1.925	213.0
r, 1.30; percent fuel, 27.64; O/F, 2.618								
1.000	600.00	3612	3074.1	0.479	1.216	-------	-------	-------
1.020	588.24	3599	3068.1	.479	1.216	0.130	3.332	23.0
1.040	576.92	3587	3062.1	.479	1.216	.182	2.408	32.3
1.200	500.00	3497	3019.0	.477	1.217	.390	1.264	69.3
1.490	403.76	3366	2956.6	.476	1.218	.570	1.032	101.1
1.783	336.46	3258	2905.2	.474	1.219	.684	1.000	121.2
2.230	269.17	3129	2844.6	.472	1.220	.797	1.030	141.3
4.000	150.00	2814	2696.9	.466	1.223	1.021	1.297	181.2
8.000	75.00	2477	2541.0	.459	1.228	1.214	1.920	215.4
r, 1.40; percent fuel, 29.15; O/F, 2.431								
1.000	600.00	3576	3239.9	0.487	1.219	-------	-------	-------
1.020	588.24	3563	3233.7	.487	1.219	0.130	3.336	23.2
1.040	576.92	3551	3227.7	.487	1.219	.182	2.410	32.6
1.200	500.00	3461	3183.8	.486	1.220	.391	1.265	69.9
1.490	403.30	3329	3119.9	.484	1.221	.571	1.032	102.2
1.785	336.08	3220	3067.6	.482	1.222	.685	1.000	122.4
2.230	268.88	3092	3006.0	.480	1.223	.798	1.030	142.7
4.000	150.00	2778	2856.1	.474	1.227	1.022	1.295	182.7
8.000	75.00	2441	2697.9	.466	1.231	1.214	1.915	217.2
r, 1.60; percent fuel, 31.98; O/F, 2.127								
1.000	600.00	3436	3551.6	0.501	1.227	-------	-------	-------
1.020	588.24	3423	3545.3	.501	1.227	0.130	3.343	23.4
1.040	576.92	3411	3539.2	.501	1.227	.183	2.416	32.9
1.200	500.00	3321	3494.5	.499	1.228	.392	1.267	70.5
1.490	402.13	3189	3428.6	.497	1.230	.574	1.032	103.4
1.790	335.11	3082	3375.6	.495	1.231	.687	1.000	123.8
2.240	268.08	2956	3313.0	.493	1.232	.800	1.030	144.1
4.000	150.00	2648	3162.2	.486	1.236	1.022	1.290	184.1
8.000	75.00	2317	3002.6	.478	1.241	1.214	1.902	218.6
r, 1.80; percent fuel, 34.59; O/F, 1.891								
1.000	600.00	3205	3839.4	0.513	1.238	-------	-------	-------
1.020	588.24	3193	3833.1	.513	1.238	0.130	3.354	23.3
1.040	576.92	3181	3827.0	.512	1.238	.183	2.423	32.8
1.200	500.00	3095	3782.8	.511	1.239	.393	1.270	70.2
1.500	400.60	2965	3716.6	.508	1.241	.579	1.031	103.3
1.797	333.83	2862	3664.3	.506	1.242	.691	1.000	123.4
2.250	267.07	2740	3602.7	.503	1.243	.803	1.029	143.5
4.000	150.00	2445	3455.5	.496	1.248	1.023	1.284	182.8
8.000	75.00	2128	3299.6	.486	1.254	1.213	1.885	216.7
r, 3.00; percent fuel, 46.85; O/F, 1.134								
1.000	600.00	1657	5188.4	0.542	1.310	-------	-------	-------
1.020	588.24	1650	5184.2	.542	1.310	0.133	3.422	19.1
1.040	576.92	1642	5180.1	.541	1.311	.187	2.471	26.9
1.200	500.00	1587	5150.4	.538	1.313	.400	1.289	57.5
1.540	390.21	1496	5101.4	.533	1.317	.606	1.028	87.0
1.845	325.18	1431	5067.2	.529	1.320	.715	1.000	102.7
2.310	260.13	1355	5027.3	.524	1.324	.825	1.027	118.4
4.000	150.00	1183	4937.8	.512	1.334	1.029	1.246	147.6
8.000	75.00	992	4841.4	.498	1.347	1.211	1.776	173.8

TABLE IV. - Concluded. THEORETICAL PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 to 8

FOR JP-4 FUEL WITH TWO FLUORINE-OXYGEN MIXTURES

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

(b) Percent fluorine in oxidant by weight, 70.37

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 1.00; percent fuel, 14.83; O/F, 5.743								
1.00	600.00	4007	2592.0	1.324	0.365	--------	--------	--------
1.02	588.24	3988	2584.9	1.325	.365	3.433	0.134	24.8
1.04	576.92	3969	2578.0	1.325	.365	2.478	.188	34.9
1.20	500.00	3832	2528.1	1.326	.363	1.292	.401	74.5
1.54	388.99	3602	2444.8	1.328	.362	1.028	.610	113.2
[a]1.85	324.15	3443	2387.4	1.330	.360	1.000	.719	133.4
2.31	259.33	3257	2320.6	1.332	.358	1.027	.828	153.7
4.00	150.00	2839	2171.7	1.338	.354	1.243	1.030	191.2
8.00	75.00	2380	2010.5	1.346	.348	1.772	1.211	224.9
r, 1.40; percent fuel, 19.60; O/F, 4.102								
1.00	600.00	4464	3064.9	1.309	0.397	--------	--------	--------
1.02	588.24	4443	3056.6	1.310	.396	3.419	0.133	26.8
1.04	576.92	4423	3048.6	1.310	.396	2.469	.187	37.7
1.20	500.00	4275	2990.2	1.311	.395	1.288	.400	80.6
1.53	390.93	4032	2894.5	1.313	.393	1.028	.604	121.8
[a]1.84	325.77	3860	2827.0	1.315	.391	1.000	.714	143.9
2.30	260.62	3659	2748.4	1.317	.390	1.027	.823	165.9
4.00	150.00	3201	2571.1	1.322	.385	1.250	1.029	207.3
8.00	75.00	2700	2379.8	1.329	.378	1.790	1.212	244.2
r, 1.50; percent fuel, 20.71; O/F, 3.829								
1.00	600.00	4479	3175.0	1.307	0.404	--------	--------	--------
1.02	588.24	4459	3166.6	1.307	.404	3.417	0.133	27.0
1.04	576.92	4438	3158.4	1.307	.404	2.467	.187	38.0
1.20	500.00	4291	3099.1	1.308	.403	1.287	.400	81.2
1.53	391.30	4050	3002.2	1.310	.400	1.028	.603	122.6
[a]1.84	326.07	3878	2933.6	1.312	.399	1.000	.713	144.9
2.30	260.87	3677	2853.7	1.314	.397	1.027	.823	167.2
4.00	150.00	3219	2672.9	1.319	.392	1.251	1.028	209.0
8.00	75.00	2719	2478.1	1.326	.386	1.794	1.212	246.2
r, 1.60; percent fuel, 21.79; O/F, 3.589								
1.00	600.00	4396	3282.1	1.297	0.414	--------	--------	--------
1.02	588.24	4376	3273.8	1.297	.413	3.408	0.133	26.8
1.04	576.92	4357	3265.8	1.298	.413	2.461	.186	37.6
1.20	500.00	4216	3207.7	1.299	.412	1.285	.399	80.4
1.53	392.53	3987	3113.6	1.301	.410	1.029	.600	121.1
[a]1.83	327.10	3822	3046.2	1.302	.408	1.000	.710	143.3
2.29	261.69	3628	2967.4	1.304	.406	1.028	.820	165.5
4.00	150.00	3184	2788.1	1.310	.401	1.255	1.028	207.3
8.00	75.00	2699	2595.3	1.317	.394	1.805	1.212	244.5
r, 2.50; percent fuel, 30.33; O/F, 2.297								
1.00	600.00	3898	4128.8	1.251	0.485	--------	--------	--------
1.02	588.24	3883	4121.3	1.251	.485	3.366	0.131	25.5
1.04	576.92	3868	4114.0	1.251	.485	2.432	.184	35.9
1.20	500.00	3758	4060.9	1.252	.483	1.273	.394	76.9
1.50	398.77	3590	3980.0	1.254	.481	1.031	.583	113.8
[a]1.81	332.31	3460	3917.4	1.255	.479	1.000	.695	135.6
2.26	265.85	3306	3843.9	1.257	.476	1.029	.807	157.5
4.00	150.00	2938	3670.1	1.262	.470	1.277	1.024	199.8
8.00	75.00	2542	3485.5	1.268	.461	1.866	1.213	236.5

[a] At throat.

4576

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

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

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

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Temperature exponent, n_T	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Isentropic exponent, γ	Thrust coefficient, C_F	Area-ratio exponent, n_ϵ	Area ratio, ε	Specific-impulse exponent, n_I	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 1.00; percent fuel, 22.71; O/F, 3.403											
10	60.00	2403	0.0509	1998.0	0.430	1.222	1.266	0.0049	2.22	0.0161	215.5
15	40.00	2232	.0525	1924.8	.425	1.225	1.350	.0062	2.90	.0165	229.8
20	30.00	2117	.0537	1876.0	.422	1.227	1.404	.0072	3.53	.0167	238.8
30	20.00	1963	.0555	1811.5	.417	1.230	1.471	.0086	4.69	.0170	250.3
40	15.00	1860	.0567	1768.6	.413	1.232	1.514	.0096	5.76	.0172	257.7
60	10.00	1722	.0586	1712.0	.408	1.236	1.569	.0112	7.71	.0175	267.0
80	7.50	1629	.0599	1674.5	.404	1.239	1.605	.0123	9.52	.0178	273.1
100	6.00	1561	.0610	1646.7	.401	1.242	1.631	.0133	11.21	.0179	277.5
150	4.00	1441	.0631	1599.3	.395	1.246	1.674	.0150	15.13	.0182	284.8
200	3.00	1361	.0646	1567.9	.390	1.250	1.702	.0163	18.74	.0185	289.6
300	2.00	1255	.0668	1526.5	.384	1.255	1.738	.0182	25.37	.0188	295.7
400	1.50	1183	.0684	1499.2	.379	1.259	1.761	.0196	31.47	.0190	299.7
600	1.00	1087	.0708	1463.3	.373	1.265	1.792	.0217	42.67	.0193	304.9
800	.75	1024	.0725	1439.6	.368	1.269	1.812	.0232	52.96	.0195	308.2
1000	.60	976	.0738	1422.3	.364	1.273	1.826	.0244	62.63	.0196	310.7
1500	.40	894	.0763	1392.7	.357	1.279	1.850	.0266	84.94	.0199	314.8
r, 1.20; percent fuel, 26.07; O/F, 2.836											
10	60.00	2398	0.0505	2334.6	0.448	1.226	1.266	0.0049	2.22	0.0161	222.0
15	40.00	2224	.0521	2257.2	.443	1.229	1.350	.0061	2.89	.0164	236.7
20	30.00	2107	.0533	2205.7	.440	1.232	1.403	.0071	3.51	.0166	246.0
30	20.00	1952	.0550	2137.7	.434	1.235	1.470	.0085	4.66	.0169	257.7
40	15.00	1847	.0562	2092.5	.431	1.238	1.512	.0095	5.71	.0171	265.3
60	10.00	1708	.0581	2032.9	.425	1.242	1.567	.0109	7.65	.0174	274.9
80	7.50	1615	.0595	1993.4	.420	1.245	1.602	.0122	9.43	.0177	281.0
100	6.00	1545	.0605	1964.3	.417	1.247	1.628	.0131	11.10	.0178	285.5
150	4.00	1425	.0626	1914.5	.410	1.252	1.671	.0148	14.96	.0181	293.0
200	3.00	1344	.0641	1881.6	.406	1.256	1.698	.0162	18.51	.0183	297.9
300	2.00	1237	.0663	1838.4	.399	1.262	1.734	.0181	25.02	.0186	304.1
400	1.50	1165	.0679	1809.8	.394	1.266	1.757	.0195	31.00	.0188	308.2
600	1.00	1069	.0702	1772.4	.386	1.272	1.787	.0215	41.96	.0191	313.4
800	.75	1004	.0719	1747.8	.381	1.277	1.806	.0230	52.02	.0193	316.8
1000	.60	957	.0733	1729.7	.377	1.281	1.820	.0242	61.46	.0195	319.3
1500	.40	875	.0758	1699.0	.370	1.288	1.844	.0264	83.19	.0198	323.4
r, 1.30; percent fuel, 27.64; O/F, 2.618											
10	60.00	2377	0.0489	2495.0	0.456	1.229	1.266	0.0047	2.21	0.0156	224.5
15	40.00	2202	.0505	2416.0	.451	1.232	1.349	.0059	2.88	.0159	239.3
20	30.00	2086	.0516	2363.5	.447	1.235	1.402	.0068	3.50	.0162	248.7
30	20.00	1930	.0532	2294.3	.442	1.238	1.469	.0082	4.64	.0165	260.5
40	15.00	1826	.0544	2248.3	.438	1.241	1.511	.0092	5.69	.0167	268.1
60	10.00	1686	.0562	2187.8	.432	1.245	1.566	.0107	7.60	.0170	277.7
80	7.50	1593	.0575	2147.7	.427	1.249	1.601	.0118	9.37	.0172	283.9
100	6.00	1523	.0586	2118.1	.424	1.251	1.626	.0127	11.02	.0173	288.4
150	4.00	1403	.0606	2067.6	.417	1.256	1.668	.0144	14.84	.0176	295.9
200	3.00	1323	.0620	2034.3	.412	1.260	1.696	.0156	18.36	.0178	300.8
300	2.00	1216	.0642	1990.5	.405	1.266	1.731	.0175	24.79	.0181	307.1
400	1.50	1144	.0657	1961.6	.399	1.271	1.754	.0188	30.69	.0183	311.1
600	1.00	1048	.0680	1923.9	.392	1.277	1.784	.0208	41.49	.0186	316.4
800	.75	984	.0696	1899.0	.387	1.282	1.803	.0222	51.40	.0188	319.8
1000	.60	937	.0709	1880.8	.382	1.286	1.817	.0234	60.68	.0189	322.2
1500	.40	855	.0733	1849.9	.375	1.293	1.840	.0255	82.04	.0192	326.4

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

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

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

Pressure ratio, P_o/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Temperature exponent, n_T	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(^oK)}$	Isentropic exponent, γ	Thrust coefficient, C_F	Area-ratio exponent, n_ε	Area ratio, ε	Specific-impulse exponent, n_I	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 1.40; percent fuel, 29.15; O/F, 2.431											
10	60.00	2341	0.0458	2651.2	0.463	1.233	1.265	0.0043	2.80	0.0148	226.3
15	40.00	2167	.0473	2571.3	.458	1.236	1.349	.0055	2.87	.0151	241.2
20	30.00	2050	.0483	2518.2	.454	1.239	1.401	.0063	3.49	.0153	250.6
30	20.00	1895	.0499	2448.1	.449	1.243	1.467	.0076	4.61	.0155	262.5
40	15.00	1791	.0510	2401.7	.444	1.245	1.510	.0085	5.65	.0157	270.1
60	10.00	1653	.0527	2340.6	.438	1.250	1.564	.0099	7.55	.0160	279.7
80	7.50	1560	.0539	2300.2	.433	1.253	1.599	.0110	9.29	.0162	286.0
100	6.00	1491	.0549	2270.4	.429	1.256	1.624	.0118	10.93	.0164	290.5
150	4.00	1372	.0567	2219.6	.422	1.262	1.666	.0134	14.71	.0166	298.0
200	3.00	1292	.0581	2186.0	.417	1.266	1.693	.0145	18.17	.0168	302.8
300	2.00	1185	.0601	2142.1	.410	1.272	1.728	.0163	24.50	.0171	309.1
400	1.50	1114	.0615	2113.1	.404	1.277	1.751	.0175	30.31	.0173	313.1
600	1.00	1020	.0636	2075.3	.396	1.284	1.780	.0193	40.93	.0175	318.3
800	.75	956	.0651	2050.4	.391	1.289	1.799	.0207	50.65	.0177	321.7
1000	.60	910	.0663	2032.2	.387	1.293	1.812	.0217	59.76	.0178	324.2
1500	.40	829	.0684	2001.3	.379	1.300	1.835	.0236	80.68	.0181	328.3
r, 1.60; percent fuel, 31.98; O/F, 2.127											
10	60.00	2218	0.0366	2955.7	0.475	1.243	1.265	0.0034	2.18	0.0121	227.7
15	40.00	2048	.0378	2875.4	.469	1.247	1.347	.0043	2.84	.0123	242.6
20	30.00	1935	.0386	2822.2	.465	1.249	1.399	.0049	3.44	.0125	251.9
30	20.00	1783	.0398	2752.3	.459	1.254	1.465	.0059	4.55	.0127	263.7
40	15.00	1682	.0407	2706.1	.454	1.257	1.506	.0067	5.56	.0128	271.2
60	10.00	1547	.0420	2645.3	.447	1.262	1.559	.0078	7.41	.0131	280.8
80	7.50	1457	.0430	2605.2	.442	1.266	1.594	.0086	9.11	.0132	287.0
100	6.00	1390	.0438	2575.8	.438	1.269	1.618	.0093	10.70	.0133	291.4
150	4.00	1274	.0452	2525.6	.430	1.275	1.659	.0105	14.35	.0135	298.8
200	3.00	1197	.0463	2492.7	.424	1.280	1.686	.0114	17.69	.0137	303.6
300	2.00	1094	.0478	2449.6	.416	1.287	1.720	.0127	23.78	.0139	309.7
400	1.50	1026	.0489	2421.3	.411	1.292	1.742	.0137	29.35	.0140	313.6
600	1.00	935	.0505	2384.4	.403	1.300	1.770	.0151	39.49	.0142	318.7
800	.75	875	.0517	2360.2	.397	1.305	1.788	.0161	48.75	.0143	322.0
1000	.60	830	.0525	2342.6	.393	1.309	1.801	.0169	57.40	.0144	324.3
1500	.40	754	.0541	2312.8	.386	1.317	1.823	.0183	77.23	.0146	328.3
r, 1.80; percent fuel, 34.59; O/F, 1.891											
10	60.00	2033	0.0239	3253.8	0.483	1.256	1.264	0.0022	2.16	0.0081	225.7
15	40.00	1871	.0246	3175.9	.477	1.261	1.345	.0027	2.80	.0083	240.3
20	30.00	1762	.0252	3124.4	.472	1.264	1.396	.0032	3.39	.0084	249.4
30	20.00	1618	.0259	3056.9	.465	1.269	1.461	.0038	4.46	.0085	260.9
40	15.00	1522	.0265	3012.4	.459	1.273	1.502	.0043	5.45	.0086	268.2
60	10.00	1394	.0274	2954.2	.452	1.279	1.554	.0050	7.23	.0087	277.5
80	7.50	1309	.0280	2915.9	.446	1.284	1.587	.0055	8.86	.0088	283.5
100	6.00	1245	.0285	2887.8	.442	1.287	1.611	.0060	10.39	.0089	287.7
150	4.00	1137	.0294	2840.3	.433	1.294	1.651	.0067	13.88	.0090	294.8
200	3.00	1064	.0300	2809.1	.428	1.299	1.676	.0073	17.06	.0091	299.4
300	2.00	969	.0310	2768.5	.420	1.307	1.709	.0081	22.84	.0092	305.2
400	1.50	905	.0317	2742.0	.414	1.312	1.730	.0087	28.11	.0093	309.0
600	1.00	821	.0326	2707.5	.406	1.320	1.757	.0096	37.67	.0094	313.8
800	.75	765	.0333	2685.1	.401	1.326	1.774	.0101	46.36	.0095	316.9
1000	.60	724	.0338	2668.7	.397	1.330	1.787	.0106	54.46	.0096	319.2
1500	.40	654	.0347	2641.2	.391	1.337	1.808	.0114	72.96	.0097	322.9
r, 3.00; percent fuel, 46.85; O/F, 1.134											
10	60.00	936		4813.8	0.494	1.351	1.258		2.02		180.5
15	40.00	842		4767.6	.486	1.359	1.333		2.57		191.3
20	30.00	780		4737.7	.481	1.364	1.380		3.06		198.0
30	20.00	700		4699.3	.474	1.371	1.437		3.96		206.3
40	15.00	647		4674.4	.470	1.375	1.473		4.76		211.5
60	10.00	579		4642.6	.465	1.381	1.518		6.20		217.9
80	7.50	535		4622.0	.462	1.384	1.547		7.49		222.0
100	6.00	503		4607.2	.460	1.387	1.567		8.69		224.9
150	4.00	449		4582.5	.457	1.391	1.600		11.39		229.6
200	3.00	414		4566.6	.455	1.393	1.621		13.83		232.6

4576

CB-4

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

WITH SEVERAL FLUORINE-OXYGEN MIXTURES

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

(b) Percent fluorine in oxidant by weight, 15

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, cal/(g)(°K)	Isentropic exponent, γ	Thrust coefficient, C_F	Area ratio, ε	Specific impulse, I, (lb)(sec)/lb
r, 1.20; percent fuel, 24.36; O/F, 3.106								
1.00	600.00	3735	2888.3	0.453	1.231	--------	--------	--------
1.04	576.92	3707	2875.9	.452	1.231	0.183	2.418	32.8
1.494	401.63	3463	2765.6	.449	1.233	0.576	1.031	103.3
1.793	334.69	3345	2712.9	.448	1.234	0.689	1.000	123.5
2.241	267.75	3206	2650.8	.446	1.236	0.801	1.030	143.7
10.00	60.00	2399	2296.9	.430	1.246	1.264	2.178	226.8
20.00	30.00	2089	2164.9	.422	1.252	1.398	3.431	250.9
20.41	29.392	2081	2161.3	.422	1.252	1.402	3.479	251.5
40.00	15.00	1814	2050.1	.413	1.259	1.505	5.536	270.1
40.83	14.696	1807	2047.0	.413	1.259	1.508	5.617	270.6
60.00	10.00	1668	1990.2	.407	1.264	1.558	7.376	279.6
100.00	6.00	1498	1921.5	.399	1.270	1.617	10.640	290.0
300.00	2.00	1180	1797.0	.382	1.286	1.717	23.660	308.1
600.00	1.00	1009	1732.7	.370	1.298	1.767	39.320	317.1
1000.00	60	896	1691.4	.362	1.307	1.799	57.190	322.7
r, 1.40; percent fuel, 27.31; O/F, 2.662								
1.00	600.00	3694	3206.2	0.469	1.235	--------	--------	--------
1.04	576.92	3667	3193.3	.469	1.235	0.183	2.421	33.5
1.496	401.08	3421	3078.3	.466	1.237	0.577	1.031	105.5
1.795	334.24	3303	3023.5	.464	1.238	0.690	1.000	126.1
2.244	267.39	3164	2959.1	.462	1.240	0.802	1.029	146.6
10.00	60.00	2358	2592.9	.446	1.251	1.264	2.170	231.0
20.00	30.00	2050	2456.7	.437	1.257	1.397	3.413	255.4
20.41	29.392	2041	2452.9	.437	1.257	1.401	3.460	256.0
40.00	15.00	1776	2338.4	.427	1.264	1.504	5.497	274.8
40.83	14.696	1769	2335.2	.427	1.265	1.506	5.576	275.3
60.00	10.00	1631	2276.8	.421	1.269	1.556	7.315	284.4
100.00	6.00	1462	2206.3	.413	1.276	1.614	10.540	295.0
300.00	2.00	1146	2078.9	.394	1.294	1.714	23.340	313.2
600.00	1.00	977	2013.3	.381	1.306	1.763	38.670	322.2
1000.00	60	865	1971.3	.373	1.315	1.794	56.130	327.8
r, 1.60; percent fuel, 30.04; O/F, 2.329								
1.00	600.00	3583	3500.2	0.484	1.241	--------	--------	--------
1.04	576.92	3555	3487.1	.484	1.241	0.184	2.425	33.8
1.499	400.25	3311	3369.2	.480	1.243	0.579	1.031	106.8
1.799	333.54	3195	3313.5	.478	1.244	0.692	1.000	127.5
2.249	266.83	3057	3247.9	.476	1.246	0.804	1.029	148.2
10.00	60.00	2265	2877.3	.459	1.258	1.263	2.158	232.8
20.00	30.00	1962	2739.8	.449	1.265	1.396	3.384	257.2
20.41	29.392	1954	2736.0	.449	1.265	1.399	3.431	257.9
40.00	15.00	1694	2620.9	.438	1.273	1.501	5.435	276.6
40.83	14.696	1687	2617.7	.438	1.273	1.504	5.513	277.1
60.00	10.00	1552	2559.1	.431	1.278	1.553	7.220	286.2
100.00	6.00	1387	2488.6	.422	1.286	1.610	10.370	296.7
300.00	2.00	1080	2361.8	.402	1.305	1.708	22.840	314.7
600.00	1.00	916	2297.0	.390	1.318	1.756	37.690	323.6
1000.00	60	809	2255.6	.381	1.327	1.786	54.540	329.1
r, 1.80; percent fuel, 32.57; O/F, 2.071								
1.00	600.00	3391	3773.0	0.497	1.249	--------	--------	--------
1.04	576.92	3364	3759.9	.496	1.249	0.184	2.430	33.8
1.503	399.08	3125	3641.6	.492	1.252	0.583	1.031	106.9
1.804	332.57	3012	3586.2	.490	1.253	0.695	1.000	127.5
2.255	266.05	2879	3521.1	.488	1.255	0.806	1.029	148.0
10.00	60.00	2115	3155.5	.468	1.268	1.263	2.141	231.8
20.00	30.00	1824	3020.6	.458	1.276	1.394	3.345	255.9
20.41	29.392	1816	3016.9	.457	1.276	1.397	3.391	256.5
40.00	15.00	1567	2904.4	.446	1.285	1.498	5.349	274.9
40.83	14.696	1560	2901.2	.446	1.286	1.500	5.425	275.4
60.00	10.00	1431	2844.3	.439	1.291	1.549	7.087	284.3
100.00	6.00	1274	2776.0	.429	1.300	1.605	10.150	294.5
300.00	2.00	982	2653.9	.408	1.320	1.700	22.160	312.1
600.00	1.00	828	2591.9	.396	1.333	1.746	36.370	320.6
1000.00	60	728	2552.6	.388	1.343	1.775	52.410	325.9
r, 2.00; percent fuel, 34.92; O/F, 1.864								
1.00	600.00	3142	4026.7	0.507	1.259	--------	--------	--------
1.04	576.92	3117	4013.9	.506	1.259	0.185	2.437	33.4
1.509	397.65	2886	3897.5	.502	1.262	0.586	1.030	106.0
1.811	331.37	2779	3843.7	.500	1.264	0.698	1.000	126.2
2.263	265.10	2652	3780.5	.497	1.266	0.809	1.029	146.4
10.00	60.00	1929	3428.3	.475	1.281	1.262	2.120	228.2
20.00	30.00	1654	3299.1	.464	1.290	1.392	3.297	251.6
20.41	29.392	1646	3295.6	.463	1.290	1.395	3.342	252.2
40.00	15.00	1412	3188.5	.451	1.301	1.493	5.245	270.1
40.83	14.696	1405	3185.5	.450	1.301	1.496	5.319	270.5
60.00	10.00	1285	3131.6	.443	1.308	1.543	6.926	279.1
100.00	6.00	1137	3067.2	.433	1.317	1.598	9.874	288.9
300.00	2.00	868	2953.0	.413	1.338	1.690	21.360	305.7
600.00	1.00	727	2895.5	.402	1.350	1.735	34.850	313.7
1000.00	60	636	2859.3	.395	1.359	1.763	50.020	318.7

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

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

(c) Percent fluorine in oxidant by weight, 30

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Isentropic exponent, γ	Thrust coefficient, C_F	Area ratio, ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 1.20; percent fuel, 22.56; O/F, 3.432								
1.00	600.00	3868	2874.8	0.434	1.252	--------	---------	-------
1.04	576.92	3838	2861.7	.434	1.252	0.184	2.432	33.9
1.505	398.78	3562	2742.5	.431	1.254	0.583	1.031	107.3
1.805	332.32	3432	2686.9	.429	1.255	0.695	1.000	127.9
2.257	265.86	3280	2621.6	.427	1.257	0.807	1.029	148.5
10.00	60.00	2407	2254.9	.412	1.269	1.263	2.138	232.3
20.00	30.00	2075	2119.6	.404	1.276	1.394	3.341	256.4
20.41	29.392	2066	2115.9	.404	1.276	1.397	3.387	257.0
40.00	15.00	1784	2003.1	.395	1.284	1.497	5.346	275.4
40.83	14.696	1776	1999.9	.395	1.284	1.500	5.422	275.9
60.00	10.00	1630	1942.7	.389	1.289	1.548	7.086	284.8
100.00	6.00	1452	1874.1	.382	1.296	1.604	10.150	295.1
300.00	2.00	1123	1751.3	.365	1.314	1.700	22.240	312.7
600.00	1.00	949	1688.7	.354	1.327	1.747	36.590	321.3
1000.00	.60	836	1649.0	.347	1.336	1.776	52.820	326.6
r, 1.40; percent fuel, 25.37; O/F, 2.942								
1.00	600.00	3836	3170.7	0.451	1.253	--------	---------	-------
1.04	576.92	3805	3157.0	.450	1.254	0.184	2.433	34.5
1.506	398.53	3530	3033.5	.447	1.256	0.584	1.031	109.3
1.807	332.11	3401	2975.9	.445	1.257	0.696	1.000	130.2
2.258	265.69	3249	2908.3	.443	1.259	0.808	1.029	151.1
10.00	60.00	2380	2529.4	.428	1.271	1.263	2.135	236.2
20.00	30.00	2050	2389.8	.419	1.278	1.393	3.333	260.7
20.41	29.392	2041	2385.9	.419	1.278	1.397	3.379	261.3
40.00	15.00	1760	2269.6	.409	1.286	1.497	5.328	280.0
40.83	14.696	1752	2266.3	.409	1.287	1.499	5.404	280.5
60.00	10.00	1607	2207.4	.403	1.292	1.547	7.059	289.5
100.00	6.00	1431	2136.8	.395	1.300	1.603	10.110	299.9
300.00	2.00	1104	2010.5	.377	1.318	1.698	22.090	317.7
600.00	1.00	932	1946.4	.366	1.331	1.745	36.290	326.4
1000.00	.60	819	1905.7	.359	1.340	1.773	52.330	331.8
r, 1.60; percent fuel, 27.98; O/F, 2.574								
1.00	600.00	3746	3445.8	0.466	1.257	--------	---------	-------
1.04	576.92	3716	3431.9	.465	1.257	0.184	2.435	34.8
1.507	398.02	3443	3305.4	.462	1.260	0.585	1.030	110.5
1.809	331.68	3316	3246.8	.460	1.261	0.697	1.000	131.6
2.261	265.35	3166	3178.0	.458	1.263	0.809	1.029	152.7
10.00	60.00	2311	2793.2	.441	1.275	1.262	2.128	238.3
20.00	30.00	1987	2651.7	.432	1.283	1.392	3.316	262.9
20.41	29.392	1978	2647.8	.431	1.283	1.396	3.361	263.5
40.00	15.00	1702	2530.2	.421	1.292	1.495	5.291	282.3
40.83	14.696	1694	2526.9	.421	1.292	1.498	5.366	282.8
60.00	10.00	1552	2467.4	.415	1.298	1.546	7.001	291.8
100.00	6.00	1379	2396.3	.406	1.306	1.601	10.010	302.2
300.00	2.00	1059	2269.4	.388	1.326	1.695	21.790	319.9
600.00	1.00	891	2205.2	.376	1.339	1.740	35.700	328.6
1000.00	.60	782	2164.6	.369	1.348	1.769	51.390	333.9
r, 1.80; percent fuel, 30.41; O/F, 2.288								
1.00	600.00	3586	3708.3	0.479	1.263	--------	---------	-------
1.04	576.92	3556	3688.4	.478	1.263	0.185	2.439	34.8
1.511	397.20	3289	3561.2	.475	1.266	0.588	1.030	110.8
1.813	331.00	3166	3502.6	.473	1.267	0.699	1.000	131.8
2.266	264.80	3020	3433.9	.470	1.269	0.810	1.029	152.8
10.00	60.00	2192	3051.4	.452	1.283	1.262	2.116	238.0
20.00	30.00	1878	2911.2	.442	1.291	1.391	3.289	262.4
20.41	29.392	1869	2907.4	.441	1.291	1.394	3.333	263.0
40.00	15.00	1603	2791.2	.431	1.301	1.493	5.232	281.6
40.83	14.696	1596	2788.0	.430	1.301	1.496	5.306	282.1
60.00	10.00	1459	2729.4	.424	1.307	1.543	6.910	291.0
100.00	6.00	1292	2659.5	.415	1.316	1.597	9.853	301.2
300.00	2.00	986	2535.6	.396	1.337	1.689	21.330	318.6
600.00	1.00	826	2473.2	.384	1.350	1.734	34.820	327.0
1000.00	.60	723	2433.8	.377	1.359	1.761	49.980	332.2
r, 2.00; percent fuel, 32.69; O/F, 2.059								
1.00	600.00	3369	3942.1	0.490	1.270	--------	---------	-------
1.04	576.92	3341	3928.4	.490	1.271	0.185	2.444	34.5
1.515	396.12	3083	3808.6	.485	1.274	0.590	1.030	110.2
1.818	330.10	2964	3745.1	.483	1.275	0.702	1.000	130.9
2.272	264.08	2825	3677.8	.480	1.277	0.813	1.028	151.7
10.00	60.00	2034	3305.4	.460	1.293	1.261	2.100	235.4
20.00	30.00	1736	3169.4	.449	1.302	1.389	3.253	259.3
20.41	29.392	1727	3165.7	.449	1.302	1.393	3.297	259.9
40.00	15.00	1475	3053.7	.437	1.313	1.490	5.155	278.0
40.83	14.696	1468	3050.5	.437	1.313	1.492	5.227	278.5
60.00	10.00	1338	2994.3	.430	1.320	1.539	6.792	287.2
100.00	6.00	1180	2927.3	.421	1.329	1.592	9.653	297.2
300.00	2.00	894	2809.2	.402	1.350	1.682	20.750	314.0
600.00	1.00	745	2750.2	.392	1.362	1.726	33.720	322.0
1000.00	.60	649	2713.1	.385	1.371	1.752	48.260	327.0

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CB-4 back

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

WITH SEVERAL FLUORINE-OXYGEN MIXTURES

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

(d) Percent fluorine in oxidant by weight, 50

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Isentropic exponent, γ	Thrust coefficient, C_F	Area ratio, ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 1.20; percent fuel, 20.03; O/F, 3.992								
1.00	600.00	4120	2855.9	0.409	1.282	--------	--------	-------
1.04	576.92	4085	2841.4	.408	1.283	0.186	2.452	35.5
1.521	394.57	3755	2707.6	.405	1.285	0.595	1.029	113.6
1.825	328.81	3606	2647.2	.403	1.287	0.705	1.000	134.7
2.281	263.05	3431	2576.6	.401	1.289	0.816	1.028	155.9
10.00	60.00	2449	2189.2	.387	1.303	1.261	2.082	240.9
20.00	30.00	2082	2048.3	.379	1.311	1.388	3.216	265.1
20.41	29.392	2072	2044.4	.379	1.311	1.391	3.259	265.7
40.00	15.00	1763	1928.7	.371	1.320	1.487	5.083	284.0
40.83	14.696	1754	1925.4	.370	1.321	1.489	5.154	284.5
60.00	10.00	1597	1867.5	.365	1.327	1.535	6.689	293.3
100.00	6.00	1406	1798.6	.358	1.335	1.588	9.493	303.3
300.00	2.00	1061	1677.4	.343	1.355	1.676	20.350	320.2
600.00	1.00	883	1617.0	.335	1.368	1.719	33.030	328.3
1000.00	60	769	1579.1	.329	1.376	1.745	47.210	333.3
r, 1.40; percent fuel, 22.62; O/F, 3.421								
1.00	600.00	4100	3120.2	0.425	1.281	--------	--------	-------
1.04	576.92	4065	3105.3	.424	1.282	0.186	2.451	36.0
1.52	394.68	3738	2967.3	.421	1.285	0.594	1.029	115.4
1.824	328.90	3590	2905.0	.419	1.286	0.705	1.000	136.9
2.28	263.12	3416	2832.1	.417	1.288	0.816	1.028	158.3
10.00	60.00	2440	2431.9	.402	1.302	1.261	2.084	244.7
20.00	30.00	2075	2286.3	.394	1.310	1.388	3.219	269.4
20.41	29.392	2065	2282.3	.394	1.310	1.391	3.262	270.0
40.00	15.00	1758	2162.7	.385	1.320	1.487	5.090	288.7
40.83	14.696	1749	2159.3	.385	1.320	1.490	5.160	289.2
60.00	10.00	1592	2099.4	.379	1.326	1.535	6.698	298.0
100.00	6.00	1402	2028.1	.372	1.335	1.588	9.507	308.3
300.00	2.00	1058	1902.8	.356	1.355	1.677	20.380	325.5
600.00	1.00	880	1840.3	.347	1.368	1.719	33.080	333.7
1000.00	60	766	1801.2	.341	1.377	1.745	47.280	338.8
r, 1.60; percent fuel, 25.04; O/F, 2.994								
1.00	600.00	4030	3368.1	0.439	1.282	--------	--------	-------
1.04	576.92	3995	3352.8	.439	1.283	0.186	2.452	36.4
1.521	394.56	3673	3212.0	.435	1.286	0.595	1.029	116.5
1.825	328.80	3527	3148.5	.434	1.287	0.705	1.000	138.2
2.281	263.04	3356	3074.2	.432	1.289	0.816	1.028	159.9
10.00	60.00	2395	2666.6	.416	1.303	1.261	2.082	247.1
20.00	30.00	2035	2518.4	.407	1.311	1.387	3.215	271.9
20.41	29.392	2025	2514.3	.407	1.312	1.391	3.258	272.6
40.00	15.00	1723	2392.6	.398	1.321	1.487	5.080	291.3
40.83	14.696	1714	2389.2	.397	1.322	1.489	5.150	291.8
60.00	10.00	1560	2328.3	.392	1.328	1.535	6.682	300.8
100.00	6.00	1373	2255.9	.384	1.337	1.587	9.480	311.1
300.00	2.00	1035	2128.7	.367	1.358	1.676	20.300	328.4
600.00	1.00	860	2065.3	.358	1.371	1.718	32.910	336.7
1000.00	60	748	2025.7	.352	1.379	1.744	47.000	341.8
r, 1.80; percent fuel, 27.31; O/F, 2.661								
1.00	600.00	3898	3600.8	0.453	1.285	--------	--------	-------
1.04	576.92	3864	3585.5	.452	1.286	0.186	2.454	36.5
1.522	394.15	3549	3443.7	.449	1.289	0.596	1.029	116.9
1.827	328.45	3407	3380.0	.447	1.290	0.706	1.000	138.6
2.283	262.76	3240	3306.5	.445	1.292	0.817	1.028	160.3
10.00	60.00	2306	2897.6	.428	1.307	1.260	2.076	247.4
20.00	30.00	1956	2749.4	.419	1.316	1.387	3.201	272.2
20.41	29.392	1946	2745.4	.418	1.316	1.390	3.244	272.8
40.00	15.00	1653	2624.0	.408	1.326	1.485	5.051	291.5
40.83	14.696	1644	2620.6	.408	1.327	1.488	5.120	292.0
60.00	10.00	1495	2560.0	.402	1.333	1.533	6.637	300.9
100.00	6.00	1314	2488.0	.394	1.343	1.586	9.403	311.2
300.00	2.00	986	2361.8	.377	1.364	1.673	20.070	328.3
600.00	1.00	818	2299.2	.367	1.376	1.715	32.470	336.5
1000.00	60	710	2260.0	.362	1.385	1.740	46.330	341.6
r, 2.00; percent fuel, 29.46; O/F, 2.395								
1.00	600.00	3708	3819.9	0.465	1.290	--------	--------	-------
1.04	576.92	3675	3804.8	.464	1.290	0.186	2.457	36.3
1.525	393.47	3371	3664.0	.460	1.294	0.598	1.029	116.5
1.83	327.89	3234	3601.2	.458	1.295	0.708	1.000	138.0
2.287	262.31	3073	3527.7	.456	1.297	0.818	1.028	159.5
10.00	60.00	2177	3126.7	.438	1.313	1.260	2.067	245.6
20.00	30.00	1841	2981.6	.428	1.323	1.386	3.179	270.1
20.41	29.392	1832	2977.7	.427	1.324	1.389	3.221	270.7
40.00	15.00	1551	2859.0	.417	1.335	1.484	5.003	289.1
40.83	14.696	1543	2855.7	.416	1.335	1.486	5.072	289.6
60.00	10.00	1400	2796.6	.410	1.342	1.531	6.564	298.4
100.00	6.00	1228	2726.6	.402	1.352	1.583	9.280	308.4
300.00	2.00	917	2604.3	.385	1.372	1.669	19.720	325.2
600.00	1.00	758	2543.9	.376	1.384	1.710	31.820	333.2
1000.00	60	657	2506.2	.371	1.391	1.735	45.320	338.1

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

[Frozen composition 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	Temperature exponent, n_T	Enthalpy h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Isentropic exponent, γ	Area ratio, ε	Area-ratio exponent, $n_ε$	Thrust coefficient, C_F	Specific-impulse exponent, n_I	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 1.00; percent fuel, 14.83; O/F, 5.743											
10	60.00	2247	0.0431	1964.4	0.346	1.349	2.01	0.0045	1.259	0.0150	233.7
15	40.00	2022	.0446	1887.1	.341	1.354	2.56	.0058	1.334	.0152	247.6
20	30.00	1875	.0457	1837.1	.338	1.359	3.06	.0067	1.380	.0154	256.3
30	20.00	1683	.0473	1772.7	.334	1.365	3.96	.0080	1.438	.0157	267.0
40	15.00	1558	.0485	1731.0	.331	1.370	4.77	.0090	1.474	.0159	273.7
60	10.00	1395	.0501	1677.6	.326	1.377	6.21	.0104	1.519	.0161	282.1
80	7.50	1289	.0513	1643.1	.323	1.383	7.51	.0114	1.547	.0163	287.3
100	6.00	1211	.0523	1618.2	.320	1.387	8.71	.0122	1.568	.0164	291.1
150	4.00	1081	0.0539	1576.7	0.316	1.394	11.48	0.0137	1.601	0.0167	297.2
200	3.00	996	.0551	1550.1	.313	1.399	13.85	.0147	1.628	.0168	301.1
300	2.00	887	.0567	1516.0	.309	1.406	18.20	.0160	1.648	.0170	306.0
400	1.50	816	.0577	1494.1	.307	1.410	22.10	.0169	1.665	.0172	309.1
600	1.00	725	.0591	1466.2	.304	1.416	29.08	.0182	1.686	.0174	313.0
800	.75	666	.0601	1448.4	.303	1.419	35.35	.0190	1.699	.0175	315.4
1000	.60	623	.0607	1435.5	.302	1.421	41.14	.0196	1.708	.0176	317.2
1500	.40	553	.0619	1414.3	.300	1.424	54.21	.0206	1.724	.0177	320.1
r, 1.40; percent fuel, 19.60; O/F, 4.102											
10	60.00	2554	0.0513	2324.9	0.376	1.332	2.04	0.0048	1.259	0.0176	253.8
15	40.00	2307	.0529	2232.6	.372	1.337	2.60	.0061	1.335	.0179	269.1
20	30.00	2145	.0540	2172.6	.369	1.341	3.12	.0070	1.383	.0181	278.7
30	20.00	1934	.0557	2095.1	.364	1.347	4.04	.0084	1.442	.0184	290.5
40	15.00	1795	.0569	2044.8	.360	1.352	4.88	.0094	1.478	.0186	297.9
60	10.00	1614	.0587	1980.1	.355	1.359	6.38	.0109	1.525	.0189	307.2
80	7.50	1496	.0600	1938.2	.351	1.364	7.73	.0120	1.554	.0191	313.1
100	6.00	1409	.0610	1907.8	.348	1.368	8.98	.0129	1.575	.0192	317.3
150	4.00	1262	0.0628	1857.1	0.343	1.376	11.82	0.0145	1.609	0.0195	324.2
200	3.00	1166	.0641	1824.4	.339	1.382	14.36	.0156	1.630	.0196	328.5
300	2.00	1042	.0659	1782.5	.334	1.390	18.93	.0171	1.658	.0199	334.0
400	1.50	961	.0671	1755.5	.331	1.395	23.03	.0182	1.675	.0200	337.8
600	1.00	856	.0687	1721.1	.327	1.402	30.38	.0196	1.697	.0202	342.0
800	.75	788	.0698	1698.9	.324	1.406	36.99	.0205	1.711	.0204	344.8
1000	.60	738	.0706	1683.0	.323	1.410	43.09	.0212	1.721	.0205	346.8
1500	.40	656	.0719	1656.5	.320	1.414	56.89	.0224	1.737	.0206	350.1
r, 1.50; percent fuel, 20.71; O/F, 3.829											
10	60.00	2573	0.0516	2428.2	0.383	1.329	2.04	0.0048	1.259	0.0177	255.9
15	40.00	2326	.0532	2328.0	.379	1.334	2.61	.0061	1.336	.0180	271.5
20	30.00	2164	.0544	2266.8	.376	1.338	3.13	.0070	1.383	.0182	281.1
30	20.00	1952	.0560	2187.7	.371	1.344	4.06	.0084	1.442	.0185	293.1
40	15.00	1813	.0573	2136.3	.367	1.348	4.90	.0094	1.479	.0187	300.6
60	10.00	1631	.0590	2070.8	.362	1.355	6.41	.0109	1.526	.0189	310.1
80	7.50	1512	.0603	2027.3	.358	1.361	7.77	.0120	1.555	.0191	316.0
100	6.00	1425	.0613	1996.2	.355	1.365	9.04	.0129	1.576	.0193	320.3
150	4.00	1278	0.0632	1944.3	0.349	1.373	11.89	0.0145	1.610	0.0195	327.2
200	3.00	1181	.0645	1910.8	.346	1.378	14.46	.0156	1.632	.0197	331.7
300	2.00	1056	.0662	1867.8	.340	1.386	19.07	.0172	1.659	.0199	337.3
400	1.50	974	.0675	1840.1	.337	1.392	23.21	.0188	1.677	.0201	340.8
600	1.00	868	.0691	1804.7	.333	1.399	30.64	.0197	1.699	.0203	345.3
800	.75	800	.0702	1782.0	.330	1.403	37.32	.0206	1.713	.0204	348.2
1000	.60	750	.0710	1765.6	.328	1.407	43.49	.0213	1.723	.0205	350.2
1500	.40	667	.0724	1738.4	.325	1.412	57.44	.0225	1.740	.0207	353.6
r, 1.60; percent fuel, 21.79; O/F, 3.589											
10	60.00	2557	0.0519	2539.7	0.392	1.319	2.06	0.0051	1.260	0.0175	254.2
15	40.00	2317	.0535	2446.1	.387	1.324	2.63	.0065	1.337	.0178	269.7
20	30.00	2159	.0548	2385.1	.384	1.328	3.16	.0075	1.385	.0180	279.4
30	20.00	1952	.0566	2306.2	.379	1.334	4.11	.0089	1.444	.0183	291.4
40	15.00	1816	.0579	2254.9	.375	1.338	4.96	.0100	1.482	.0185	299.0
60	10.00	1638	.0597	2188.6	.370	1.345	6.51	.0116	1.529	.0188	308.5
80	7.50	1521	.0611	2145.5	.366	1.350	7.91	.0128	1.559	.0190	314.5
100	6.00	1435	.0622	2114.3	.362	1.354	9.20	.0137	1.580	.0192	318.8
150	4.00	1290	0.0642	2062.0	0.357	1.362	12.13	0.0154	1.615	0.0194	325.5
200	3.00	1194	.0656	2028.1	.353	1.367	14.78	.0166	1.637	.0196	330.3
300	2.00	1070	.0675	1984.7	.348	1.375	19.53	.0183	1.665	.0199	336.0
400	1.50	989	.0688	1956.6	.344	1.380	23.81	.0195	1.683	.0201	339.6
600	1.00	884	.0707	1920.7	.340	1.387	31.49	.0211	1.706	.0203	344.2
800	.75	815	.0719	1897.5	.337	1.392	38.41	.0222	1.720	.0204	347.1
1000	.60	766	.0728	1880.8	.335	1.395	44.81	.0229	1.731	.0206	349.9
1500	.40	682	.0744	1853.0	.331	1.400	59.30	.0243	1.748	.0207	352.5
r, 2.50; percent fuel, 30.33; O/F, 2.297											
10	60.00	2424	0.0386	3431.6	0.458	1.270	2.14	0.0039	1.263	0.0120	246.3
15	40.00	2223	.0399	3339.9	.453	1.274	2.76	.0050	1.343	.0123	262.0
20	30.00	2089	.0408	3279.5	.449	1.277	3.34	.0057	1.394	.0124	271.8
30	20.00	1912	.0422	3200.6	.443	1.282	4.38	.0068	1.457	.0127	284.3
40	15.00	1795	.0431	3148.7	.439	1.285	5.34	.0076	1.497	.0129	292.0
60	10.00	1639	.0446	3080.9	.432	1.291	7.07	.0088	1.548	.0131	302.0
80	7.50	1536	.0456	3036.5	.428	1.295	8.65	.0097	1.580	.0133	308.3
100	6.00	1459	.0464	3004.0	.424	1.298	10.13	.0104	1.604	.0134	312.9
150	4.00	1329	0.0479	2949.0	0.417	1.304	13.51	0.0117	1.642	0.0136	320.4
200	3.00	1242	.0490	2913.0	.413	1.309	16.58	.0126	1.667	.0138	325.3
300	2.00	1128	.0506	2866.2	.406	1.315	22.16	.0140	1.699	.0140	331.5
400	1.55	1052	.0516	2835.7	.402	1.320	27.25	.0149	1.719	.0141	335.4
600	1.00	953	.0531	2796.2	.396	1.326	36.46	.0162	1.746	.0143	340.5
800	.75	888	.0542	2770.4	.392	1.330	44.85	.0171	1.762	.0144	343.8
1000	.60	840	.0550	2751.7	.389	1.334	52.66	.0178	1.774	.0145	346.2
1500	.40	758	.0565	2720.1	.384	1.340	70.52	.0191	1.795	.0147	350.1

4576

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

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

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

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Isentropic exponent, γ	Thrust coefficient, C_F	Area ratio, ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 1.0; percent fuel, 11.01; O/F, 8.083								
1.000	600.00	3962	2621.2	0.366	1.247	-----	-----	-----
1.040	576.92	3931	2610.0	.366	1.247	0.184	2.429	31.2
1.503	399.31	3654	2508.9	.363	1.250	.582	1.031	98.9
1.803	332.76	3523	2461.5	.361	1.251	.694	1.000	117.9
2.254	266.21	3368	2405.8	.359	1.253	.806	1.029	136.9
10.000	60.00	2479	2092.2	.346	1.265	1.263	2.140	214.6
20.000	30.00	2141	1976.3	.340	1.271	1.394	3.350	236.9
20.414	29.392	2132	1973.1	.339	1.271	1.398	3.400	237.5
40.000	15.00	1844	1876.4	.333	1.278	1.498	5.380	254.6
40.827	14.696	1836	1873.6	.333	1.278	1.501	5.450	255.1
60.000	10.00	1687	1824.5	.330	1.282	1.551	7.140	263.3
100.000	6.00	1507	1765.4	.325	1.289	1.606	10.25	272.9
300.000	2.00	1175	1659.1	.315	1.299	1.703	22.61	289.3
600.000	1.00	1000	1604.6	.309	1.306	1.751	37.45	297.4
1000.000	.60	887	1569.7	.305	1.312	1.780	54.40	302.5
1500.000	.40	805	1544.8	.302	1.316	1.801	73.21	306.0
r, 1.5; percent fuel, 15.65; O/F, 5.389								
1.000	600.00	4008	3060.4	0.399	1.230	-----	-----	-----
1.040	576.92	3979	3048.7	.398	1.231	0.183	2.418	31.9
1.494	401.55	3717	2944.7	.394	1.233	.576	1.031	100.3
1.793	334.63	3590	2895.0	.392	1.235	.689	1.000	120.0
2.241	267.70	3441	2836.5	.390	1.236	.801	1.030	139.6
10.000	60.00	2570	2503.1	.375	1.248	1.264	2.18	220.2
20.000	30.00	2236	2379.0	.368	1.254	1.398	3.47	243.5
20.414	29.392	2227	2375.6	.368	1.254	1.401	3.47	244.1
40.000	15.00	1940	2271.1	.352	1.227	1.504	5.52	262.1
40.827	14.696	1932	2268.1	.360	1.261	1.507	5.60	262.6
60.000	10.00	1783	2214.8	.356	1.265	1.557	7.35	271.2
100.000	6.00	1601	2150.3	.351	1.270	1.615	10.60	281.4
300.000	2.00	1262	2033.5	.337	1.275	1.716	23.60	298.9
600.000	1.00	1081	1973.0	.331	1.290	1.766	39.31	307.6
1000.000	.60	963	1934.0	.327	1.296	1.797	57.34	313.1
1500.000	.40	878	1906.2	.323	1.300	1.819	77.41	318.9
r, 2.0; percent fuel, 19.84; O/F, 4.041								
1.00	600.00	4206	3456.0	0.432	1.211	-----	-----	-----
1.040	576.92	4177	3443.6	.432	1.211	0.182	2.405	32.8
1.484	404.42	3926	3335.4	.429	1.212	.568	1.032	102.4
1.780	337.02	3802	3282.4	.428	1.213	.682	1.000	122.9
2.225	269.61	3655	3219.8	.425	1.215	.795	1.030	143.3
10.000	60.00	2786	2357.7	.409	1.226	1.266	2.22	228.2
20.000	30.00	2449	2721.4	.401	1.231	1.403	3.52	252.8
20.414	29.392	2440	2717.6	.401	1.231	1.406	3.57	253.4
40.000	15.00	2147	2601.7	.393	1.237	1.513	5.72	272.6
40.827	14.696	2139	2598.4	.393	1.237	1.516	5.80	273.2
60.000	10.00	1986	2538.7	.388	1.240	1.567	7.66	282.5
100.000	6.00	1797	2466.1	.382	1.245	1.628	11.12	293.5
300.000	2.00	1442	2332.7	.368	1.257	1.735	25.12	312.6
600.000	1.00	1250	2262.6	.360	1.264	1.788	42.25	322.2
1000.000	.60	1122	2217.1	.354	1.270	1.822	62.05	328.3
1500.000	.40	1029	2184.3	.349	1.274	1.846	84.24	332.6
r, 2.8; percent fuel, 25.73; O/F, 2.887								
1.000	600.00	4262	4013.3	0.475	1.204	-----	-----	-----
1.040	576.92	4234	3999.9	.475	1.204	0.182	2.400	34.1
1.480	405.39	3987	3883.3	.471	1.206	.566	1.033	106.3
1.776	337.83	3865	3825.8	.469	1.207	.680	1.000	127.7
2.220	270.26	3719	3757.8	.466	1.208	.793	1.030	149.1
10.000	60.00	2856	3362.0	.450	1.218	1.267	2.23	238.0
20.000	30.00	2520	3212.4	.442	1.223	1.405	3.55	264.0
20.414	29.392	2511	3208.3	.441	1.223	1.408	3.60	264.7
40.000	15.00	2219	3080.6	.433	1.228	1.516	5.80	284.9
40.827	14.696	2210	3076.9	.433	1.228	1.519	5.88	285.4
60.000	10.00	2057	3010.9	.428	1.231	1.571	7.78	295.3
100.000	6.00	1867	2930.4	.422	1.236	1.633	11.32	307.0
300.000	2.00	1509	2781.8	.406	1.247	1.742	25.73	327.3
600.000	1.00	1313	2703.3	.396	1.255	1.796	43.43	337.6
1000.000	.60	1183	2652.1	.382	1.235	1.831	63.95	344.2
1500.000	.40	1087	2615.1	.392	1.294	1.856	86.99	348.8

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

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

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

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Isentropic exponent, γ	Thrust coefficient, C_F	Area ratio, ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
r, 3.0; percent fuel, 27.07; O/F, 2.694								
1.000	600.00	4249	4140.1	0.485	1.202	-----	------	-----
1.040	576.92	4221	4136.5	.485	1.202	0.182	2.399	34.3
1.479	405.68	3978	4009.0	.481	1.204	.565	1.033	106.8
1.775	338.07	3857	3950.9	.479	1.205	.679	1.000	128.3
2.219	270.45	3713	3882.1	.476	1.206	.793	1.031	149.8
10.000	60.00	2857	3481.4	.459	1.215	1.267	2.24	239.4
20.000	30.00	2524	3329.7	.451	1.220	1.405	3.55	265.5
20.414	29.392	2514	3325.5	.451	1.220	1.409	3.61	266.2
40.000	15.00	2224	3195.9	.443	1.225	1.517	5.82	286.6
40.827	14.696	2216	3192.2	.443	1.225	1.520	5.91	287.2
60.000	10.00	2064	3125.2	.438	1.229	1.573	7.81	297.2
100.000	6.00	1875	3043.3	.431	1.233	1.635	11.38	308.9
300.000	2.00	1518	2892.0	.415	1.244	1.244	25.90	329.5
600.000	1.00	1323	2812.0	.405	1.252	1.799	43.76	339.9
1000.000	.60	1193	2759.7	.397	1.258	1.834	64.50	346.6
1500.000	.40	1097	2721.9	.392	1.262	1.850	87.79	351.3
r, 3.5; percent fuel, 30.22; O/F, 2.309								
1.00	600.00	4172	4437.8	0.509	1.197	-----	------	-----
1.040	576.92	4145	4424.2	.509	1.197	0.181	2.395	34.5
1.476	406.42	3912	4306.1	.505	1.199	.563	1.033	107.0
1.772	338.68	3795	4247.4	.503	1.200	.677	1.000	128.7
2.210	270.95	3657	4177.8	.500	1.201	.791	1.031	150.4
10.000	60.00	2829	3770.8	.483	1.210	1.267	2.25	240.9
20.000	30.00	2506	3616.4	.474	1.214	1.406	3.59	267.4
20.414	29.392	2497	3612.1	.474	1.214	1.411	3.64	268.0
40.000	15.00	2215	3479.7	.465	1.219	1.519	5.87	288.7
40.827	14.696	2207	3475.9	.465	1.219	1.522	5.96	289.3
60.00	10.00	2058	3407.2	.460	1.222	1.575	7.90	299.5
100.000	6.00	1874	3323.2	.453	1.226	1.638	11.52	311.4
300.000	2.00	1525	3167.5	.436	1.237	1.749	26.34	332.5
600.000	1.00	1333	3084.4	.425	1.245	1.805	44.62	343.1
1000.000	.60	1204	3030.6	.418	1.250	1.841	65.90	349.9
1500.000	.40	1110	2991.4	.418	1.276	1.866	89.83	354.8
r, 4.0; percent fuel, 33.10; O/F, 2.021								
1.000	600.00	4041	4710.9	0.531	1.192	-----	------	-----
1.040	576.92	4016	4697.4	.531	1.192	0.181	2.392	34.3
1.479	407.14	3796	4581.2	.527	1.194	.561	1.033	106.3
1.768	339.27	3685	4522.9	.524	1.195	.676	1.000	127.9
2.210	271.42	3553	4453.9	.522	1.196	.790	1.031	149.5
10.000	60.00	2763	4048.9	.504	1.204	1.268	2.26	240.1
20.000	30.00	2454	3894.3	.495	1.209	1.408	3.61	266.6
20.414	29.392	2445	3890.0	.495	1.209	1.412	3.67	267.3
40.000	15.00	2175	3757.4	.486	1.213	1.521	5.93	288.0
40.827	14.696	2167	3753.6	.485	1.214	1.524	6.02	288.6
60.000	10.00	2024	3684.7	.480	1.216	1.578	7.98	298.8
100.000	6.00	1847	3600.3	.473	1.220	1.642	11.66	310.9
300.000	2.00	1509	3443.3	.455	1.231	1.754	26.76	322.1
600.000	1.00	1323	3359.5	.444	1.238	1.811	45.44	342.9
1000.000	.60	1198	3304.6	.435	1.242	1.848	67.23	349.8
1500.000	.40	1106	3264.7	.437	1.273	1.874	91.79	354.7
r, 5.0; percent fuel, 38.22; O/F, 1.617								
1.000	600.00	3708	5194.5	0.569	1.184	-----	------	-----
1.040	576.92	3685	5181.7	.568	1.184	0.181	2.387	33.4
1.470	408.30	3492	5072.3	.564	1.185	.558	1.034	103.1
1.763	340.24	3394	5016.9	.562	1.186	.673	1.000	124.3
2.200	272.20	3277	4951.3	.559	1.187	.787	1.031	145.5
10.000	60.00	2570	4563.0	.539	1.196	1.269	2.28	234.4
20.000	30.00	2292	4414.5	.530	1.200	1.410	3.65	260.5
20.414	29.392	2284	4410.4	.529	1.200	1.414	3.71	261.2
40.000	15.00	2040	4282.2	.519	1.205	1.525	6.01	281.8
40.827	14.696	2033	4278.5	.519	1.205	1.528	6.11	282.3
60.000	10.00	1903	4211.7	.513	1.207	1.583	8.11	292.4
100.000	6.00	1742	4129.6	.506	1.211	1.647	11.89	304.4
300.000	2.00	1433	3976.2	.486	1.222	1.762	27.42	325.6
600.000	1.00	1262	3893.9	.474	1.229	1.821	46.75	336.4
1000.000	.60	1146	3839.6	.467	1.239	1.858	69.35	343.4
1500.000	.40	1061	3800.2	.347	.894	1.885	94.91	348.5

TABLE VI. - EQUILIBRIUM COMPOSITION IN COMBUSTION CHAMBER FOR JP-4 FUEL WITH SEVERAL MIXTURES OF FLUORINE AND OXYGEN

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

(a) Percent fluorine in oxidant by weight, 0 and 15

Fluorine in oxidant, percent by weight	0	0	0	0	0	0	0	15	15	15	15	15
Equivalence ratio, r	1.00	1.20	1.30	1.40	1.60	1.80	3.00	1.20	1.40	1.60	1.80	2.00
Fuel in propellant, percent by weight	22.71	26.07	27.64	29.15	31.98	34.59	46.85	24.36	27.31	30.04	32.57	34.92
Oxidant-to-fuel weight ratio, O/F	3.403	2.836	2.618	2.431	2.127	1.891	1.134	3.106	2.662	2.329	2.071	1.864
Combustion temperature, T_0, °K	3612	3628	3612	3576	3436	3205	1657	3735	3694	3583	3391	3194
Equilibrium composition (mole fraction[a])												
Graphite	----	----	----	----	----	----	0.00130	----	----	----	----	----
CH_4	----	----	----	----	----	----	.01146	----	----	----	----	----
CO	0.21540	0.28284	0.31453	0.34444	0.39669	0.43518	.50434	0.27899	0.33350	0.38082	0.41784	0.44375
CO_2	.19895	.16574	.14764	.12914	.09344	.06430	.00187	.12887	.10148	.07399	.05029	.03287
F	----	----	----	----	----	----	----	.00196	.00127	.00066	.00025	.00007
H	.02369	.03125	.03378	.03488	.03118	.03080	.00001	.03600	.04157	.04049	.03136	.01895
H_2	.04043	.06578	.08240	.10247	.15462	.21932	.47514	.05643	.08849	.13422	.19331	.25696
HF	----	----	----	----	----	----	----	.13772	.12643	.11617	.10663	.09787
H_2O	.30785	.31844	.31891	.31534	.29328	.25101	.00588	.21795	.22411	.21422	.18608	.14561
O	.03303	.02262	.01675	.01124	.00343	.00057	----	.02924	.01603	.00601	.00138	.00019
O_2	.09621	.04189	.02480	.01324	.00248	.00025	----	.04321	.01553	.00367	.00051	.00004
OH	.08444	.07146	.06119	.04923	.02488	.00857	----	.06962	.05159	.02975	.01235	.00369

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

TABLE VI. - Continued. EQUILIBRIUM COMPOSITION IN COMBUSTION CHAMBER FOR JP-4 FUEL WITH SEVERAL MIXTURES OF FLUORINE AND OXYGEN

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

(b) Percent fluorine by weight, 30 and 50

Fluorine in oxidant, percent by weight	30	30	30	30	30	50	50	50	50	50
Equivalence ratio, r	1.2	1.4	1.6	1.8	2.0	1.2	1.4	1.6	1.8	2.0
Fuel in propellant, percent by weight	22.56	25.37	27.98	30.41	32.69	20.03	22.62	25.04	27.31	29.46
Oxidant-to-fuel weight ratio, O/F	3.432	2.942	2.574	2.288	2.059	3.992	3.421	2.994	2.661	2.395
Combustion temperature, T_c, °K	3868	3836	3745	3586	3369	4120	4100	4030	3898	3708
Equilibrium composition (mole fraction[a])										
CO	0.27490	0.32271	0.36485	0.39931	0.42512	0.26919	0.30910	0.34426	0.37403	0.39783
CO_2	.09303	.07342	.05330	.03511	.02100	.04779	.03600	.02403	.01274	.00340
F	.00657	.00434	.00247	.00113	.00041	.03110	.01970	.01170	.00603	.00263
H	.04100	.04927	.05159	.04507	.03210	.04266	.05907	.06978	.07028	.05941
H_2	.04381	.07145	.11109	.16415	.22495	.01966	.04028	.07122	.11541	.17137
HF	.27194	.25268	.23492	.21810	.20220	.43396	.41429	.39356	.37227	.35057
H_2O	.12550	.13727	.13581	.11860	.08855	.03012	.04043	.04264	.03336	.01221
O	.03829	.02242	.00969	.00276	.00050	.05424	.03301	.01515	.00436	.00048
O_2	.04197	.01648	.00453	.00076	.00008	.03186	.01270	.00347	.00048	.00001
OH	.06300	.04994	.03175	.01502	.00510	.03942	.03544	.02420	.01105	.00209

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

TABLE VI. - Concluded. EQUILIBRIUM COMPOSITION IN COMBUSTION CHAMBER FOR JP-4 FUEL WITH SEVERAL MIXTURES OF FLUORINE AND OXYGEN

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

(c) Percent fluorine by weight, 70.37 and 100

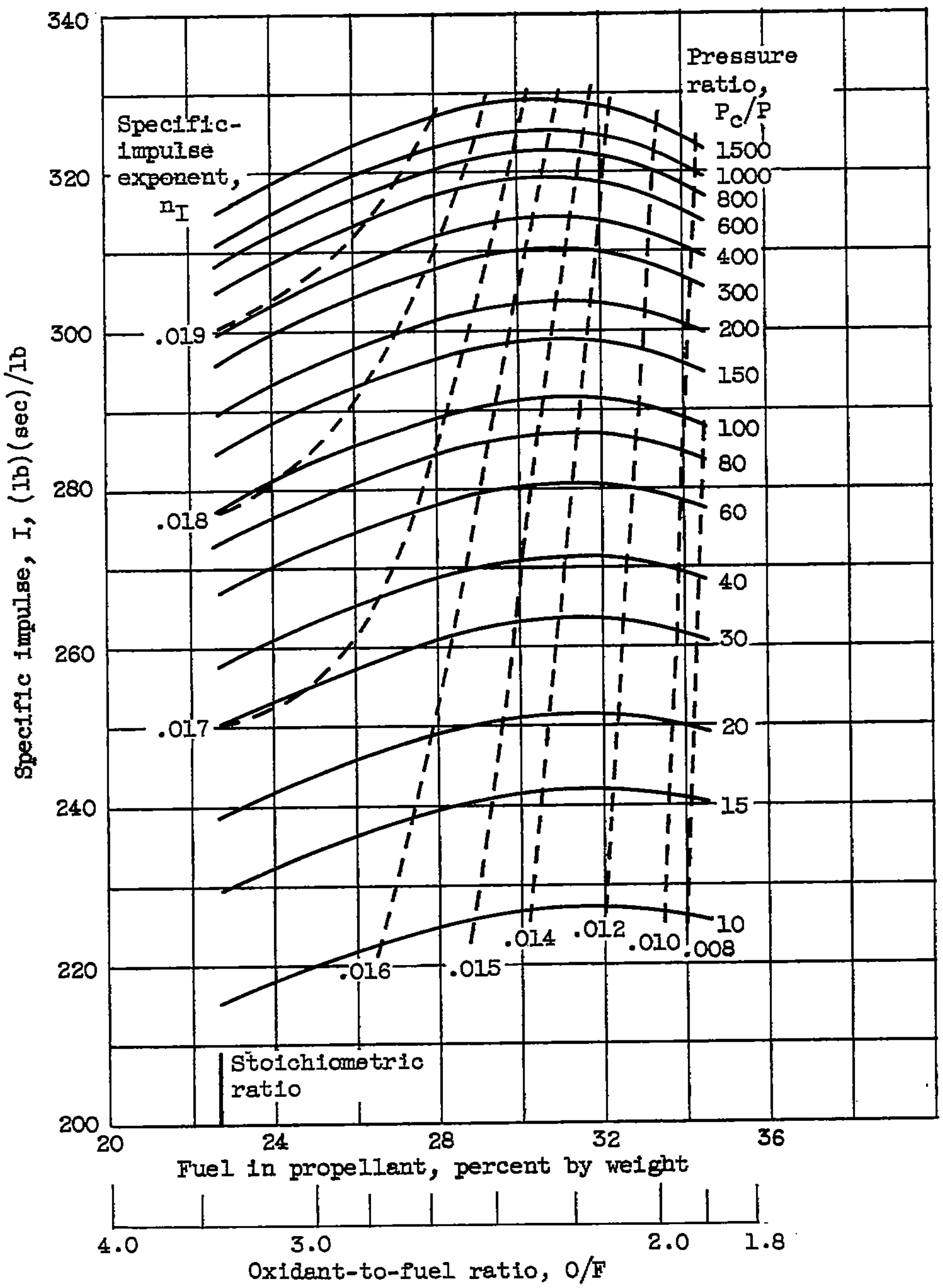
Fluorine in oxidant, percent by weight	70.37	70.37	70.37	70.37	70.37	100	100	100	100	100	100	100	100
Equivalence ratio, r	1.00	1.40	1.50	1.60	2.50	1.00	1.50	2.00	2.80	3.00	3.50	4.00	5.00
Fuel in propellant, percent by weight	14.83	19.80	20.71	21.79	30.33	11.01	15.65	19.84	25.73	27.07	30.22	33.10	38.22
Oxidant-to-fuel weight ratio, O/F	5.743	4.102	3.829	3.589	2.297	8.083	5.389	4.041	2.887	2.694	2.309	2.021	1.617
Combustion temperature, T_c, °K	4007	4464	4479	4396	3898	3962	4008	4206	4262	4249	4172	4041	3708
Equilibrium composition (mole fraction[a])													
C(Gas)	----	----	0.00099	0.00409	0.00069	0.00015	0.00049	0.00377	0.00392	0.00356	0.00231	0.00114	0.00016
Graphite	----	----	----	----	.14949	----	----	----	.24806	.27409	.31993	.34819	.38045
CF	----	----	.00117	.00419	.00047	.00453	.00732	.01170	.00645	.00522	.00271	.00116	.00016
CF_2	----	----	.00005	.00015	.00001	.00430	.00351	.00124	.00037	.00026	.00011	.00004	----
CF_3	----	----	.00001	.00002	----	.01100	.00462	.00039	.00006	.00004	.00001	----	----
CF_4	----	----	----	----	----	.06446	.01327	.00022	.00002	.00001	----	----	----
C_2F_2	----	----	.00042	.00748	.00114	.06582	.13462	.14101	.04176	.03008	.01223	.00442	.00053
CH_4	----	----	----	----	.00002	----	----	----	----	----	----	.00001	.00003
CO	0.20066	0.29436	.30754	.30371	.22398	----	----	----	----	----	----	----	----
CO_2	.03547	.00312	.00001	----	----	----	----	----	----	----	----	----	----
F	.25010	.12346	.10077	.08758	.00660	.42994	.25679	.10382	.05296	.04365	.02517	.01310	.00310
F_2	.00006	.00001	.00001	----	----	.00018	----	.00001	----	----	----	----	----
H	.00339	.04781	.06245	.06988	.06463	.00184	.00421	.02577	.04509	.04901	.05545	.05526	.04012
H_2	.00018	.00871	.01423	.02255	.11438	.00004	.00028	.00577	.01659	.02373	.04127	.06600	.12595
HF	.45135	.50784	.51231	.52035	.43859	.41810	.57484	.65115	.58271	.57034	.54081	.51067	.44949
H_2O	.00027	.00081	----	----	----	----	----	----	----	----	----	----	----
O	.03517	.01043	.00003	----	----	----	----	----	----	----	----	----	----
O_2	.02039	.00037	----	----	----	----	----	----	----	----	----	----	----
OH	.00294	.00308	.00001	----	----	----	----	----	----	----	----	----	----

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

TABLE VII. - THEORETICAL PERFORMANCE FOR EXPANSION TO 1 ATMOSPHERE FOR JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES

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

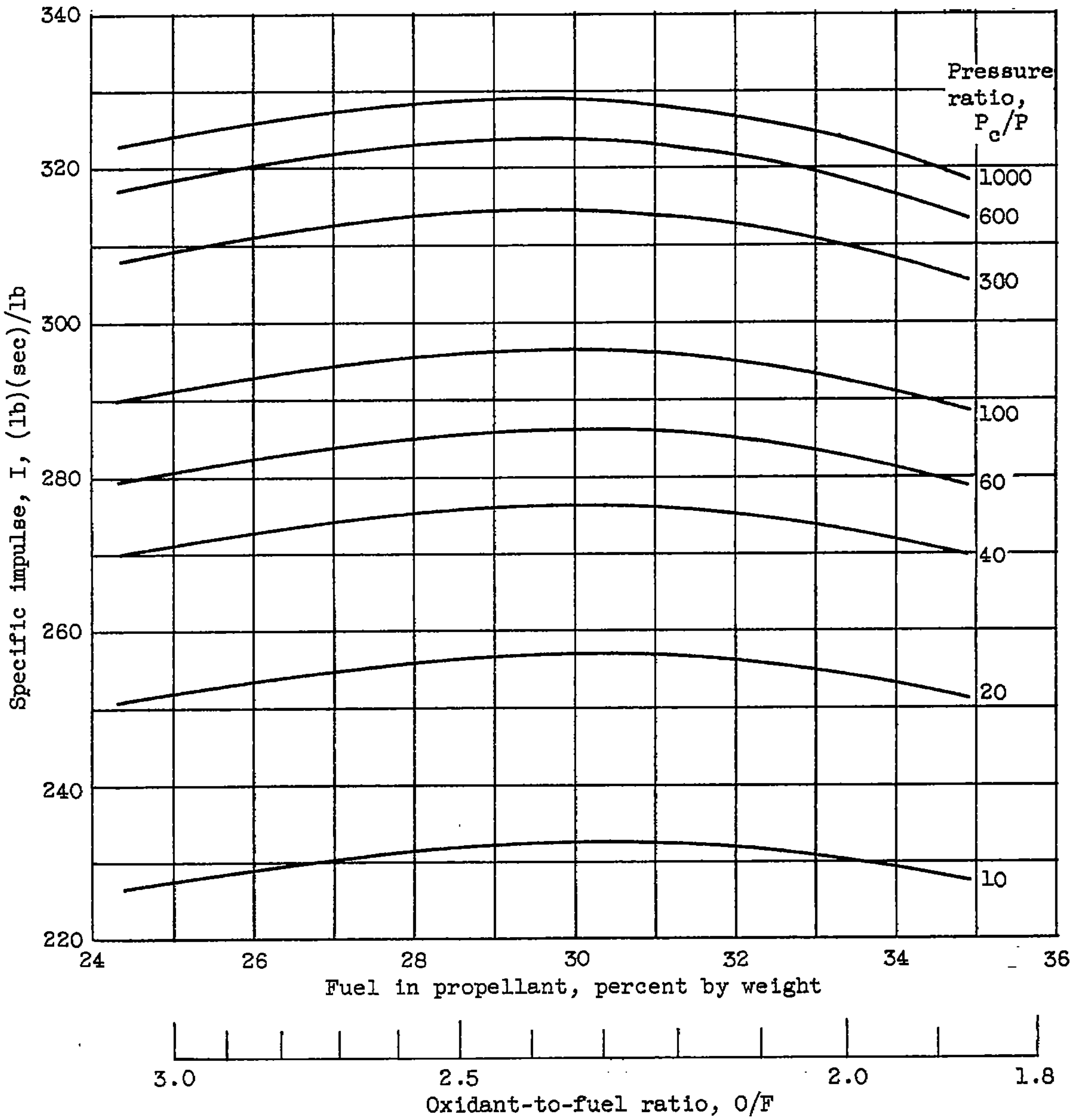
Equivalence ratio, r, $\frac{4(C)+(H)}{2(O)+F}$	Fuel, percent by weight	Oxidant-to-fuel weight ratio, O/F	Combustion temperature, T_c, °K	Exit temperature, T_e, °K	Characteristic velocity, c*, ft/sec	Coefficient of thrust, C_F	Area ratio, ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
Percent fluorine in oxidant, 0 (100 percent oxygen)								
1.0	22.71	3.403	3612	1853	5475	1.517	5.84	258.2
1.2	26.07	2.836	3628	1840	5643	1.515	5.80	265.8
1.3	27.64	2.618	3612	1818	5707	1.514	5.77	268.6
1.4	29.15	2.431	3576	1784	5755	1.513	5.73	270.6
1.5	30.59	2.269	3518	1737	5785	1.511	5.69	271.7
1.6	31.98	2.127	3436	1675	5794	1.509	5.64	271.8
1.8	34.59	1.891	3205	1515	5747	1.504	5.52	268.7
2.0	37.01	1.702	2923	1333	5630	1.499	5.39	262.3
3.0	46.85	1.134	1657	644	4618	1.476	4.83	211.8
Percent fluorine in oxidant by weight, 15								
1.2	24.36	3.106	3735	1807	5773	1.508	5.617	270.6
1.4	27.31	2.662	3694	1769	5880	1.506	5.576	275.3
1.6	30.04	2.329	3583	1687	5929	1.504	5.513	277.1
1.8	32.57	2.071	3391	1560	5906	1.500	5.425	275.4
2.0	34.92	1.864	3142	1405	5818	1.496	5.319	270.5
Percent fluorine in oxidant by weight, 30								
1.2	22.56	3.432	3868	1776	5918	1.500	5.422	275.9
1.4	25.37	2.942	3836	1752	6019	1.499	5.404	280.5
1.6	27.98	2.574	3745	1694	6074	1.498	5.366	282.8
1.8	30.41	2.288	3586	1596	6068	1.496	5.306	282.1
2.0	32.69	2.059	3369	1468	6005	1.492	5.227	278.5
Percent fluorine in oxidant by weight, 50								
1.2	20.03	3.992	4120	1754	6147	1.489	5.154	284.5
1.4	22.62	3.421	4100	1749	6245	1.490	5.160	289.2
1.6	25.04	2.994	4030	1714	6305	1.489	5.150	291.8
1.8	27.31	2.661	3898	1644	6314	1.488	5.120	292.0
2.0	29.46	2.395	3708	1543	6270	1.486	5.072	289.6
Percent fluorine in oxidant by weight, 70.37								
1.00	14.83	5.743	4007	1549	5974	1.476	4.83	274.2
1.25	17.87	4.595	4359	1726	6338	1.480	4.91	291.5
1.40	19.60	4.102	4464	1786	6484	1.481	4.94	298.4
1.50	20.71	3.829	4479	1803	6539	1.482	4.96	301.1
1.60	20.79	3.589	4396	1807	6491	1.484	5.03	299.5
1.75	23.35	3.282	4269	1803	6422	1.488	5.12	297.0
2.00	25.83	2.872	4168	1816	6402	1.492	5.23	297.0
2.50	30.33	2.297	3898	1787	6277	1.500	5.41	292.6
3.00	34.31	1.914	3618	1721	6111	1.505	5.55	285.9
4.00	41.05	1.436	3125	1555	5783	1.512	5.72	271.8
Percent fluorine in oxidant, 100 (zero percent oxygen)								
1.00	11.01	8.083	3962	1836	5466	1.501	5.454	255.1
1.50	15.65	5.389	4008	1932	5605	1.507	5.599	262.6
2.00	19.84	4.041	4206	2139	5799	1.516	5.805	273.2
2.80	25.73	2.887	4262	2210	6047	1.519	5.883	285.4
3.00	27.07	2.694	4249	2216	6080	1.520	5.905	287.2
3.50	30.22	2.309	4172	2207	6116	1.522	5.962	289.3
4.00	33.10	2.021	4041	2167	6092	1.524	6.017	288.6
5.00	38.22	1.617	3708	2033	5945	1.528	6.105	282.3



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

Exponent n_I for use in equation $I = I_{600}\left(\frac{P_c}{600}\right)^{n_I}$.

Figure 1. - Theoretical specific impulse of JP-4 fuel 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, 15.

Figure 1. - Continued. Theoretical specific impulse of JP-4 fuel 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.

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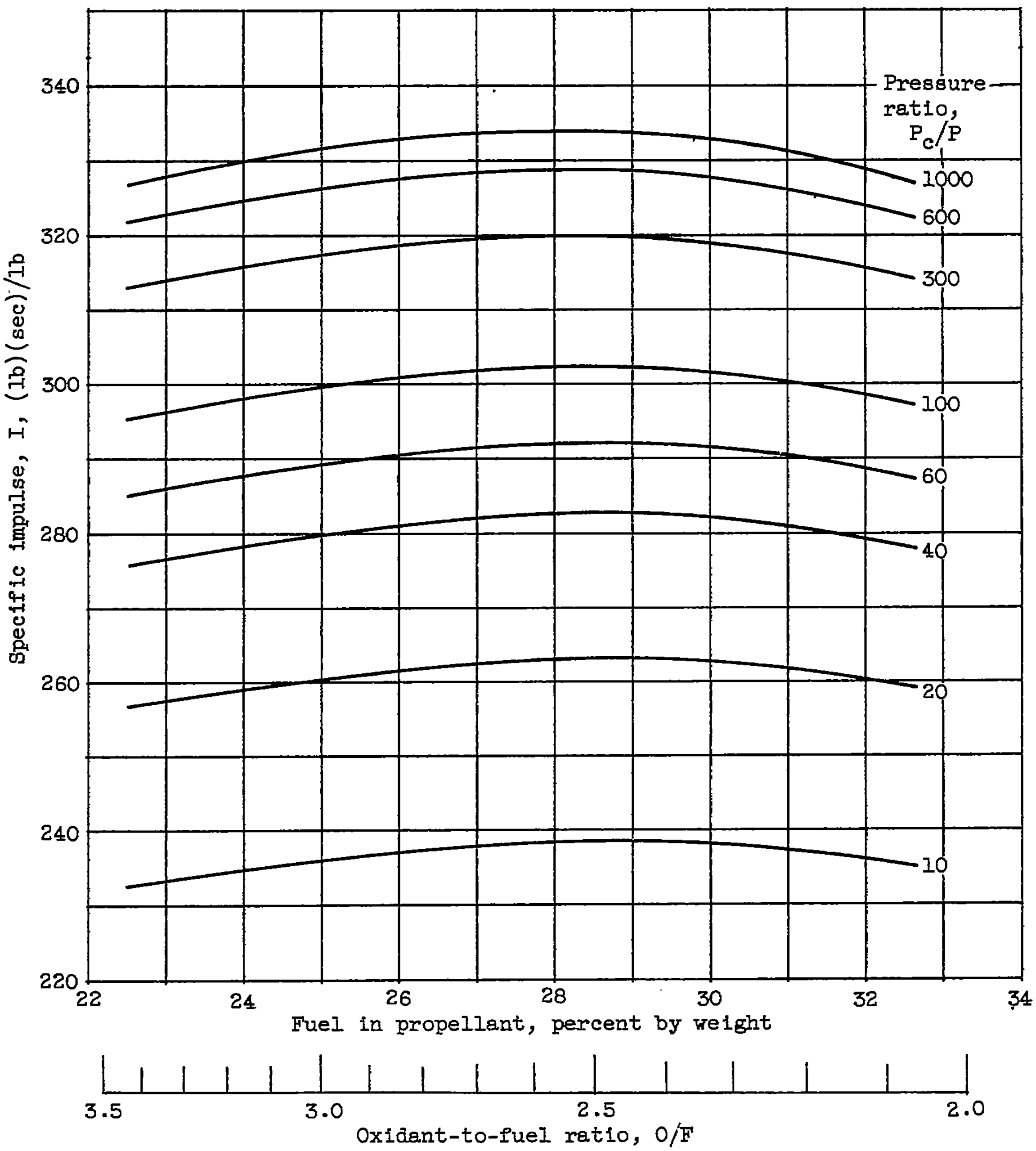
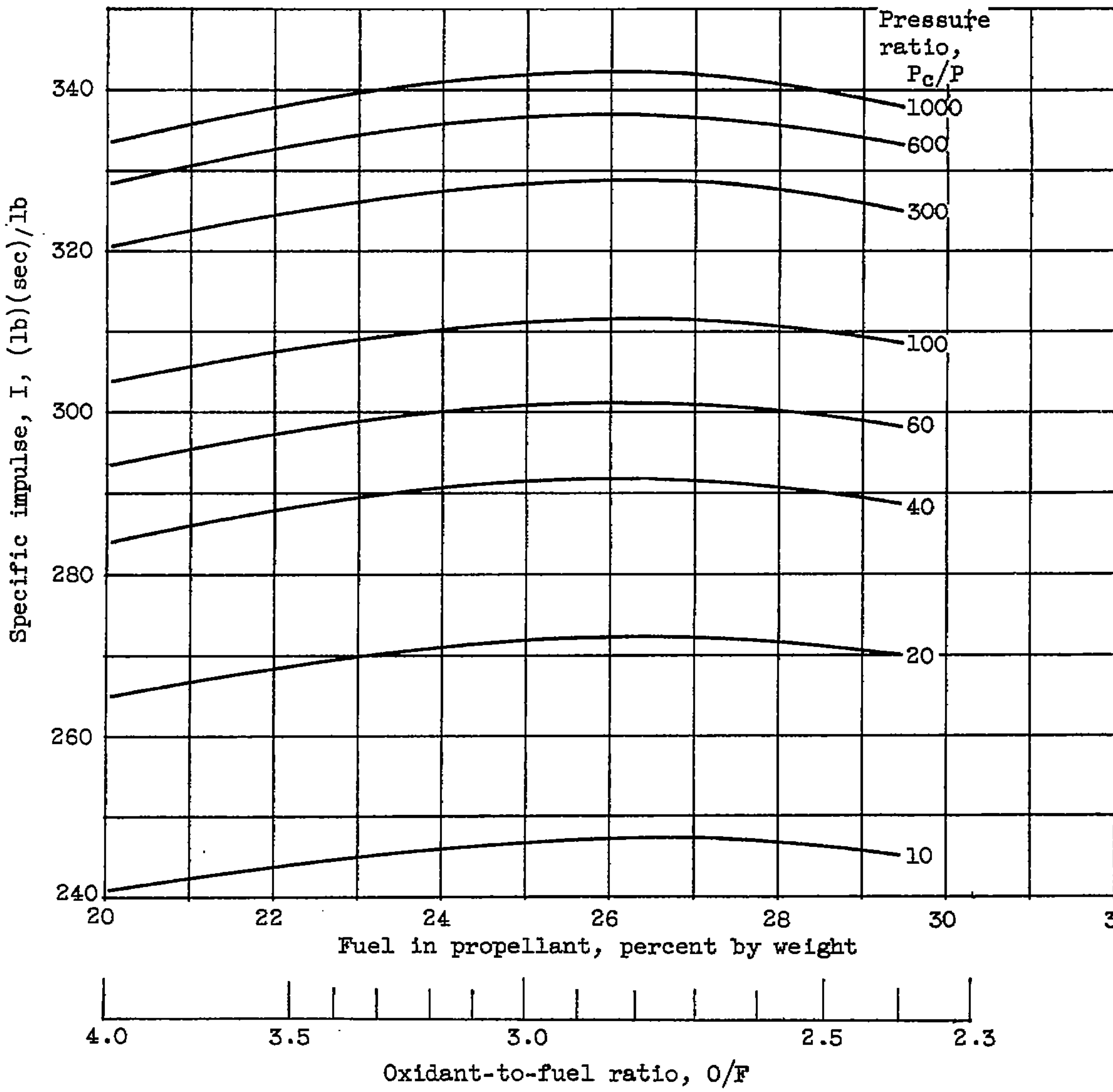


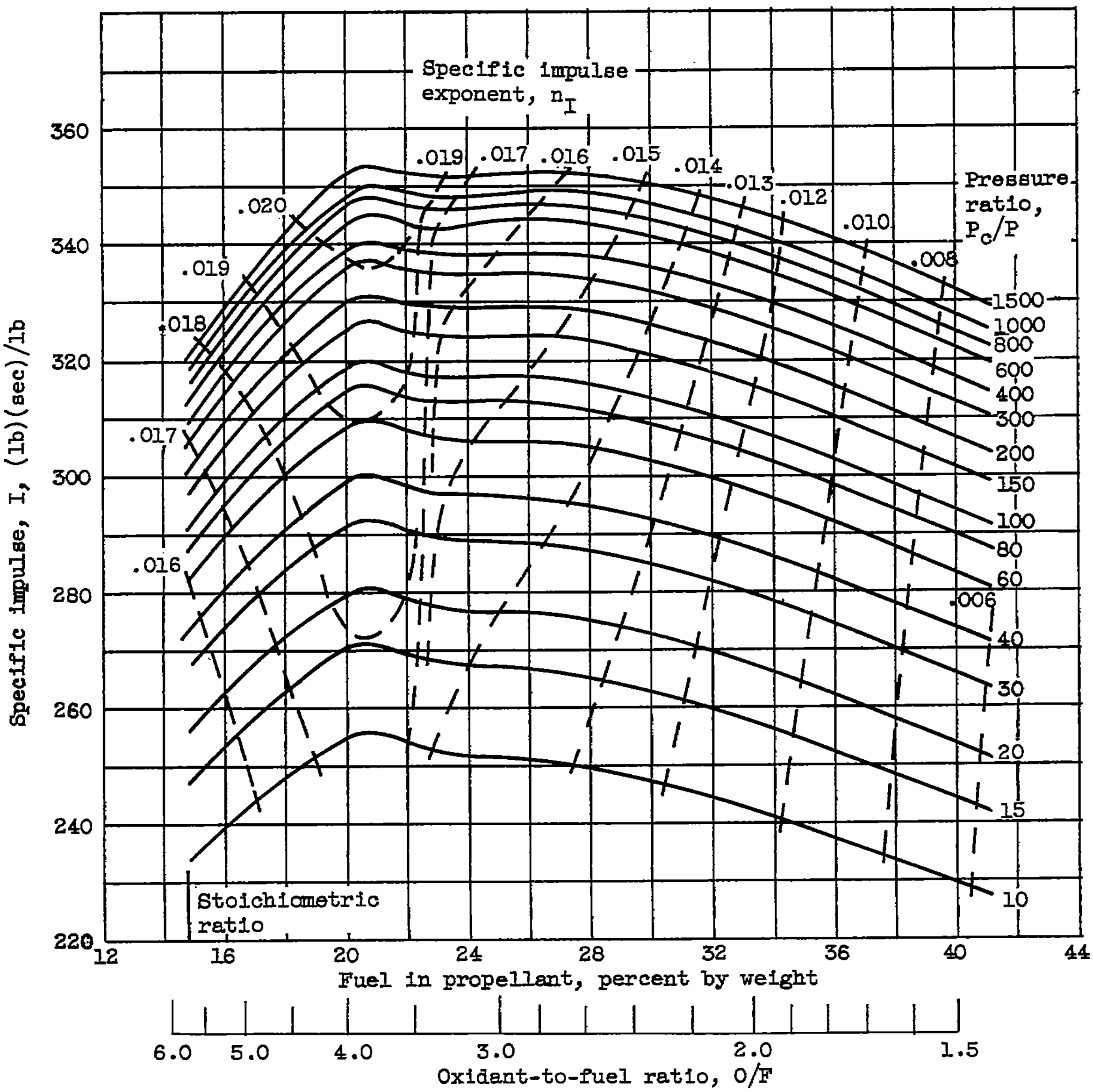
(c) Percent fluorine in oxidant by weight, 30.

Figure 1. - Continued. Theoretical specific impulse of JP-4 fuel 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, 50.

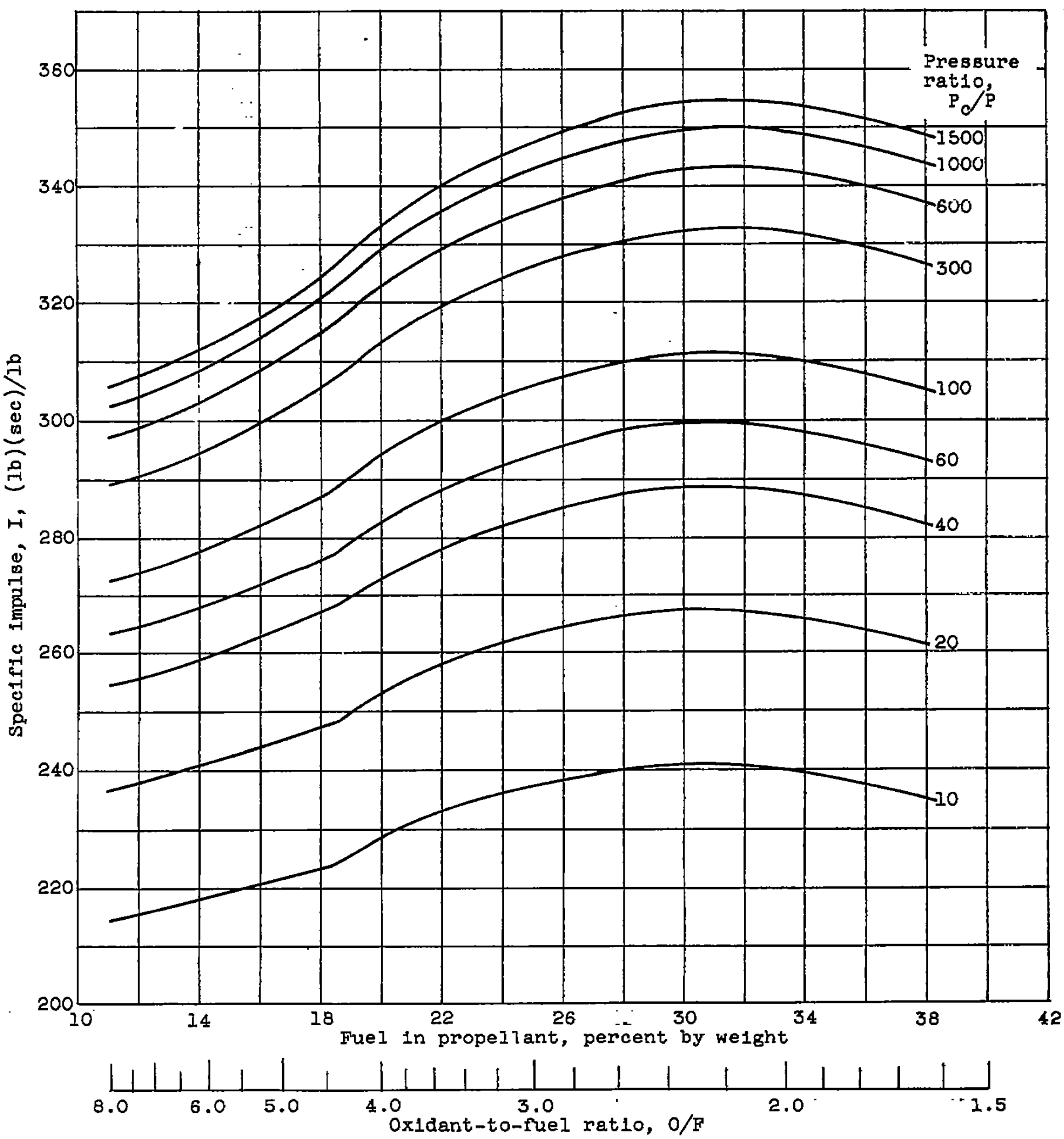
Figure 1. - Continued. Theoretical specific impulse of JP-4 fuel with several fluorine-oxygen mixtures. Frozen composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



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

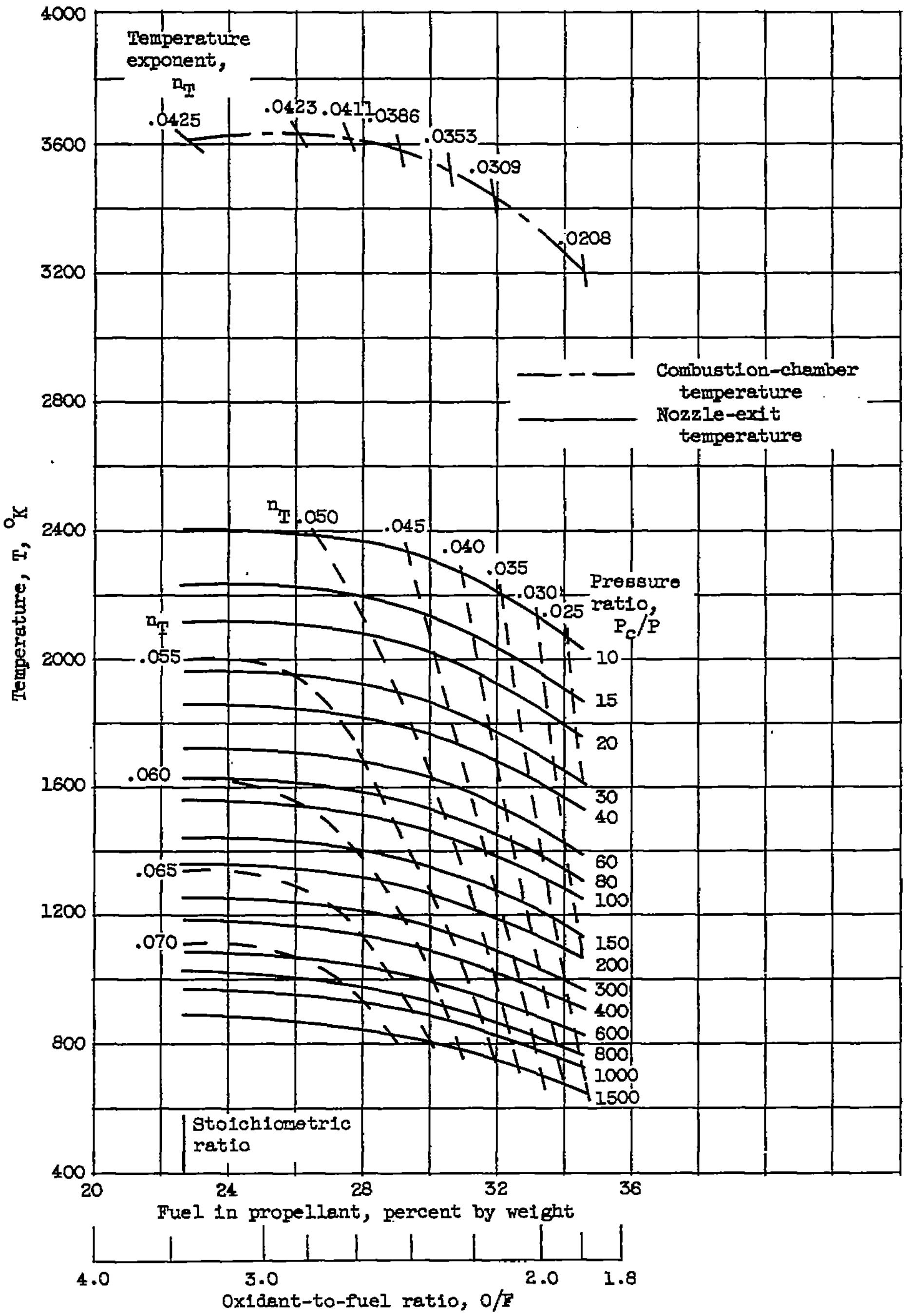
Exponent n_I for use in equation $I = I_{600}\left(\frac{P_c}{600}\right)^{n_I}$.

Figure 1. - Continued. Theoretical specific impulse of JP-4 fuel 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, 100 (zero percent oxygen).

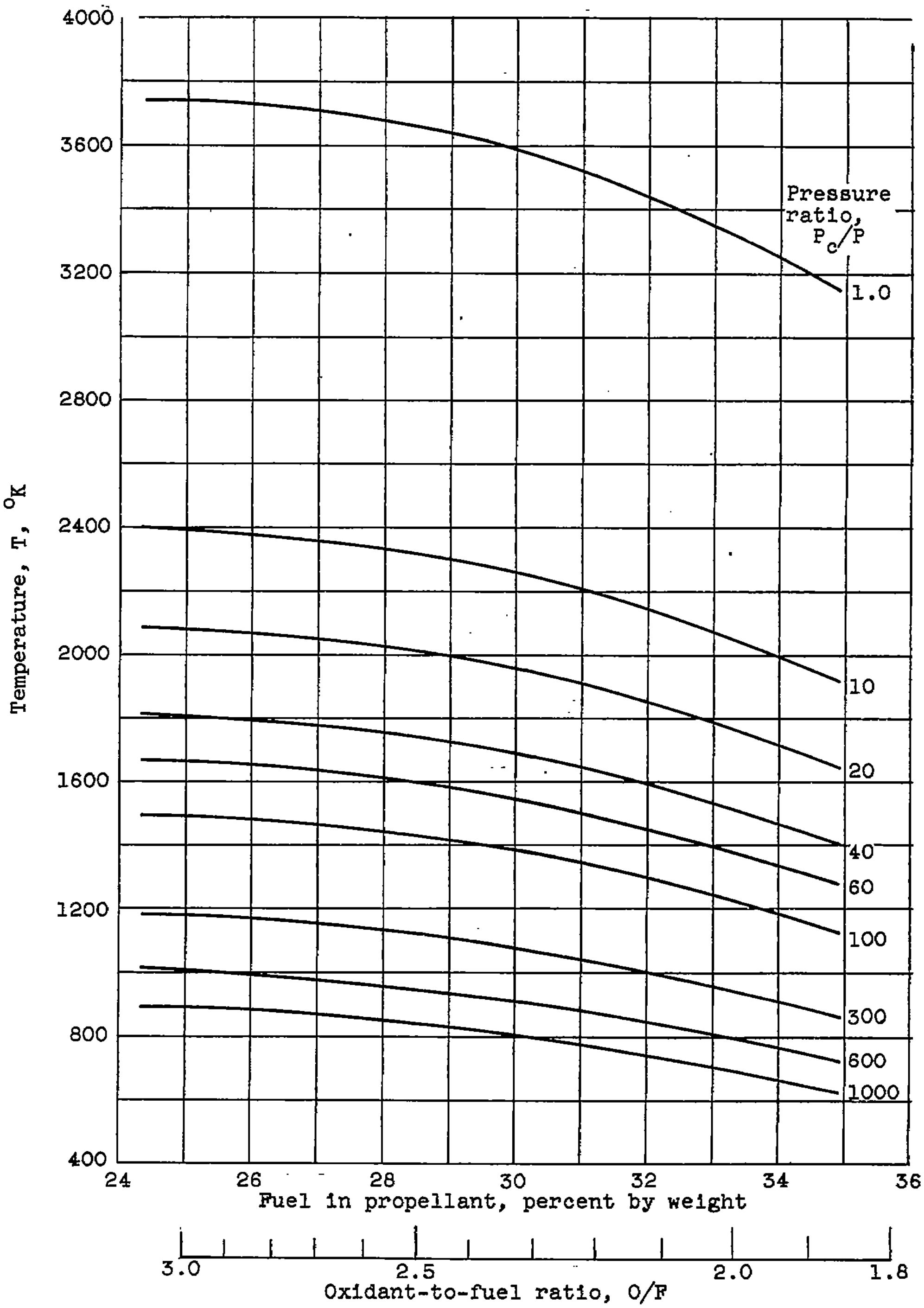
Figure 1. - Concluded. Theoretical specific impulse of JP-4 fuel with several fluorine-oxygen mixtures. Frozen composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



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

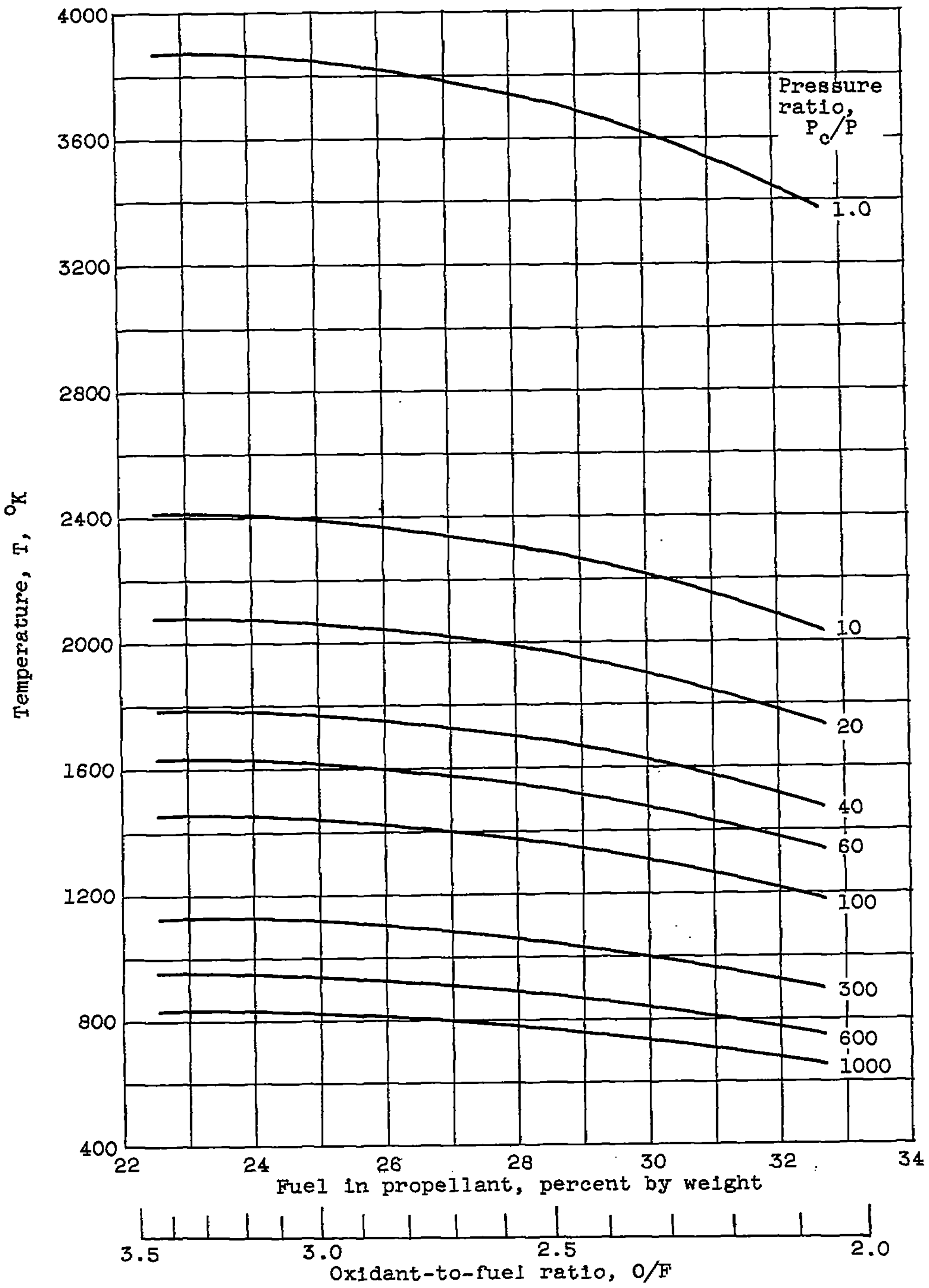
Exponent n_T for use in equation $T = T_{600}\left(\frac{P_c}{600}\right)^{n_T}$.

Figure 2. - Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel 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.



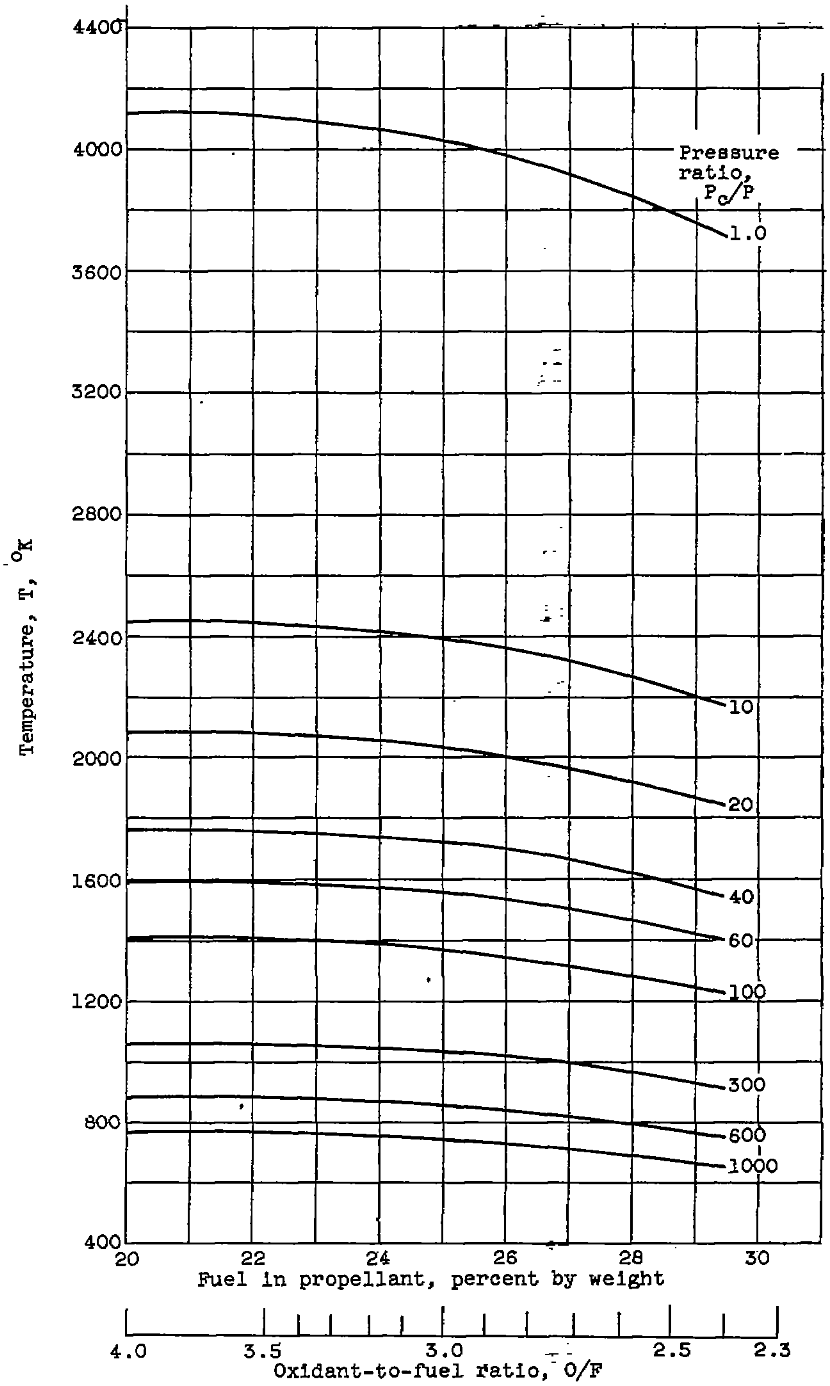
(b) Percent fluorine in oxidant by weight, 15.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel 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.



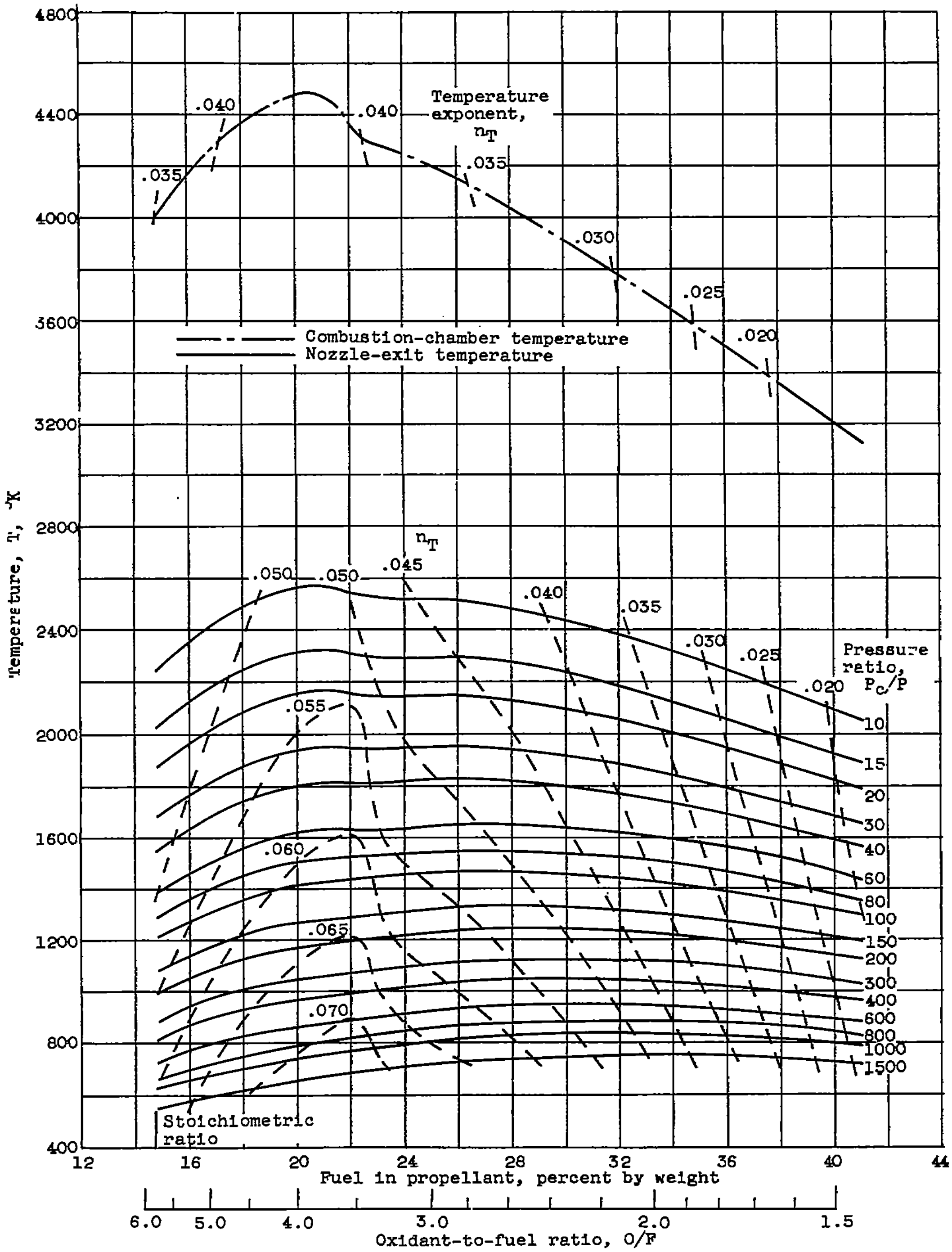
(c) Percent fluorine in oxidant by weight, 30.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel 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, 50.

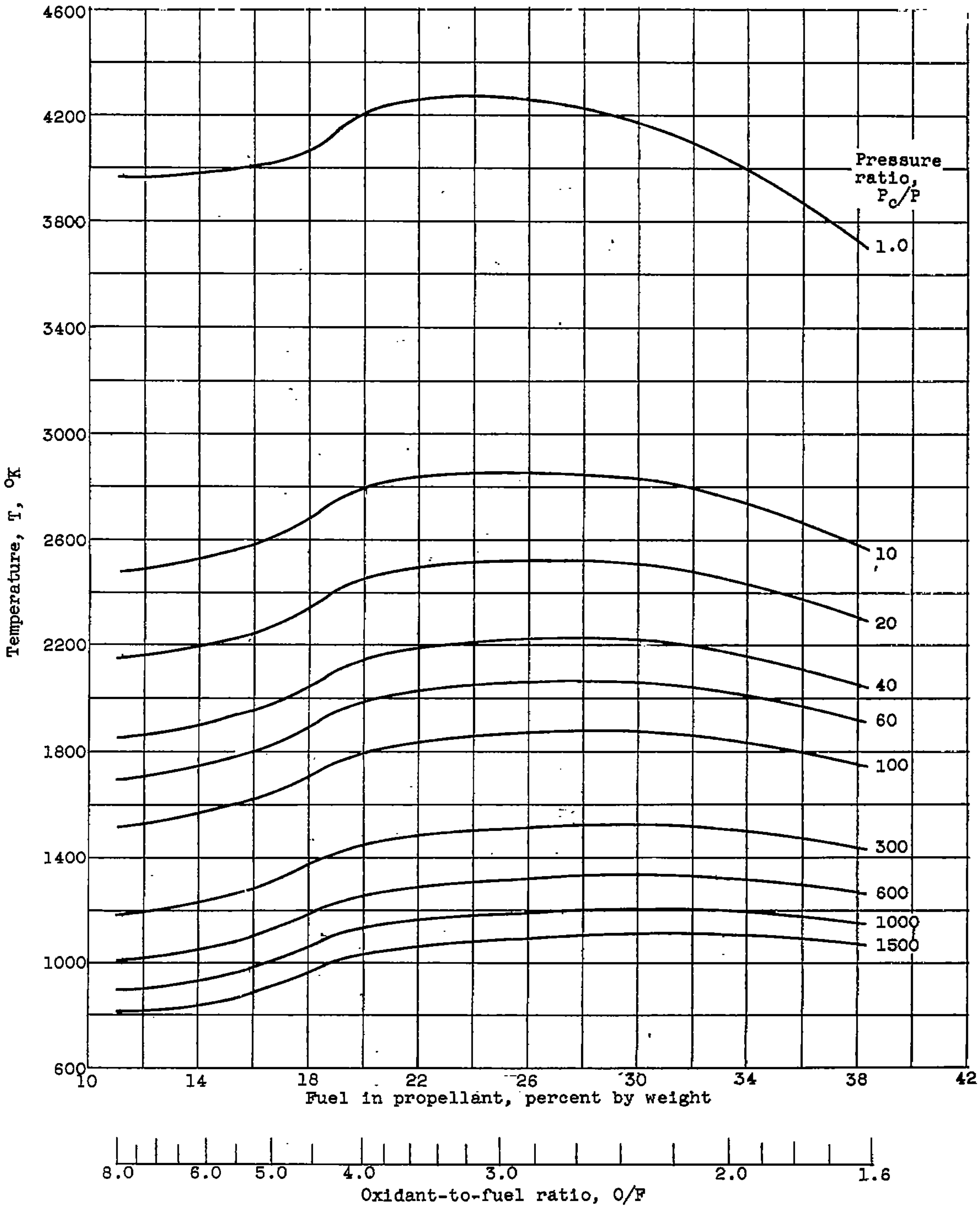
Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel with several fluorine-oxygen mixtures. Frozen composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to pressure ratio indicated.



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

Exponent n_T for use in equation $T = T_{600}\left(\frac{P_c}{600}\right)^{n_T}$.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel 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, 100 (zero percent oxygen).

Figure 2. - Concluded. Theoretical combustion-chamber temperature and nozzle-exit temperature for JP-4 fuel 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.

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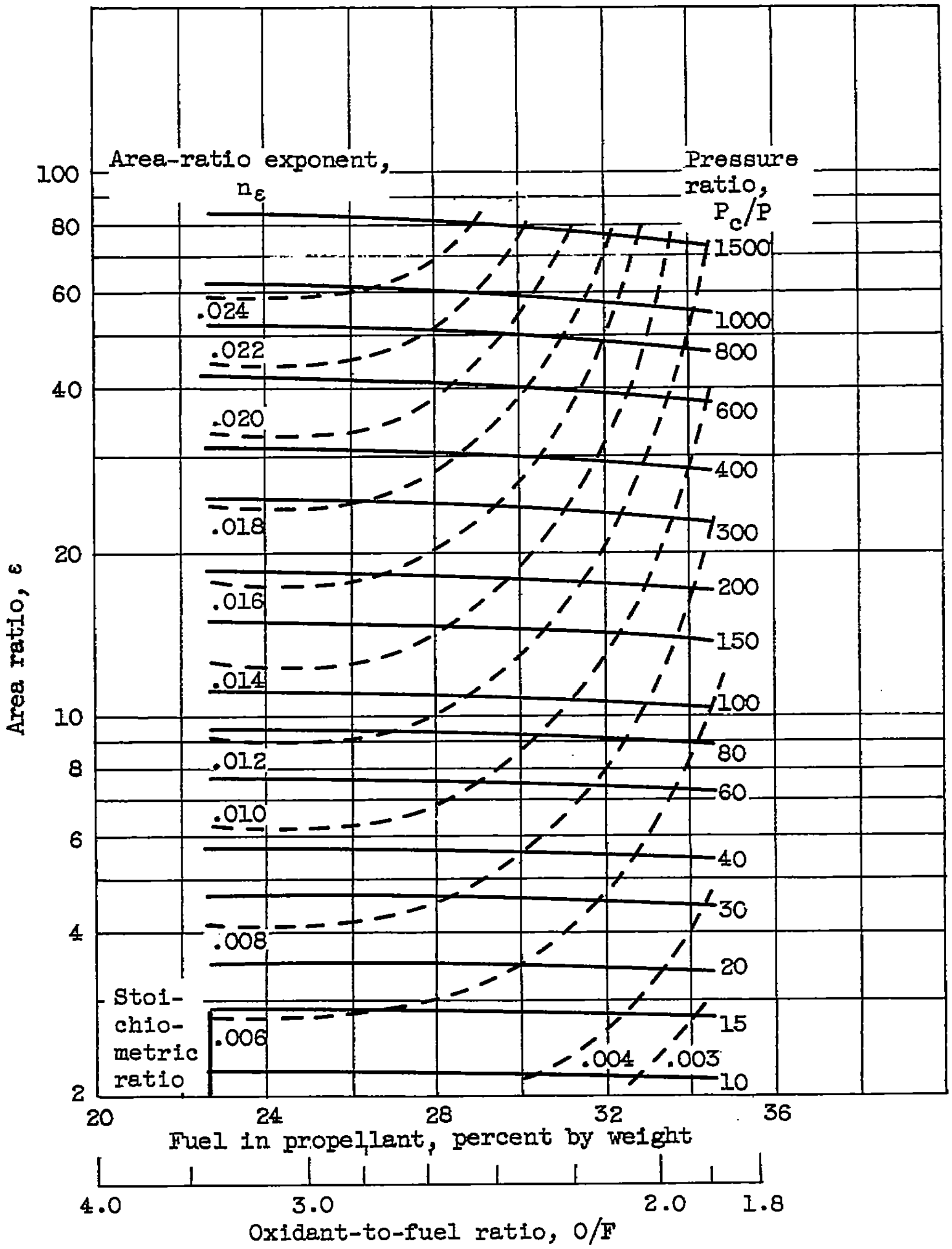
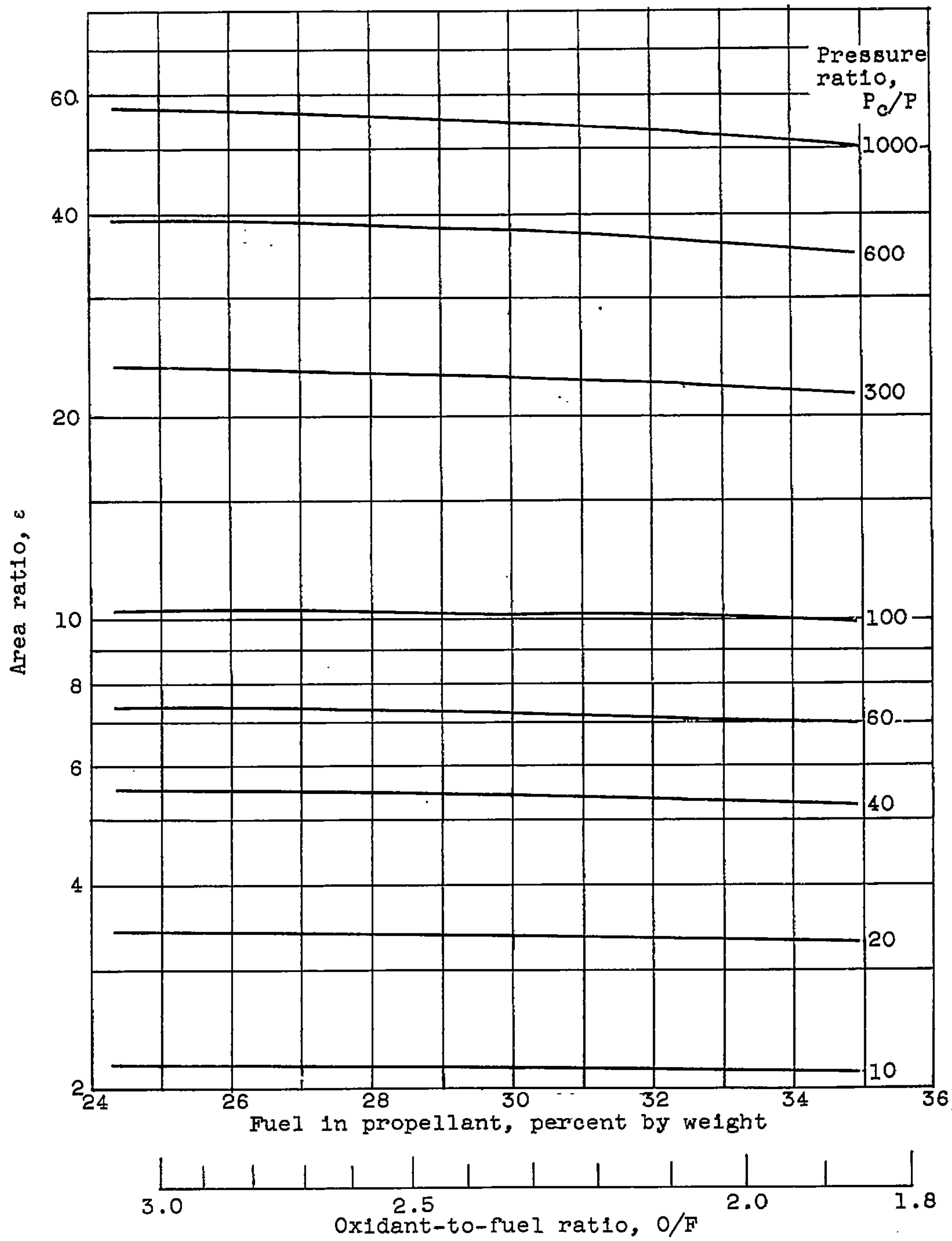


(a) Percent fluorine in oxidant, 0 (100 percent oxygen).

Exponent n_ε for use in equation $\varepsilon = \varepsilon_{600}\left(\frac{P_c}{600}\right)^{n_\varepsilon}$.

Figure 3. - Theoretical ratio of nozzle area to throat area for JP-4 fuel 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, 15.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel 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.

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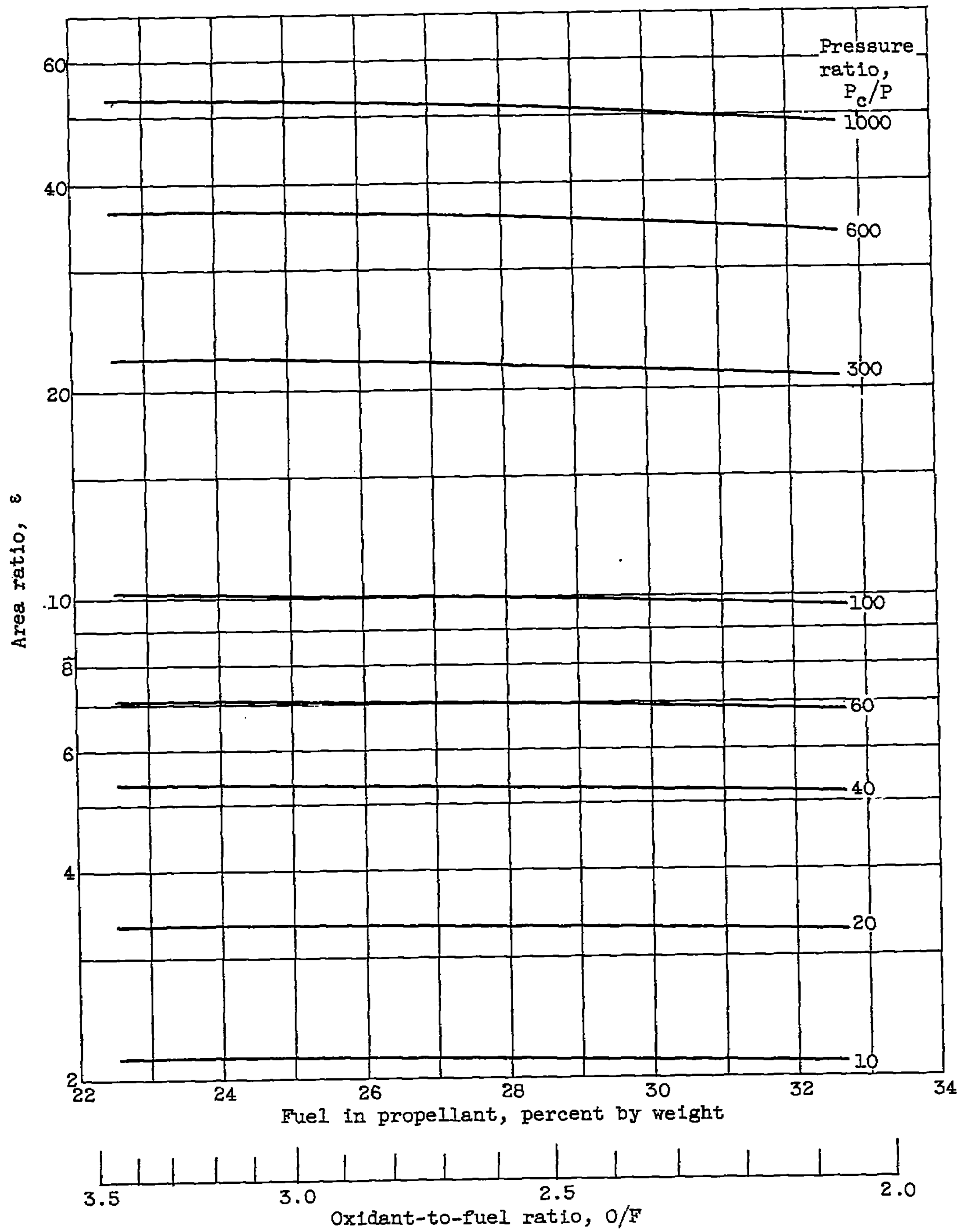

(c) Percent fluorine in oxidant by weight, 30.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel 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.

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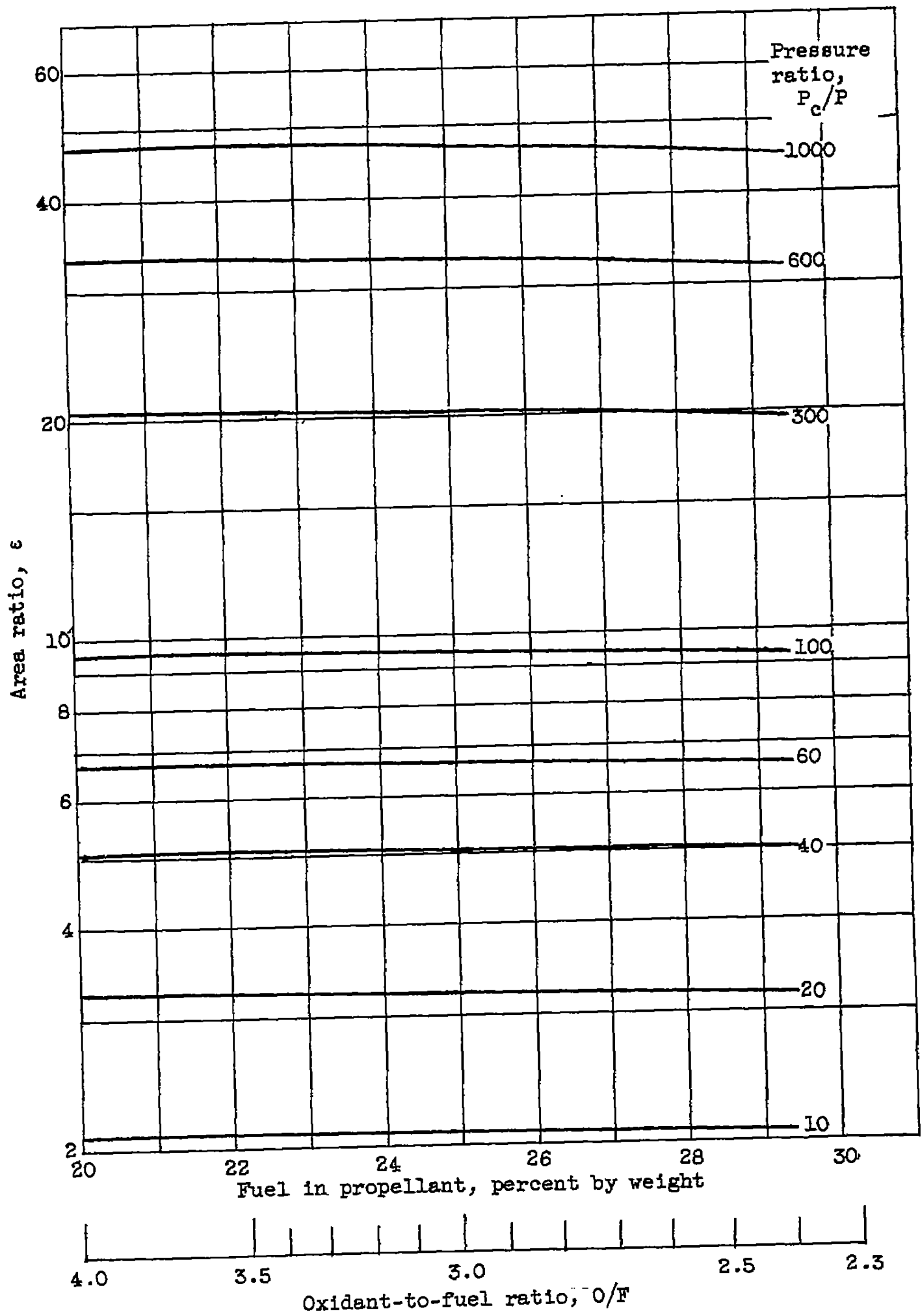

(d) Percent fluorine in oxidant by weight, 50.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel 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.

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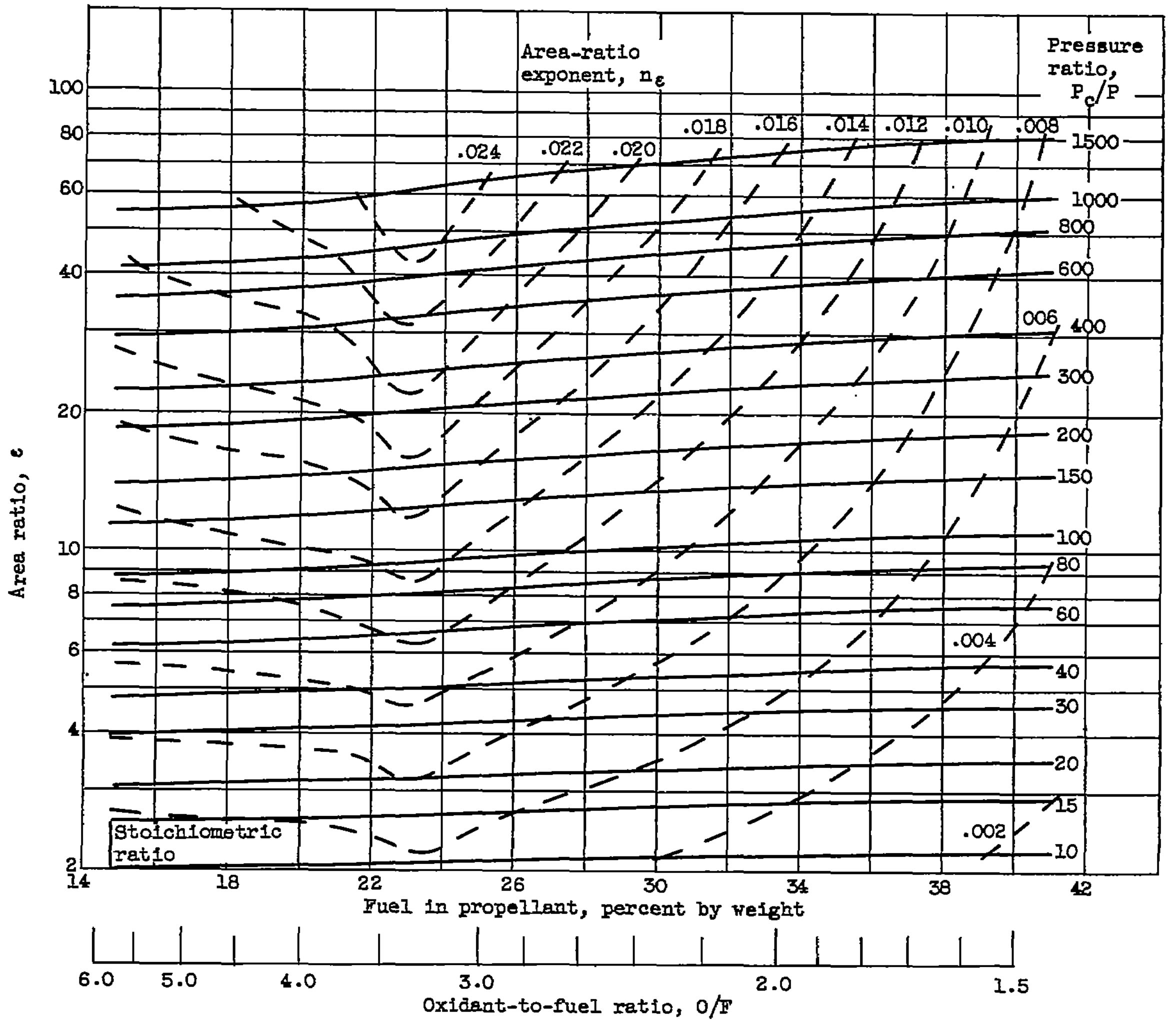
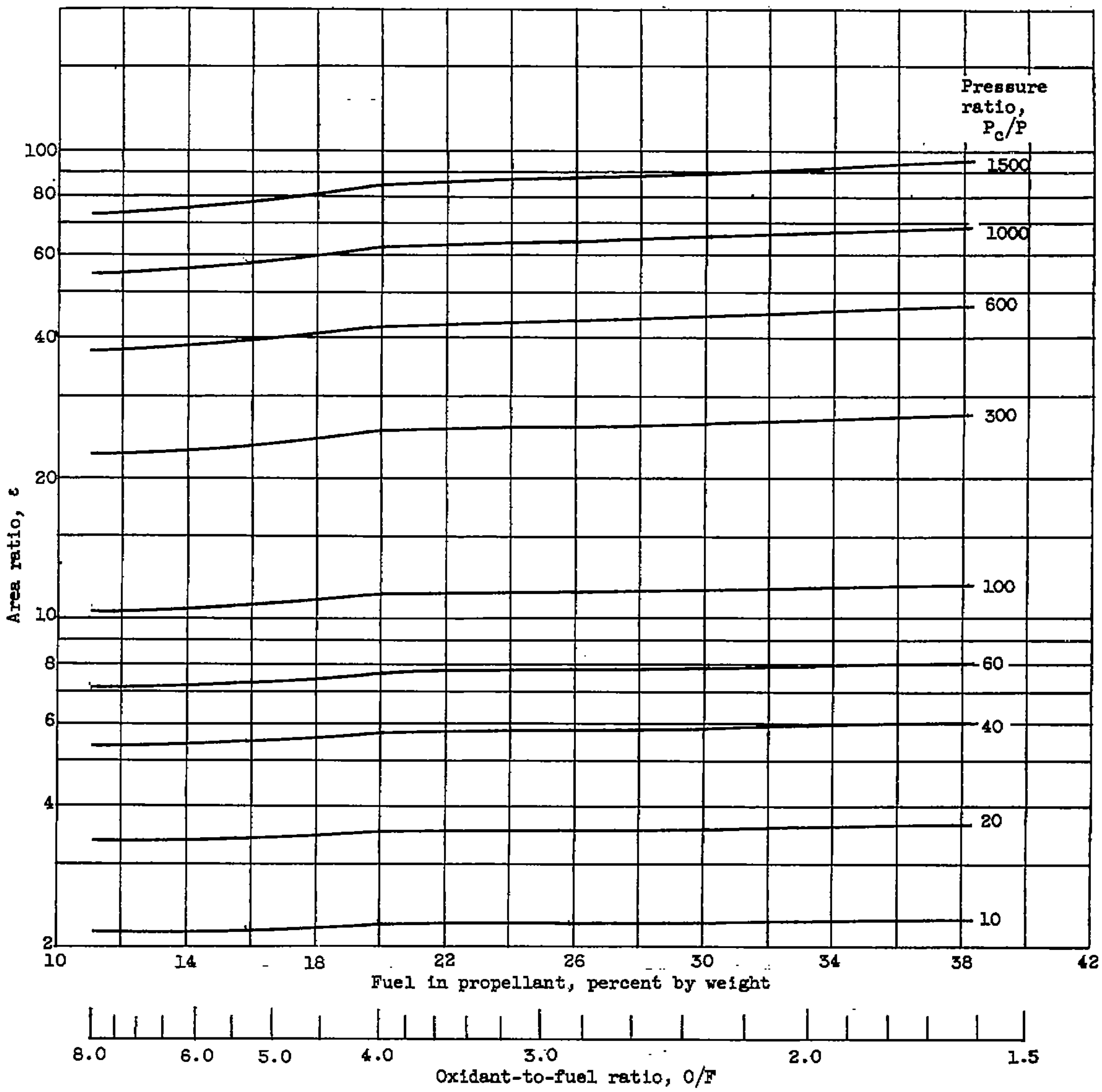


(e) Percent fluorine in oxidant by weight, 70.37.

Exponent n_ε for use in equation $\varepsilon = \varepsilon_{600}\left(\frac{P_c}{600}\right)^{n_\varepsilon}$.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for JP-4 fuel 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, 100 (zero percent oxygen).

Figure 3. - Concluded. Theoretical ratio of nozzle area to throat area for JP-4 fuel 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.

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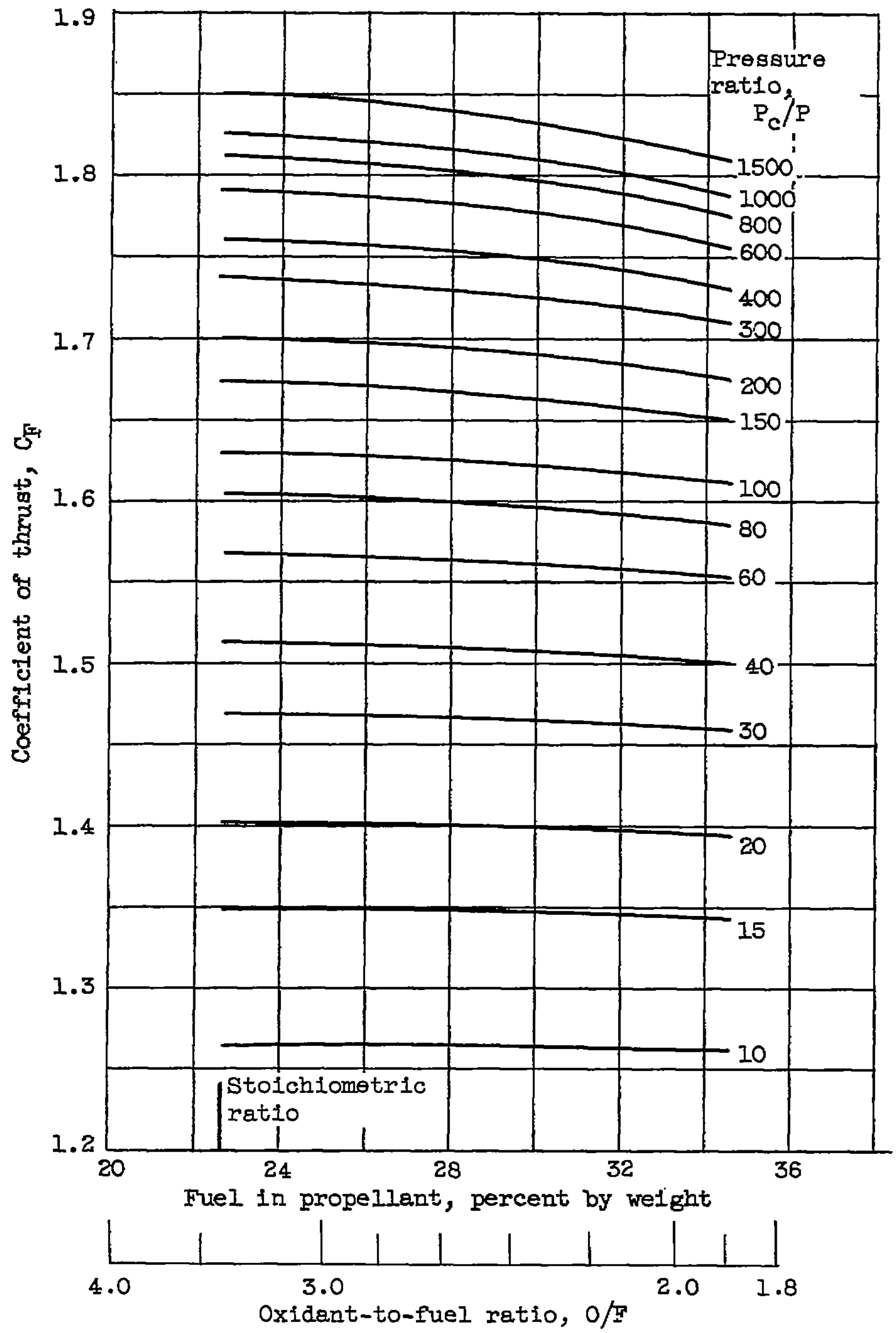
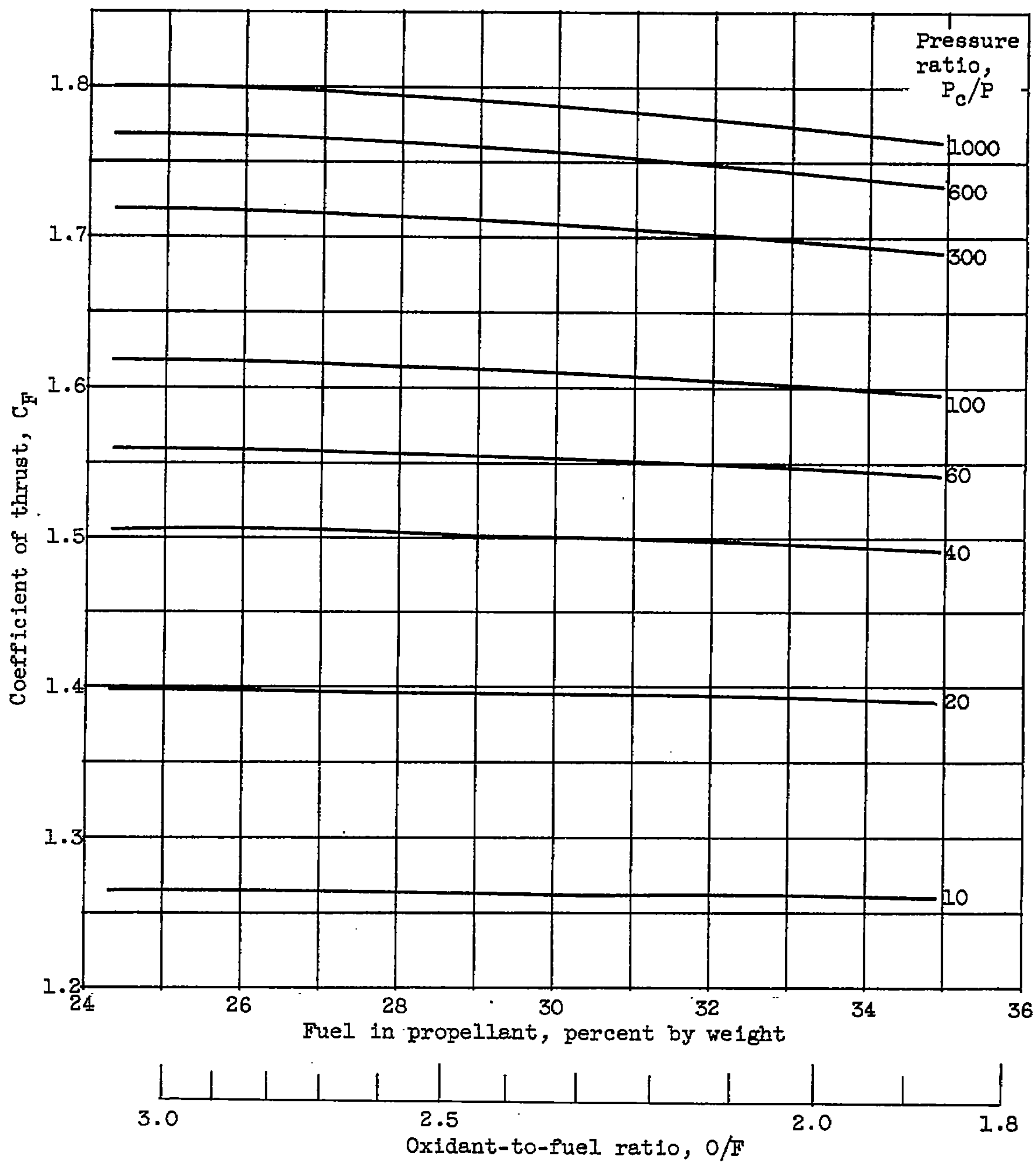


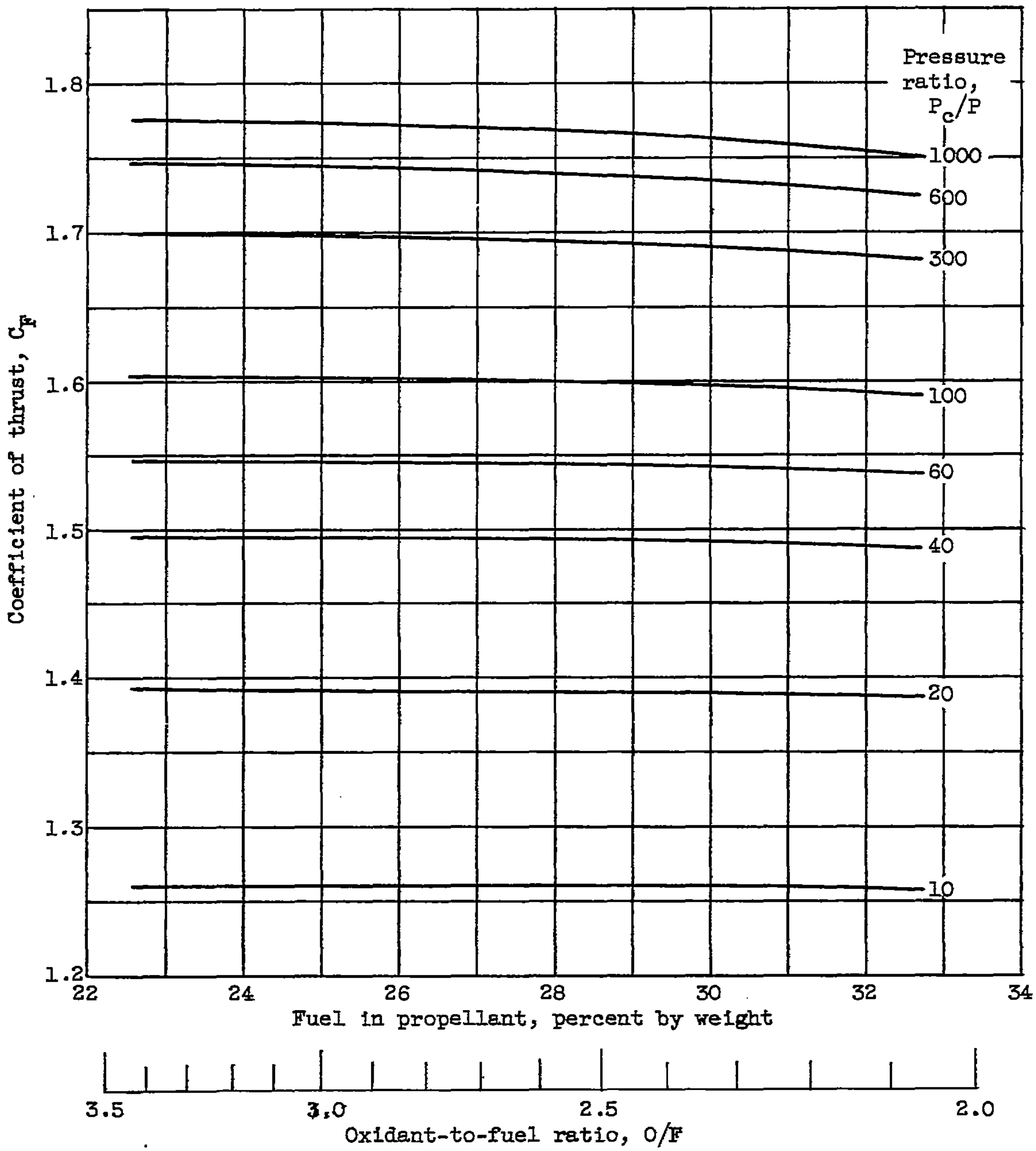
(a) Percent fluorine in oxidant, 0 (100 percent oxygen).

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



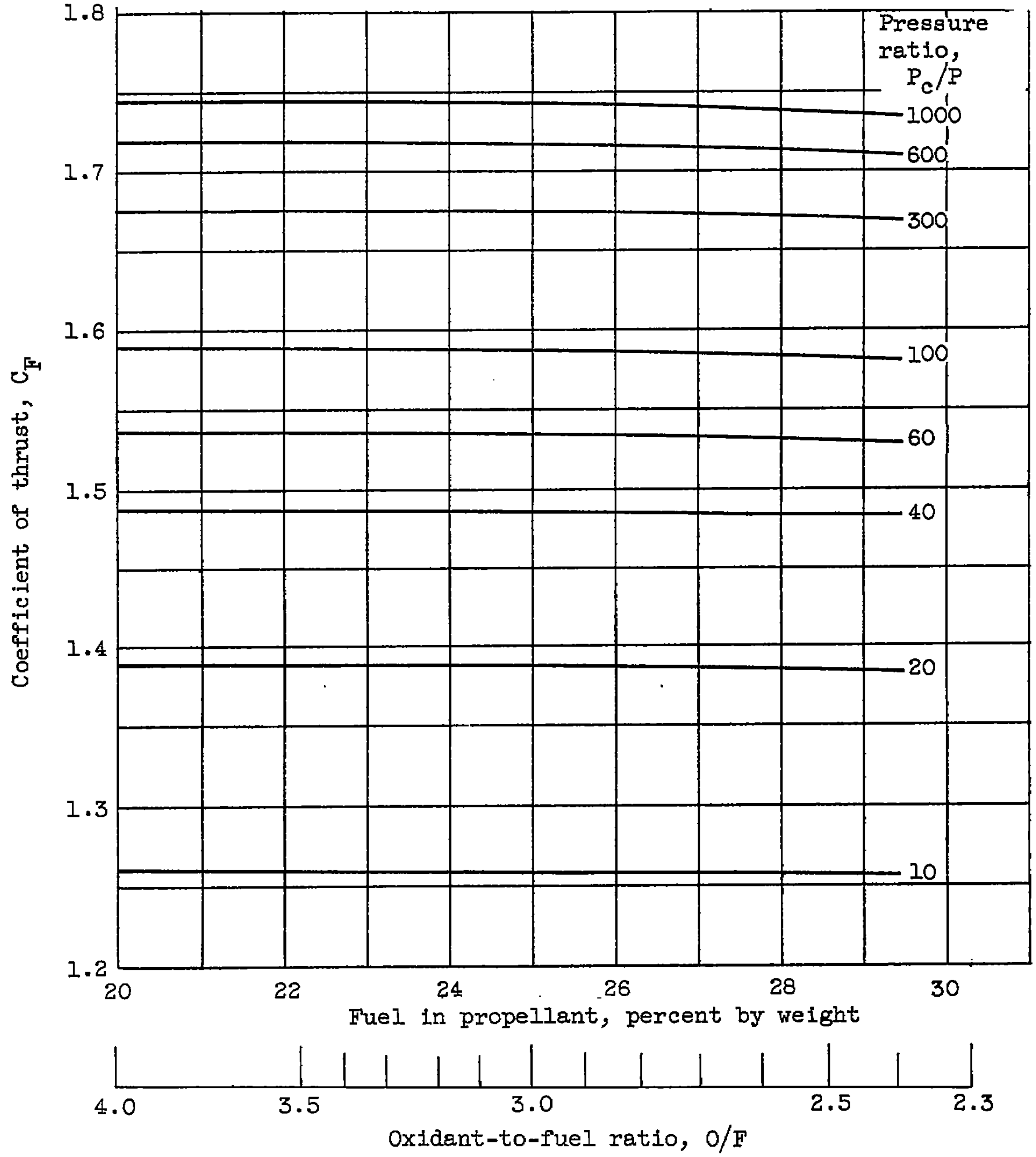
(b) Percent fluorine in oxidant by weight, 15.

Figure 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel 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.



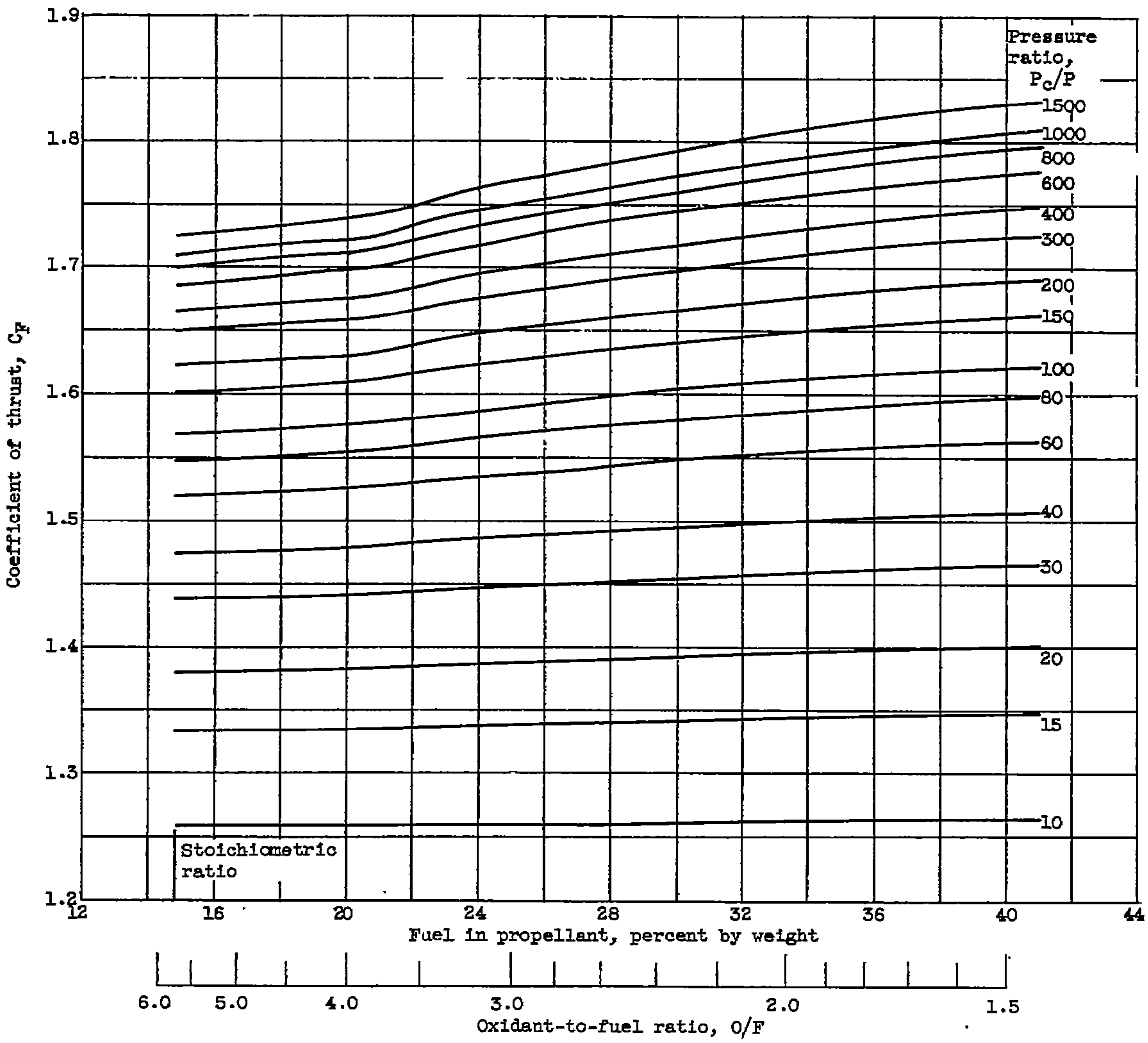
(c) Percent fluorine in oxidant by weight, 30.

Figure 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel 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.



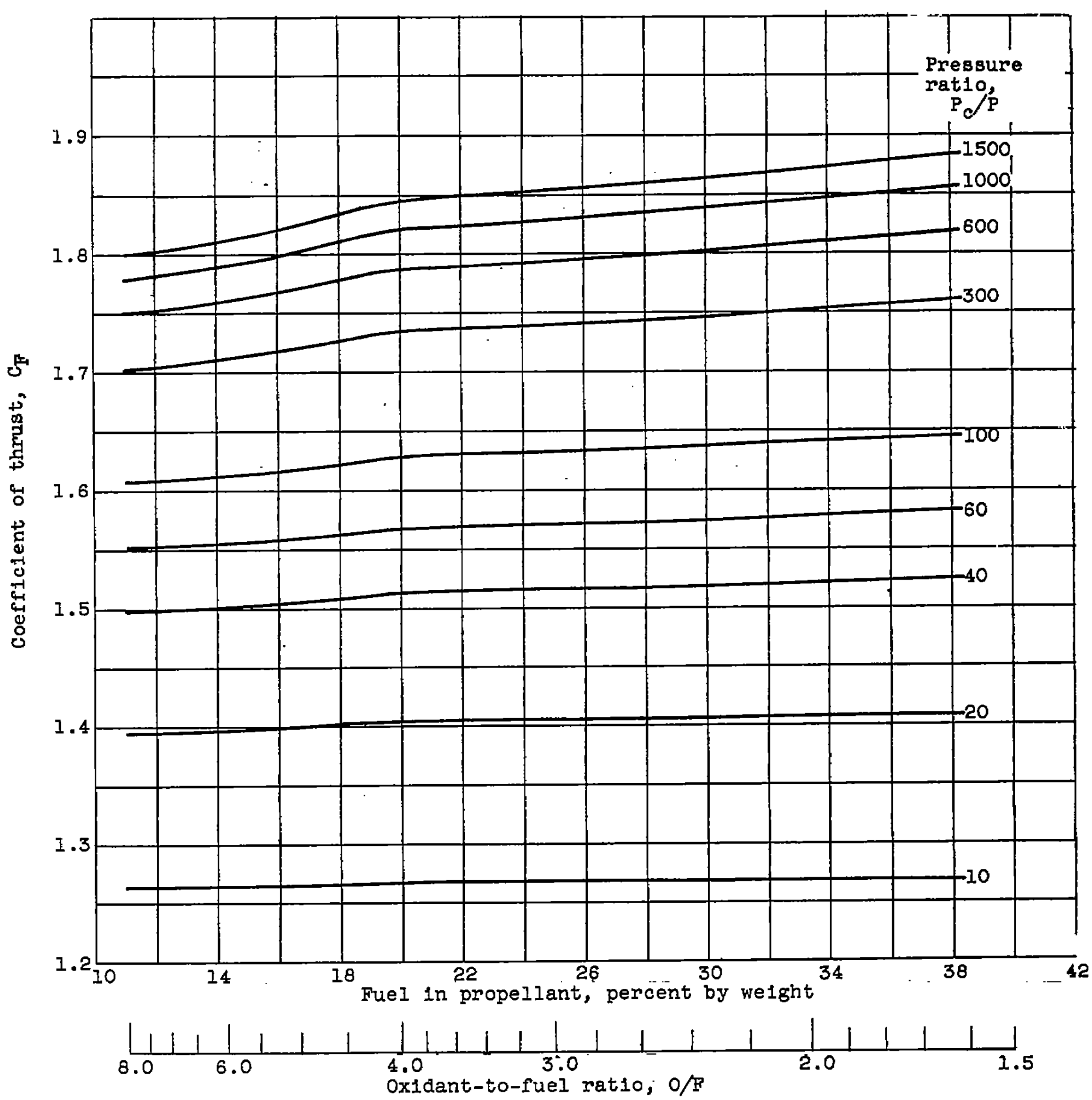
(d) Percent fluorine in oxidant by weight, 50.

Figure 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel 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 4. - Continued. Theoretical coefficient of thrust for JP-4 fuel 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, 100 (zero percent oxygen).

Figure 4. - Concluded. Theoretical coefficient of thrust for JP-4 fuel 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.

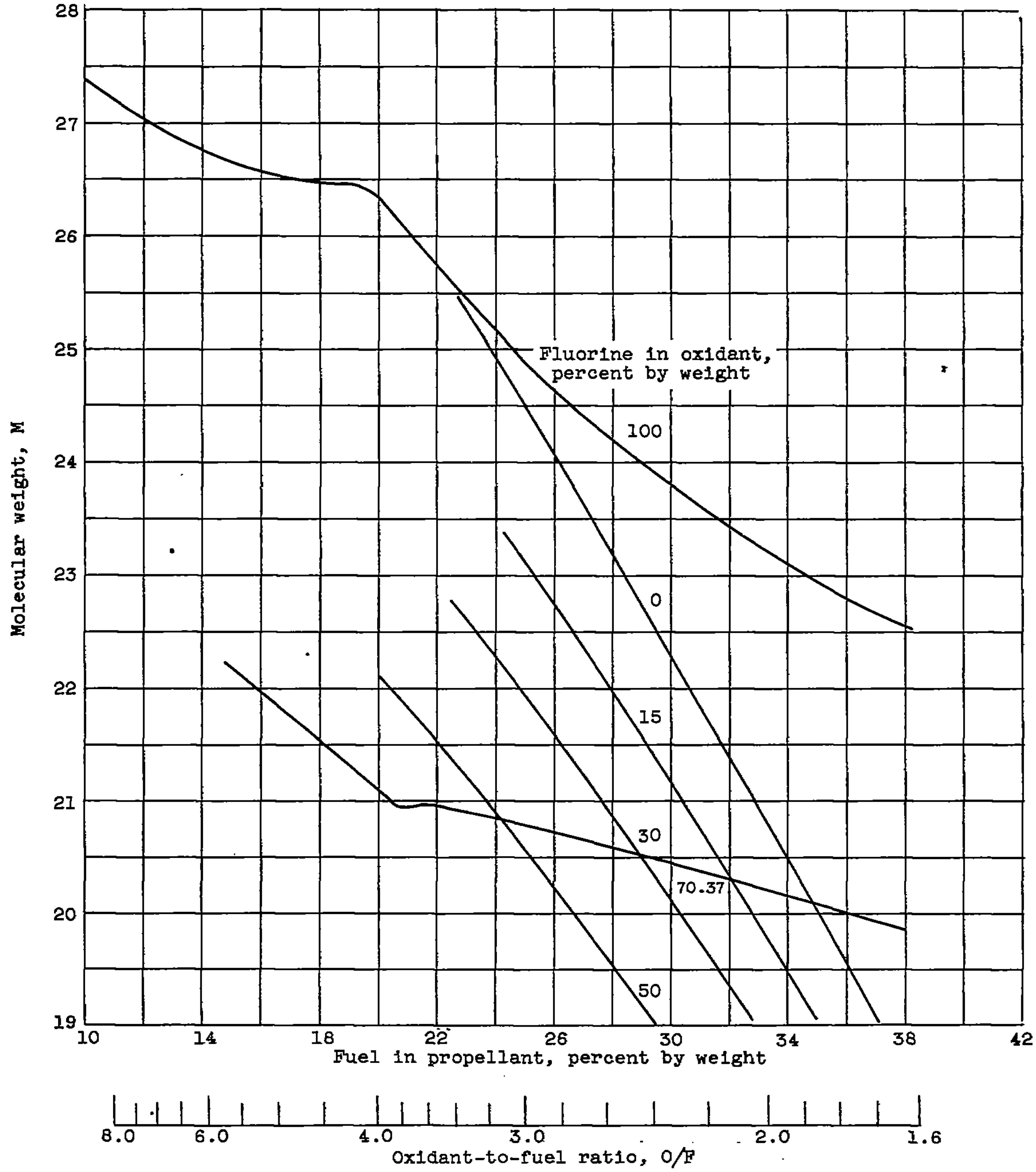


Figure 5. - Theoretical combustion-chamber molecular weight for JP-4 fuel with several fluorine-oxygen mixtures. Combustion-chamber pressure, 600 pounds per square inch absolute.

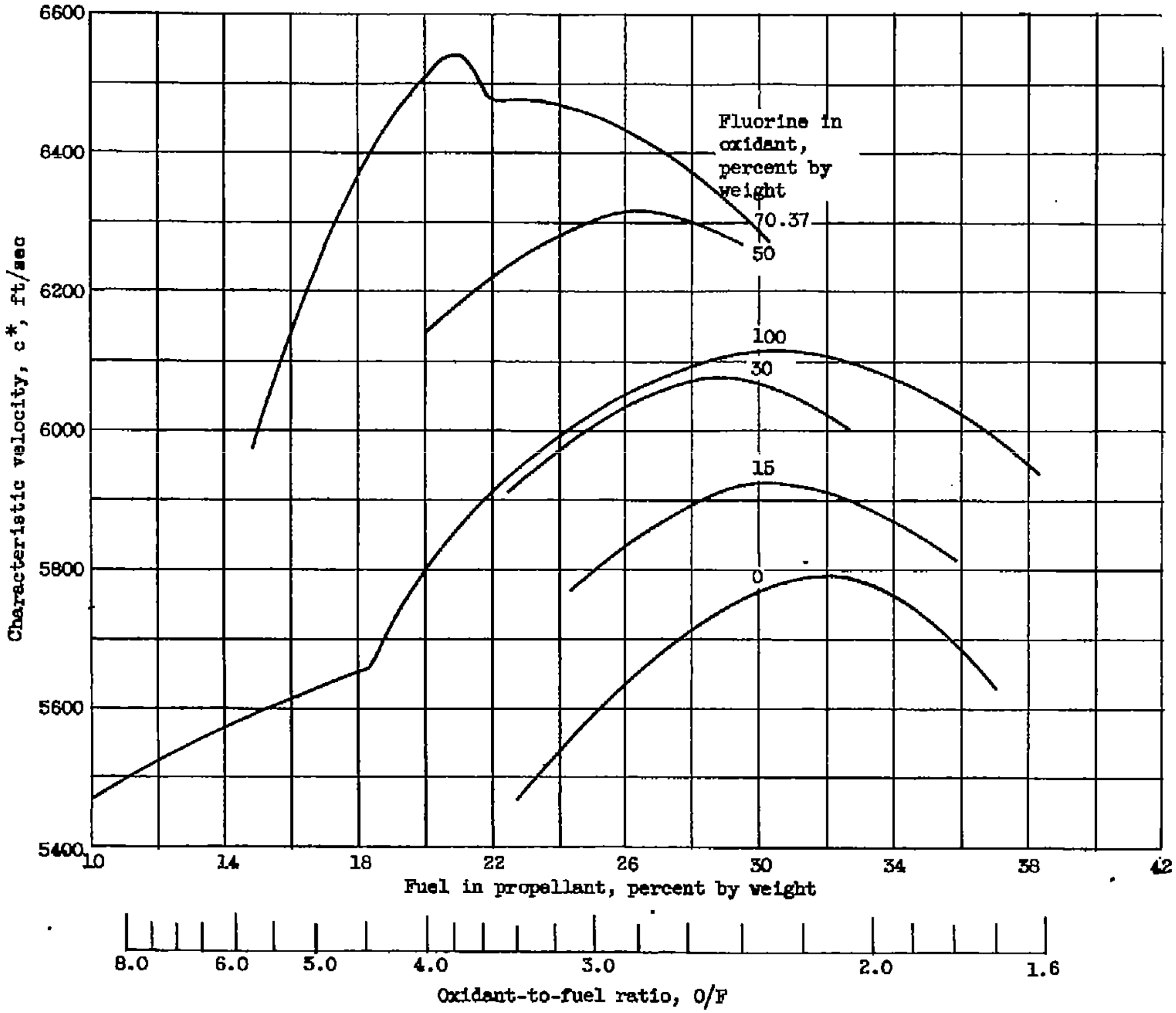


Figure 6. - Theoretical characteristic velocity for JP-4 fuel with several fluorine-oxygen mixtures. Isentropic expansion assuming frozen composition from combustion-chamber pressure, 600 pounds per square inch absolute.

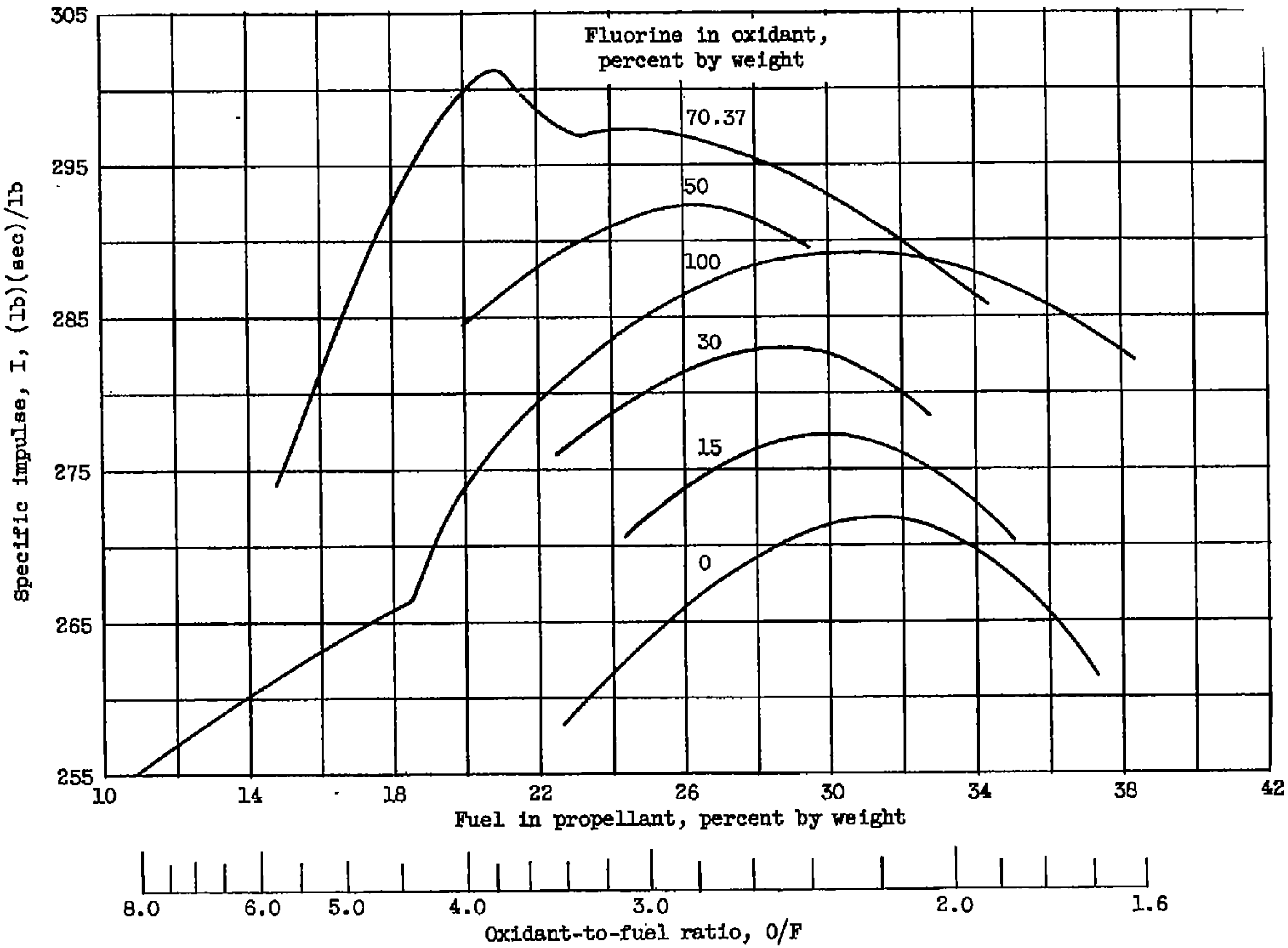


Figure 7. - Theoretical specific impulse for JP-4 fuel with several fluorine-oxygen mixtures. Isentropic expansion assuming frozen composition from combustion-chamber pressure of 600 pounds per square inch absolute to exit pressure of 1 atmosphere.

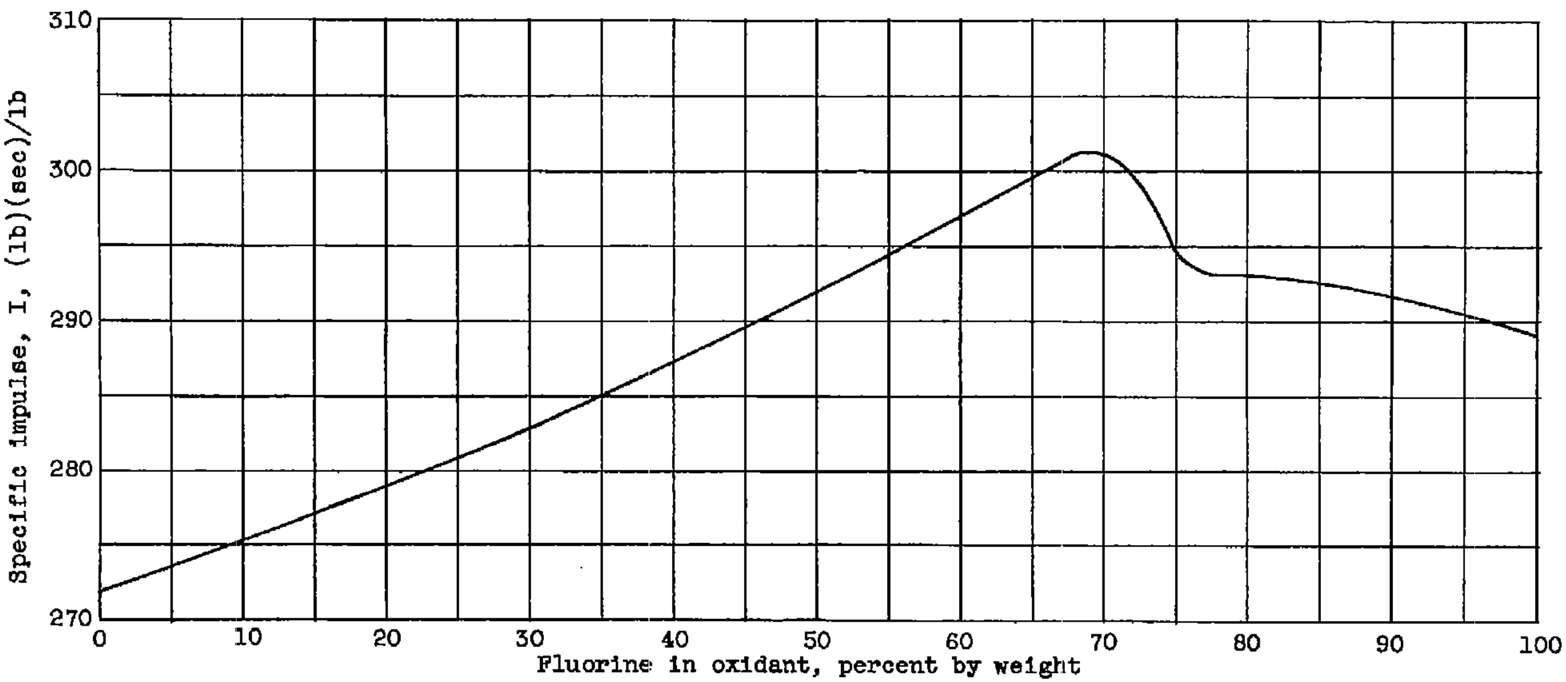


Figure 8. - Theoretical specific impulse of JP-4 fuel with fluorine-oxygen mixtures at equivalence ratios for which specific impulse is maximum. Frozen composition during isentropic expansion from combustion-chamber pressure of 600 pounds per square inch absolute to 1 atmosphere.