To: Mr. Chas. J. McCarthy 56

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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RÉSUMÉ OF PRESENT DATA ON LOAD DISTRIBUTION ON SLOTS AND FLAPS

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This report covers a study of the generally available data on load distribution on slots and flaps. The study was made by the National Advisory Committee for Aeronautics at the request of the Matériel Division, Army Air Corps, in a letter dated January 4, 1934, to furnish information applicable to design criteria for slots and flaps of various types.

The data are presented in three main sections:

I. SLOTS (HANDLEY PAGE TYPE)

A. Resultant force on slat.- Several investigations have been made to determine the direction and magnitude of the resultant forces on the slat, mainly for the purpose of designing the automatic operating mechanism and supporting linkages (references 1, 2, 3, and 4). In at least one case (reference 2)*, the investigation was made for both the full-open and for the retracted position of the slat.

Figure 1 shows the force vectors acting on the slat in both the open and closed positions. The magnitudes of the vectors are tabulated on the figure as coefficients of resultant force C_R, in terms of the slat area. It should be noted that these values apply only to the particular wing and slat arrangements tested, and a separate test will be required to obtain satisfactory data for each different wing and slat combination used.

B. Normal and longitudinal forces on slat, and c.p. of normal force.- Probably the most complete data on these characteristics of the slat have been obtained in some British tests (reference 4) of a slotted wing in flight. A slat spanning the upper R.A.F. 34 wing of a Bristol Fighter was used. Pressures were measured over two sections, one at mid semispan and one near the wing tip. (See fig. 2.)

The normal- and longitudinal-force coefficients obtained (in terms of slat area) are shown in figure 3. This figure also shows the relation between the c.p. of the normal force on the slat and angle of attack of the main wing. The maximum measured value of the normal-force coefficient was about 2.40 at the mid-semispan section, compared with 1.70 near the tip. At both of the sections tested the c.p. of the slat load is close to 40 percent of the slat chord in the working range, and the load is approximately normal to the slat chord.

Measurements have also been made in the N.A.C.A. variable-density wind tunnel to determine the pressure distribution over the midspan section of an R.A.F. 31 airfoil with a leading-edge slot fully open (reference 5). Figures 4, 5, and 6 show a few representative pressure-distribution diagrams for the slotted airfoil with the slat completely extended. The results of these tests are in close agreement with the British flight tests in that the maximum normol-force coefficient of the slat had a value of about 2.35, and was approximately normal to the slat chord at the 43 percent chord location.

It may be said, in general, that as an approximate basis for stress analysis, the $C_{L_{max}}$ on the slat (based on main wing area with slat retracted) can be taken as the increase in $C_{L_{max}}$ which the slat gives to the combination, the total force on the slat being normal to its chord. This statement, however, should be accepted subject to further verification by investigations of several different wing sections and slots.

<u>C. Other data</u>.- It is likely that Handley Page, in England, and possibly the Curtiss Company, in this country, have made further tests on slat loads. The results of those tests would presumably be available to anyone desiring to use slots under license.

II. AUXILIARY AIRFOILS (FIXED)

<u>A. Normal and longitudinal forces on the auxiliary</u>.- Some data are available from wind-tunnel tests made to de-

termine the division of air load between fixed auxiliary airfoils and a Clark Y main wing for a few representative cases (reference 6). The arrangements tested and the results of those tests are shown in figures 7 and 8. The load on the auxiliary airfoils is divided into normal and longitudinal components and these are given in terms of the total lift on the main wing plus the auxiliary.

An auxiliary airfoil having a symmetrical section (fig. 7) carried about 20 percent of the total load throughout the entire angle-of-attack range tested. A highly cambered N.A.C.A. 22 auxiliary airfoil (fig. 8) carried about the same portion of the total load at high lift coefficients, but a higher proportion if the angle of attack was reduced. The total loads on the wing with auxiliary airfoils may be found in reference 6. No other load data for these devices are available at the present time.

III. FLAPS

<u>A. Ordinary trailing-edge flaps</u>. <u>1. Normal force on the flap</u>.- Measurements have been made in the N.A.C.A. variable-density wind tunnel to determine the pressure distribution over the midspan section of an R.A.F. 30 airfoil with trailing-edge flaps (reference 7). The air forces on the flap and on the fixed part of the wing were determined from the direct pressure measurements.

The force acting on the flap normal to its chord is plotted in coefficient form (based on flap area) in figure 9 for different flap deflections and angles of attack. Displacement of the flap to angles of 40° (the largest tested) produces a progressive increase in the normal force on the flap up to the stall of the wing. Increasing the angle of attack from negative values to positive values, in general, also increases the normal force somewhat for down-flap deflections, while the opposite is true for up-flap movements. The maximum value of the normal-force coefficient attained at the 40° flap deflection (up to the stall of the wing) was about 0.90 although the maximum lift of the wing was not reached with this deflection. ($C_{N_{max}}$ of wing with $\delta = 40^\circ$ was 1.68.) A few representative pressure-distribution diagrams are shown in figures 10, 11, and 12.

2. Hinge moments of the flap.- The moments about the flap hinge are plotted on figure 9 in terms of hinge-moment coefficients based on flap area and chord. The hinge moment increases almost linearly with increase in flap deflection up to the stall of the wing. Increasing the angle of attack of the wing up to the stall decreases the hinge moments slightly. The center of pressure of the normal force on the flap may be computed, if desired, from the hinge-moment and normal-force coefficients.

3. Analytical determination of flap load.- An analytical expression has been derived in reference 8 which enables the computation of the lift coefficient of the flap. The theoretical results seem to show a fair agreement with the meager experimental results available.

The expression for the flap lift coefficient, which is independent of aspect ratio, was derived as

$$C_{L_f} = n_o\, C_L - n\delta$$

where C_L is the lift coefficient of the wing with flap, and δ is the corresponding flap deflection. Values of the parameters n_o and n are given in figure 13 for different ratios of flap chord to total chord.

B. Split trailing-edge flaps. 1. Normal force, and c.p. of normal force on flap.- Direct measurements of the forces acting on split flaps and on the complete wing have been made in the N.A.C.A. 7 by 10 foot wind tunnel (reference 9). Clark Y wing models were used with two different sizes of full-span split flaps, one having a narrow chord (15 percent c.), and the other a medium chord (25 percent c.).

Figures 14 and 15 show that the normal force on the split flaps increases both with angle of attack and with flap deflection for angles of attack below the stall. The value of the normal-force coefficient (based on flap area) is about 1.40 at the angle of attack and flap deflection for maximum lift with either of the flaps tested ($C_{L_{max}}$ = 2.06). The center of pressure of the load on the split flaps, in general, moves forward with decreasing flap deflection and with increasing angle of attack from small negative angles up to the stall.

C. Zap flaps.- Load data are available from the Zap Corporation to those who deal with them directly.

D. Fowler flaps.- An investigation is now under way in the N.A.C.A. 7 by 10 foot wind tunnel in which the flap loads will be measured directly. In addition, the Glenn L. Martin Company may have some data available for those who deal with them directly.

E. External flaps (Junkers or Wragg type).- No load data available at present.

FUTURE RESEARCH

An investigation has been approved by the National Advisory Committee for Aeronautics, but not yet undertaken because of the press of other work, in which pressure-distribution measurements are to be made on large wing models in the 7 by 10 foot wind tunnel. It is intended to include all of the most promising high-lift devices previously investigated in the tunnel. The results will show the span and the chord load distribution, as well as the total loads and c.p. locations on the main wing and on the high-lift devices. It is also planned to investigate by means of pressure distribution the loading on various high-lift devices as applied to an F-22 airplane in the full-scale tunnel.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 22, 1934.

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1. Aeronautics Staff: Forces on Leading Wing of N-22 Airfoil with Handley-Page Automatic Slot. Report No. 371, Construction Department, Navy Yard, Washington, D. C., 1928.

2. Aeronautics Staff: Tests of Four Airfoils with Handley-Page Automatic Slot. Report No. 400, Construction Department, Navy Yard, Washington, D. C., 1929.

3. Bradfield, F. B., and Clark, K. W.: Wind Tunnel Experiments on the Design of an Automatic Slot for R.A.F. 28 Section, and on Interconnection with Ailerons. R. & M. No. 1165, British A.R.C., 1928.

4. Ormerod, A.: Slotted R.A.F. 34 Bristol Fighter - Measurement of Forces on Slat in Flight. R. & M. No. 1477, British A.R.C., 1932.

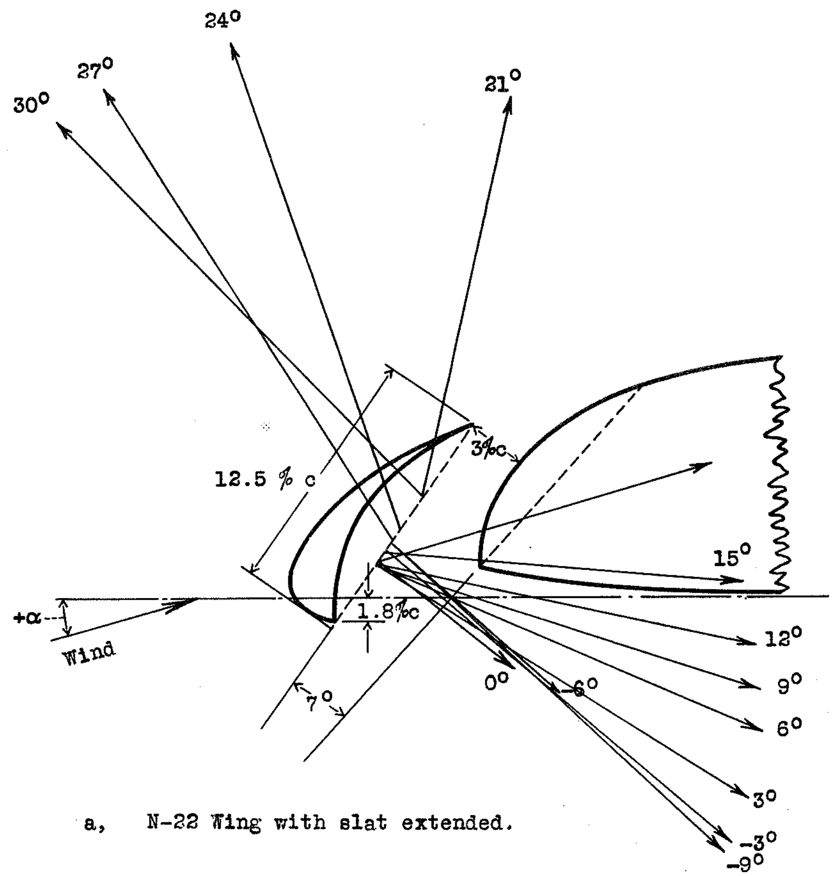
5. Jacobs, Eastman N.: Pressure Distribution on a Slotted R.A.F. 31 Airfoil in the Variable Density Wind Tunnel. T.N. No. 308, N.A.C.A., 1929.

6. Weick, Fred E., and Sanders, Robert: Wind-Tunnel Tests on Combinations of a Wing with Fixed Auxiliary Airfoils Having Various Chords and Profiles. T.R. No. 472, N.A.C.A., 1933.

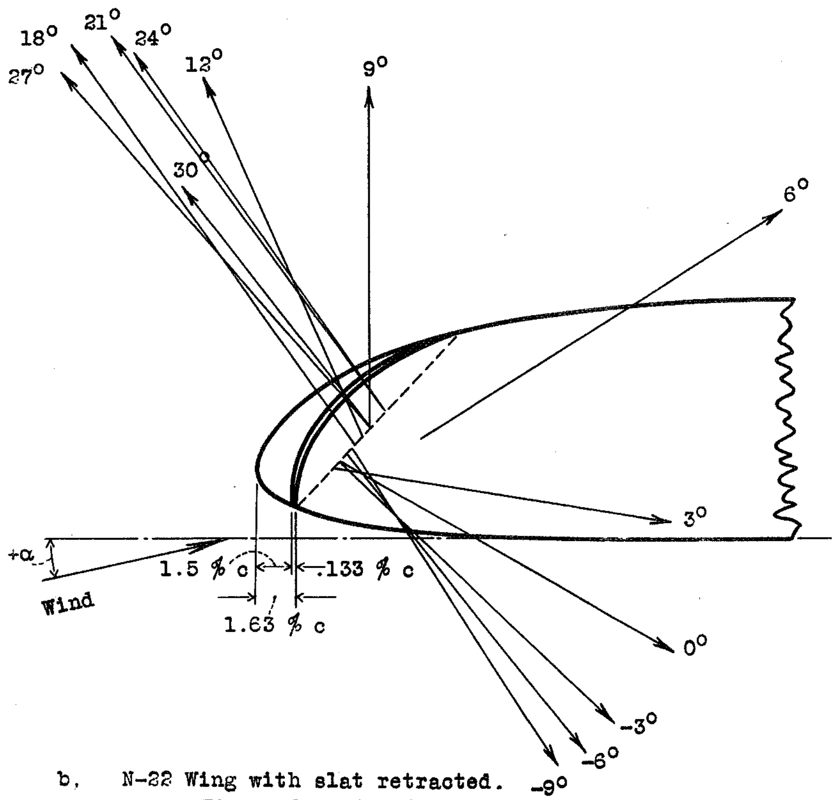
7. Jacobs, Eastman N., and Pinkerton, Robert M.: Pressure Distribution Over a Symmetrical Airfoil Section with Trailing Edge Flap. T.R. No. 360, N.A.C.A., 1930.

8. Pinkerton, Robert M.: Analytical Determination of the Load on a Trailing Edge Flap. T.N. No. 353, N.A.C.A., 1930.

9. Wenzinger, Carl J.: Wind-Tunnel Measurements of Air Loads on Split Flaps. Confidential Report, N.A.C.A., 1933.



a, N-22 Wing with slat extended.



b, N-22 Wing with slat retracted.

Angle of attack of main airfoil, α		-9°	-6°	-3°	0°	3°	6°	9°	12°	15°	18°	21°	24°	27°	30°
C_R on slat	Slot closed	1.49	1.02	0.75	0.60	0.45	0.35	0.56	1.12	1.61	2.19	4.05	5.48	4.14	2.48
	Slot open	1.05	1.01	.89	.81	.72	.59	.52	.68	.65	.51	.50	.84	1.37	1.90
c.p. in % of slat c from L.E.	Slot closed	19.7	30.9	26.6	26.6	22.4	-18.6	44.2	40.4	18.6	35.1	54.8	55.4	44.7	45.8
	Slot open	40.4	39.4	36.7	30.8	29.8	29.2	28.7	28.2	35.6	31.9	62.8	46.8	41.5	62.8

Figure 1. - Resultant forces on slat of N-22 slotted wing.

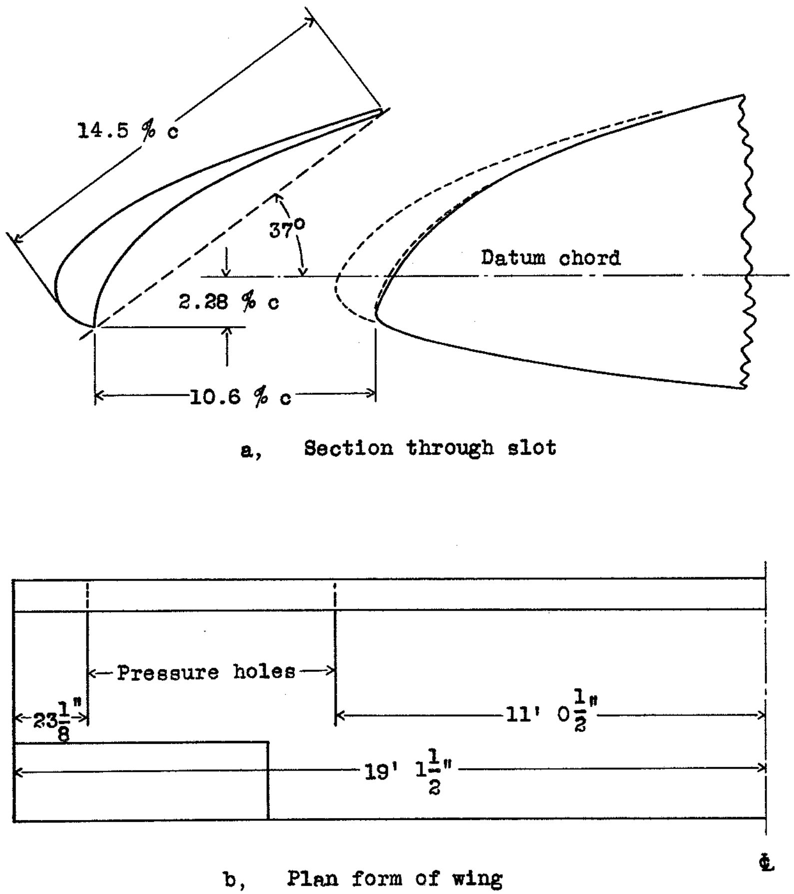


Figure 2.- Slotted R.A.F.34 wing showing position of pressure holes and details of slot.

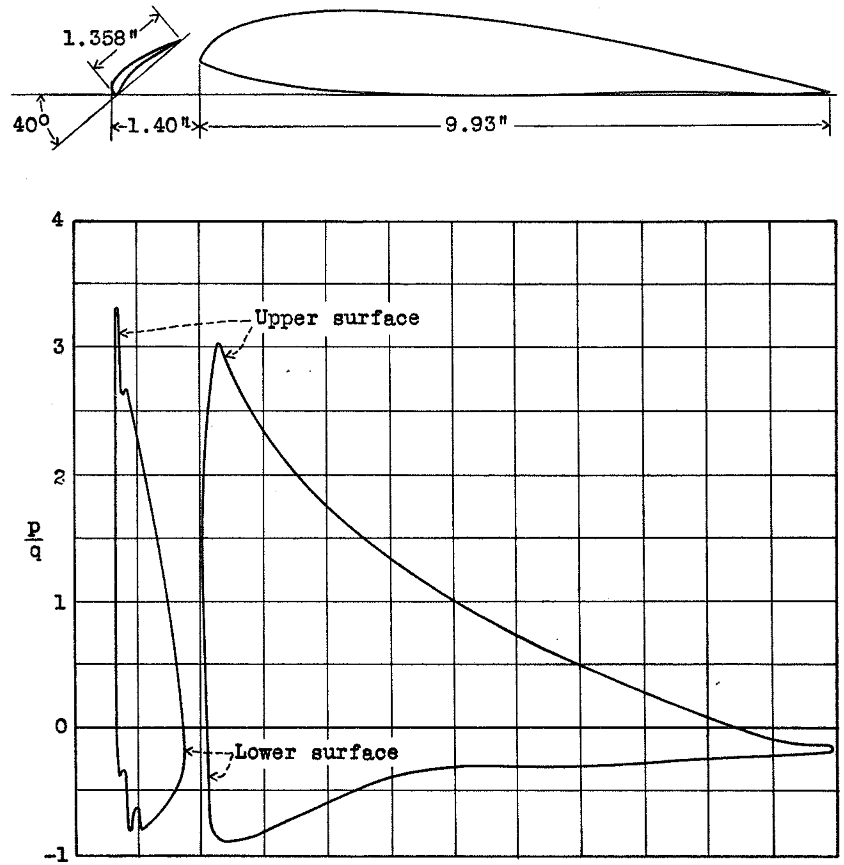


Figure 4.- Pressure distribution diagram for slotted R.A.F.31 airfoil. $\alpha = 16^{\circ}$, R.N. = 6,600,000

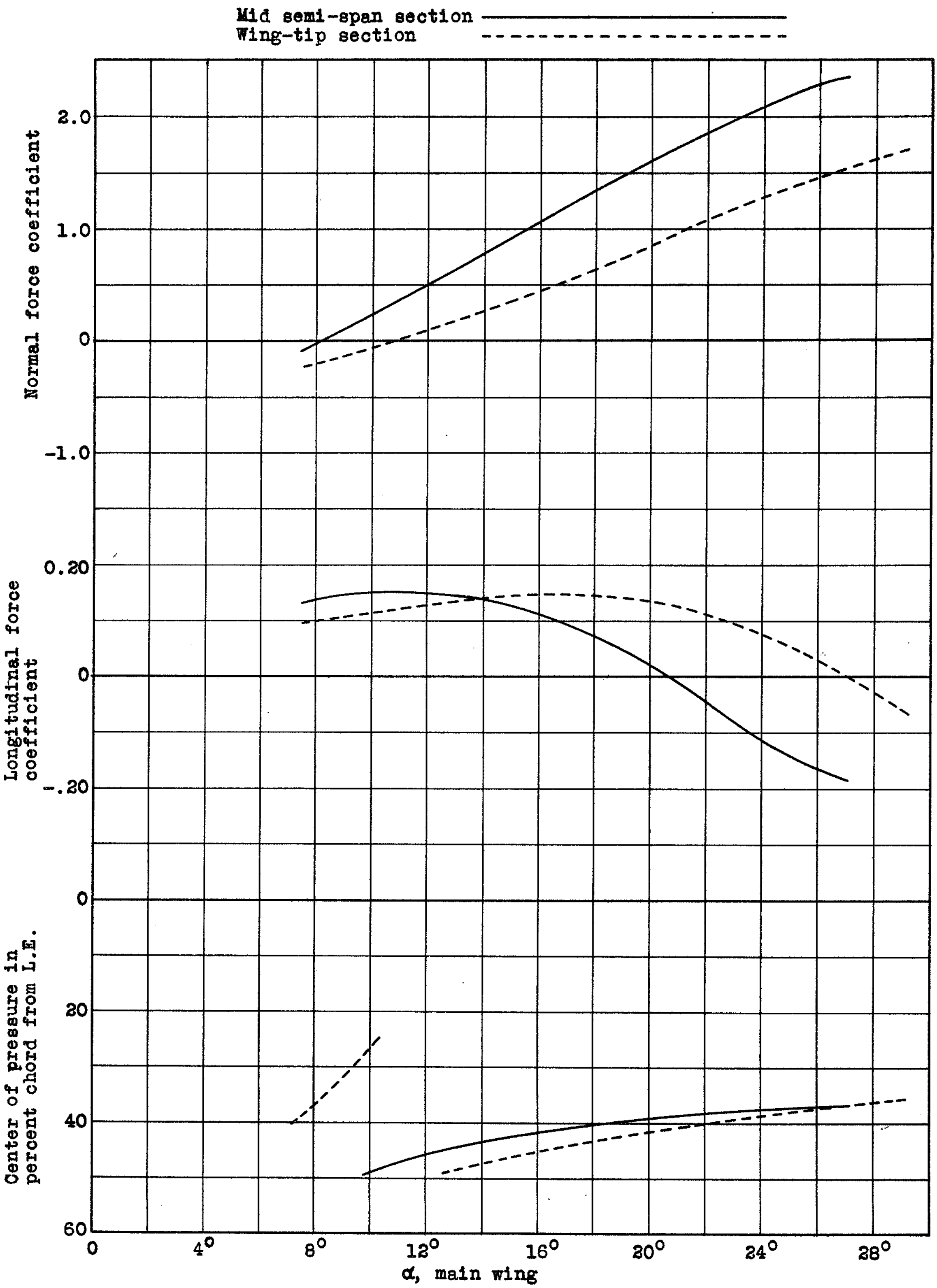


Figure 3.- Slotted R.A.F. 34. Characteristics of slat at the measured sections.

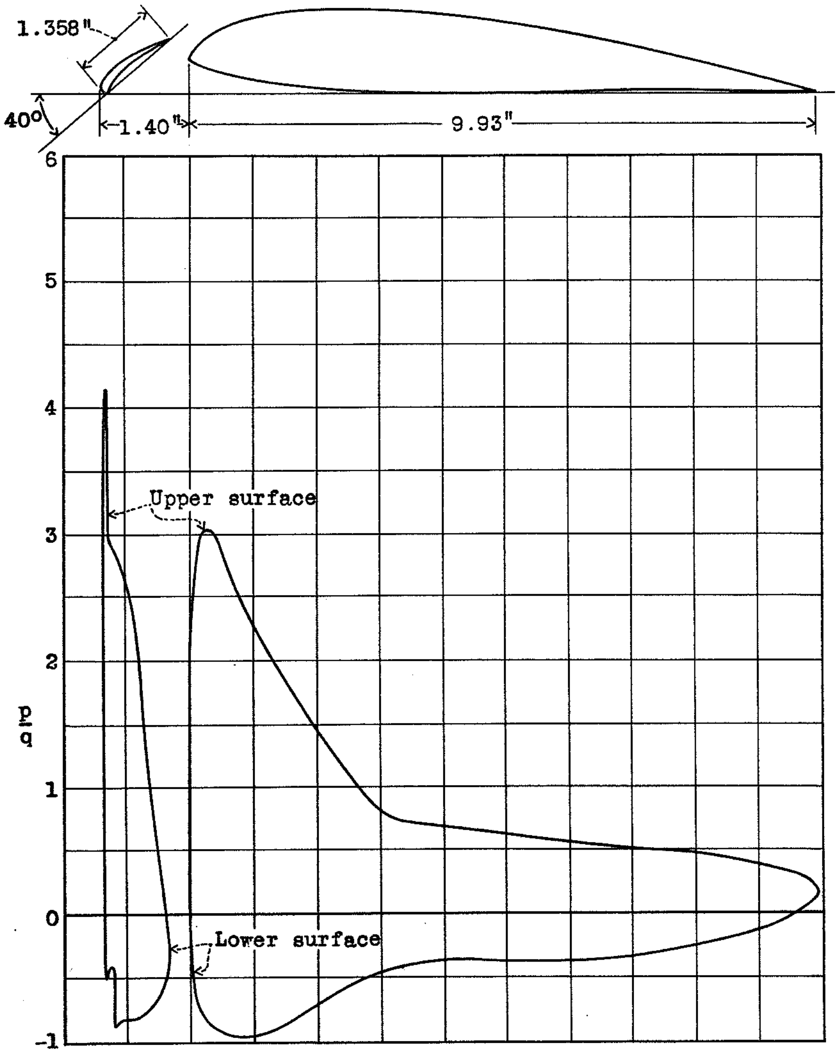


Figure 5. - Pressure distribution diagram for slotted R.A.F.31 airfoil. $\alpha = 25^\circ$, R.N.= 6,150,000

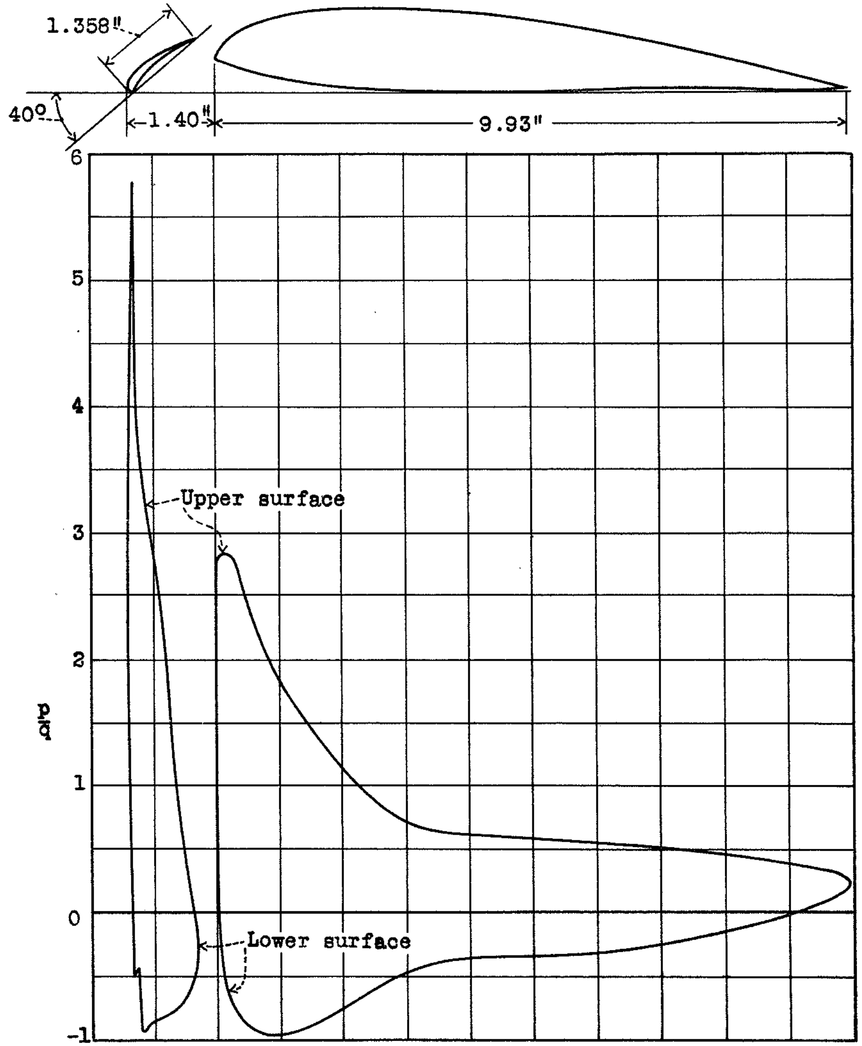


Figure 6. - Pressure distribution diagram for slotted R.A.F.31 airfoil. $\alpha = 31^\circ$, R.N.= 6,150,000

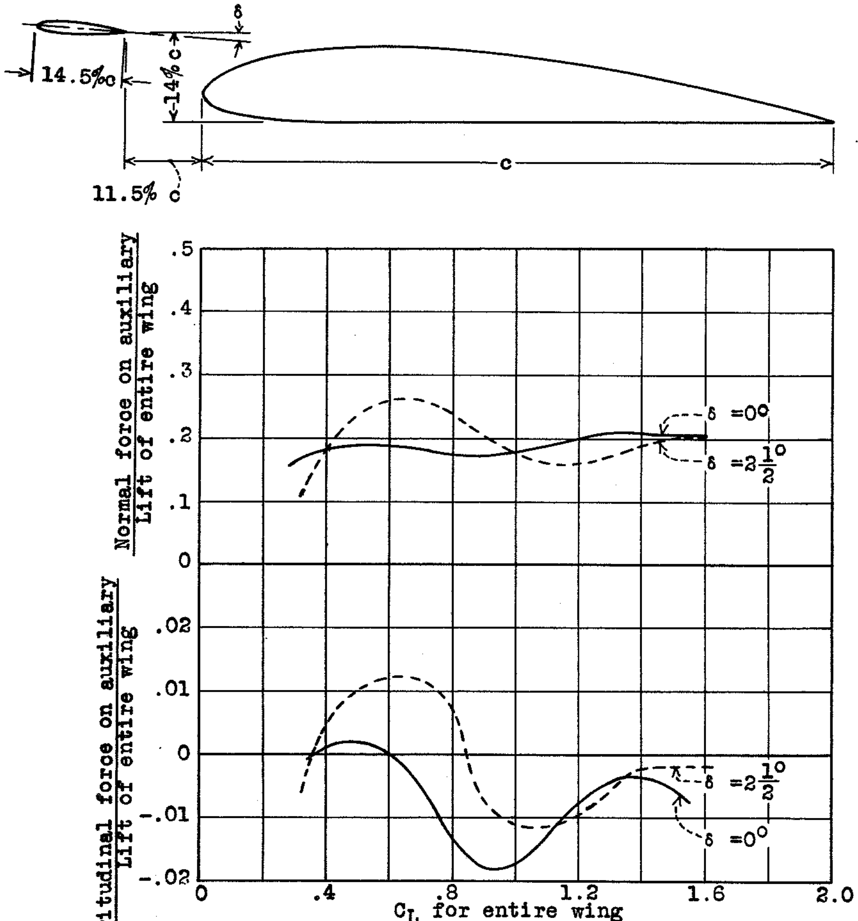


Figure 7.-Normal and longitudinal components of the force on a 14.5 percent chord N.A.C.A. 0012 auxiliary airfoil.

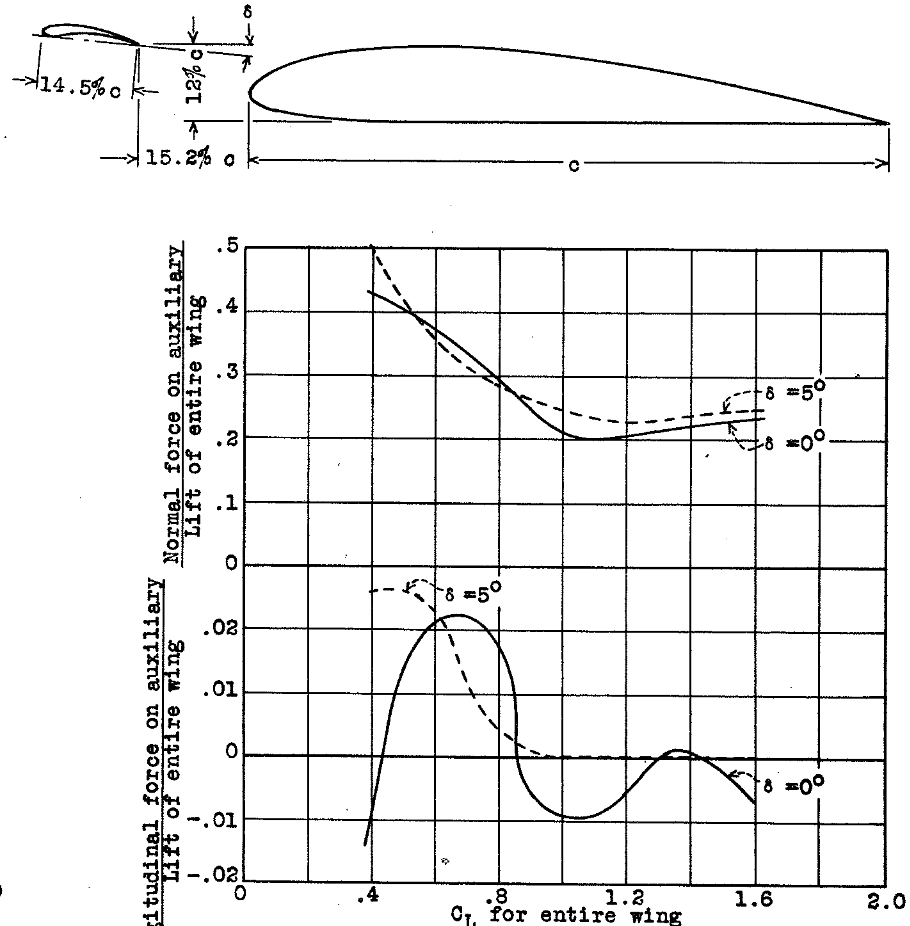


Figure 8.-Normal and longitudinal components of the force on a 14.5 percent chord N.A.C.A. 22 auxiliary airfoil.

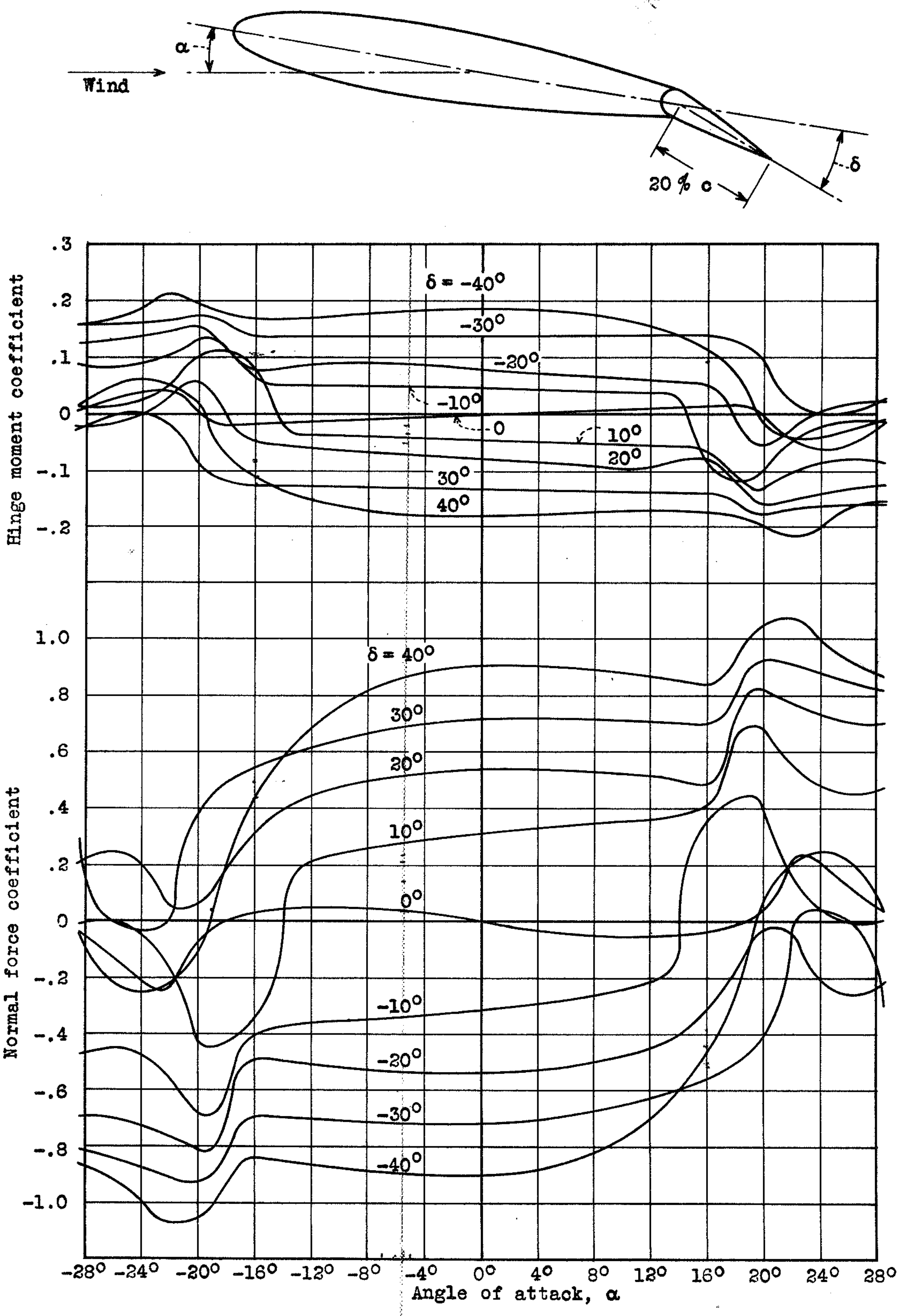


Figure 9.- Normal force and hinge moment coefficient for a 20 percent chord flap on a R.A.F. 30 airfoil. R.N. = 6,700,000.

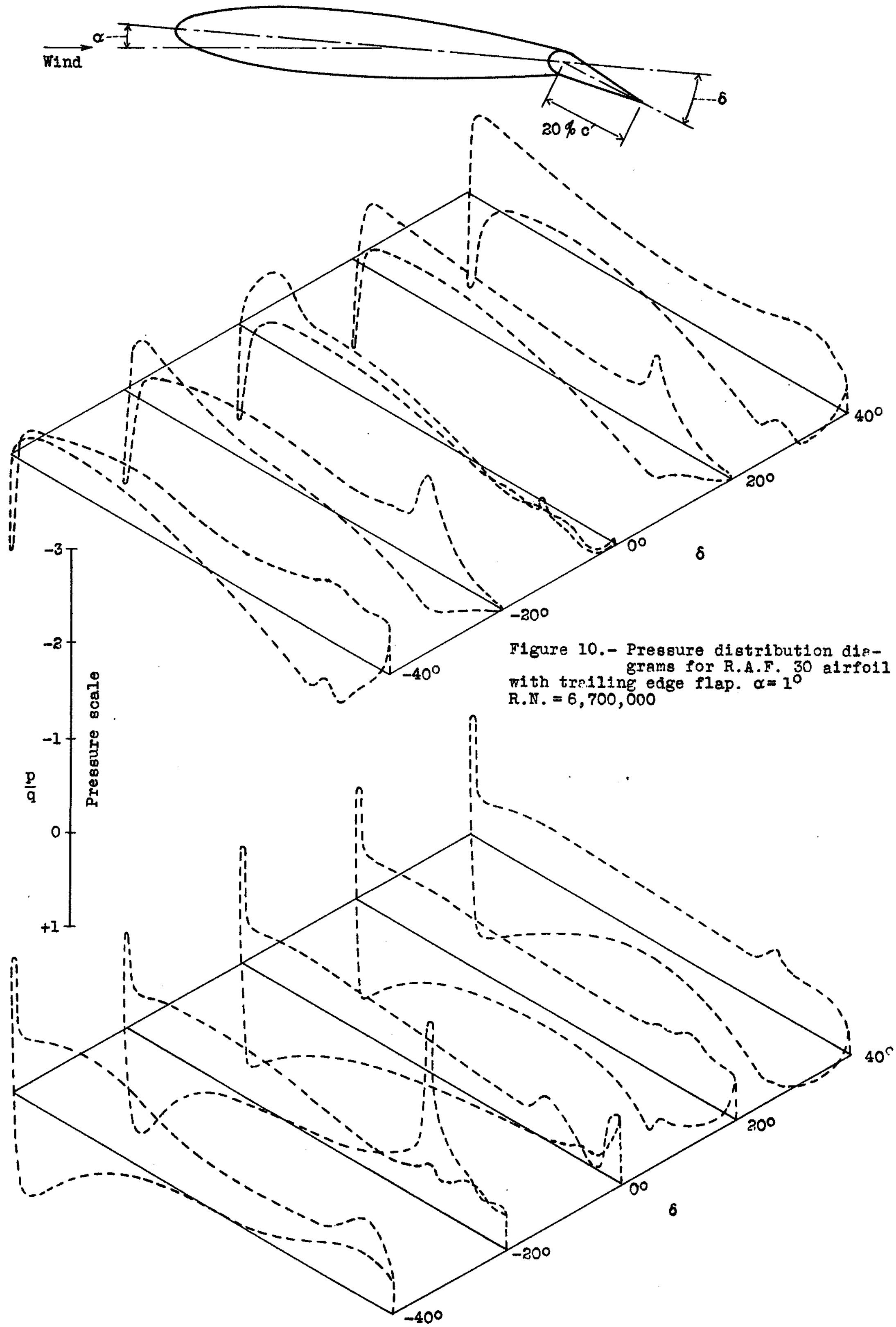


Figure 10.- Pressure distribution diagrams for R.A.F. 30 airfoil with trailing edge flap. $\alpha = 1^\circ$ R.N. = 6,700,000

Figure 12.- Pressure distribution diagrams for R.A.F. 30 airfoil with trailing edge flap. $\alpha = 25^\circ$ R.N. = 6,700,000.

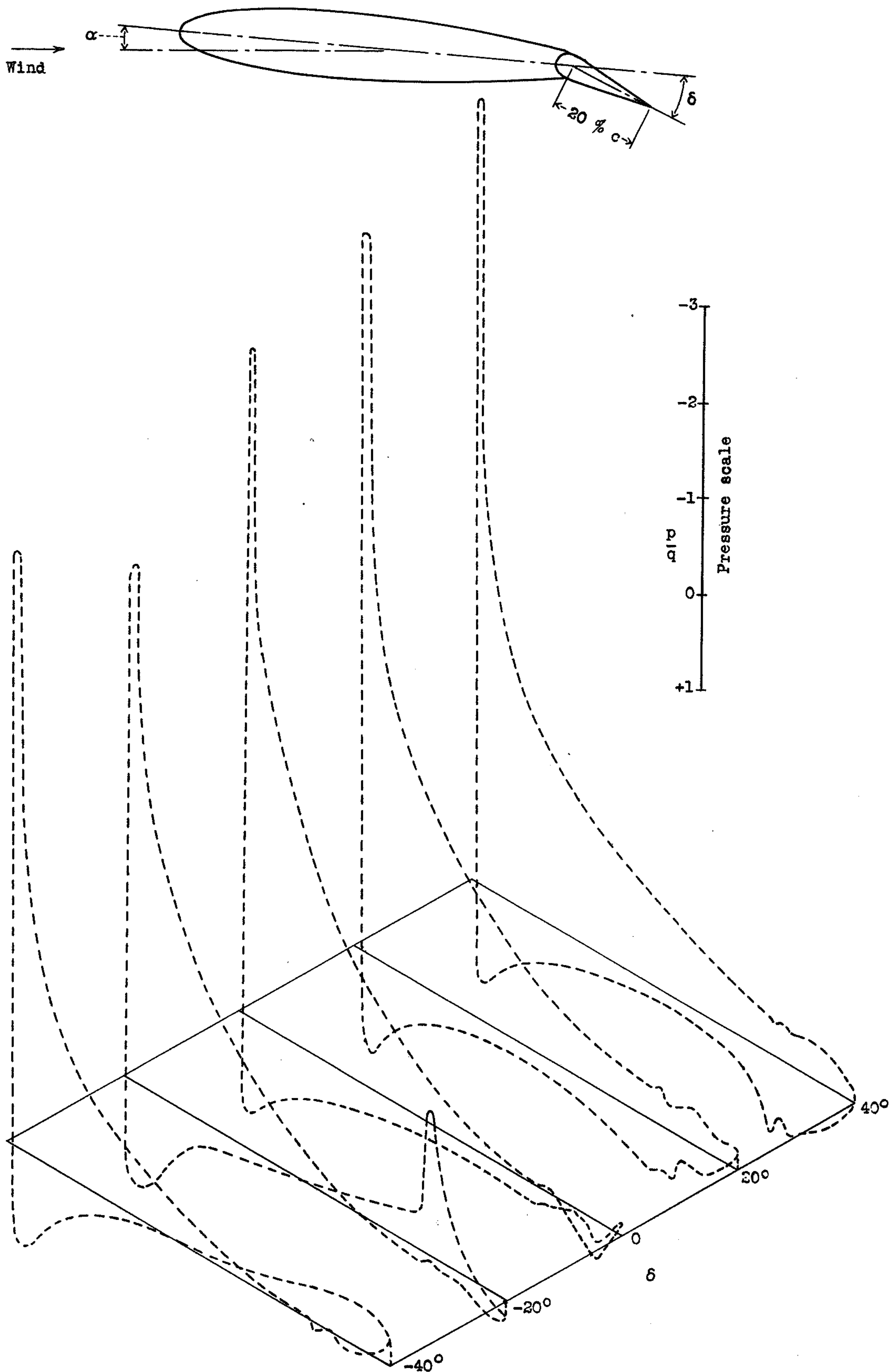


Figure 11. - Pressure distribution diagrams for R.A.F.30 airfoil with trailing edge flap. α = 16°
R.N. = 6,700,000.

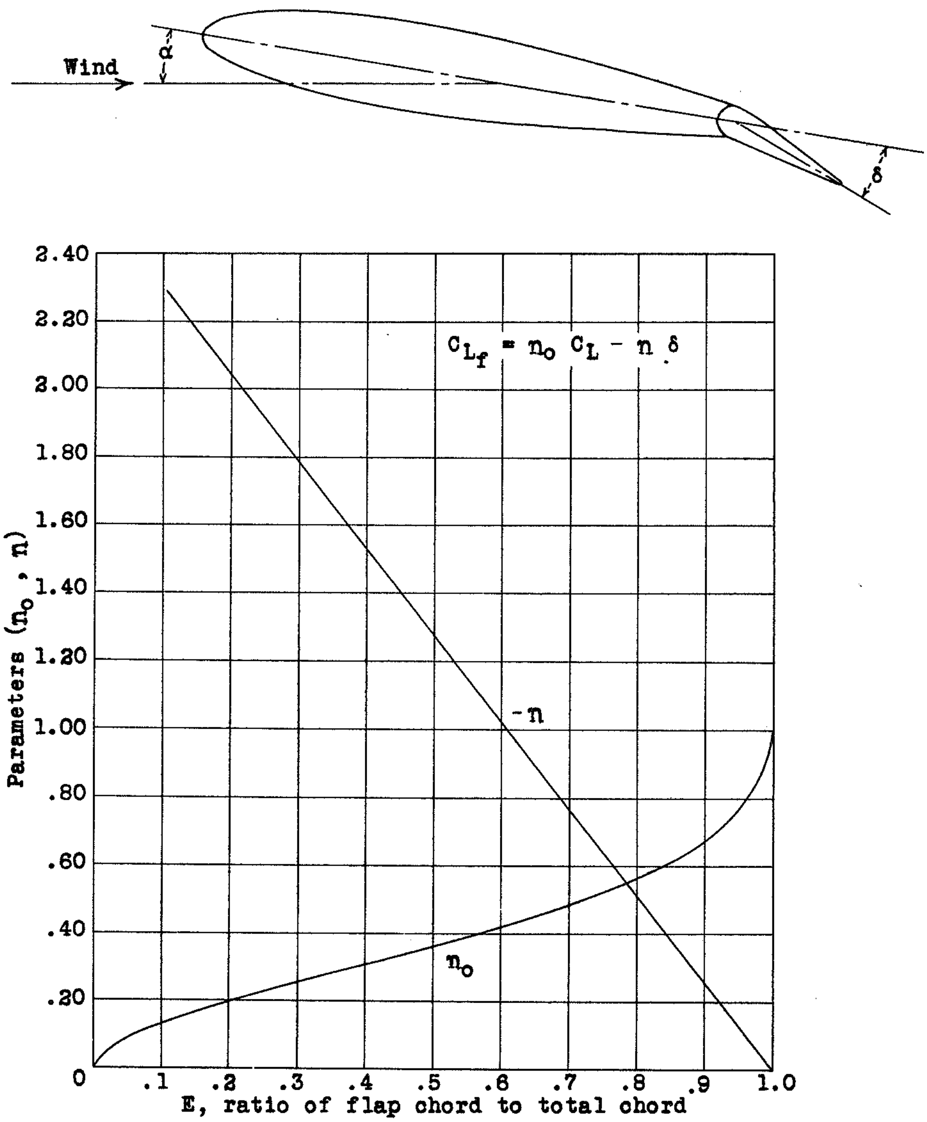


Figure 13.- Theoretical parameters.

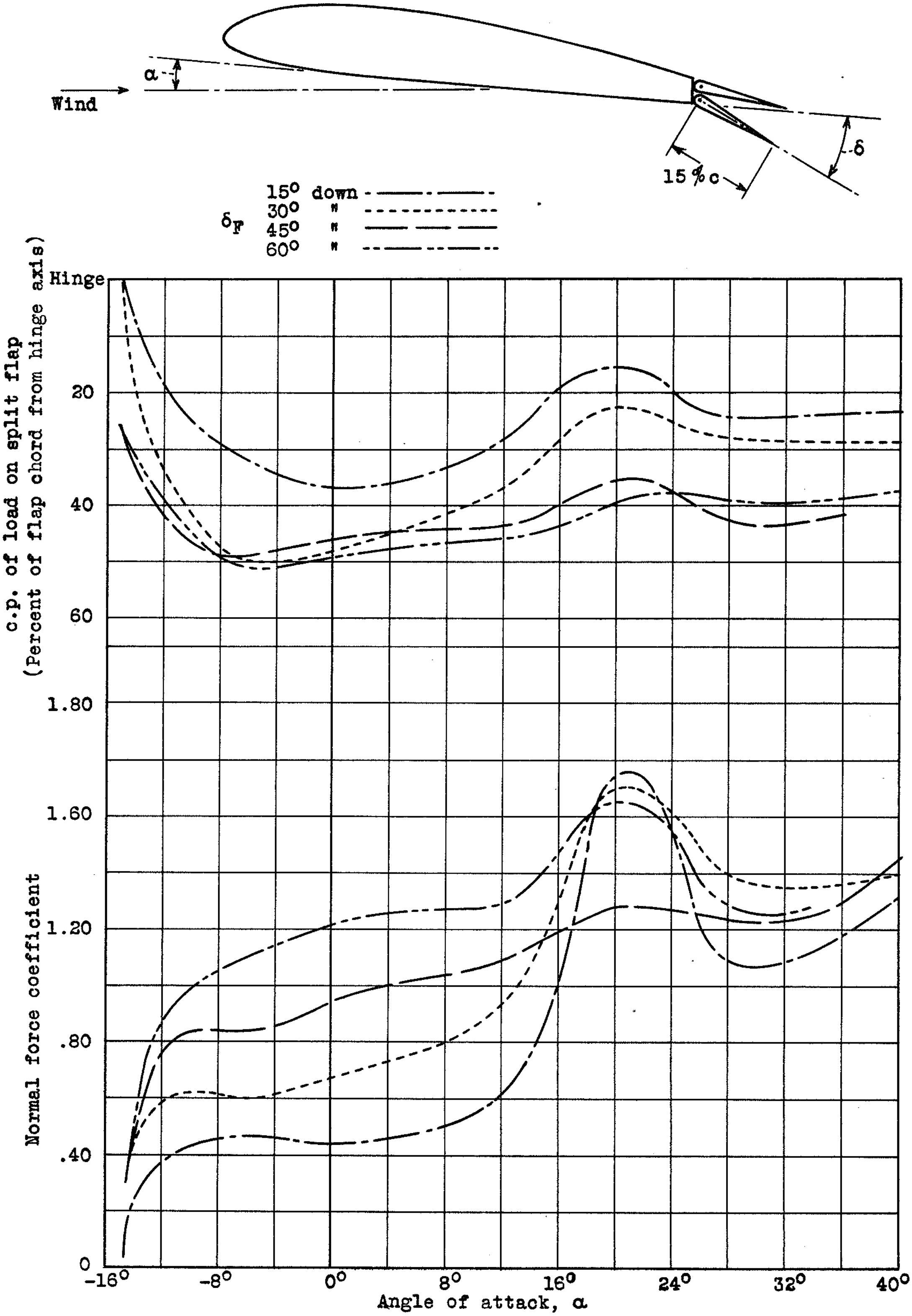


Figure 14.- Normal force and c.p. location on 15 percent chord full-span split flap (Clark Y wing).

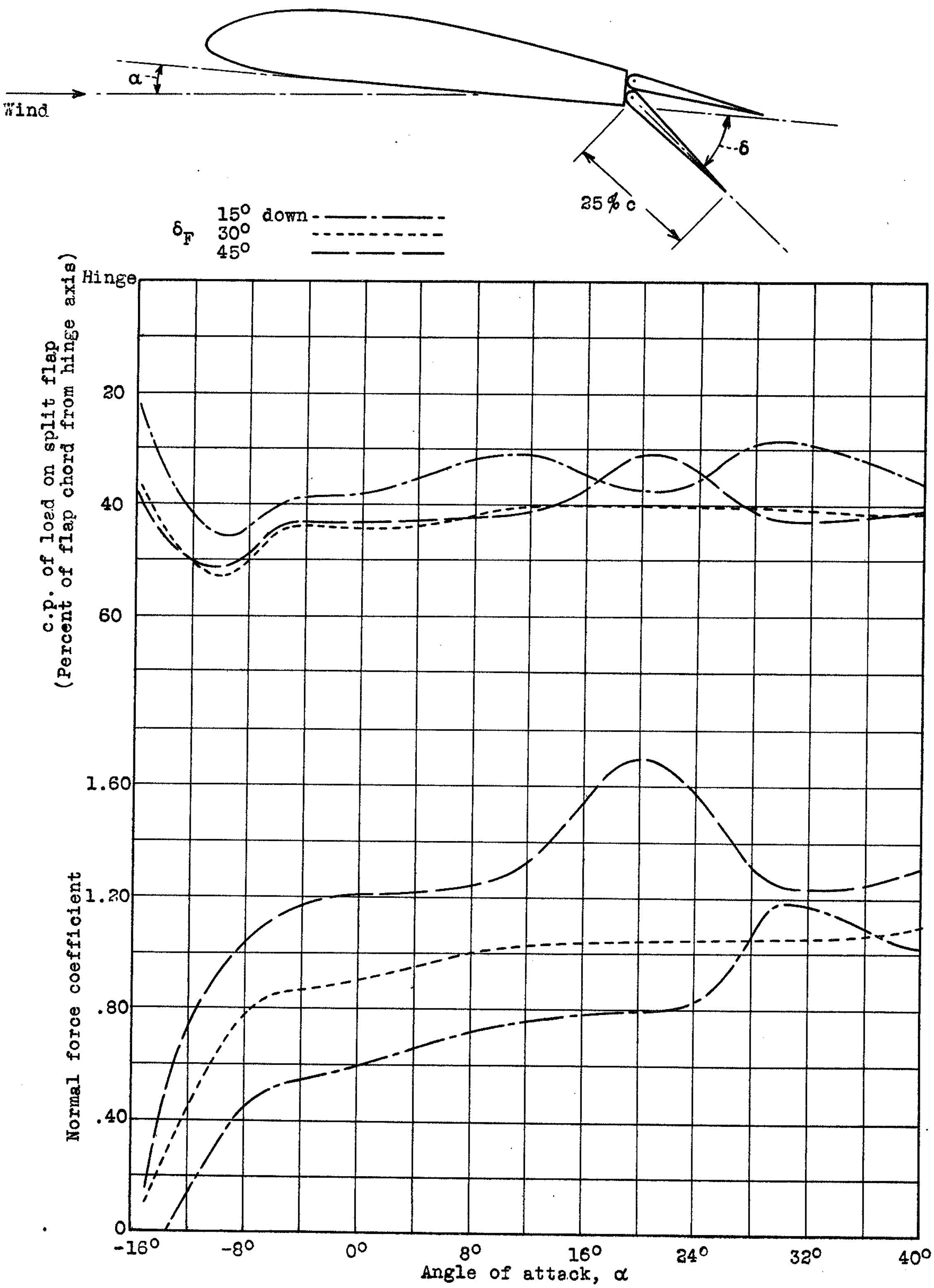


Figure 15.- Normal force and c.p. location on 25 percent chord full-span split flap (Clark Y wing).