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WIND-TUNNEL INVESTIGATION OF PERFORATED SPLIT FLAPS FOR USE AS DIVE BRAKES ON A RECTANGULAR NACA 23012 AIRFOIL

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SUMMARY

Aerodynamic characteristics of a rectangular NACA 23012 airfoil with single and double perforated split flaps have been determined in the NACA 7- by 10-foot wind tunnel. A large range of flap spans and deflections and a large range of spanwise and chordwise locations of the flaps were investigated. Dynamic pressure surveys were made behind the wing at the approximate location of the tail, in order to determine the extent and location of the wake for each flap arrangement. Tests were also made with a full-span plain flap to determine the effect of the various split-flap arrangements on aileron control.

The results indicated that single or double perforated split flaps may be used to obtain satisfactory dive control without undue buffeting effects, and that while lateral control may be obtained with a plain aileron behind single split flaps, the aileron is effectively blanketed and rendered useless behind double split flaps. Additional tests are recommended to develop a satisfactory lateral-control device for use with the perforated double split flaps.

INTRODUCTION

The NACA has undertaken an extensive investigation for the purpose of developing devices suitable for limiting the diving speeds of airplanes. As a part of this investigation, a study has been made of test results obtained during the development of devices designed primarily for other purposes, such as high lift or lateral control, but which may also be used for dive control. The slot-lip aileron combined with a full-span slotted flap is one of

these dual-purpose devices and data for its use have been presented in reference 1. A study has also been made of a large amount of uncorrelated data on various airfoil-flap combinations from tests previously made for the Bureau of Aeronautics. This study indicated that perforated double split flaps would give the desired characteristics for use as dive-control devices. The present investigation was made to determine in more detail the aerodynamic characteristics of various arrangements of single and double split flaps on a rectangular NACA 23012 airfoil, and to determine the wake characteristics of these devices in order that designers may more closely evaluate their effects on the performance of complete airplanes.

APPARATUS AND TESTS

Model

The airfoil model used (fig. 1) was of laminated mahogany built to the NACA 23012 profile. The model was rectangular in plan form with an aspect ratio of 6. (10-in. chord and 60-in. span). The perforated split flaps were made of sheet steel and had a chord of 2 inches (20 percent of the airfoil chord). The perforations in the flaps were symmetrically spaced circular holes (see flap detail, fig. 1) and removed 33.1 percent of the original flap area. In order to facilitate partial span-flap tests, each flap was made in ten equal segments, each segment having a span of 20 percent of the wing semispan. The segments on each semispan were numbered from 1 to 5 progressively from the plane of symmetry outboard to the wing tip. Split-flap deflections were measured with respect to the airfoil surface at the flap hinge point, and except where otherwise specified the gap between the airfoil and flap was sealed with modeling clay. The 20-percent chord plain flap was built of laminated mahogany and the gap between the airfoil and flap was sealed with cellulose tape. Plain-flap deflections were measured with respect to the airfoil chord line.

Wind Tunnel and Equipment

The tests were made in the closed-throat NACA 7- by 10-foot wind tunnel described in references 2 and 3. The wake surveys were made with a rake of eight $\frac{3}{8}$-inch pitot tubes spaced 2 inches. The rake was adjustable so

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that dynamic pressure could be recorded at 1-inch intervals along a vertical line 27 inches long which was located 30 inches (3.0c) behind the quarter-chord point of the airfoil and 5 inches (0.5c) to the right of the plane of symmetry. This position was believed to be representative of the location of the hinge line and midpoint of the semispan of the horizontal tail surfaces of airplanes on which dive-control devices would be used. The ratio of the dynamic pressures in the wake to the dynamic pressures at the same points with the model removed (support strut in place) were determined from readings of an inclined-tube alcohol manometer.

Figure 2 is a three-quarter rear view of the model mounted in the wind tunnel.

Tests

Test conditions.- The dynamic pressure maintained for all tests was 16.37 pounds per square foot, which corresponds to a velocity of about 80 miles per hour under standard sea-level conditions and to an average test Reynolds number of 609,000 based on the chord of the model (10 in.).

Test procedure.- The tests consisted of the determination of the lift, drag, and pitching-moment coefficients and of the wake characteristics for various deflections and locations of the flaps. Double split flaps were located 60 and 80 percent of the chord from the airfoil leading edge, and single split flaps (lower-surface) were located 10, 20, 30, 40, 60, and 80 percent of the chord from the airfoil leading edge. In addition, several tests were made with the full-span 20-percent-chord plain flap deflected $\pm 20^{\circ}$ to determine the effects of the various split-flap arrangements on aileron control. The forces and moments were determined at intervals of 2° throughout the angle-of-attack range from below zero lift to above maximum lift. The wake surveys were made at intervals of 4° throughout the same range.

RESULTS AND DISCUSSION

In the presentation of results, the following symbols are used:

C_L lift coefficient, $\frac{L}{q_o S}$

C_D drag coefficient, $\frac{D}{q_o S}$

$C_{m_{c/4}}$ pitching-moment coefficient about the quarter-chord point of the airfoil chord, $\frac{m}{q_o c S}$

q/q_o dynamic pressure ratio

where

L lift

D drag

m pitching moment

q dynamic pressure at point in wake, $\frac{1}{2} \rho V^2$

q_o average dynamic pressure for air stream, $\frac{1}{2} \rho V_o^2$

c airfoil chord

c_f flap chord

S airfoil area

b airfoil span

b_f flap span

and

α angle of attack

δ_a plain-flap deflection

δ_{f_U} upper-surface split-flap deflection

δ_{f_L} lower-surface split-flap deflection

the subscript L_o refers to the characteristics at zero lift.

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Since the support-strut interference and tares were relatively small, these corrections were applied only to the plain-airfoil data. The standard jet-boundary corrections which were applied to all the force-test data, are:

$$\Delta\alpha_i = \delta \frac{S}{C} C_L \, 57.3^\circ$$

$$\Delta C_{D_i} = \delta \frac{S}{C} C_L^2$$

where C is the jet cross-sectional area. A value of $\delta = 0.112$ for the closed-throat wind tunnel was used in correcting the results. It should be noted that, owing to the various span-load distributions of the airfoil with the various split-flap arrangements, these corrections are not strictly applicable to all of the data. No correction for tunnel effect has been applied to the wake location. This correction is small because of the relatively small model used.

Double Split Flaps

The aerodynamic and wake characteristics of a rectangular NACA 23012 airfoil with double split flaps located 0.80c from the airfoil leading edge are presented in figures 3a to 7b. The aerodynamic characteristics are presented as curves plotted against lift coefficient; and the wake characteristics are shown as curves of dynamic pressure ratio, q/q_o, plotted against distance above and below the extended chord line of the airfoil.

The results presented in figures 4a and 4b show the effect of the airfoil trailing edge and of the flap perforations on full-span and partial-span double split flaps. Removing the airfoil trailing edge from behind the full-span perforated flaps had practically no effect on the wake or on the aerodynamic characteristics at zero lift but did appreciably increase the available maximum-lift coefficient. Covering the perforations in both full-span and partial-span flaps increased the drag coefficient but caused an unsteady condition of the model which was indicated by the amplitude of the scale deflections, and which was not encountered with the perforated flaps. Perforations which remove an area of about 30 percent of the original area of full-span double split flaps reduce the increment of drag coefficient at zero lift by about 15 percent. These data agree with the previous data mentioned in the

Introduction. Both sets of data indicate also that the increment of drag coefficient caused by unperforated full-span double split flaps at zero lift may be reasonably predicted by the formula:

$$\Delta C_D = 0.0031\ H^{1.35}$$

where H, in percent wing chord, is the total projected frontal height of the airfoil and flaps.

Various partial-span arrangements of the double split flaps (figs. 5a through 7b) were tested in an attempt to increase the total drag by utilizing induced drag, to increase the maximum-lift coefficient available for the pull-out, and to lower the wake in order to keep the horizontal tail surface out of the disturbed air flow. The drag and maximum-lift coefficients were not appreciably affected but the wake characteristics were definitely improved.

Since the aerodynamic characteristics at and near zero lift were considered of particular interest to the designer, the results from figures 6a and 7a were replotted against flap span in figure 8a. The partial-span center-section flaps gave higher drag and higher maximum-lift coefficients than the tip-section flaps at the same angle of attack and pitching-moment coefficient. The increment of drag coefficient was approximately proportional to the flap span. The center-section flaps naturally produced a larger wake in the region of the tail surfaces than did the tip-section flaps. This effect can be seen in figure 8b, which is a series of envelopes, from the angle of attack for zero lift to near the angle of attack for maximum lift, of the wake curves of figures 1b, 1c, 6b, and 7b.

The aerodynamic and wake characteristics of the rectangular NACA 23012 airfoil with full-span and partial-span perforated double split flaps located 0.60c from the airfoil leading edge are presented in figures 9a and 9b. These results show that moving the flaps forward increased the drag coefficient, due to the increased frontal projection, but that the available maximum-lift coefficient was considerably reduced. Because of the large reduction in maximum lift with the movement of the flap forward, no further tests were made with an upper-surface flap forward of the 0.80c location.

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Single Split Flaps

The aerodynamic and wake characteristics of a rectangular NACA 23012 airfoil with lower-surface perforated split flaps located at 0.10c, 0.20c, and 0.30c from the airfoil leading edge are presented in figures 10a to 13b. The use of these flaps produced a large change in the angle of attack for zero lift.

An attempt was made to decrease the change in angle of attack for zero lift by introducing a gap between the airfoil surface and the flap (fig. 14a). The presence of the gap decreased the angle-of-attack change and had no appreciable effect on the other aerodynamic characteristics. One test (fig. 14a) with two-thirds of the perforations covered, produced the same results previously noted in the discussion of the double split flaps: an increase in the drag coefficient, but also a definitely unsteady condition of the model.

The results of the tests, with a 0.10c gap between airfoil surface and flap, with the flap located 0.40c, 0.60c, and 0.80c from the airfoil leading edge are given in figures 15a to 16b. Moving the flap had little effect on the angle of attack for zero lift, but as the flap was moved back the maximum-lift and negative pitching-moment coefficients increased and the drag coefficient at zero lift decreased.

Another attempt was made to improve the characteristics of the airfoil with the flap located at 0.40c with a 0.10c gap by deflecting the trailing-edge plain and upper-surface perforated split flaps (figs. 17a and 17b). The use of either of these trailing-edge flaps changed the angle of attack for zero lift from a large negative value to a small positive value and increased the drag coefficient slightly. The trailing-edge flap, however, decreased the maximum-lift coefficient, increased the positive pitching-moment coefficient, and raised the wake so that it was nearer the location of the tail surfaces. The advantages of the system could probably be realized without encountering the disadvantages by using partial-span tip-section upper-surface perforated split flaps, or by up-rigging a plain, plug-type, slot-lip, or upper-surface aileron.

The results of tests of various partial-span arrangements of the lower-surface perforated split flap located at 0.40c with a 0.10c gap are presented in figures 18a

through 20b. Since the characteristics at and near zero lift were considered of particular interest to the designer, the results from figures 19a and 20a were replotted against flap span in figure 21a, and the wake-curve envelopes are presented in figure 21b. The single split flap was similar to the double split flaps, in that the increment of drag coefficient due to the flaps was approximately proportional to flap span and in that the tip-section flap gave much smaller wakes in the region of the tail. Unlike the double split flaps, the tip-section single split flap gave slightly better aerodynamic characteristics than did the center-section flaps.

The results in figures 10a through 21a indicated that the formula developed for the prediction of drag coefficients due to the double split flaps was not directly applicable to the single split flaps.

Diving Speed

The relationship between drag coefficient, wing loading, and indicated velocity for an airplane in a vertical dive is shown in figure 22. For other diving angles, the velocity given on the chart should be multiplied by the square root of the sine of the diving angle, referred to the horizontal. From this chart and the data in figures 3a through 21a, it may be shown that the use of full-span perforated double split flaps would probably limit to 200 miles per hour the indicated diving speed of an airplane with a wing loading of 35 pounds per square foot, and limit to 250 miles per hour the diving speed of an airplane with a wing loading of 55 pounds per square foot. Corresponding values obtained with the use of perforated single split flaps are: 200 miles per hour for a wing loading of 30 pounds per square foot, and 250 miles per hour for a wing loading of 45 pounds per square foot.

Aileron Control

Tests were made to determine the effect of the perforated double split flaps on the lateral control available from a plain aileron by deflecting a full-span plain flap behind the double split flaps. The results of these tests when compared with the results of tests of the plain flap on the plain airfoil indicated that the double split flaps would effectively blanket a plain aileron and render it

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useless for obtaining lateral control. (See figs. 23, 24, and 25.) One interesting possibility for obtaining lateral control for a wing equipped with double split flaps is suggested by the results (fig. 3a) of tests made with differential deflections of the two flaps. If the outboard portions of the double split flaps were mounted on the regular ailerons, the regular aileron system would provide lateral control. The lower-surface flap could be deflected to a higher angle than the upper-surface flap in order to obtain an upfloating tendency which, when used with a differential aileron linkage, would tend to reduce the high aileron-operating forces that might otherwise be encountered.

The results presented in figures 23, 26a, and 27 indicate that a perforated lower-surface flap with a 0.10c gap between the airfoil surface and the flap has little or no detrimental effect on the lateral control to be obtained from a plain aileron.

CONCLUDING REMARKS

The data presented indicate that double or single split flaps may be used to provide satisfactory dive control without undue buffeting effects if the flap area is reduced about 30 percent by perforations.

While the lateral control available from a plain aileron appeared to be practically unaffected by a perforated lower-surface split flap with a gap between the airfoil surface and flap, the aileron was effectively blanketed and rendered useless when behind the perforated double split flaps. Additional tests are recommended to develop a lateral control device for use with the perforated double split flaps.

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REFERENCES

1. Rogallo, F. M.: Aerodynamic Characteristics of a Slot-Lip Aileron and Slotted Flap for Dive Brakes. NACA ACR, April 1941.

2. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the National Advisory Committee for Aeronautics. NACA Rep. No. 412, 1931.

3. Wenzinger, Carl J., and Harris, Thomas A.: Wind-Tunnel Investigation of an N.A.C.A. 23012 Airfoil with Various Arrangements of Slotted Flaps. NACA Rep. No. 664, 1939.

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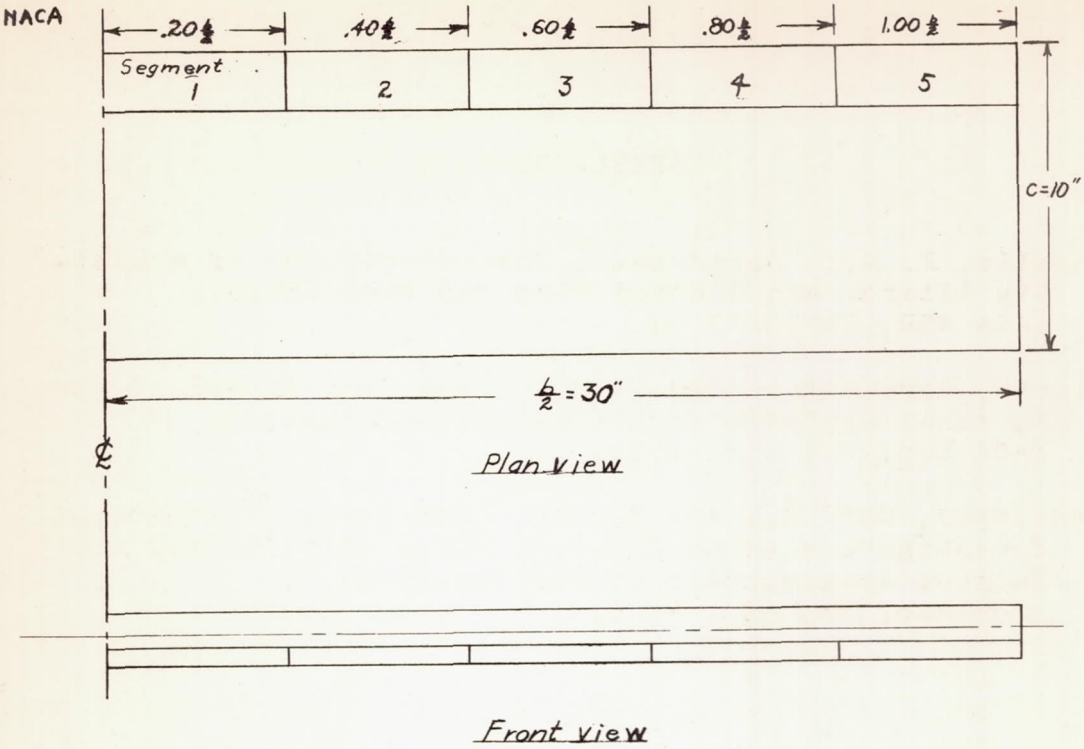

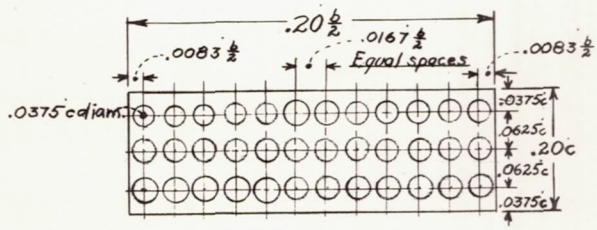

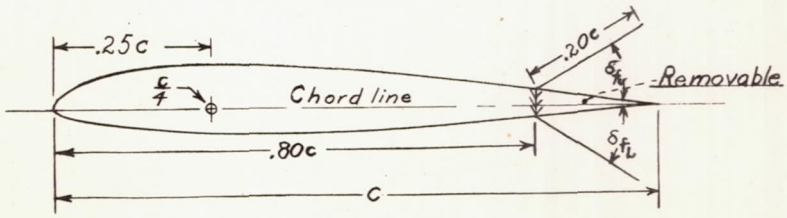

FIGURE 1 - 10-by 60-inch rectangular NACA 23012 airfoil with 0.20c perforated split flaps. Perforations remove 33.1 percent of the original flap area.

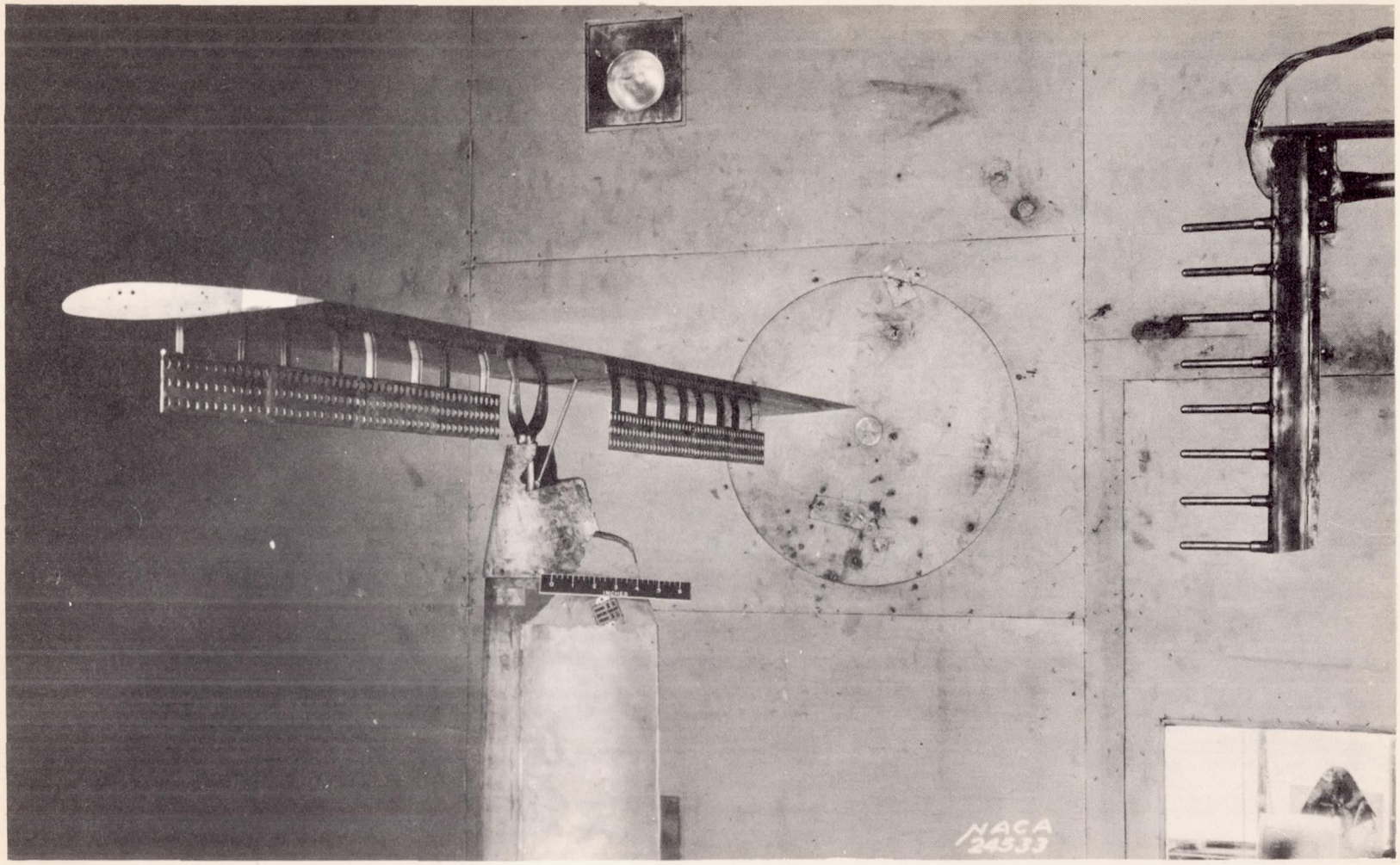

Figure 2.- Three-quarter rear view of the 10- by 60- inch rectangular NACA 23012 airfoil with a 0.20c, 80- percent- span tip- section perforated split flap located 0.40c from the wing leading edge mounted in the NACA 7- by 10- foot wind tunnel. Gap between wing surface and flap, 0.10c; δ_{f_L}, 90°.

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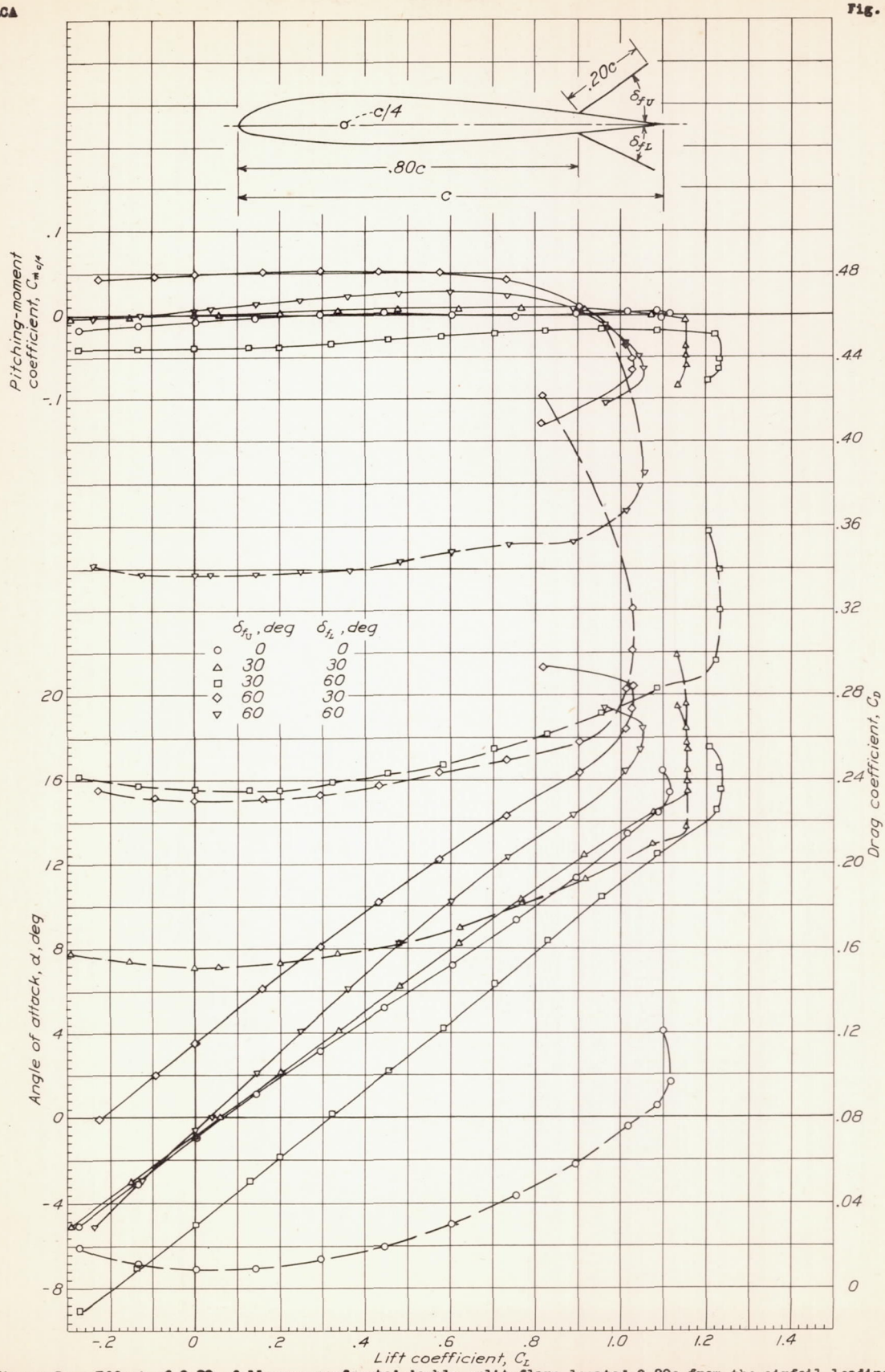

Figure 3a.- Effect of 0.20c full-span perforated double split flaps located 0.80c from the airfoil leading edge on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil.

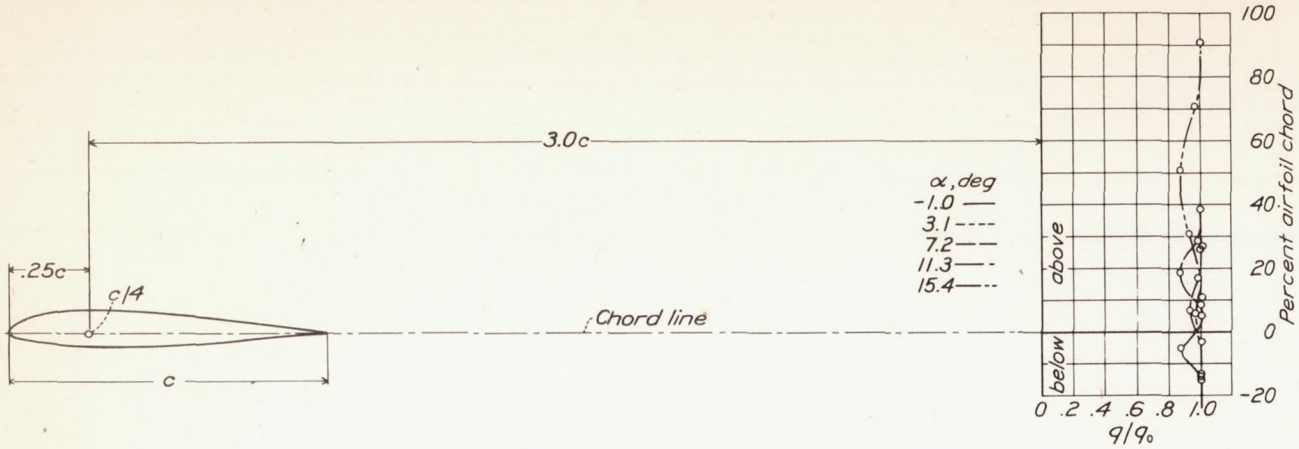

Figure 3b.- Wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil.

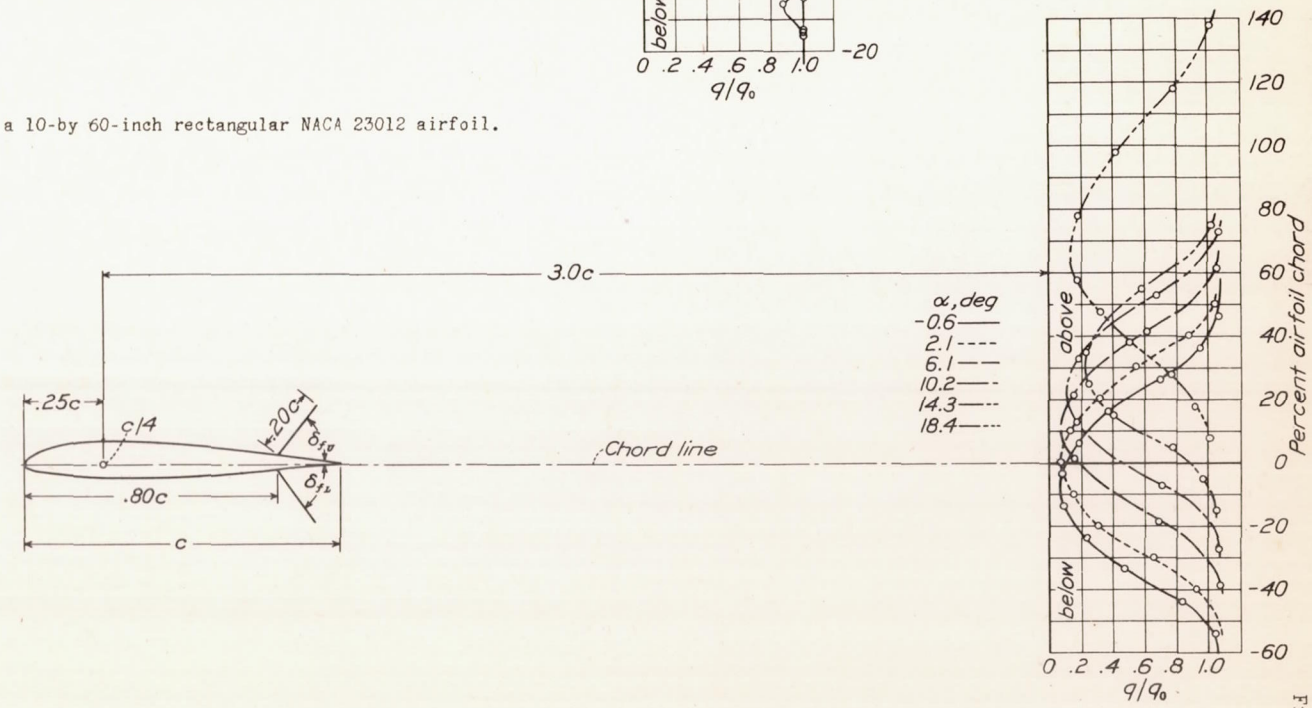

Figure 3c.- Wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with 0.20c full-span perforated double split flaps located 0.80c from the airfoil leading edge. $\delta_{f_U}, 60^\circ; \delta_{f_L}, 60^\circ$.

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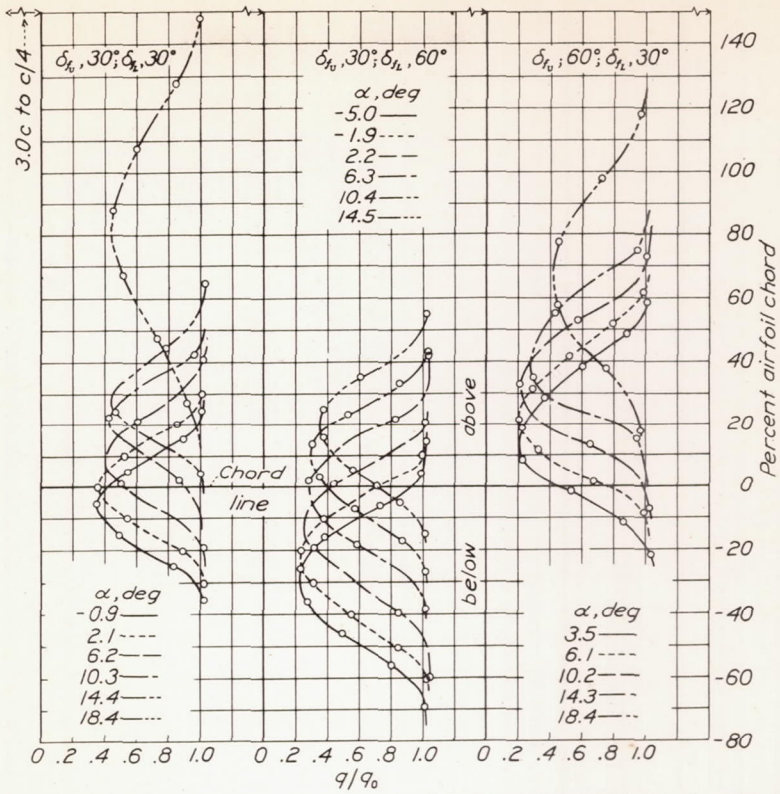

Figure 3d.- Effect of 0.20c full-span perforated double split flaps located 0.80c from the airfoil leading edge on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil.

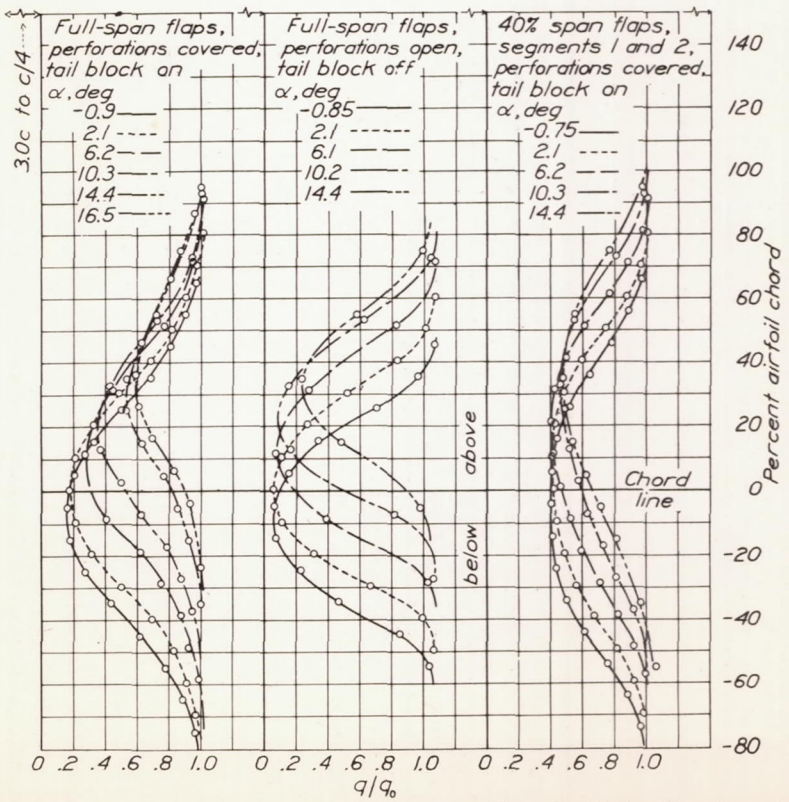

Figure 4b.- Effect of flap perforations on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with double split flaps located 0.80c from the airfoil leading edge. δ_{f_U},60°,δ_{f_L},60°.

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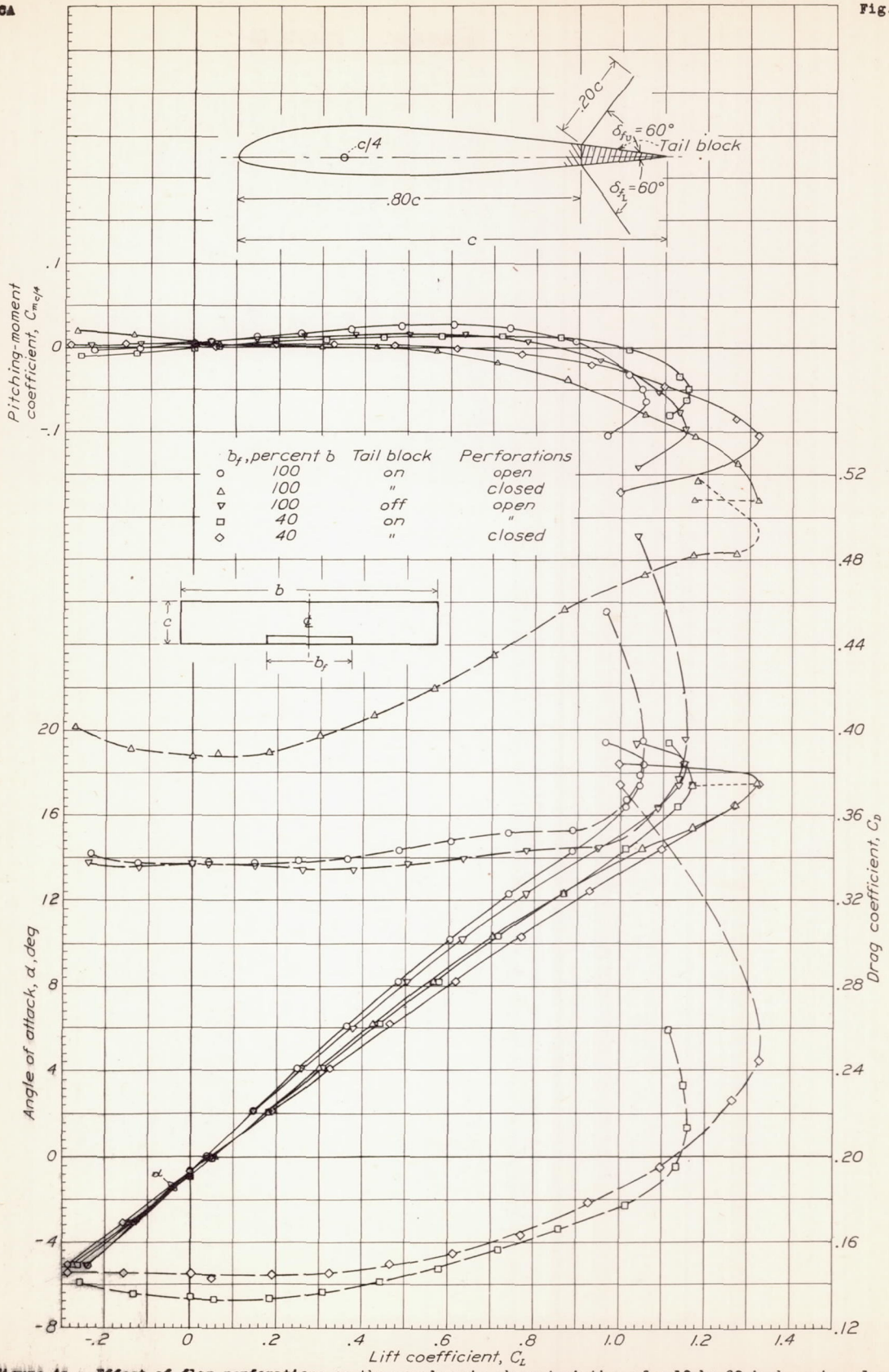

Figure 4a.- Effect of flap perforations on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with double split flaps located 0.80c from the airfoil leading edge. δ_{f_U},60°; δ_{f_L},60°.

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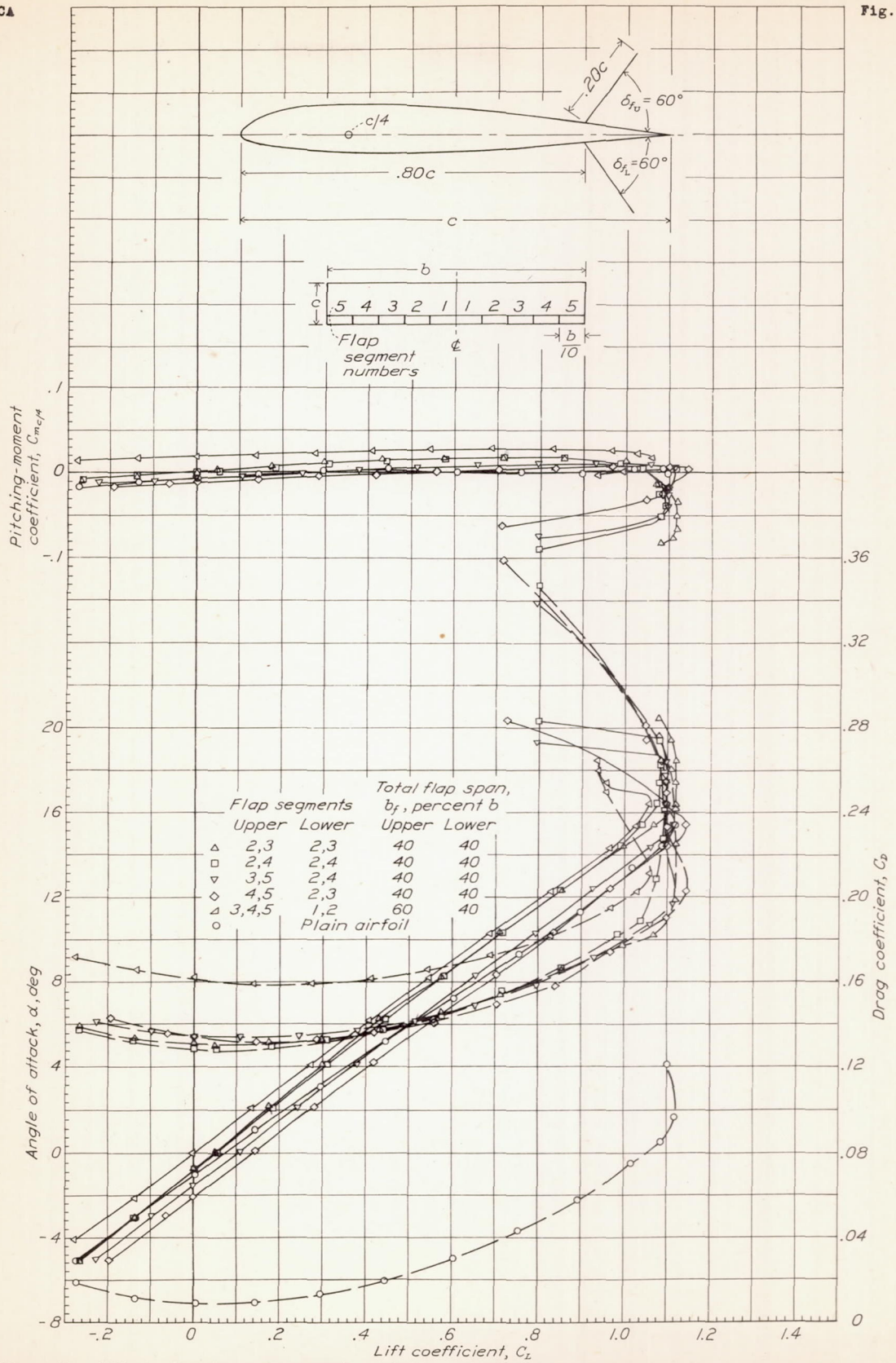

Figure 5a.- Effect of various arrangements of 0.20c partial-span perforated double split flaps located 0.80c from the airfoil leading edge on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. δ_{f_U},60°; δ_{f_L},60°.

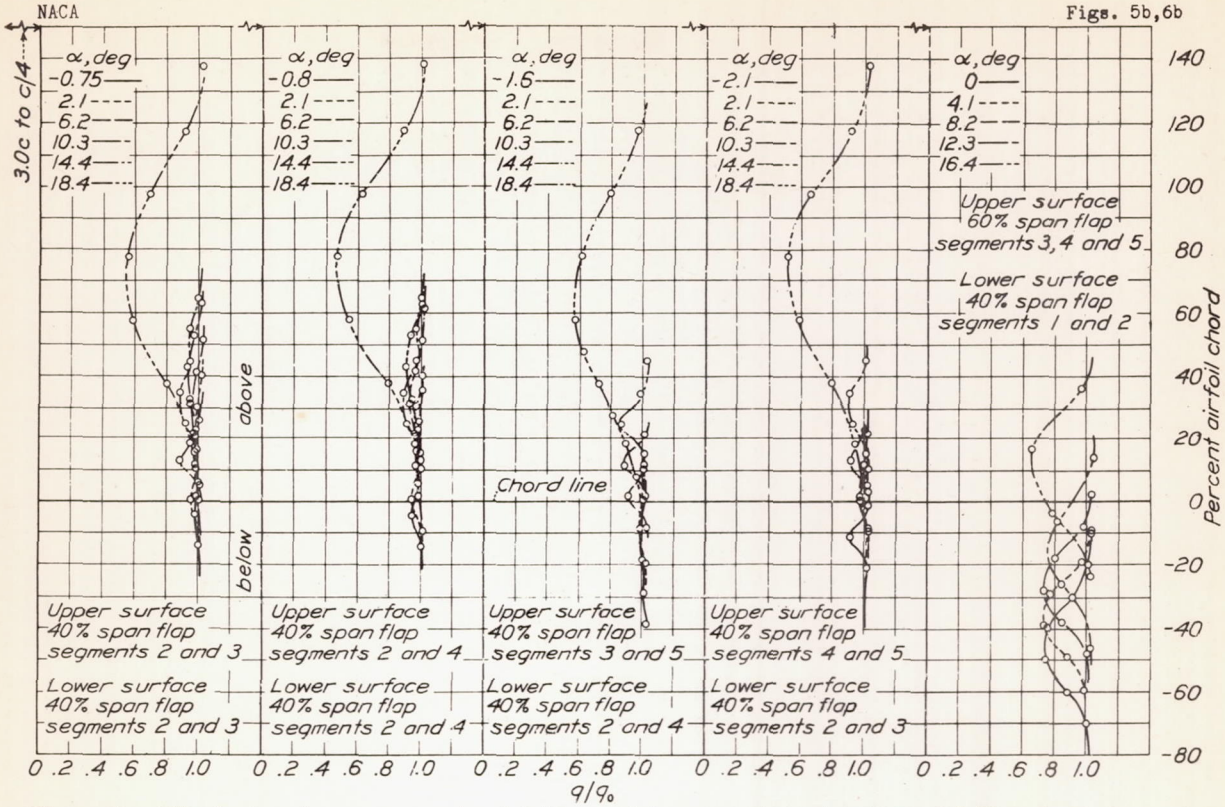

Figure 5b.- Effect of various arrangements of 0.20c partial-span perforated double split flaps located 0.80c from the airfoil leading edge on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. $\delta_{f_U},60^\circ;\delta_{f_L},60^\circ$.

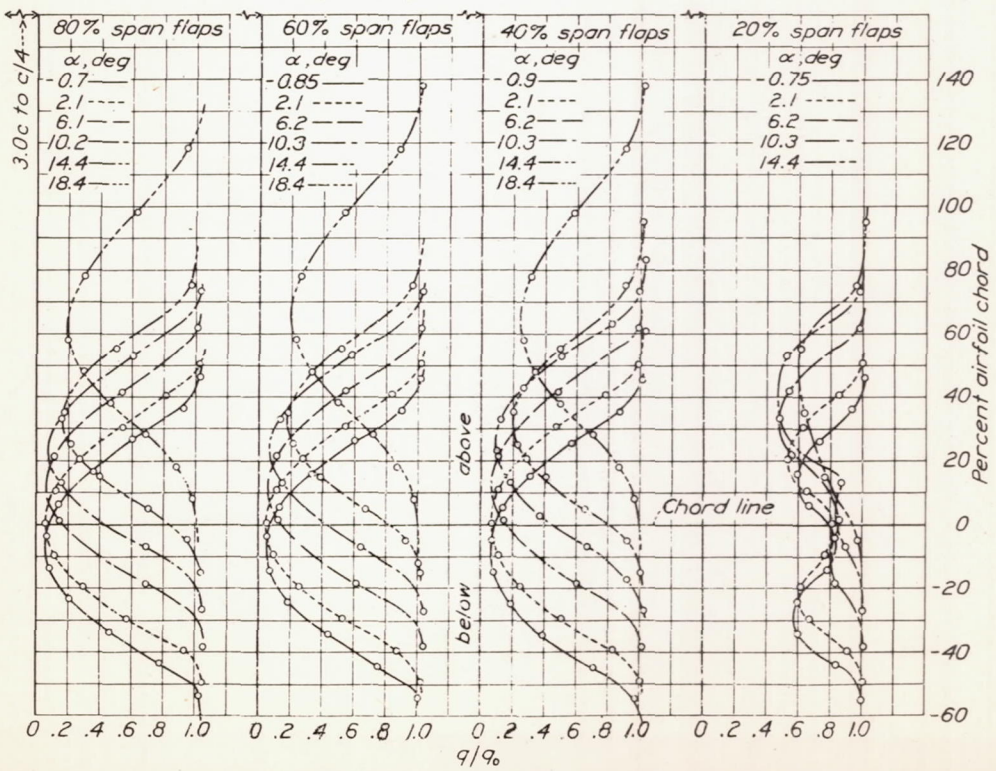

Figure 6b.- Effect of 0.20c partial span center-section perforated double split flaps located 0.80c from the airfoil leading edge on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. $\delta_{f_U},60^\circ;\delta_{f_L},60^\circ$

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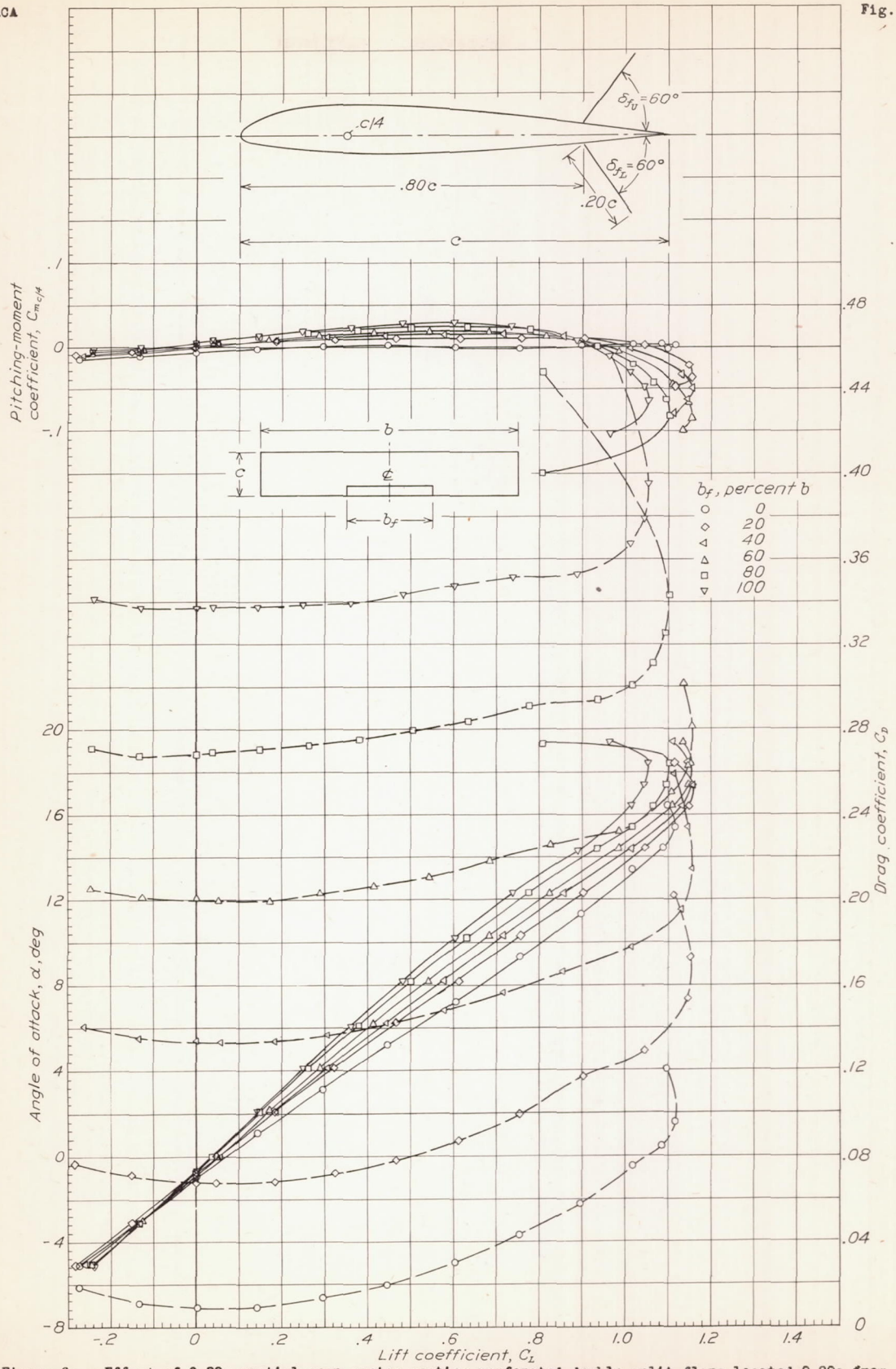

Figure 6a.- Effect of 0.30c partial-span center-section perforated double split flaps located 0.80c from the airfoil leading edge on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. δ_{f_U},60°;δ_{f_L},60°.

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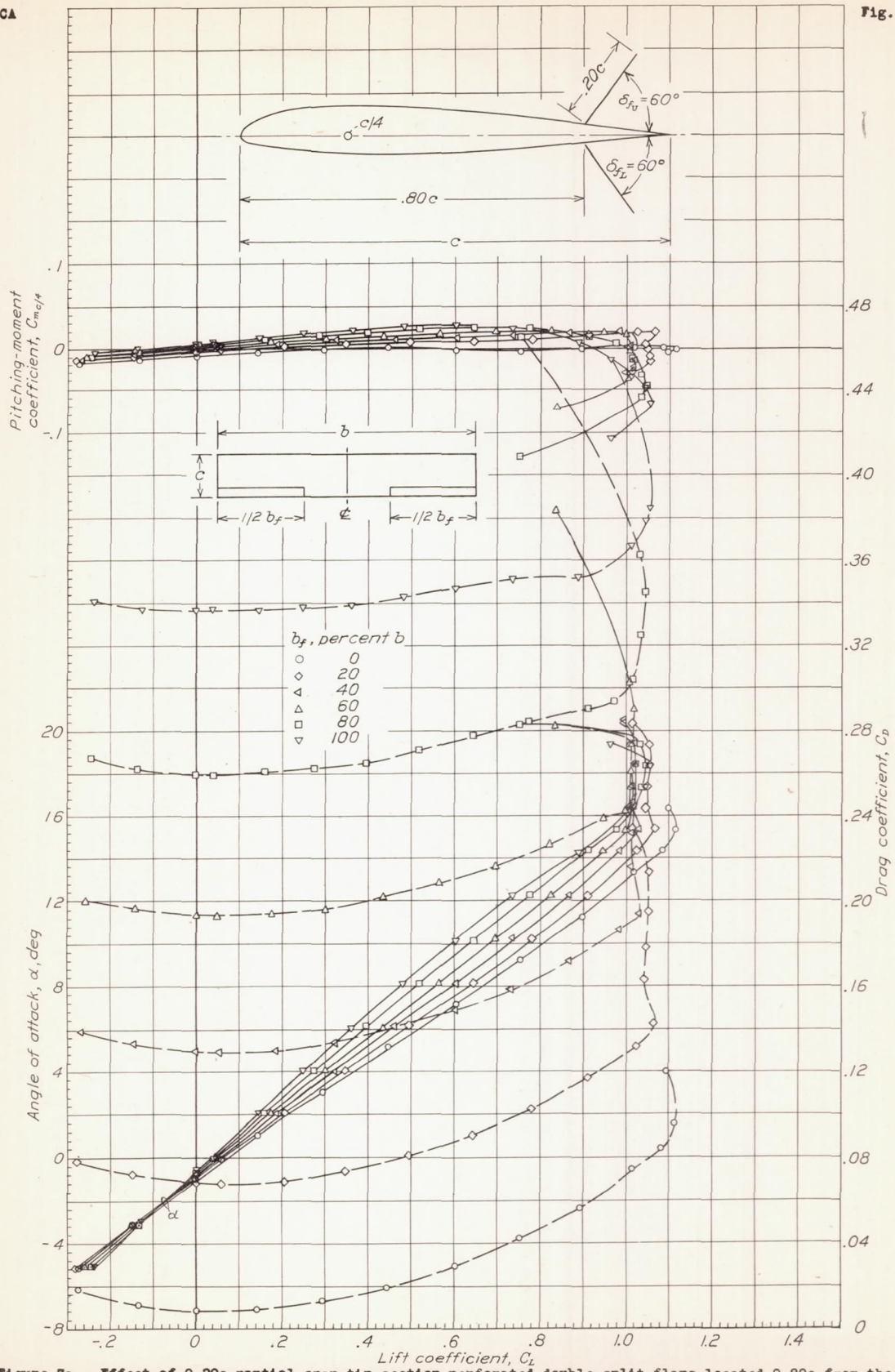

Figure 7a.- Effect of 0.20c partial-span tip-section perforated double split flaps located 0.80c from the airfoil leading edge on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. δ_{f_U},60°;δ_{f_L},60°.

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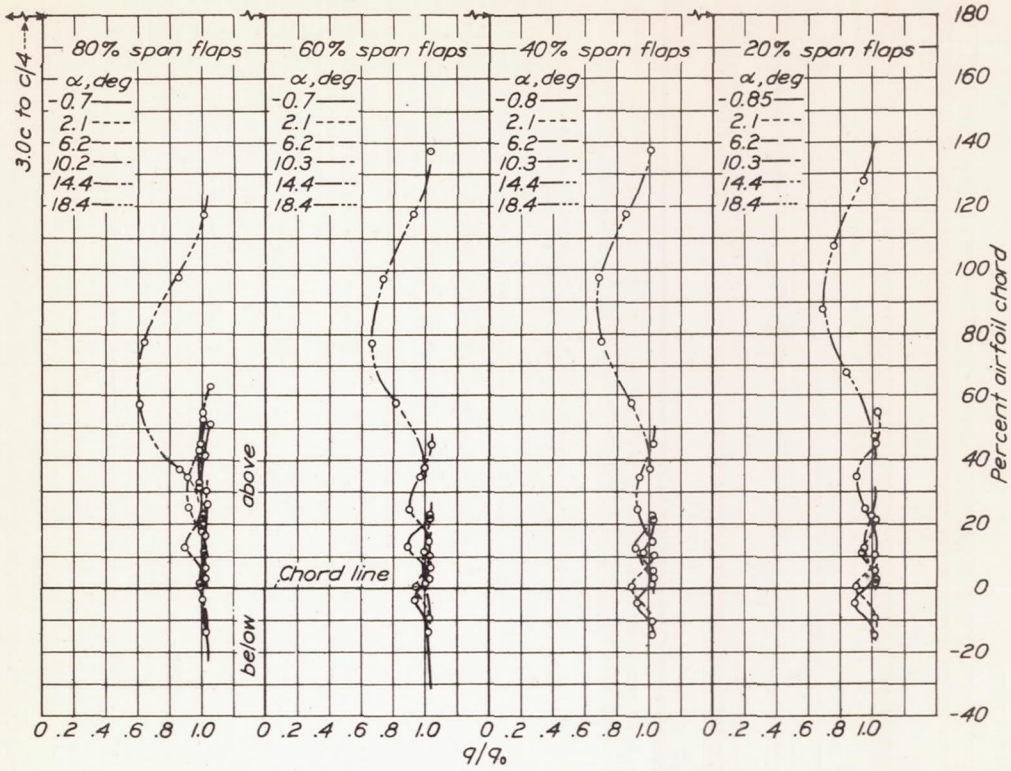

Figure 7b.- Effect of 0.20c partial-span tip-section perforated double split flaps located 0.80c from the airfoil leading edge on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. $\delta_{f_U}, 60^\circ, \delta_{f_L}, 60^\circ$.

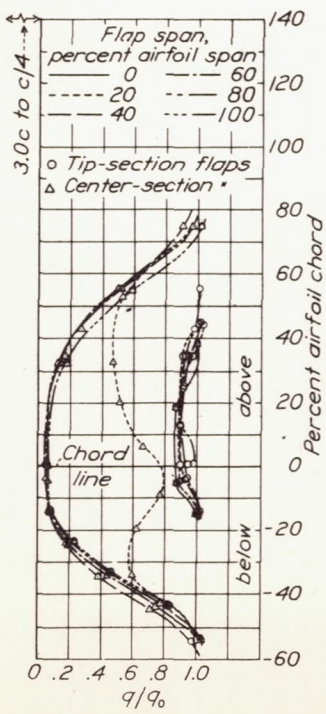

Figure 8b.- Effect of flap span on the envelopes of the wake curves below the stall of a 10-by 60-inch rectangular NACA 23012 airfoil with 0.20c perforated double split flaps located 0.80c from the airfoil leading edge. $\delta_{f_U}, 60^\circ$; $\delta_{f_L}, 60^\circ$.

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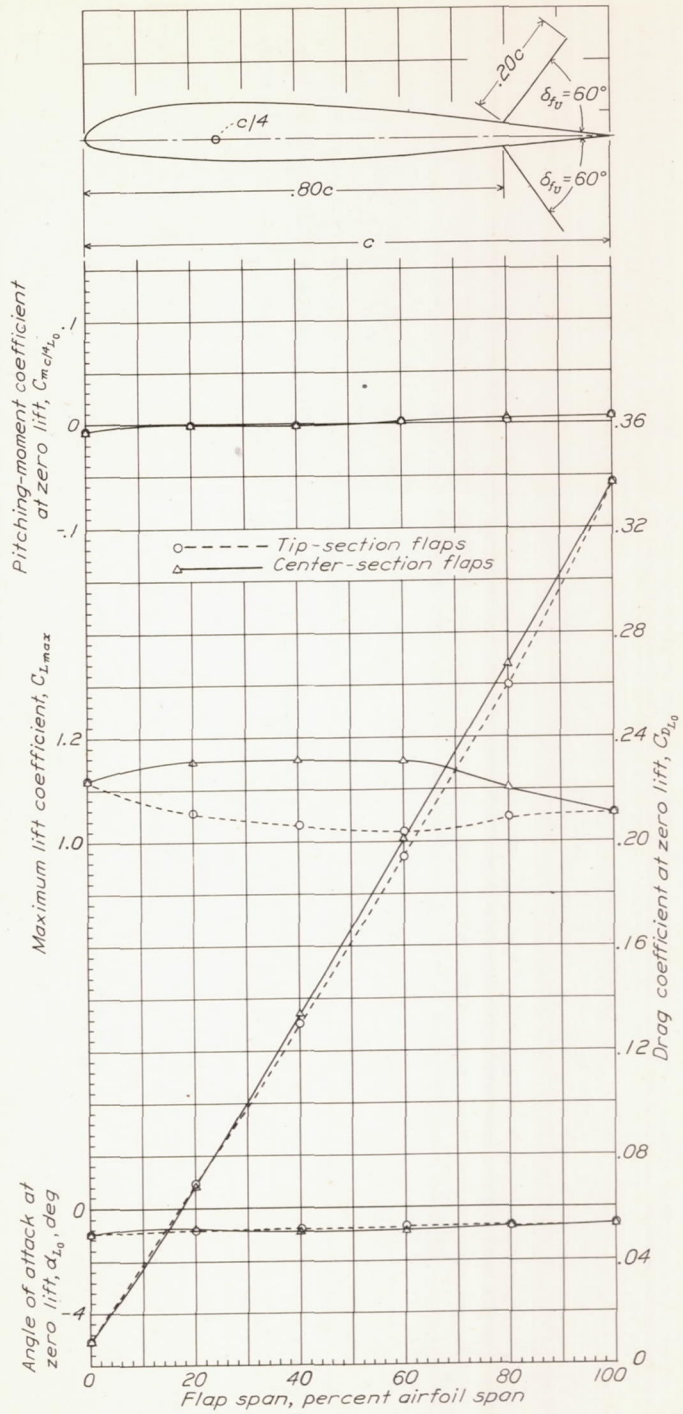

Figure 8a.- Effect of flap span on some of the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with 0.20c perforated double split flaps located 0.80c from the airfoil leading edge. δ_{f_U},60°;δ_{f_L},60°.

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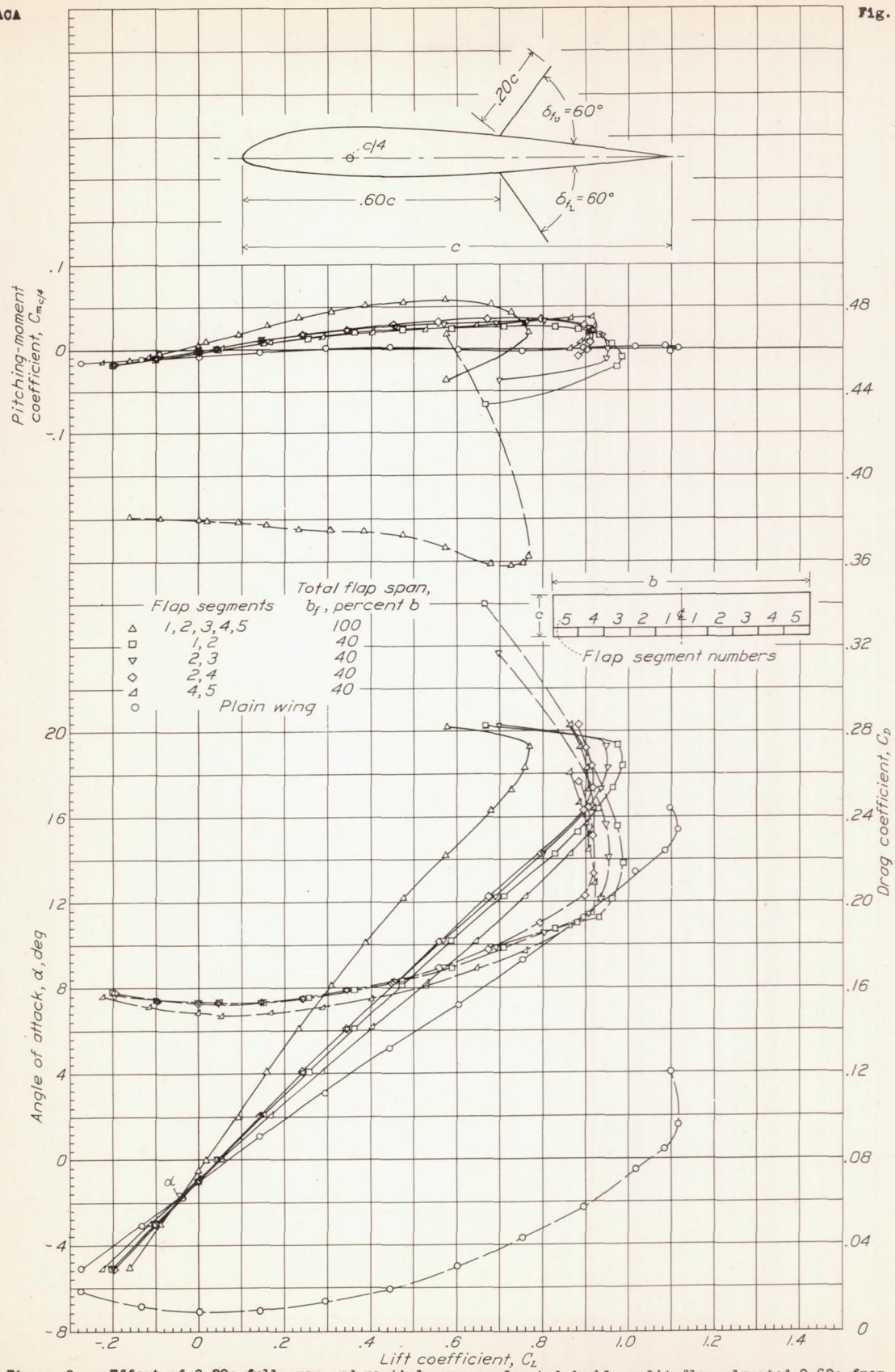

Figure 9a.- Effect of 0.20c full-span and partial-span perforated double split flaps located 0.60c from the airfoil leading edge on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. δ_{f_U},60°;δ_{f_L},60°.

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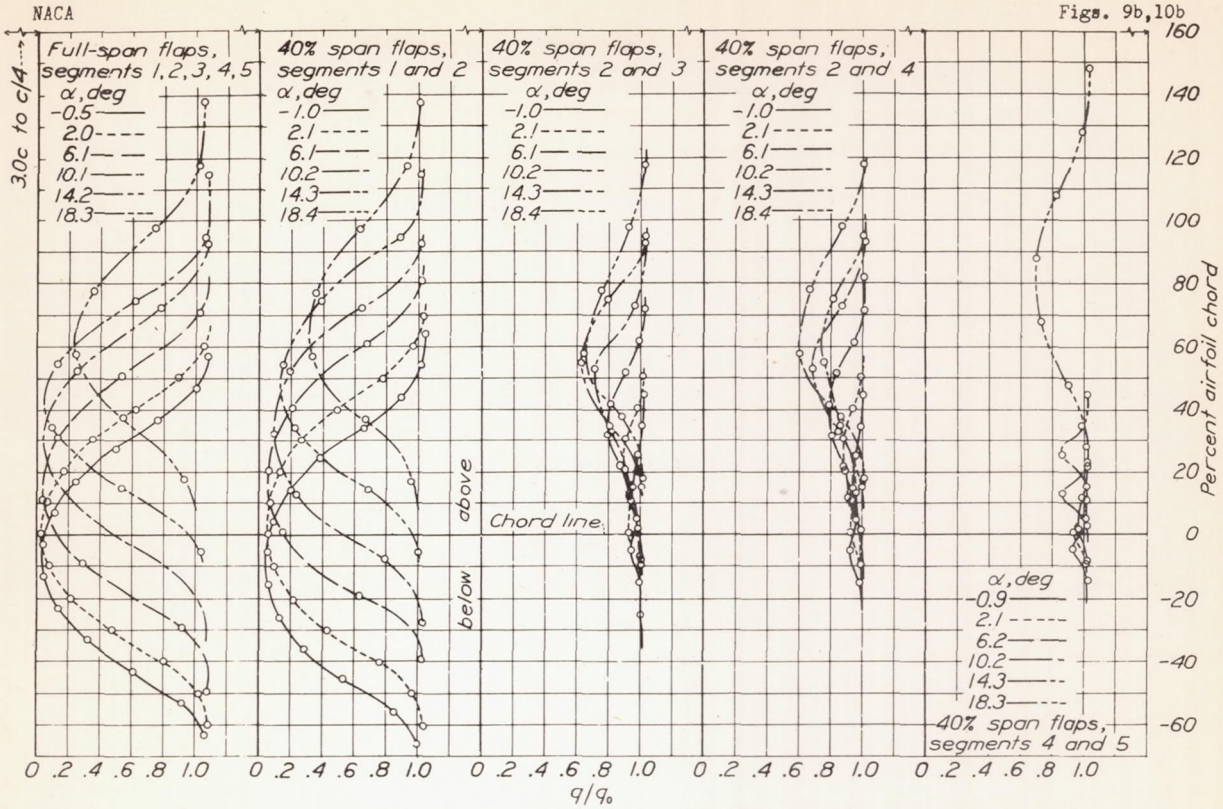

Figure 9b.- Effect of 0.20c full-span and partial-span perforated double split flaps located 0.60c from the airfoil leading edge on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. $\delta_{f_U}, 60°; \delta_{f_L}, 60°$.

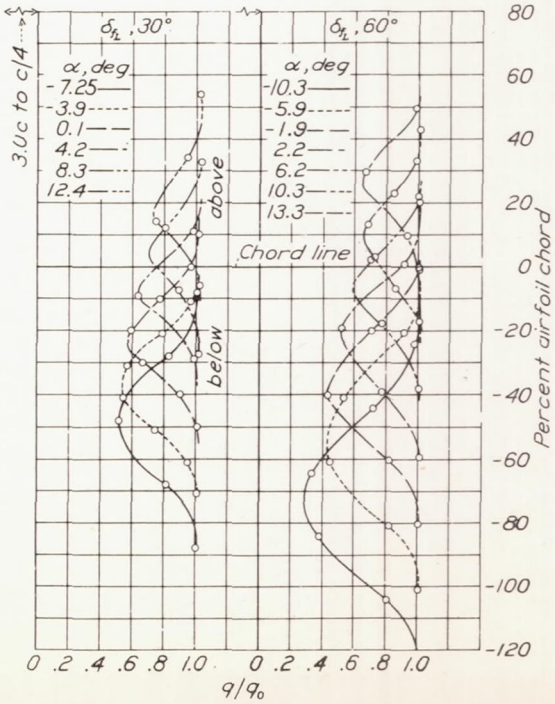

Figure 10b.- Effect of a 0.20c full-span perforated single split flap located 0.10c from the airfoil leading edge on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil.

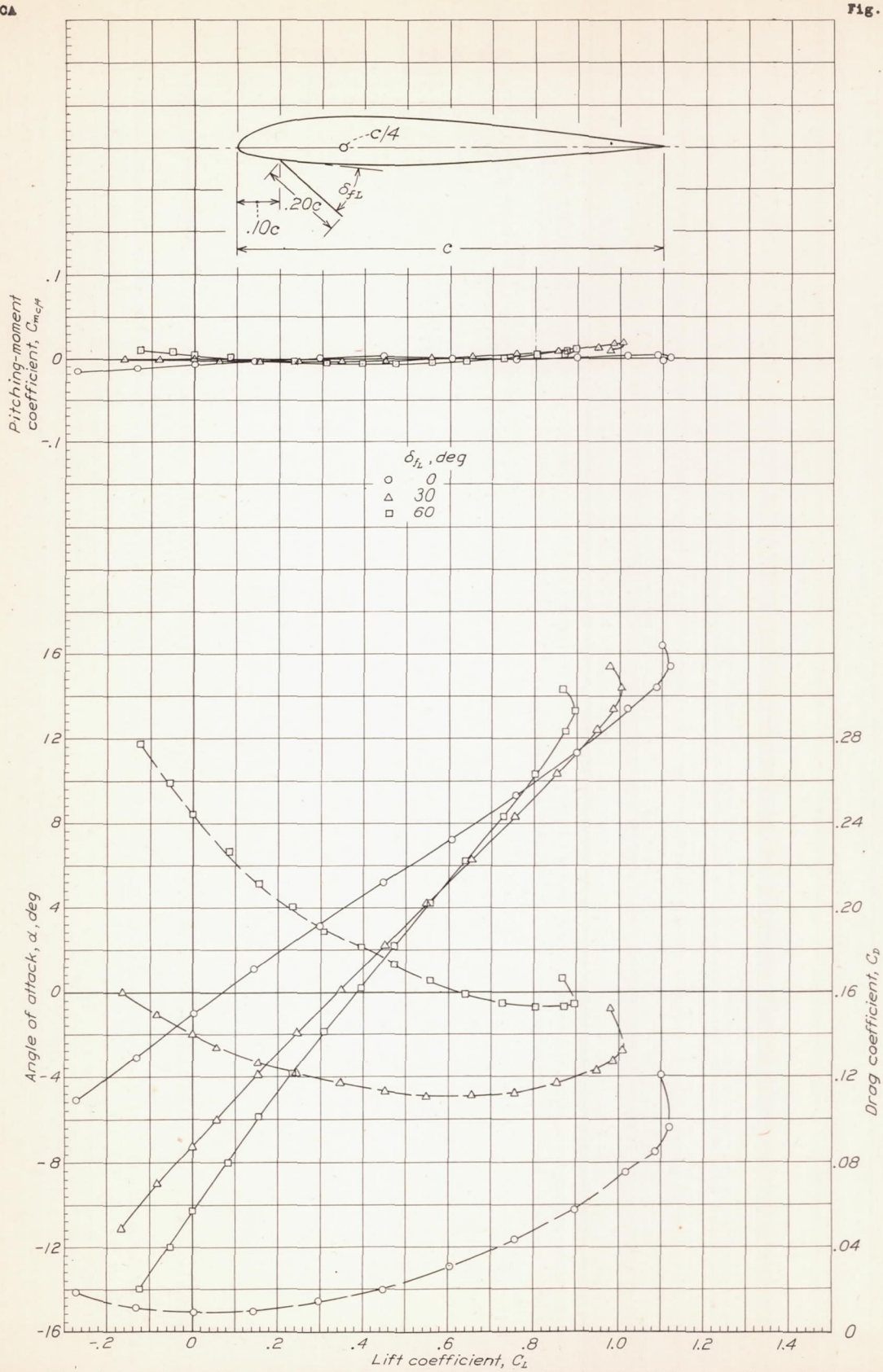

Figure 10a.- Effect of a 0.20c full-span perforated single split flap located 0.10c from the airfoil leading edge on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil.

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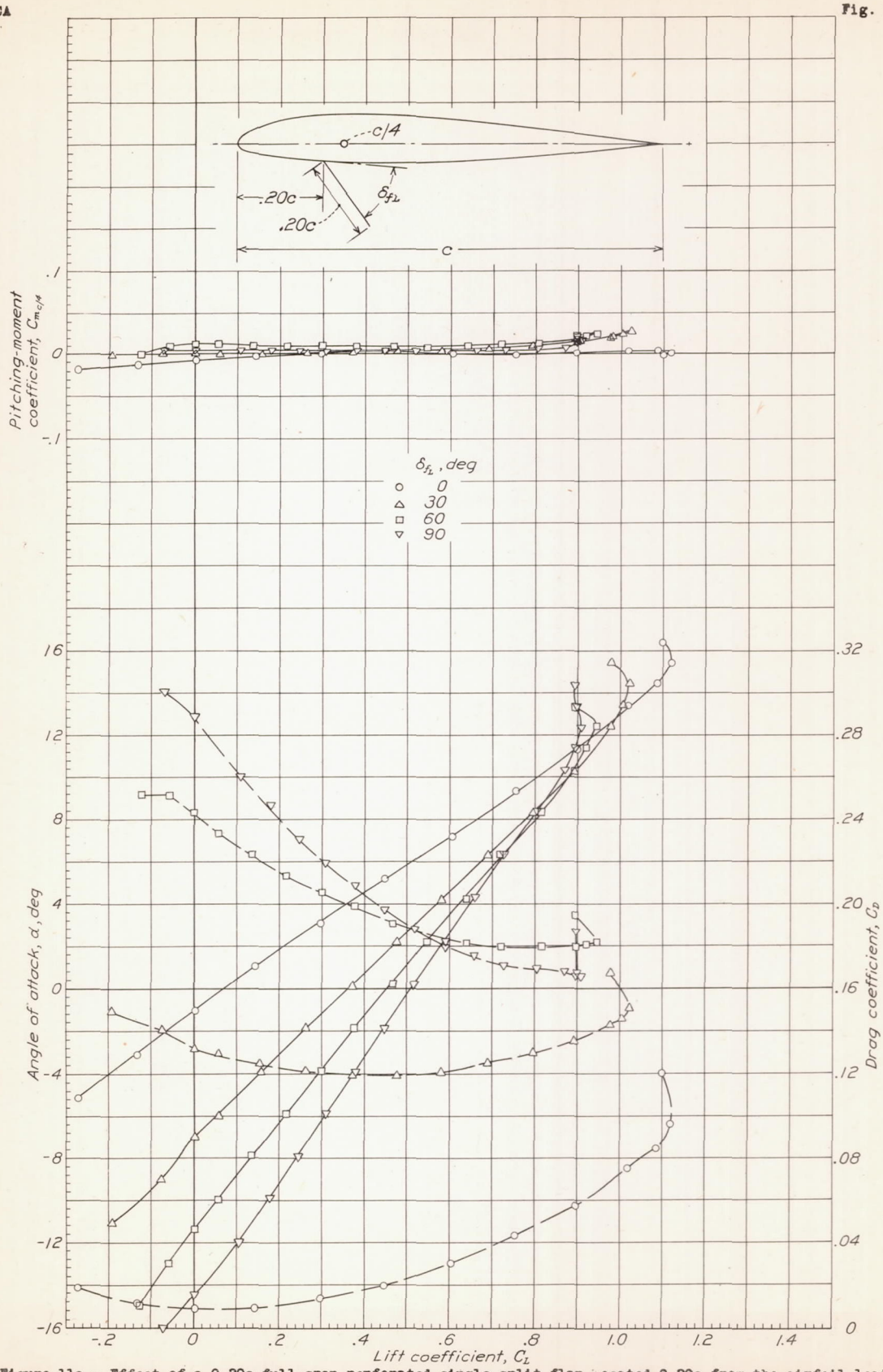

Figure 11a.- Effect of a 0.20c full-span perforated single split flap located 0.20c from the airfoil leading edge on the aerodynamic characteristics of a 10- by 60-inch rectangular NACA 23012 airfoil.

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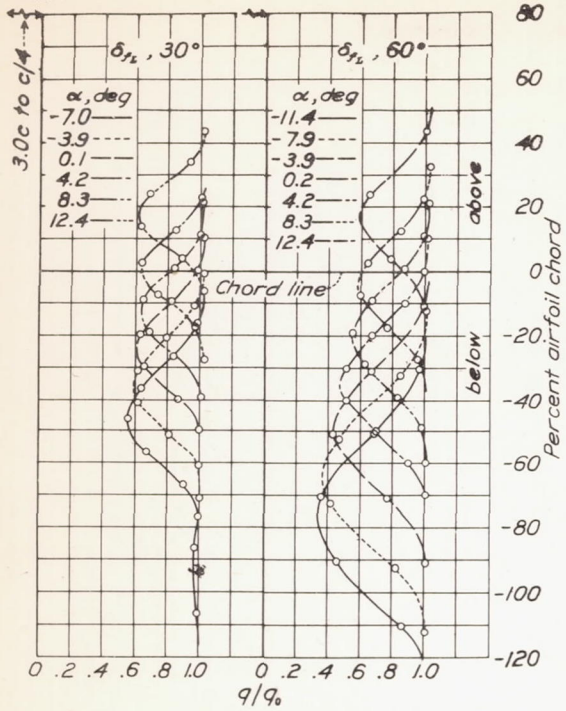

Figure 11b.- Effect of a 0.20c full-span perforated single split flap located 0.20c from the airfoil leading edge on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil.

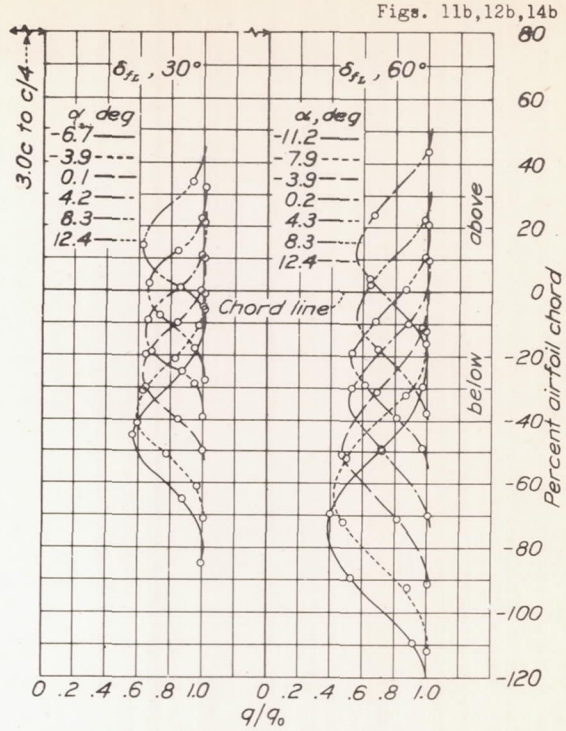

Figure 12b.- Effect of a 0.20c perforated single split flap located 0.30c from the airfoil leading edge on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil.

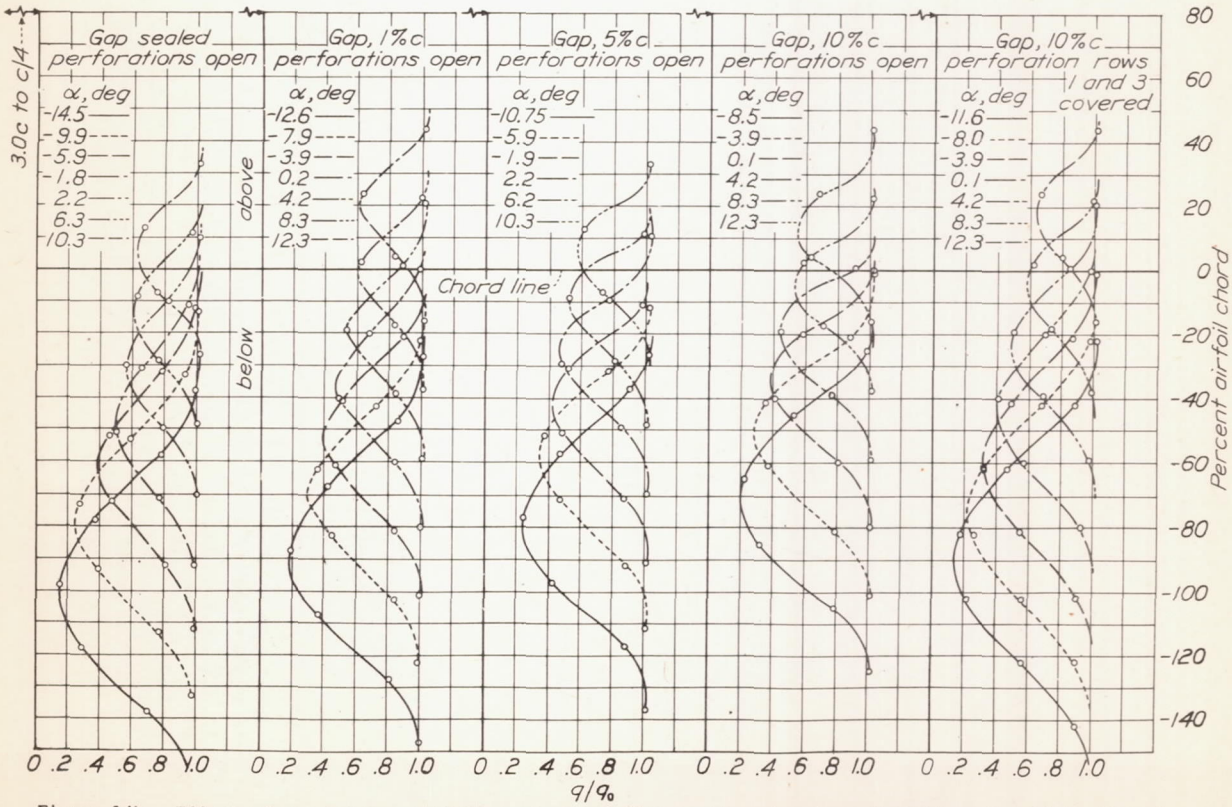

Figure 14b.- Effect of gap between airfoil surface and flap on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated single split flap located 0.20c from the airfoil leading edge. δ_{f_L},90°.

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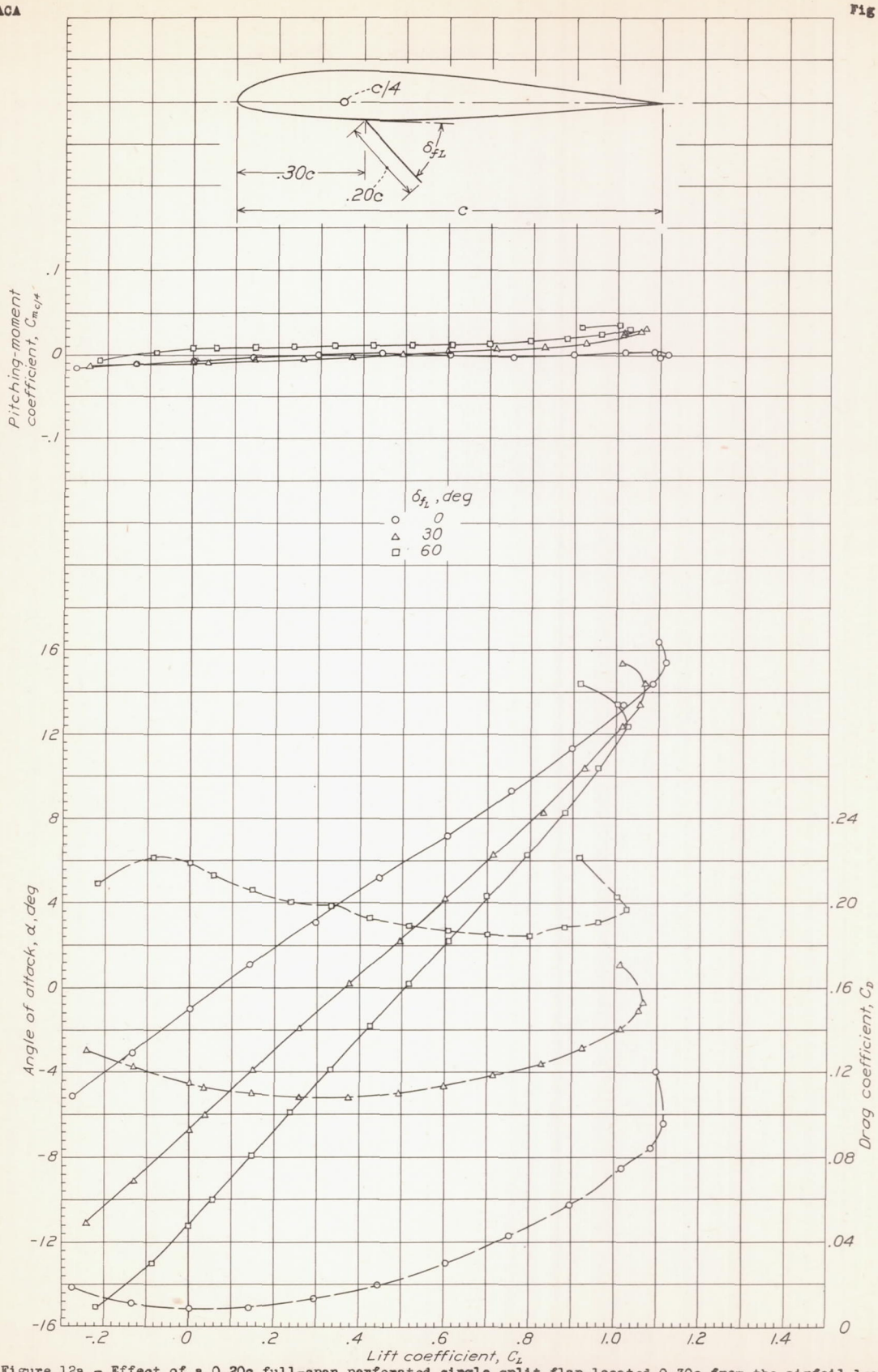

Figure 12a.- Effect of a 0.20c full-span perforated single split flap located 0.30c from the airfoil leading edge on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil.

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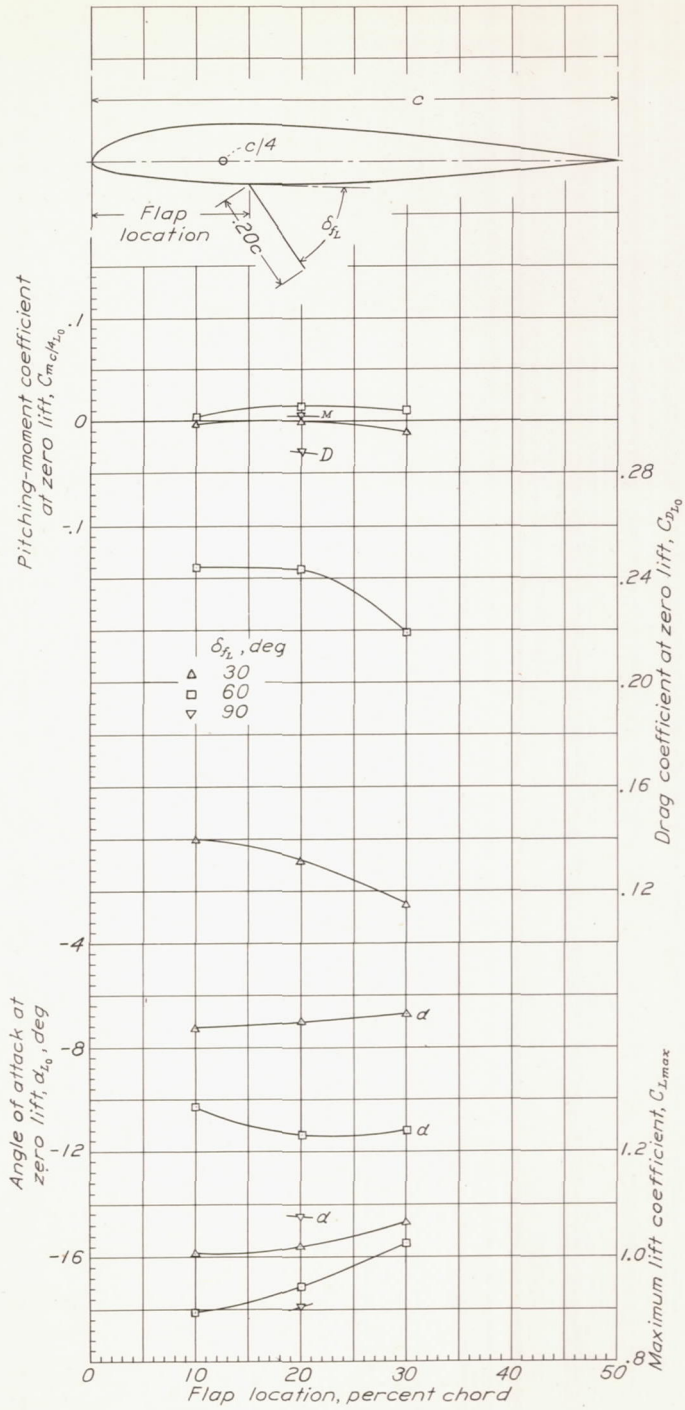

Figure 13a.- Effect of flap location on some of the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated single split flap.

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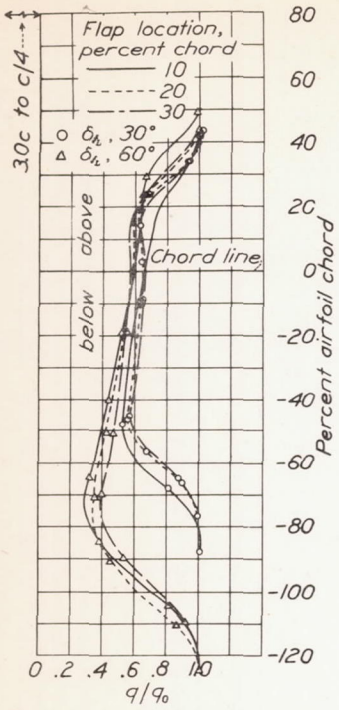

Figure 13b.- Effect of flap location on the envelopes of the wake curves below the stall of a 10- by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated single split flap.

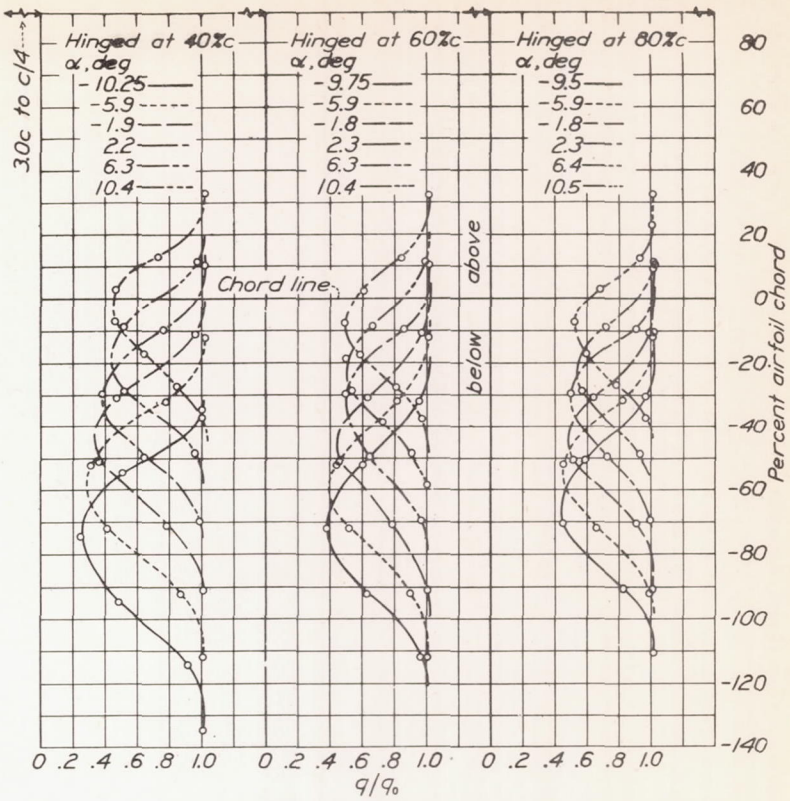

Figure 15b.- Effect of flap location on the wake characteristics of a 10-by 60- inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated single split flap. Gap between airfoil and flap, 0.10c; δ_{f_L}, 90°.

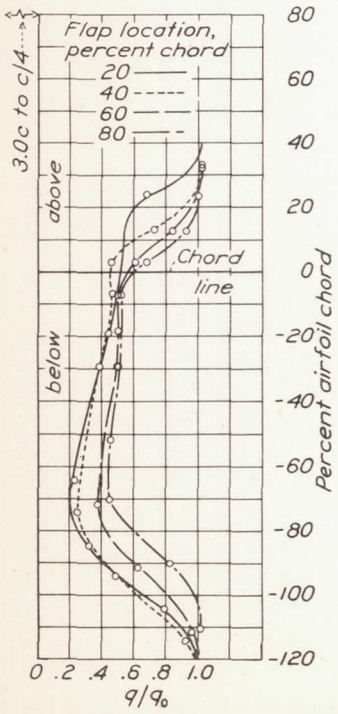

Figure 16b.- Effect of flap location on the envelopes of the wake curves below the stall of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated single split flap. Gap between airfoil surface and flap, 0.10c; δ_{f_L}, 90°.

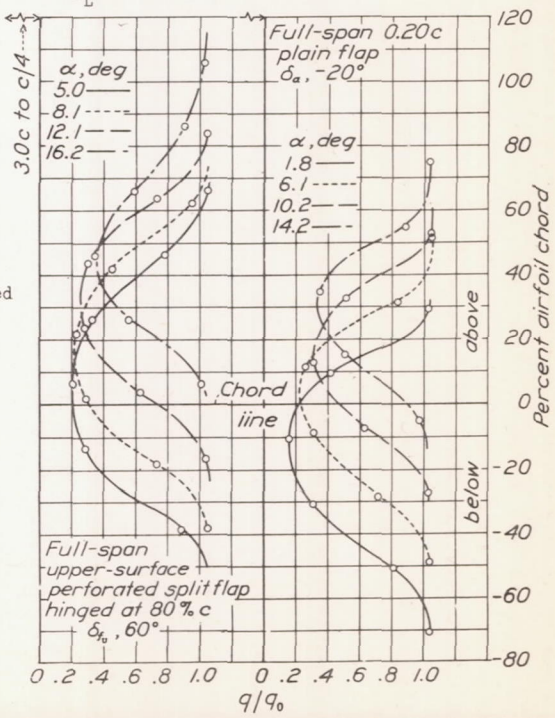

Figure 17b.- Effect of 0.20c full-span trailing-edge plain and upper-surface perforated split flaps on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated lower surface split flap located 0.40c from the airfoil leading edge. Gap between airfoil surface and lower-surface split flap, 0.10c; δ_{f_L}, 90°.

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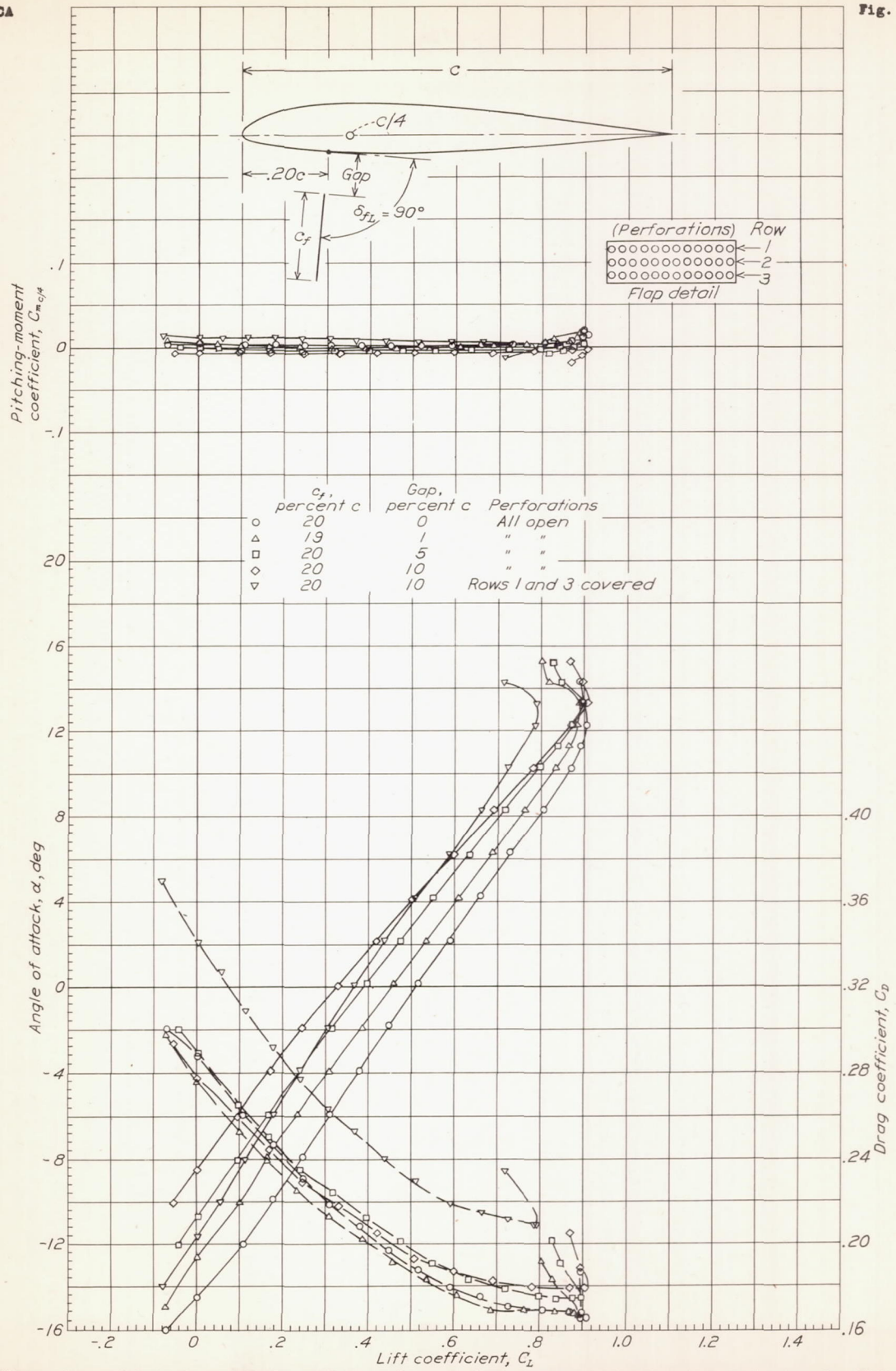

Figure 14a.- Effect of gap between airfoil surface and flap on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated single split flap located 0.20c from the airfoil leading edge. δ_{f_L}, 90°.

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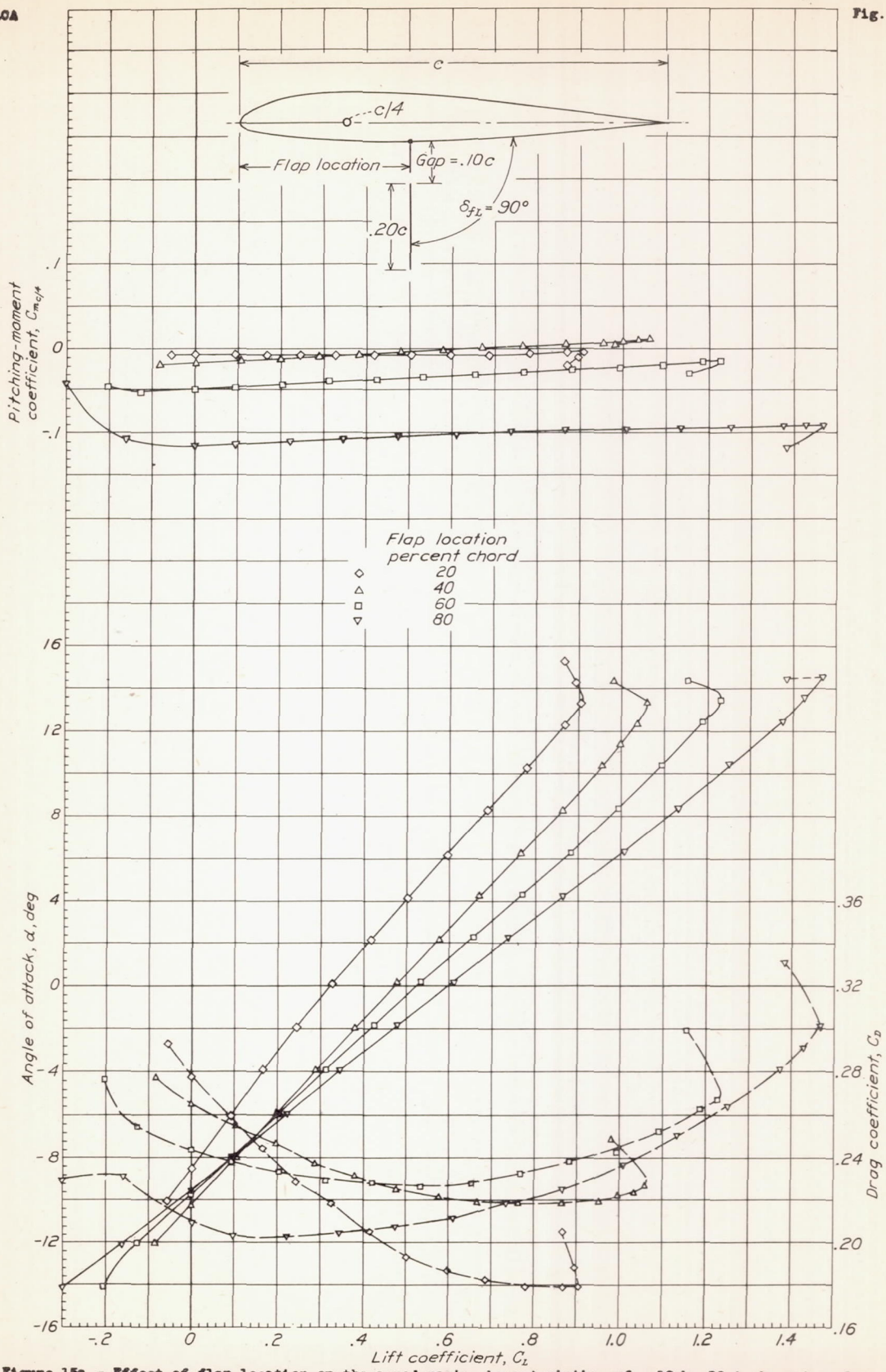

Figure 15a.- Effect of flap location on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated single split flap. Gap between airfoil surface and flap, 0.10c; δ_{f_L}, 90°.

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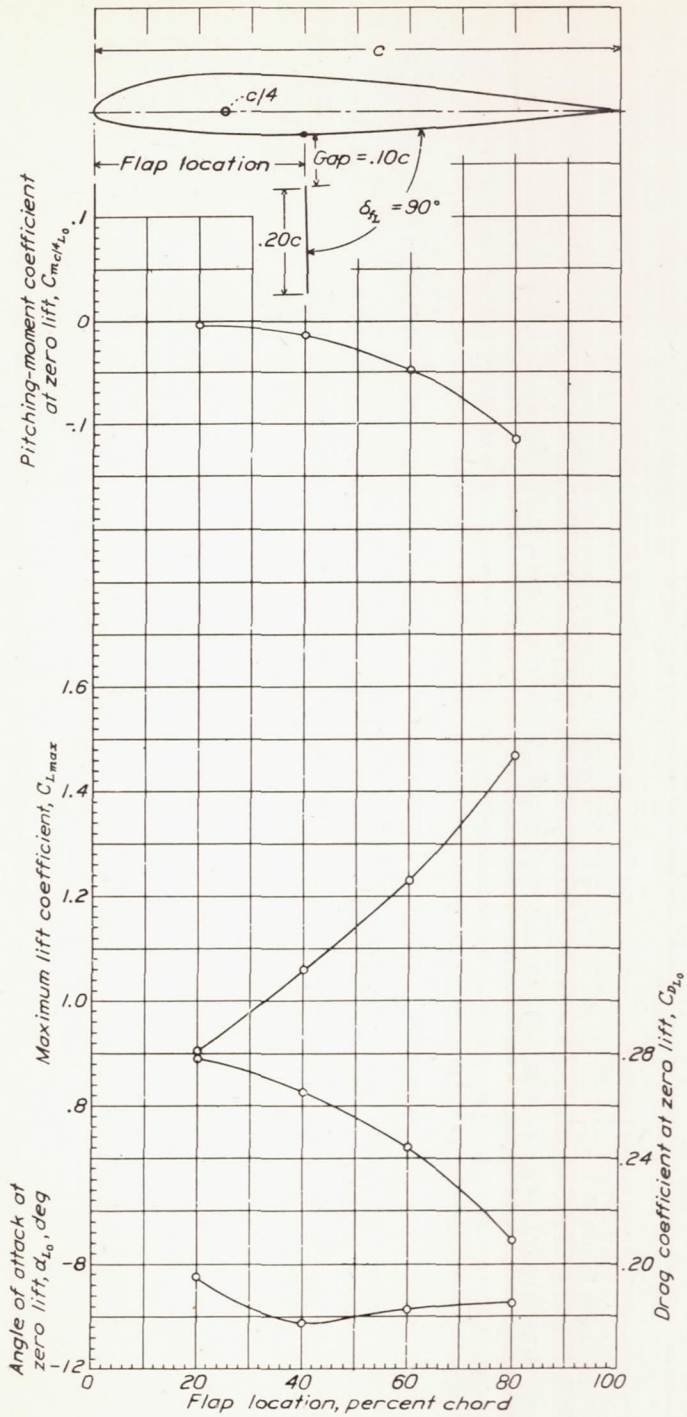

Figure 16a.- Effect of flap location on some of the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated single split flap. Gap between airfoil surface and flap, 0.10c; δ_{f_L}, 90°.

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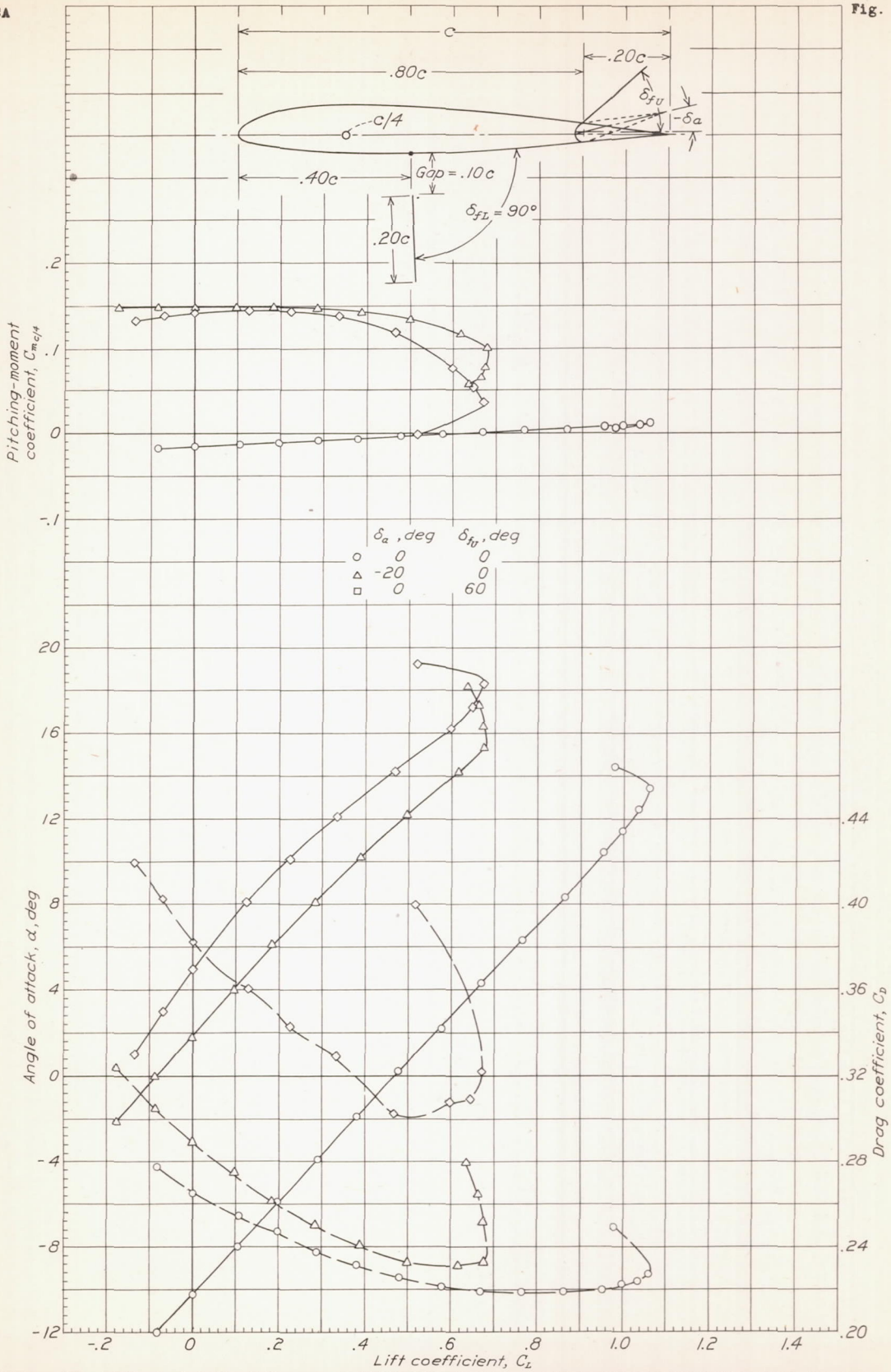

Figure 17a.- Effect of 0.20c full-span trailing-edge plain and upper-surface perforated split flaps on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated lower-surface split flap located 0.40c from the airfoil leading edge. Gap between airfoil surface and lower-surface split flap, 0.10c; δ_{f_L}, 90°.

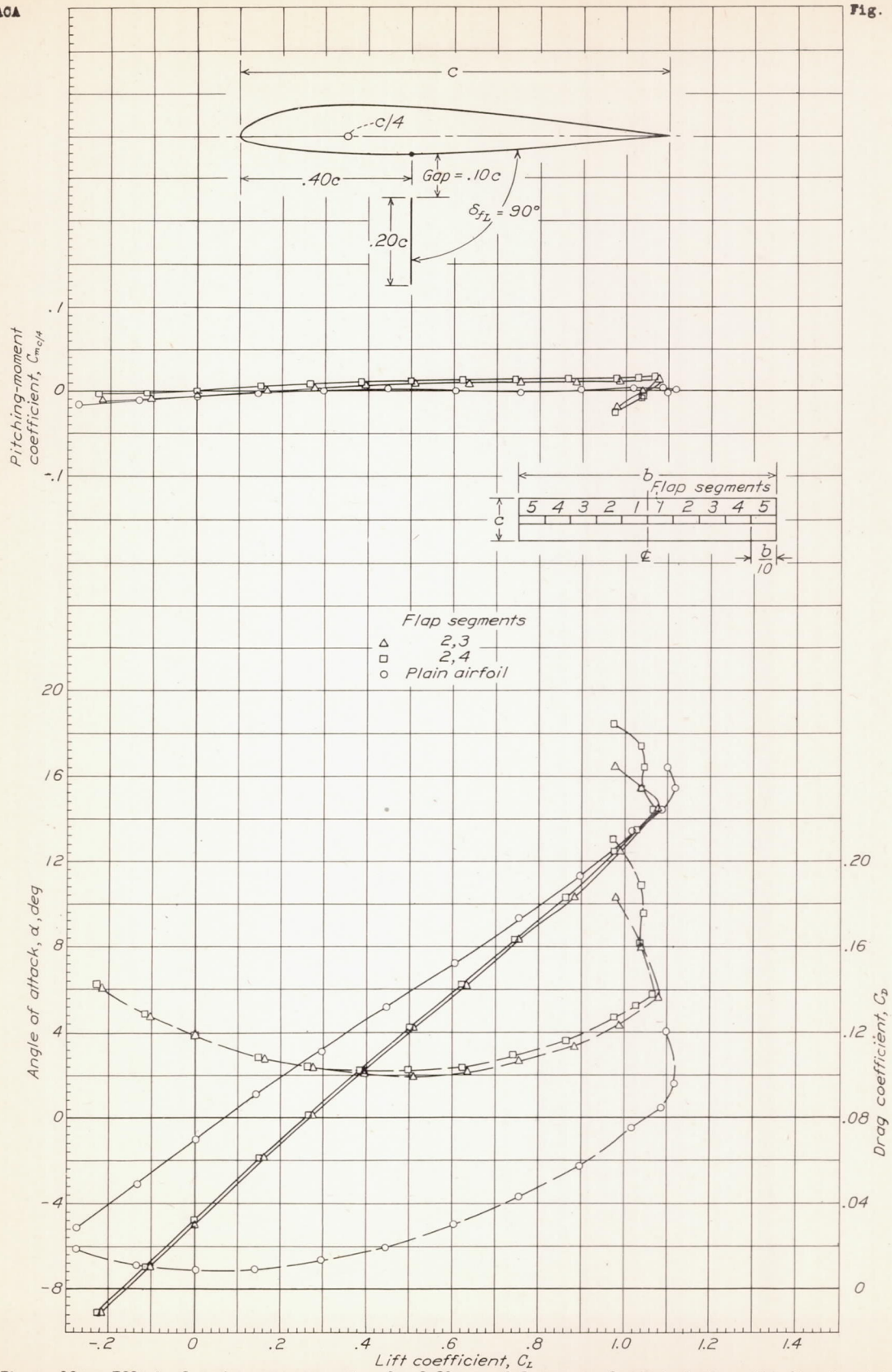

Figure 18a.- Effect of various arrangements of a 0.20c partial-span perforated single split flap located 0.40c from the airfoil leading edge on the aerodynamic characteristics of a 10-by 60-inch NACA 23012 airfoil. Gap between airfoil surface and flap, 0.10c; δ_{f_L}, 90°.

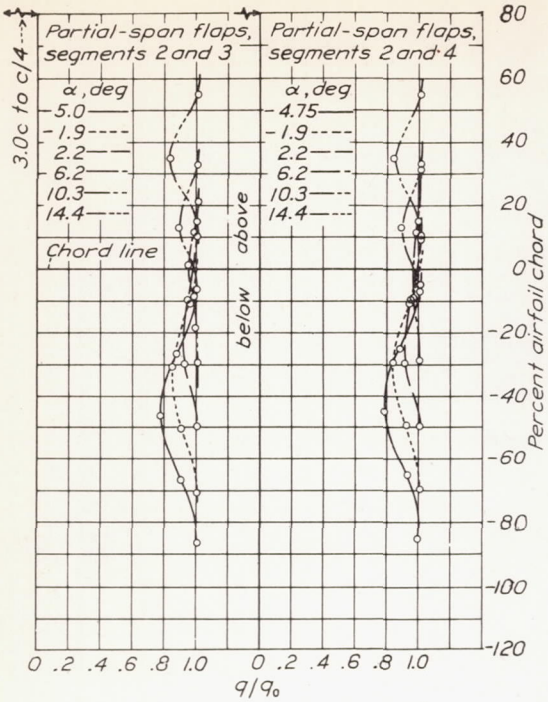

Figure 18b.- Effect of various arrangements of a 0.20c partial-span perforated single split flap 0.40c from the airfoil leading edge on the wake characteristics of a 10- by 60-inch NACA 23012 airfoil. Gap between airfoil surface and flap, 0.10c; δ_{f_L}, 90°.

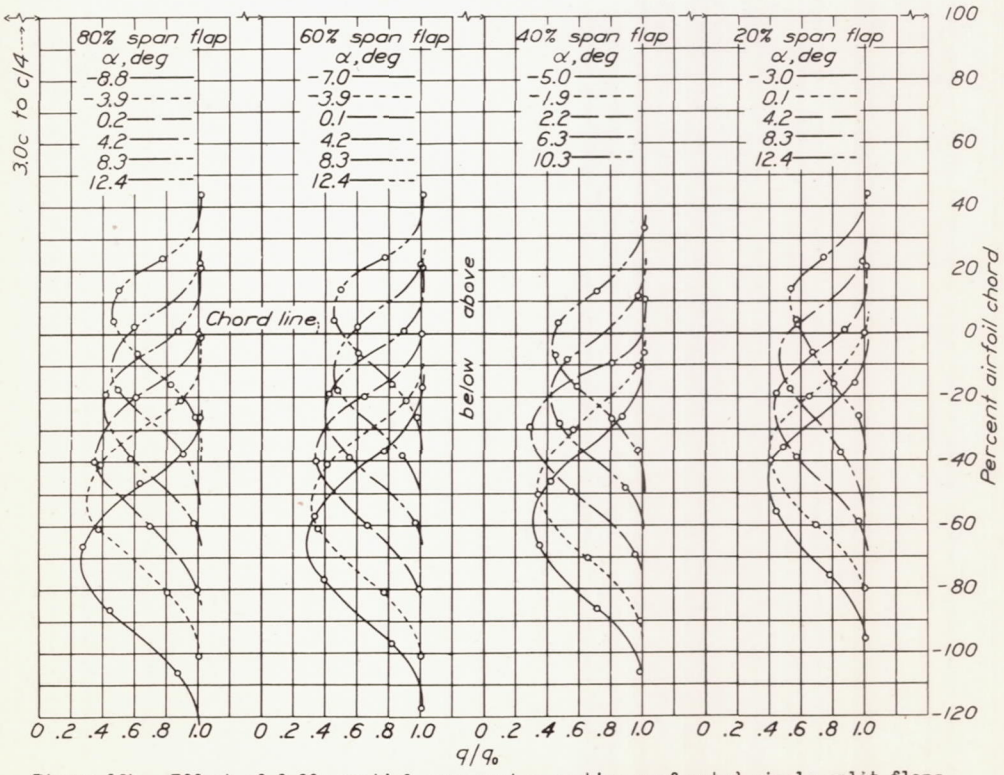

Figure 19b.- Effect of 0.20c partial-span center-section perforated single split flaps located 0.40c from the airfoil leading edge on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. Gap between airfoil surface and flap, 0.10c; δ_{f_L}, 90°.

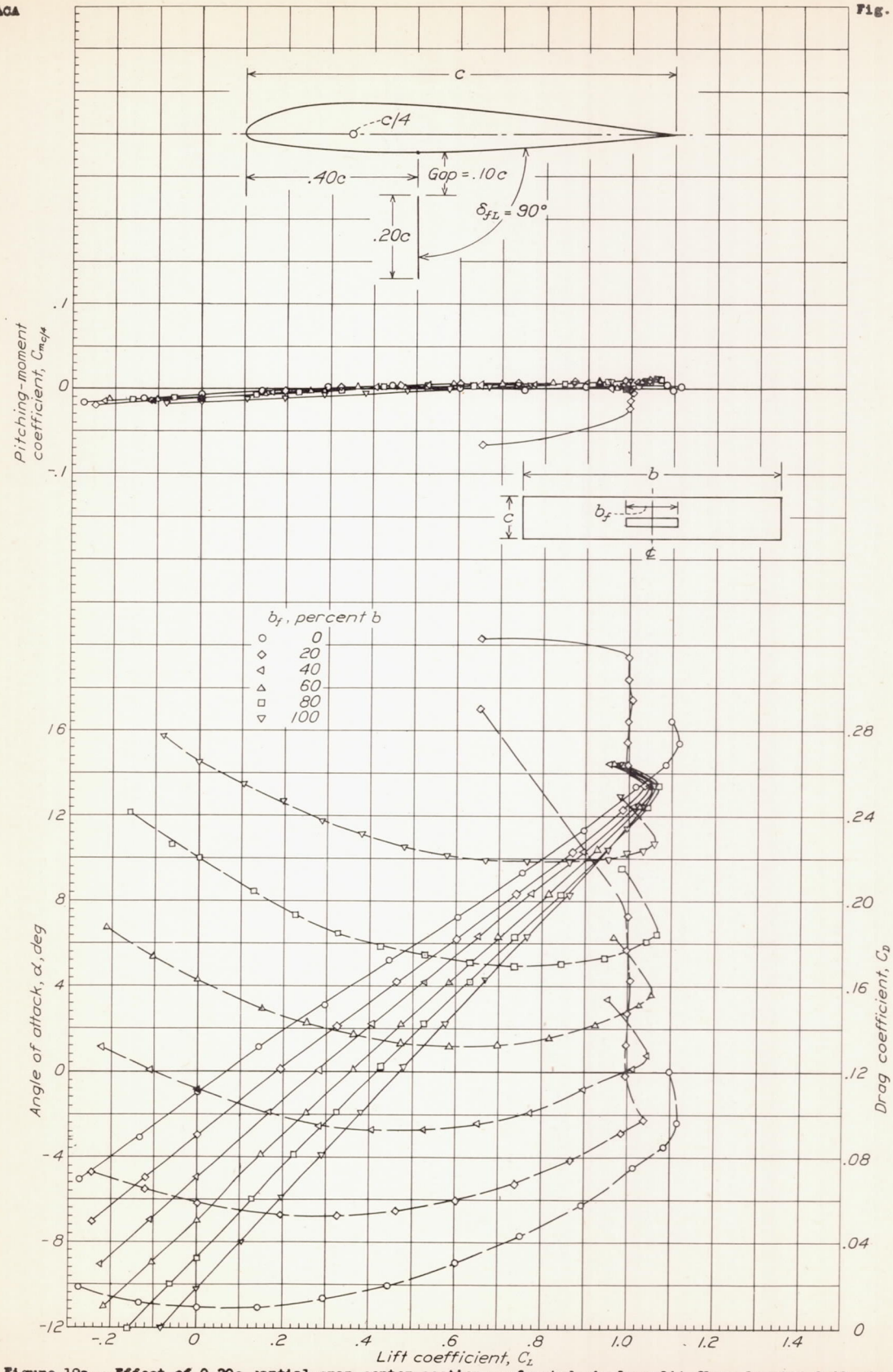

Figure 19a.- Effect of 0.20c partial-span center-section perforated single split flaps located 0.40c from the airfoil leading edge on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. Gap between airfoil surface and flap, 0.10c; δ_{f_L}, 90°.

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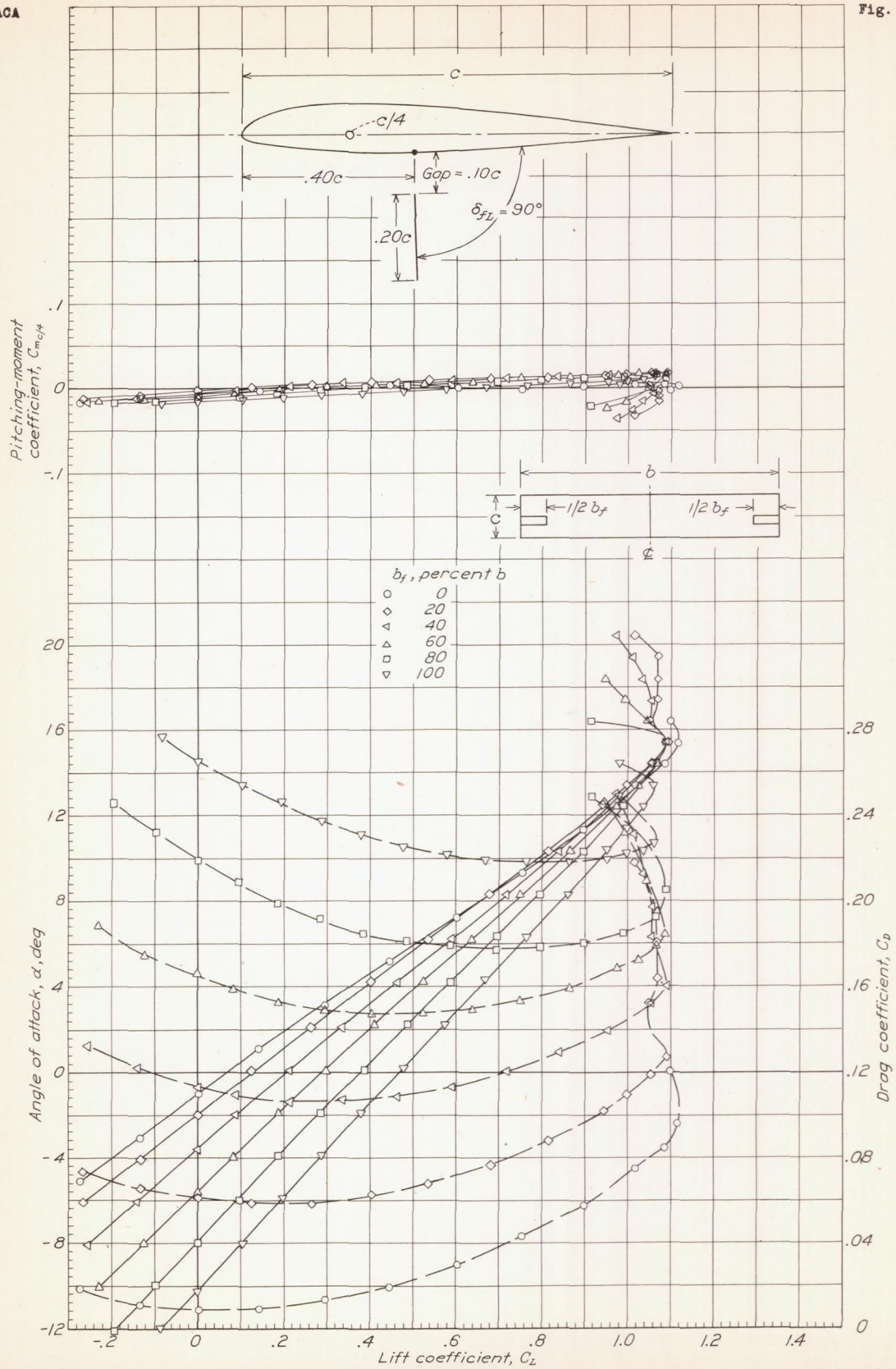

Figure 20a.- Effect of 0.20c partial-span tip-section perforated single split flaps located 0.40c from the airfoil leading edge on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. Gap between airfoil surface and flap, 0.10c; δ_{f_L}, 90°.

L-445

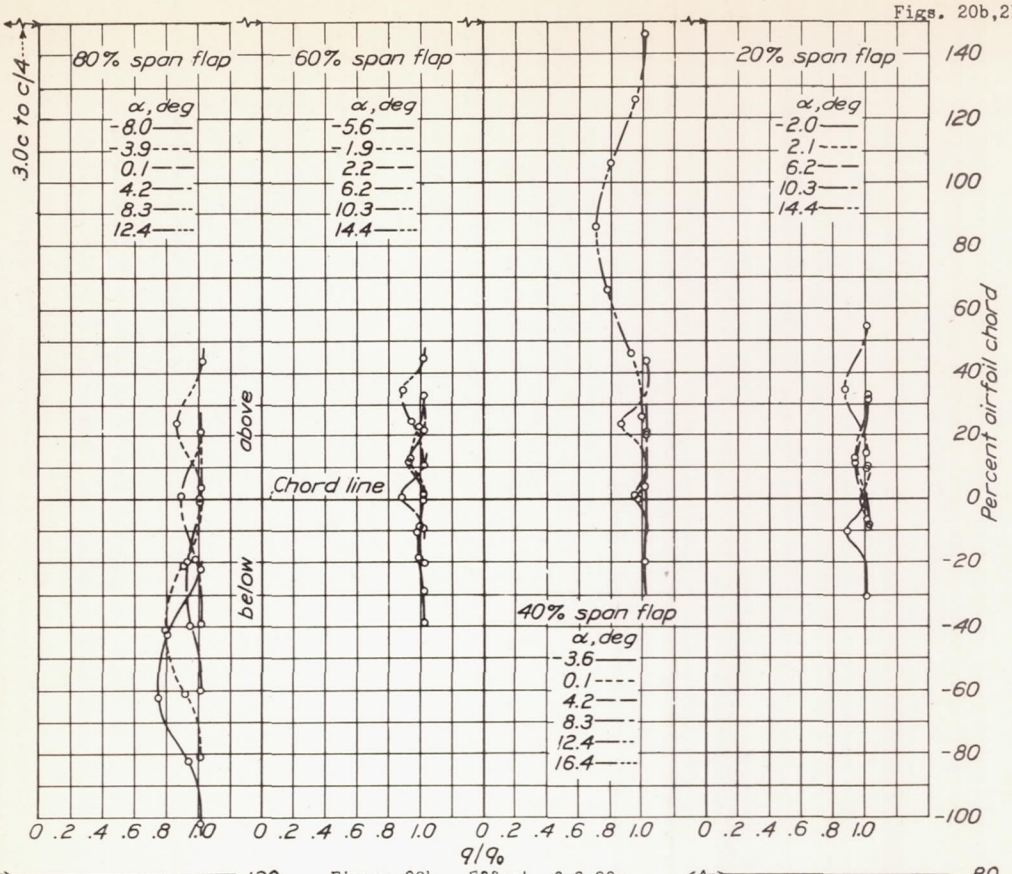

Figure 20b.- Effect of 0.20c partial-span tip-section perforated single split flaps located 0.40c from the airfoil leading edge on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil. Gap between airfoil surface and flap, 0.10c; δ_{f_L}, 90°.

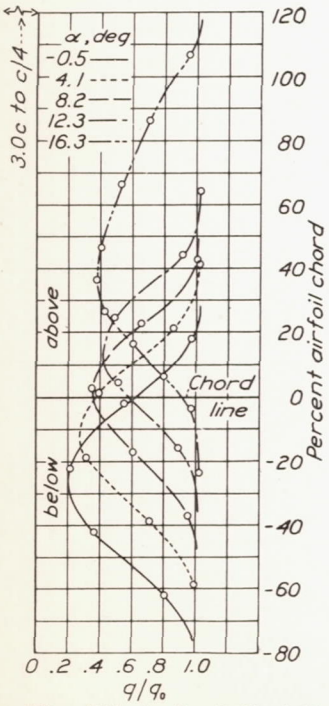

Figure 26b.- Effect of a 0.20c full-span trailing-edge plain flap on the wake characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated single split flap located 0.60c from the airfoil leading edge. Gap between airfoil surface and split flap, 0.10c; δ_{f_L}, 90°.

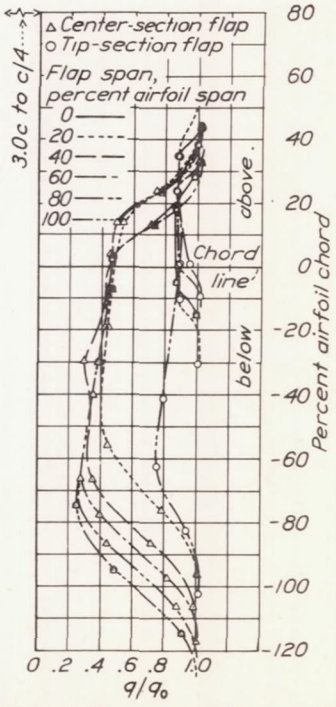

Figure 21b.- Effect of flap span on the envelopes of the wake curves below the stall of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c perforated single split flap located 0.40c from the airfoil leading edge. Gap between airfoil surface and flap, 0.10c; δ_{f_L}, 90°.

L-445

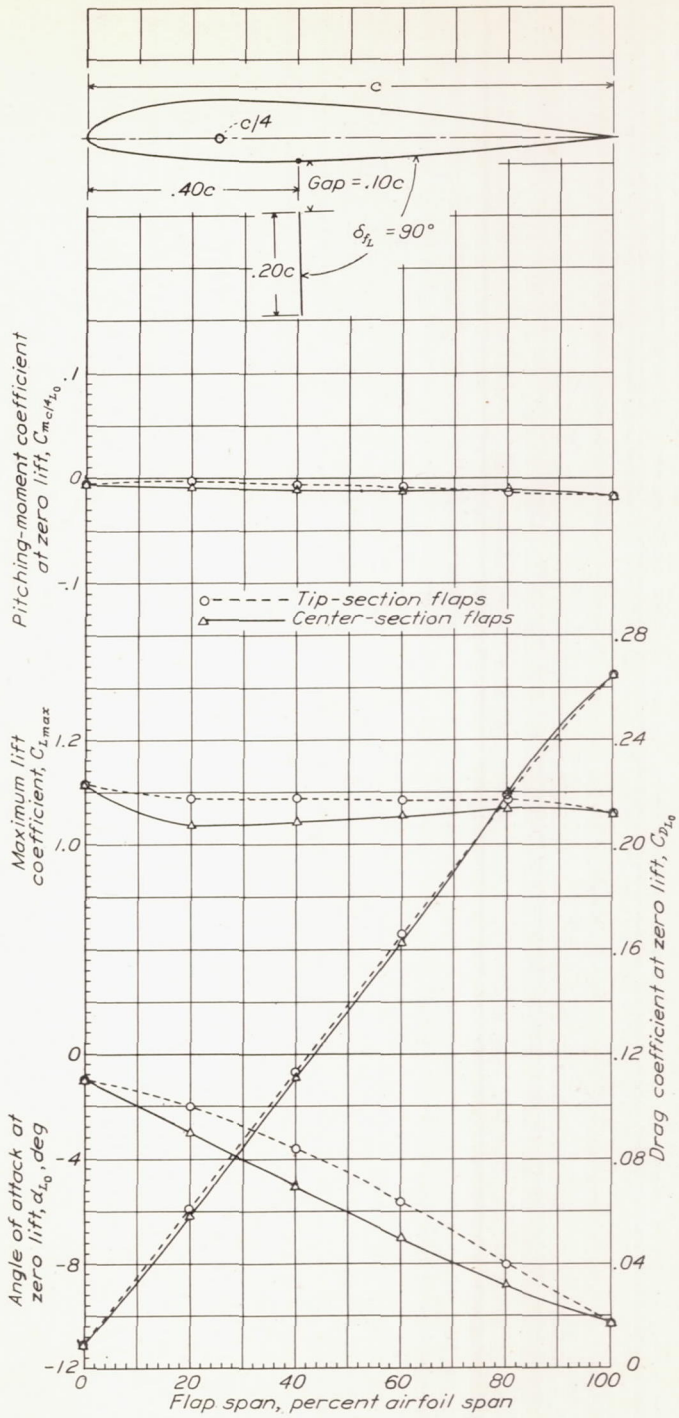

Figure 21a.- Effect of flap span on some of the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c perforated single split flap located 0.40c from the airfoil leading edge. Gap between airfoil surface and flap, 0.10c; δ_{f_L}, 90°.

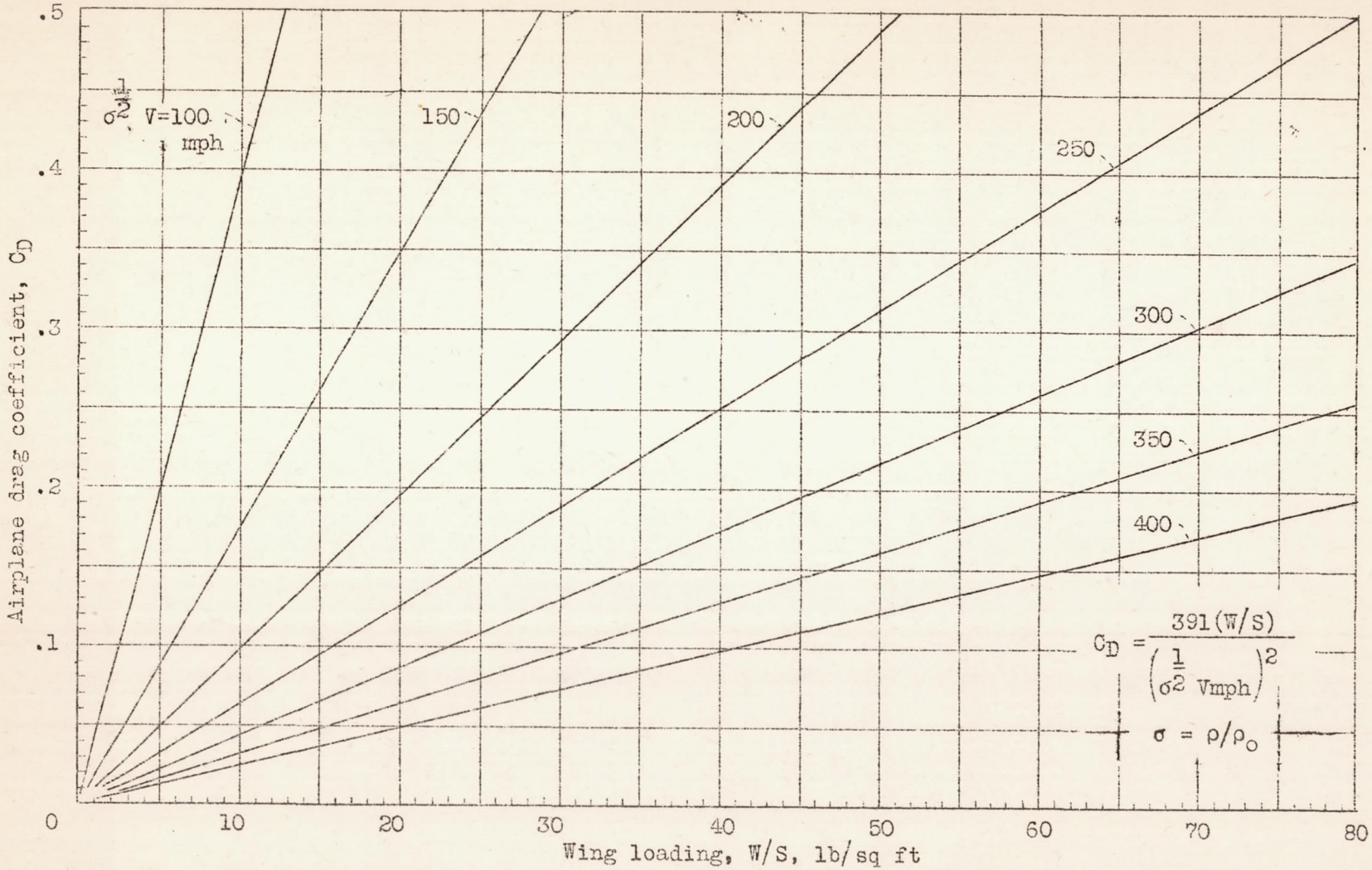

Figure 22.- Indicated terminal diving speeds of airplanes with various wing loadings and drag coefficients.

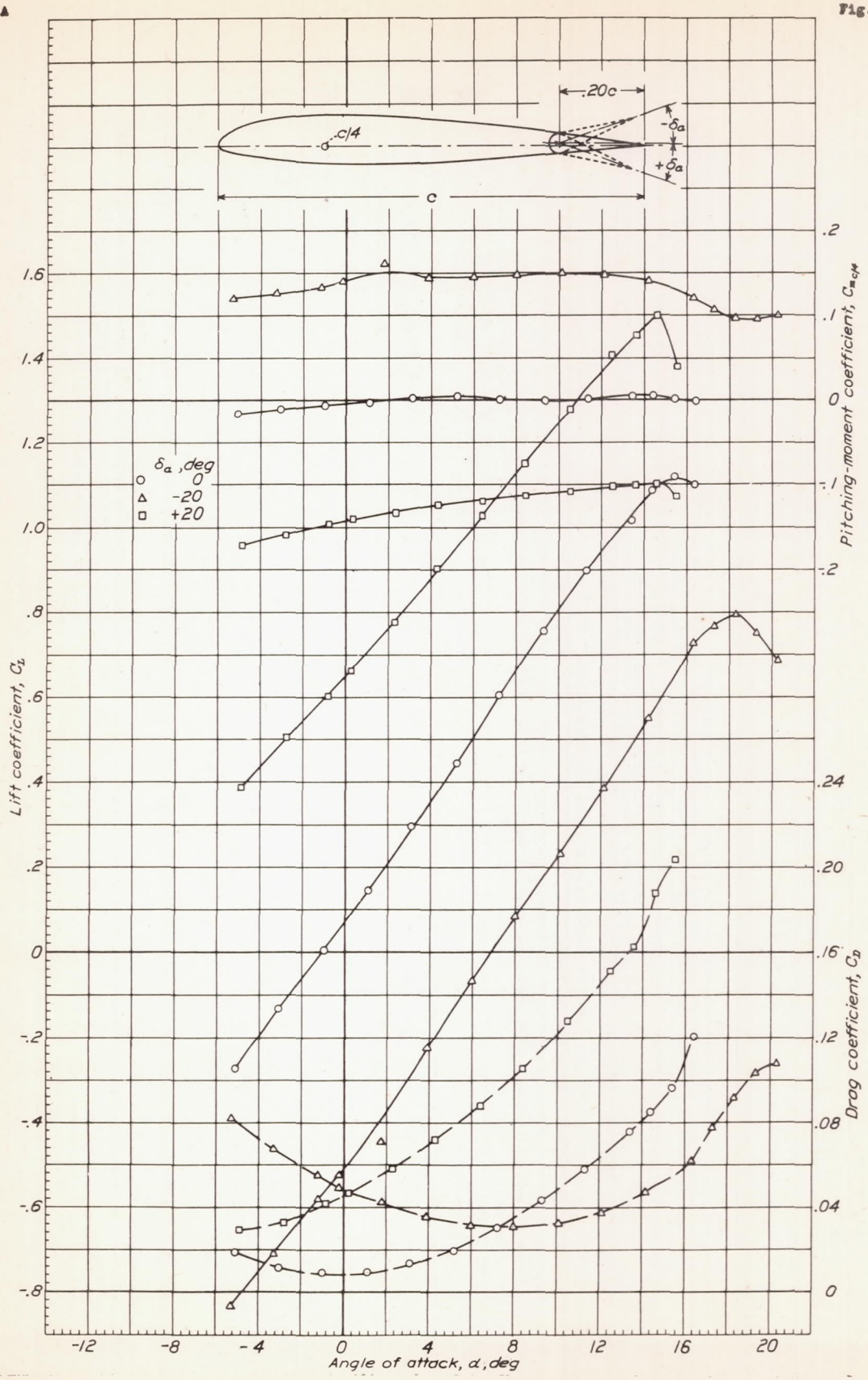

Figure 23.- Effect of a 0.20c full-span trailing-edge plain flap on the aerodynamic characteristics of a 10- by 60-inch rectangular NACA 23012 airfoil.

L-445

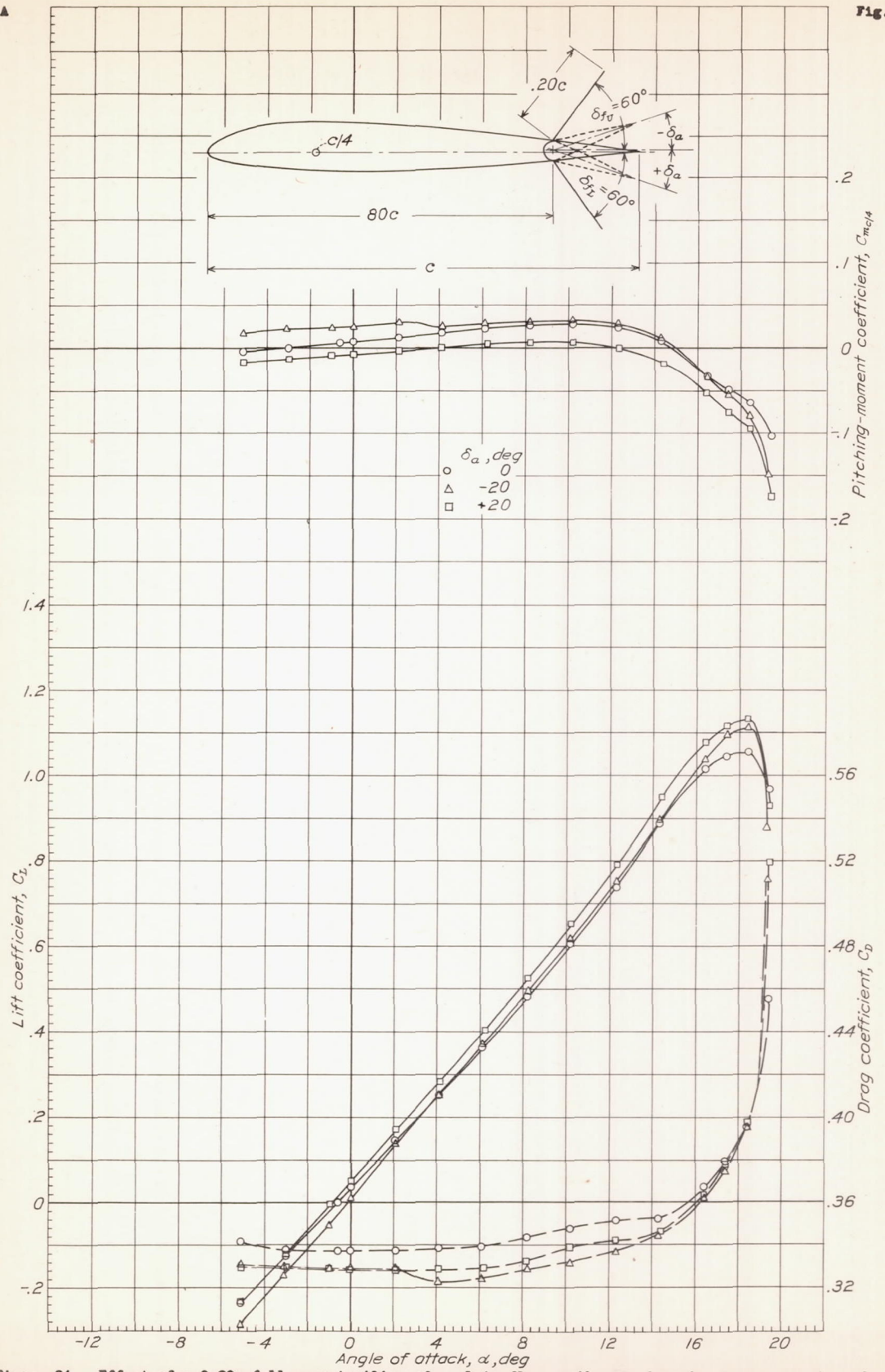

Figure 24.- Effect of a 0.20c full-span trailing-edge plain flap on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with 0.20c full-span perforated double split flaps located 0.80c from the airfoil leading edge. δ_{f_U},60°; δ_{f_L},60°.

L-747

L-447

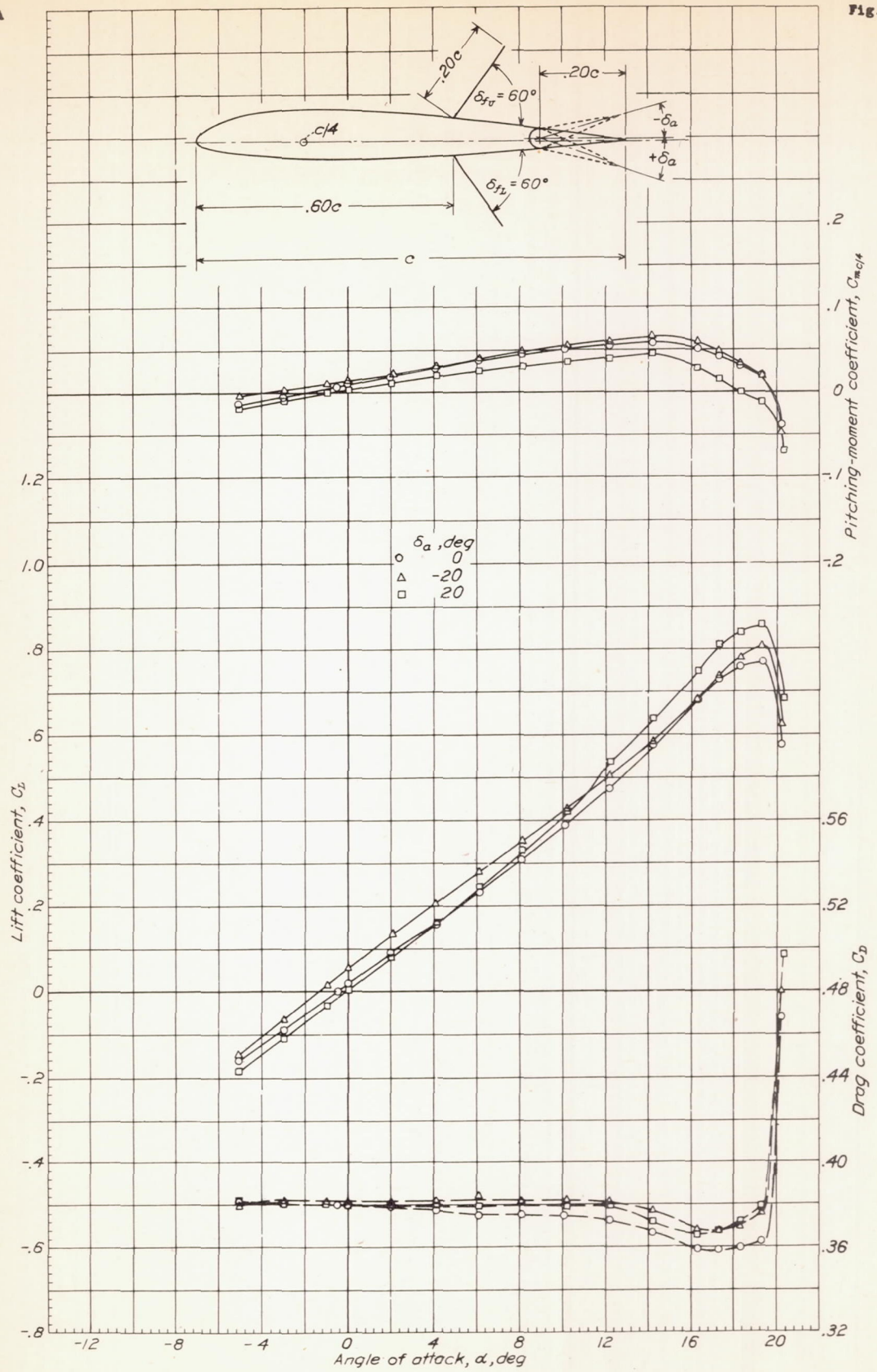

Figure 25.- Effect of a 0.20c full-span trailing-edge plain flap on the aerodynamic characteristics of a 10- by 60-inch rectangular NACA 23012 airfoil with 0.20c full-span perforated double split flaps located 0.60c from the airfoil leading edge. δ_{f_U}, 60°; δ_{f_L}, 60°.

L-449

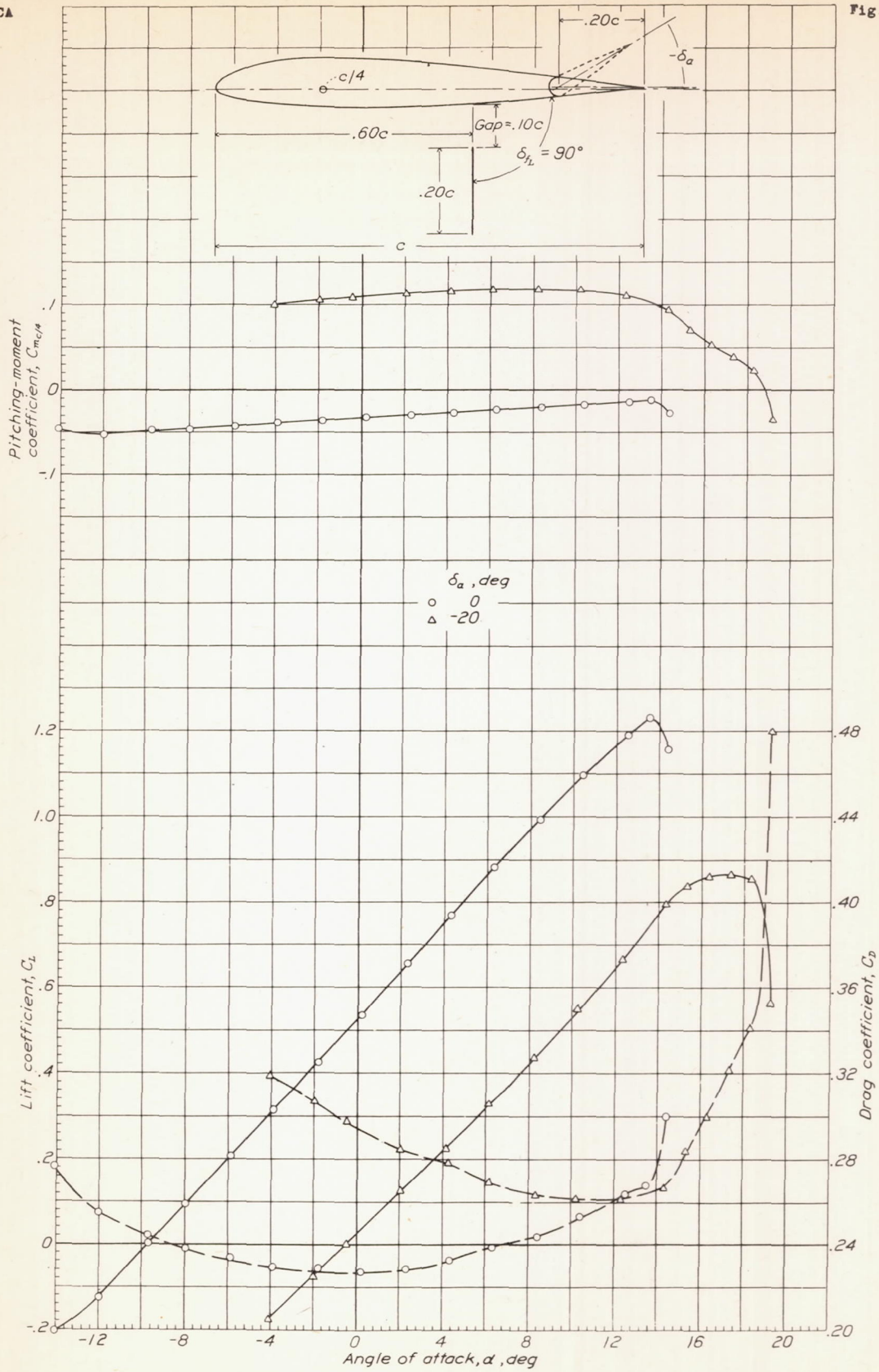

Figure 26a.- Effect of a 0.20c full-span trailing-edge plain flap on the aerodynamic characteristics of a 10- by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated single split flap located 0.60c from the airfoil leading edge. Gap between airfoil surface and split flap, 0.10c; δ_{f_L}, 90°.

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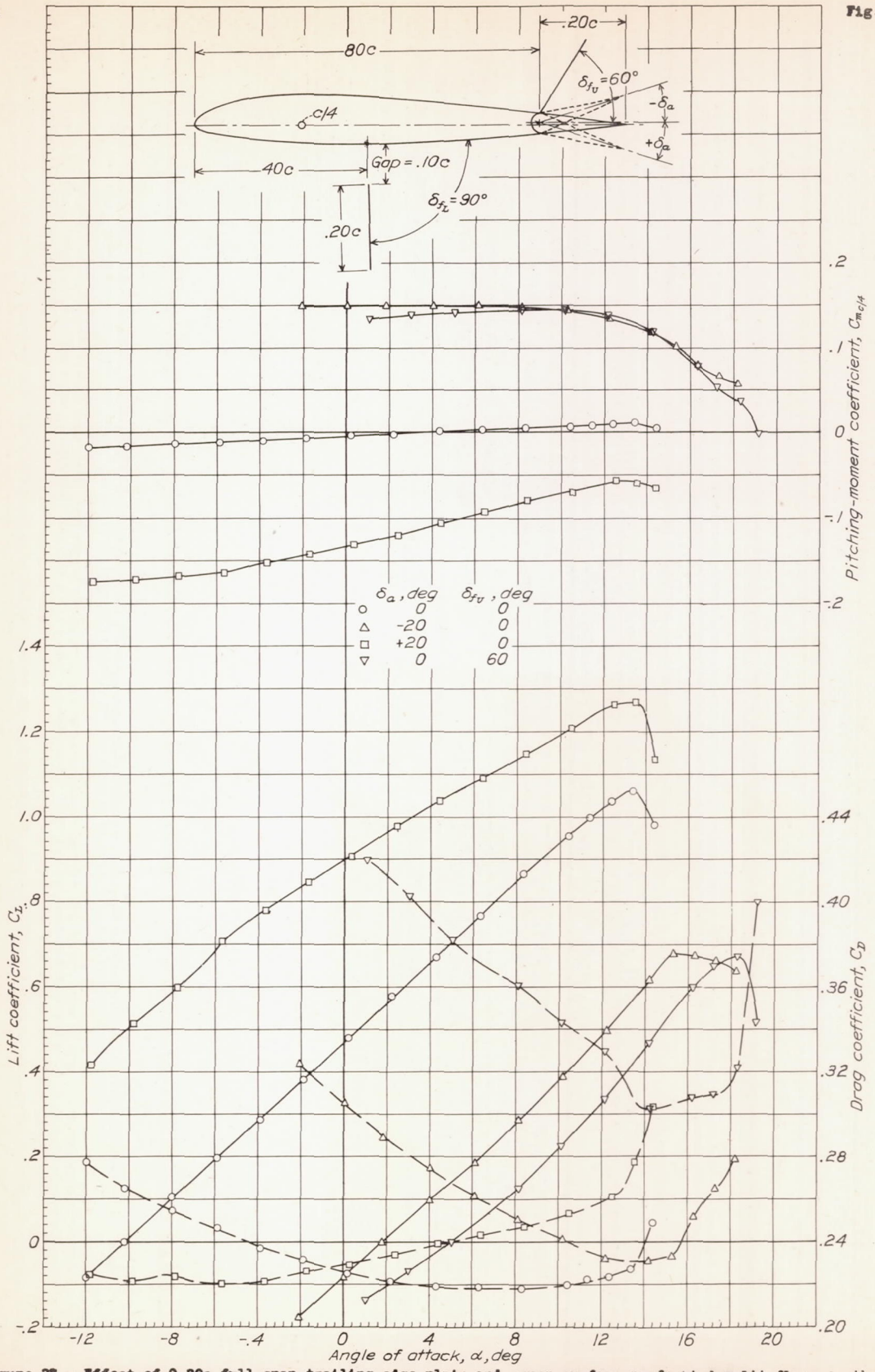

Figure 27.- Effect of 0.20c full-span trailing-edge plain and upper-surface perforated split flaps on the aerodynamic characteristics of a 10-by 60-inch rectangular NACA 23012 airfoil with a 0.20c full-span perforated lower-surface split flap located 0.40c from the airfoil leading edge. Gap between airfoil surface and lower-surface split flap, 0.10c; δ_{f_L}, 90°.