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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 782

WIND-TUNNEL TESTS OF AN NACA 23021 AIRFOIL EQUIPPED WITH  
A SLOTTED EXTENSIBLE AND A PLAIN EXTENSIBLE FLAP

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SUMMARY

An investigation has been made in the NACA 7- by 10-foot wind tunnel of a large-chord NACA 23021 airfoil equipped with two arrangements of a completely extended 15-percent-chord extensible flap. One of the flaps had a faired juncture, without a gap; the other was provided with a slot between the trailing edge of the airfoil and the nose of the flap. Complete aerodynamic section characteristics are presented for the various flap deflections for both flap arrangements in the completely extended position.

The results showed that the basic airfoil gave the lowest profile-drag coefficients over the low lift range, the airfoil with the plain extensible flap gave the lowest profile-drag coefficients over the moderate lift range, and the airfoil with the slotted extensible flap gave the lowest profile-drag coefficients over the high lift range. The airfoil with the slotted extensible flap had the same maximum lift at a flap deflection of  $25^\circ$  as the airfoil with the plain extensible flap had at a flap deflection of  $60^\circ$ . The results of comparisons of the airfoil pitching-moment coefficients obtained with the two types of flap are dependent upon the basis chosen for comparison.

INTRODUCTION

The National Advisory Committee for Aeronautics has undertaken an extensive investigation of various wing-flap combinations to furnish information applicable to the aerodynamic design of high-lift devices for improving the safety and the performance of airplanes. Two characteristics of high-lift devices considered desirable are high lift with variable drag for landing and high lift with low

drag for take-off and initial climb. Other desirable aerodynamic features are: no increase in drag with the flap neutral; small change in pitching moment with flap deflection; low forces required to operate the flap; and freedom from possible hazard due to icing.

As part of an investigation of a balanced split flap, tests have been made of an NACA 23021 airfoil equipped with two arrangements of a 0.15c chord extensible flap. The arrangements were tested only in the completely extended condition. One of the extensible flaps has a slot and is the completely extended Fowler flap; the other arrangement has no slot and is somewhat similar to the new Zap type of flap.

#### MODEL

The basic airfoil was built to the NACA 23021 profile and has a chord of 3 feet and a span of 7 feet; the section ordinates are given in reference 1. The 15-percent-chord flap used was built to the Clark Y profile. The flap was attached to the airfoil by special hinges permitting a wide variation in the location and the deflection of the flap with respect to the airfoil. A section view of the airfoil with the slotted extensible flap is shown in figure 1. The nose of the flap was located 1.5 percent of the airfoil chord below the trailing edge of the airfoil for all flap deflections. The airfoil with the plain extensible flap is shown in figure 2. For this installation the nose point of the flap was located from the conditions that it be below the trailing edge of the airfoil and that the upper surface of the flap be approximately tangent to the extended upper surface of the airfoil. The airfoil-flap junction was sealed and smoothly faired with modeling clay on both upper and lower surfaces. The flap deflections for both arrangements were measured with respect to the airfoil chord line.

#### TESTS AND RESULTS

The models were mounted in the closed test section of the NACA 7- by 10-foot wind tunnel (reference 2) so that they completely spanned the jet except for small clearances at each end. The main airfoil was rigidly

attached to the balance frame by torque tubes, which extended through the upper and the lower boundaries of the tunnel. The angle of attack of the model was set from outside the tunnel by rotating the torque tubes with a calibrated drive. Since approximately two-dimensional flow is obtained with this type of installation, the section characteristics of the model under test can be determined.

All the tests were made at a dynamic pressure of 16.37 pounds per square foot, which corresponds to a velocity of about 80 miles per hour under standard atmospheric conditions and to an average test Reynolds number of about 2,190,000. Because of the wind-tunnel turbulence, the effective Reynolds number was approximately 3,500,000. For all tests, the Reynolds number is based on the chord of the airfoil with the flap retracted and on a turbulence factor of 1.6 for the tunnel. For each arrangement of wing and flap, tests were made through an angle-of-attack range from  $-6^\circ$  to the stall.

The test results are given in standard section non-dimensional coefficient form corrected as explained in reference 2.

$c_l$	section lift coefficient ( $l/qc$ )
$c_{d_0}$	section profile-drag coefficient ( $d_0/qc$ )
$c_{m(a.c.)_0}$	section pitching-moment coefficient about the aerodynamic center of the plain airfoil
	$\left( \frac{m(a.c.)_0}{qc^2} \right)$

where

$l$	section lift
$d_0$	section profile drag
$m(a.c.)_0$	section pitching moment
$q$	dynamic pressure ( $\frac{1}{2}\rho V^2$ )
$c$	chord of basic airfoil with flap retracted

and

$\alpha_0$  angle of attack for infinite aspect ratio

$\delta_f$  flap deflection with respect to airfoil chord line

The various measurements made in the tests are believed to be accurate within the following limits:

$\alpha_0$ - - - - -	$\pm 0.1^\circ$	$c_{d_0}(c_i = 1.0)$ - - - - -	$\pm 0.0006$
$c_{l_{max}}$ - - - - -	$\pm 0.03$	$c_{d_0}(c_i = 2.0)$	$\pm 0.002$
$c_{n(a.c.)_0}$ - - - - -	$\pm 0.003$	$\delta_f$ - - - - -	$\pm 0.3^\circ$
$c_{d_{0min}}$ - - - - -	$\pm 0.0003$	Flap position - - -	$\pm 0.002c$

No corrections have been applied to the data for the flap hinge fittings. The relative merits of the various arrangements are probably inappreciably affected because the same hinge fittings were used throughout the tests.

The results of the tests are presented as aerodynamic section characteristics in figures 3 to 6.

#### DISCUSSION

It should be remembered that the flaps were tested only in the completely extended condition. Extending the flap for either flap arrangement increased the wing chord, and, since the lift coefficients are based on the wing chord with the flap retracted, the slope of the lift curve and the maximum lift coefficient were considerably increased. (See figs. 3 and 4.) A comparison of the slopes of the lift curves given in figures 3 and 4 shows that for flap deflections less than  $25^\circ$  the slopes are greater for the airfoil with the slotted extensible flap than for the airfoil with the plain extensible flap, probably because the slotted extensible flap is unstalled for the low deflections. For deflections greater than  $25^\circ$ , the slopes of the lift curves are about the same for both airfoil-flap arrangements. In general, there is less change in the angle of attack for maximum lift with changes in flap deflection for the slotted extensible flap arrangement than for the plain extensible flap arrangement.

The plain extensible flap must be deflected approximately twice as much as the slotted extensible flap to give the same maximum lift coefficient. As shown in figure 5, this fact is true for only slotted extensible flap deflections less than  $25^\circ$ , but, since almost the same maximum lift coefficient is obtained for a  $25^\circ$  deflection of the slotted extensible flap as for a  $60^\circ$  deflection of the plain extensible flap, there would be no need to use higher slotted extensible flap deflections for take-off. Increased drag may be desired, however, for landing and higher flap deflections may be used for the landing condition.

A comparison of the optimum arrangements of the two types of flap, from considerations of low profile drag at a given lift coefficient, is made in figure 6. This figure shows that the basic airfoil has the lowest profile drag for lift coefficients less than 0.8. For lift coefficients between 0.8 and 1.4, the airfoil with the plain extensible flap deflected  $10^\circ$  has the lowest profile drag. It should be noted that the airfoil with the plain extensible flap deflected  $0^\circ$  might have had somewhat lower profile-drag characteristics if it had been possible to fair the lower surface to a better profile. For lift coefficients greater than 1.4, the airfoil with the slotted extensible flap has the lower profile drag, provided it is not deflected more than  $25^\circ$ .

A comparison of the pitching-moment coefficients corresponding to the envelope polars of figure 6 shows that the airfoil with the plain extensible flap has lower pitching-moment coefficients than the airfoil with the slotted extensible flap. It should be remembered, however, that this comparison is made solely on the basis of low profile drag for take-off and no account is taken of the added safety factor afforded by the slotted extensible flap, which would be operating at a lower percentage of the maximum lift coefficient.

The pitching-moment coefficients of the two arrangements may also be compared at such flap deflections that each arrangement has the same maximum lift coefficient, and therefore the take-off lift coefficient will be the same percentage of the maximum lift coefficient for each wing-flap arrangement. In this case the slotted extensible flap has the lower pitching-moment coefficients. Probably an even more critical criterion for a comparison of pitching-moment coefficients is the landing condition.

For this condition, however, both flaps would probably be deflected full downward and they would have very nearly equal pitching-moment coefficients. Other effects, such as stability and balance changes due to power, the span of the flaps, the characteristics of the tail, and, in general, all of the other factors connected with the individual design of each airplane, would have to be considered in making a valid comparison of the pitching-moment coefficients obtained with different wing-flap combinations.

#### CONCLUDING REMARKS

The basic airfoil gave the lowest profile-drag coefficients over the low lift range, the airfoil with the plain extensible flap gave the lowest profile-drag coefficients over the moderate lift range, and the airfoil with the slotted extensible flap gave the lowest profile-drag coefficients over the high lift range. The airfoil with the slotted extensible flap had the same maximum lift at a flap deflection of  $25^\circ$  as the airfoil with the plain extensible flap had at a flap deflection of  $60^\circ$ . The results of comparisons of the airfoil pitching-moment coefficients obtained with the two types of flap are dependent upon the basis chosen for comparison.

Langley Memorial Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va., October 1, 1940.

#### REFERENCES

1. Wenzinger, Carl J., and Harris, Thomas A.: Wind-Tunnel Investigation of an N.A.C.A. 23021 Airfoil with Various Arrangements of Slotted Flaps. Rep. No. 677, NACA, 1939.
2. Wenzinger, Carl J., and Harris, Thomas A.: Wind-Tunnel Investigation of an N.A.C.A. 23012 Airfoil with Various Arrangements of Slotted Flaps. Rep. No. 664, NACA, 1939.

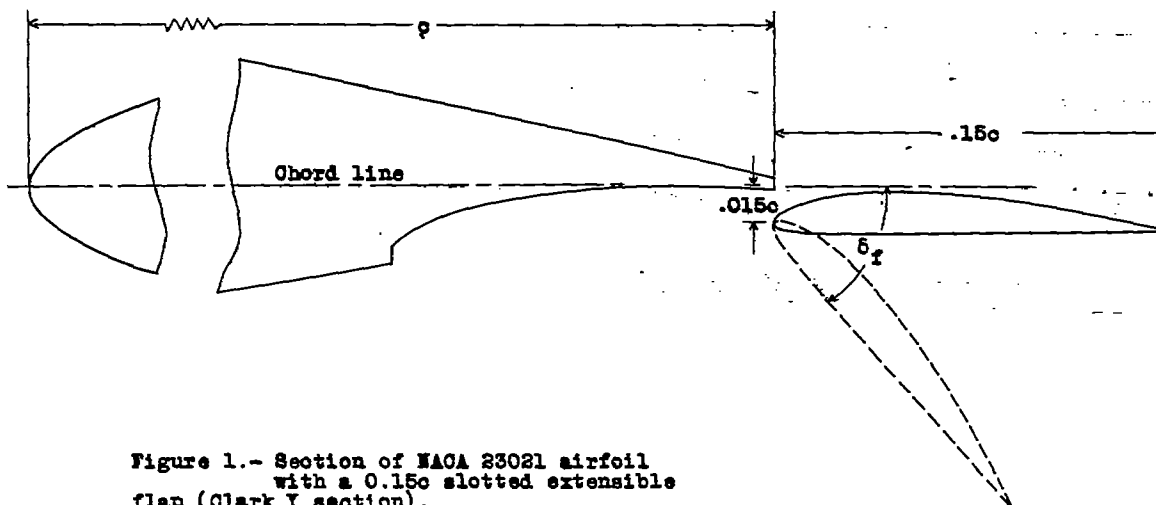


Figure 1.- Section of NACA 23021 airfoil with a  $0.15c$  slotted extensible flap (Clark Y section).

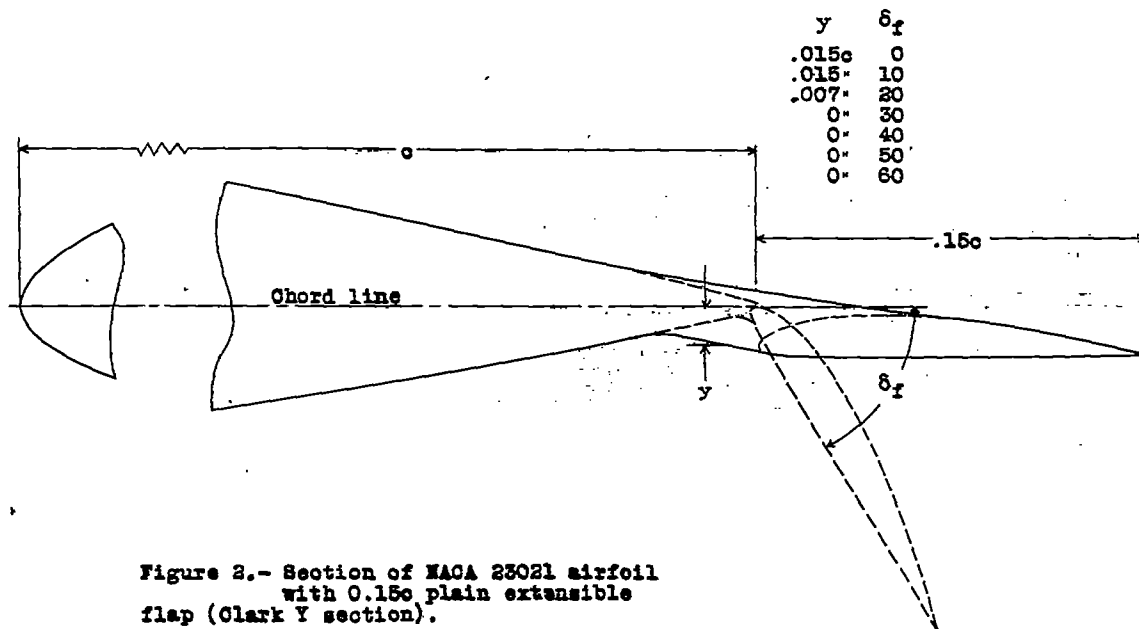


Figure 2.- Section of NACA 23021 airfoil with  $0.15c$  plain extensible flap (Clark Y section).



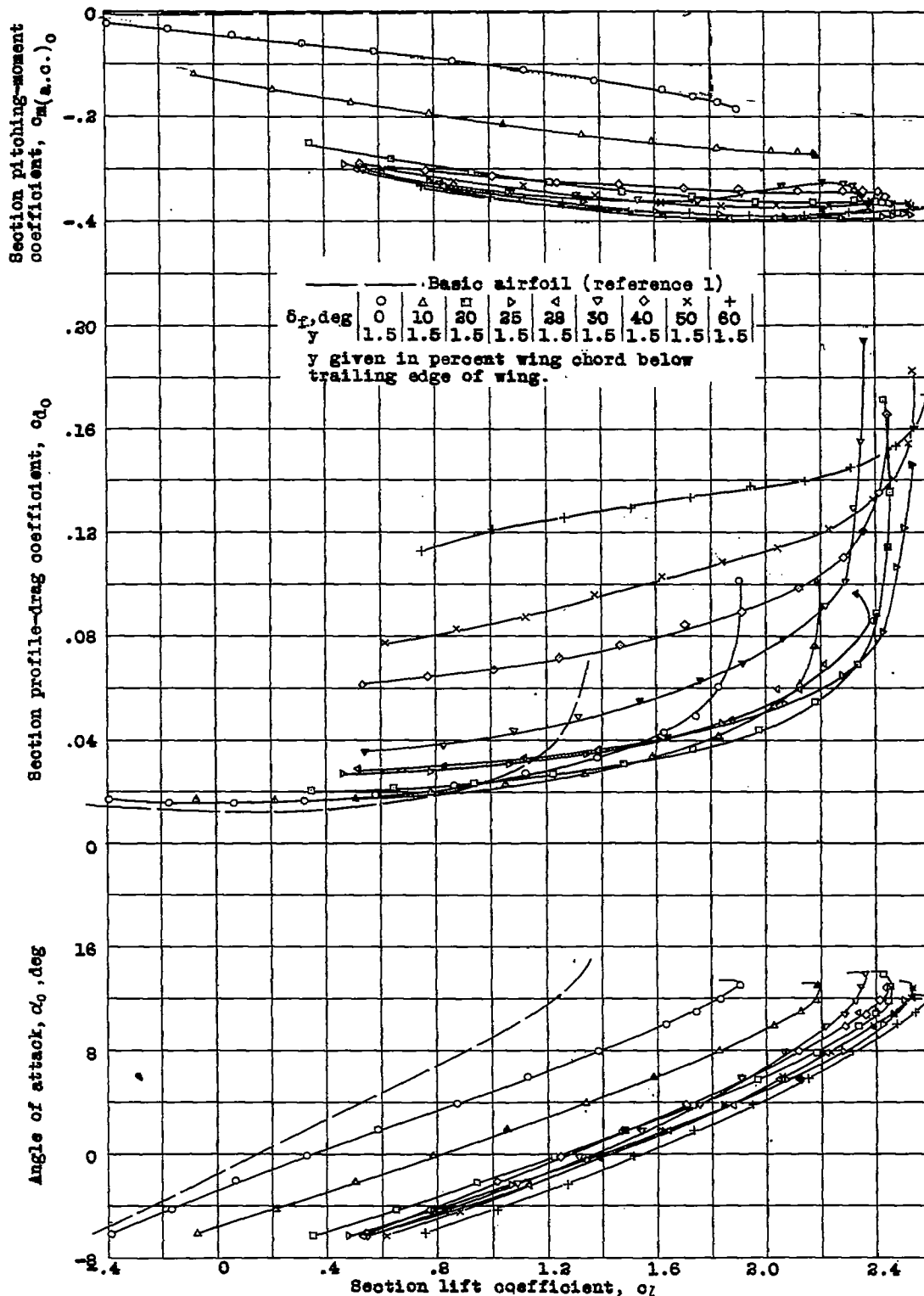


Figure 3.- Section aerodynamic characteristics of the NACA 23021 airfoil with a 0.15c slotted extensible flap. (Clark-Y section).

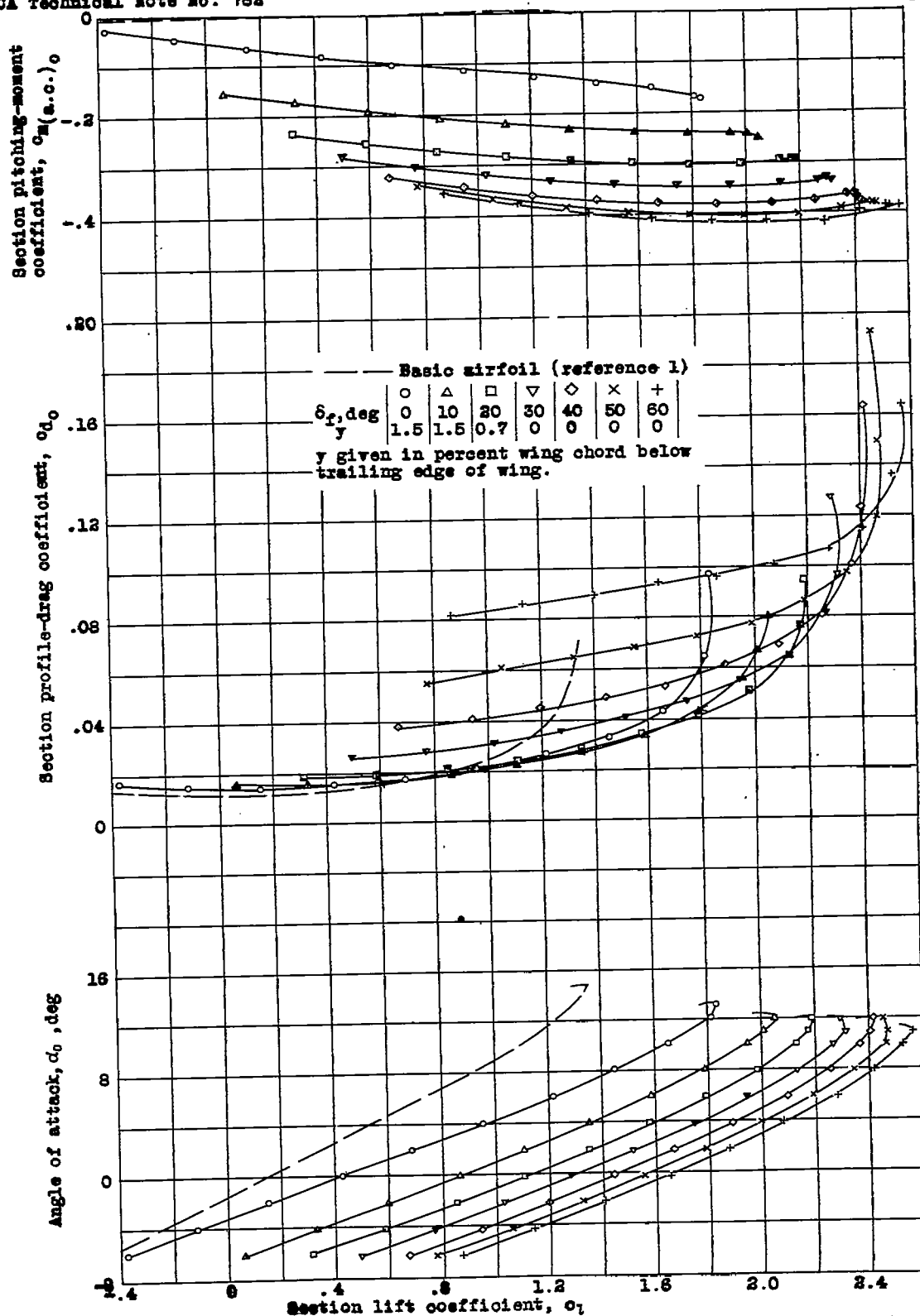


Figure 4.- Section aerodynamic characteristics of the NACA 23021 airfoil with a 0.15c plain extensible flap (Clark Y section).

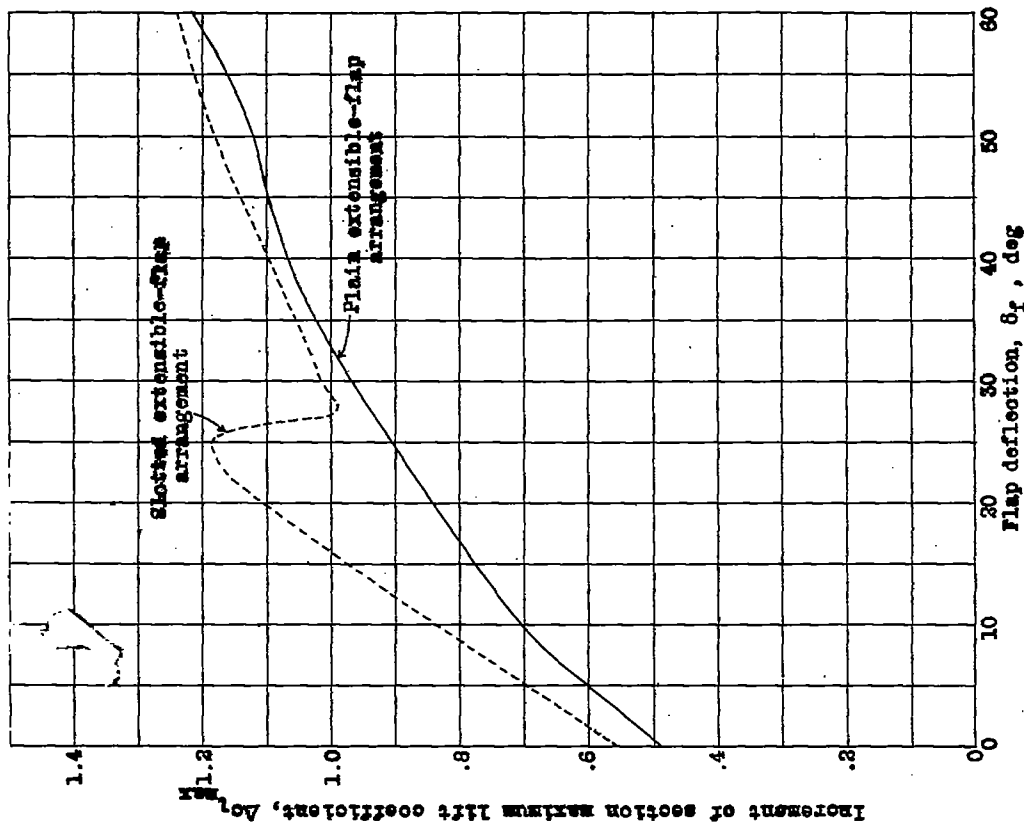


Figure 5.- Comparison of the increment of maximum lift coefficient for the two types of flap on an NACA 23021 airfoil.

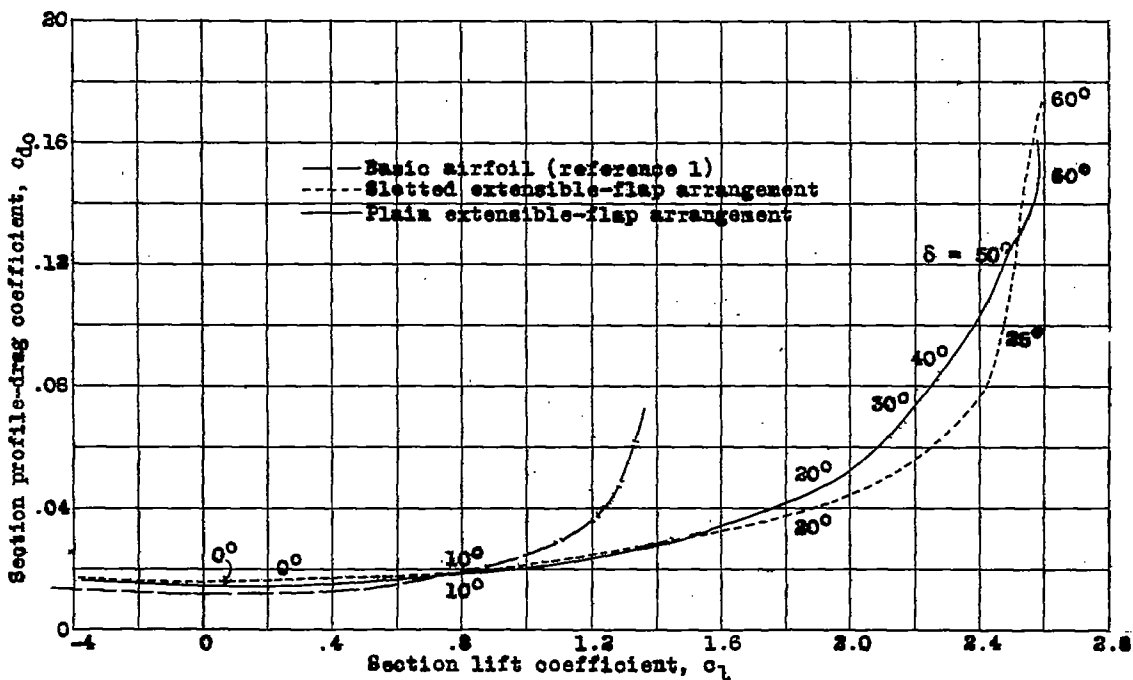


Figure 6.- Comparison of the profile-drag characteristics of the two types of flap on an NACA 23021 airfoil.