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RESEARCH MEMORANDUM

AN EXPLORATORY INVESTIGATION OF THE RELATIVE MERITS OF SPLIT AND CHORD-EXTENSION FLAPS ON A 45° SWEPT-BACK WING

By Edward J. Hopkins

Ames Aeronautical Laboratory
Moffett Field, Calif.

NATIONAL ADVISORY COMMITTEE
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AN EXPLORATORY INVESTIGATION OF THE RELATIVE MERITS OF SPLIT AND CHORD-EXTENSION FLAPS ON A 45° SWEPT-BACK WING

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SUMMARY

A wind-tunnel investigation was conducted to explore the relative merits of split and chord-extension flaps on a 45° swept-back wing. The tests were made at low speed on a semispan model equipped with split flaps of 60- and 90-percent span, and with a full-span chord-extension flap.

The split flaps gave only a very small increase in the maximum lift coefficient but were effective in extending the linear variation of pitching-moment coefficient with lift coefficient to a higher value of lift coefficient. In addition, these flaps reduced considerably the angle of attack for a given lift coefficient.

The chord-extension flap was considerably more effective than the split flap in increasing the maximum lift coefficient. The chord-extension flap deflected 25° produced a maximum lift coefficient increment of 0.55 but gave nonlinear lift and pitching-moment characteristics.

Assuming the pitching moments to be balanced with a conventional horizontal tail, the split flap produces no increase of maximum lift coefficient while the chord-extension flap would provide a sizeable increment of maximum lift coefficient.

INTRODUCTION

One of the major problems encountered in the design of highly swept-back wings is that of obtaining sufficiently high lift coefficients for landing at reasonably low speeds. The experimental data of reference 1 indicate that flap effectiveness is markedly reduced by large amounts of sweep, resulting in low values of the maximum lift coefficient.

Tests of various lateral-control devices on a 45° swept-back wing, including chord-extension controls (reference 2), suggested that chord-extension flaps might be used efficiently as high-lift devices for swept wings. Accordingly, an exploratory investigation was conducted to determine the effectiveness of a full-span chord-extension flap on a semispan model of a 45° swept-back wing of aspect ratio 4.5. This flap was tapered in plan form, having the maximum chord at the wing tip. The wing area was increased and the aspect ratio of the wing was reduced when the flap was extended. For comparison, split flaps of 60- and 90-percent span were also investigated.

COEFFICIENTS, SYMBOLS, AND CORRECTIONS

The coefficients and symbols used in the presentation of the results are as follows:

C_L lift coefficient $\left(\frac{\text{lift}}{qS}\right)$

$C_{L_{max}}$ maximum lift coefficient

$\Delta C_{L_{max}}$ increment of maximum lift coefficient due to flap

C_D drag coefficient $\left(\frac{\text{drag}}{qS}\right)$

C_m pitching-moment coefficient about the lateral axis through a point at 25 percent of the mean aerodynamic chord (pitching moment/$q\bar{S}\bar{c}$)

α angle of attack, degrees

q dynamic pressure, pounds per square foot

S area of semispan wing, square feet

$\bar{c}$ mean aerodynamic chord, feet

A aspect ratio $\left(\frac{2b^2}{S}\right)$

b wing semispan measured perpendicular to plane of symmetry, feet

λ taper ratio $\left(\frac{\text{tip chord}}{\text{root chord}}\right)$

δ_f flap deflection below the chord line, measured in a plane parallel to the plane of symmetry, degrees

C_{L_α} lift-curve slope $(dC_L/d\alpha)$, per degree

c airfoil chord

Subscript

u uncorrected values of the coefficients

The following wind-tunnel-wall corrections, determined from reference 3 for an unswept wing of the same aspect ratio, taper ratio, and span, were applied to the data:

$$\alpha = \alpha_u + 0.652\ C_{L_{u\delta_f = 0}} + 0.0642\ C_{L_u}$$

$$C_L = 0.996\ C_{L_u}$$

$$C_D = C_{D_u} + 0.0133\ C_{L_u}{}^2$$

$$C_m = C_{m_u} + 0.00188\ C_{L_u}$$

Previous calculations for a similar plan form indicated a negligible error would be involved in applying the unswept corrections to this swept-back wing. No end-plate drag tares were applied to the data; therefore, the drag coefficients presented are not the absolute values of these coefficients. However, the incremental drag coefficients caused by the extension of the flaps can be considered as essentially correct.

MODEL AND APPARATUS

The model used for the tests was a semispan wing mounted on a turntable flush with the wind-tunnel floor which served as a reflection plane corresponding to the plane of symmetry (fig. 1). The 25-percent-chord line of the wing was swept back 45°. The wing had an aspect ratio of 4.5, a taper ratio of 0.5, and an NACA 64A210 (a = 0.8) profile parallel to the plane of symmetry. Complete model dimensions are given in figure 2.

The 20-percent-chord split flaps of 60-percent and 90-percent span were tested at a deflection of 60°. The chord-extension flap extended beyond the wing trailing edge and was tapered in plan form from the tip to the root of the wing. This flap was tested with deflections of 3° and 25° below the extended chord line. The 3° deflection corresponded to the extension of this flap along the mean camber line at the trailing edge of the airfoil (fig. 2).

RESULTS AND DISCUSSION

The tests were conducted at a dynamic pressure of 30 pounds per square foot corresponding to a Reynolds number of 1.8×10^{6} based on the mean aerodynamic chord of the wing.

Split Flaps

The split flaps of 60-percent and 90-percent span increased the maximum lift coefficient by only small amounts, 0.03 and 0.09, respectively, as shown in figure 3. However, the angle of attack for a given lift coefficient was greatly reduced by the deflection of these flaps. For example, the angle of attack required for a lift coefficient of 1.0 was reduced from 19° to 7.9° by the split flap of 90-percent span. Although the longitudinal instability near the maximum lift coefficient was not eliminated by the split flaps, the occurrence of the instability was delayed to a higher value of lift coefficient. Also, the range of linear variation of pitching-moment coefficient with lift coefficient was extended to a higher value of lift coefficient (fig. 3).

Chord-Extension Flap

The chord-extension flap was considerably more effective in producing maximum lift increments than were the split flaps. This is shown in figure 3 and the following table which compares the performance of the flaps:

Flaps	δ_f	$C_{L_{max}}$	$\Delta C_{L_{max}}$	α at $C_{L_{max}}$	$(C_{L_\alpha})_{\alpha = 0^{\circ}}$
Retracted	0°	1.09	- - -	28°	0.054
0.6-span split	60°	1.12	0.03	15°	.054
0.9-span split	60°	1.18	.09	13°	.054
Chord-extension	3°	1.43	.34	27°	.064
Chord-extension	25°	1.64	.55	26°	.054

As shown in the preceding table, the angle of attack for maximum lift was relatively unaffected by the chord-extension flap but was reduced considerably by the split flaps. The increase of lift-curve slope with the chord-extension flap deflected 3° was approximately the increase that would be predicted, considering the 25.7-percent increase in the wing area and the effective reduction of the wing aspect ratio from 4.5 to 3.6. The 25° deflection of the chord-extension flap resulted in undesirable nonlinear lift and pitching-moment characteristics, indicating that 25° may have been beyond the optimum deflection of this type of flap.

Resultant Lift Coefficients After Balancing Pitching-Moment Coefficients

A larger change in pitching-moment coefficient was obtained with the chord-extension flap than with the split flaps. To obtain a more equitable comparison of the maximum lift coefficients obtainable with these flaps, the loss of lift coefficient due to balancing the pitching-moment coefficient with a conventional horizontal tail has been considered. A horizontal tail length of 2.5 times the length of the mean aerodynamic chord was assumed. The following table presents a comparison of the lift coefficients resulting after balancing the pitching-moment coefficients corresponding to 0.9 of the maximum lift coefficients. The value of 0.9 of the maximum lift coefficient was chosen to avoid making the comparison within the range of rapidly changing pitching moments near the stall.

Flaps	δ_f	$0.9\ C_{L_{max}}$	Corresponding C_m	Increment of C_L due to balancing C_m	Resultant C_L
Retracted	0°	0.98	0.013	0.01	0.99
0.6-span split	60°	1.01	-.095	-.04	.97
0.9-span split	60°	1.06	-.170	-.07	1.00
Chord-extension	3°	1.29	-.210	-.09	1.20
Chord-extension	25°	1.48	-.451	-.18	1.29

When the change of lift coefficient due to balancing the pitching-moment coefficient is considered, it is apparent that an appreciable gain in lift coefficient is still realized with the chord-extension flap but that no increase in lift coefficient is produced by the split flap.

CONCLUSIONS

The results of the investigation of the relative merits of split and chord-extension flaps on a 45° swept-back wing indicated:

1. A very small increase in the maximum lift coefficient was obtained with the split flaps; but the angle of attack for a given lift coefficient was considerably reduced.

2. The split flaps extended the linear variation of pitching-moment coefficient with lift coefficient to a higher value of lift coefficient.

3. The chord-extension flap deflected 25° increased the maximum lift coefficient of the wing from 1.09 to 1.64 but caused nonlinear lift and pitching-moment characteristics.

4. Assuming the pitching moments to be balanced with a conventional horizontal tail, the split flap would produce no increase of maximum lift coefficient while the chord-extension flap would provide an appreciable increment of maximum lift coefficient.

Ames Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Moffett Field, Calif.

REFERENCES

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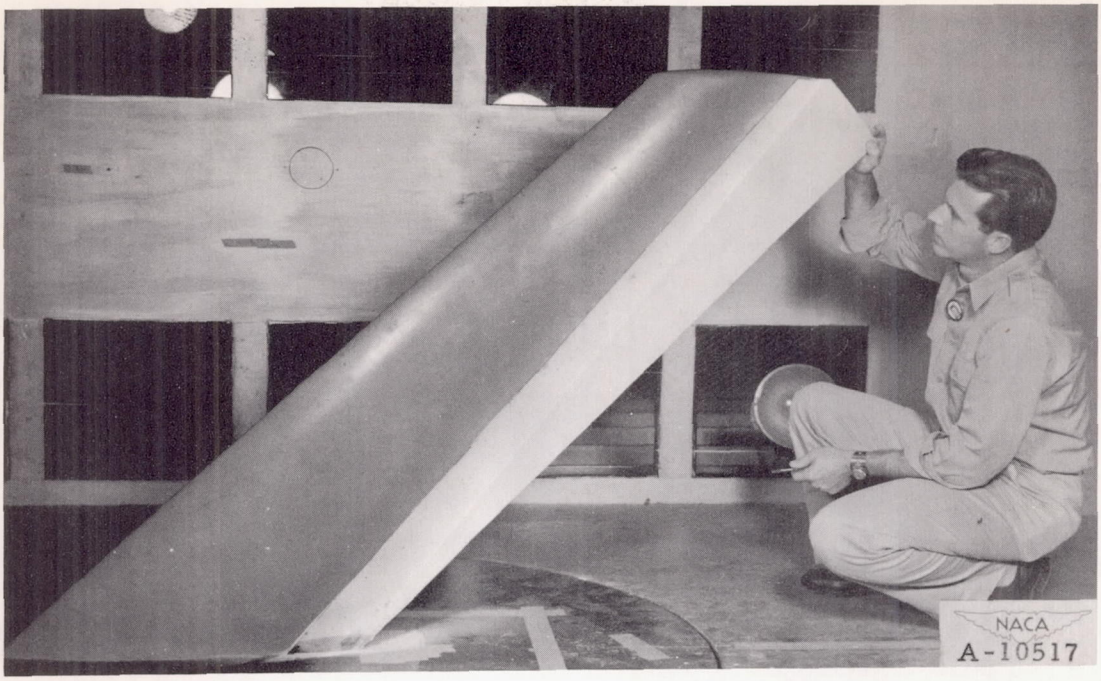
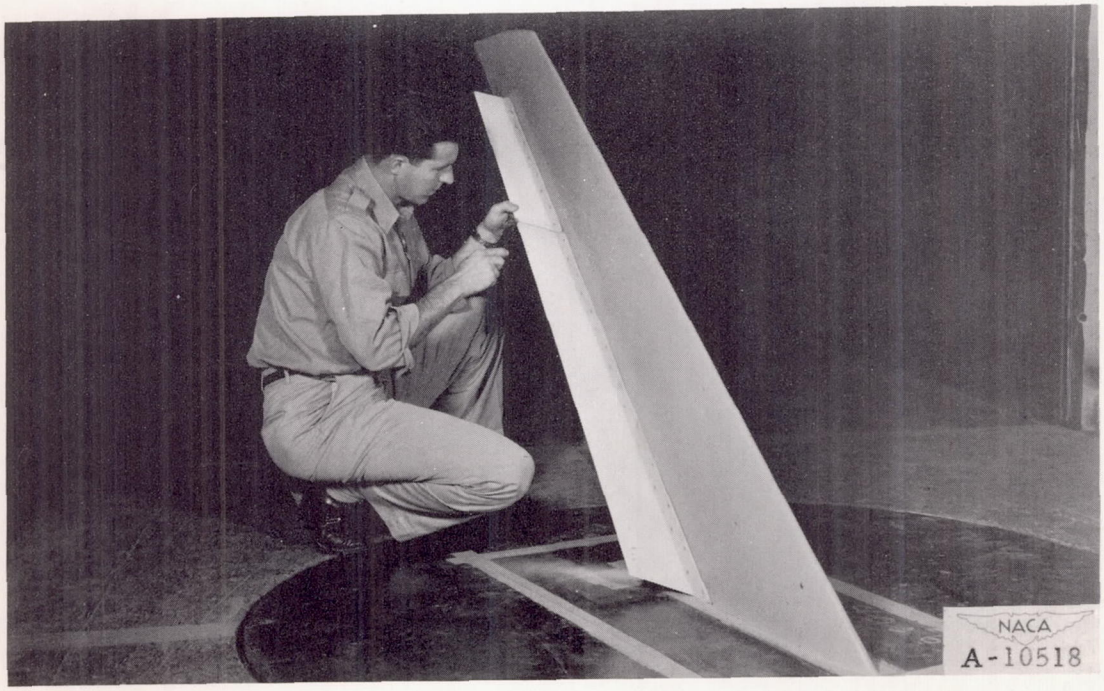


(a) Chord-extension flap deflected 25°.



(b) Split flap of 90-percent span deflected 60°.

Figure 1.- The 45° swept-back wing mounted in the Ames 7- by 10-foot wind tunnel.

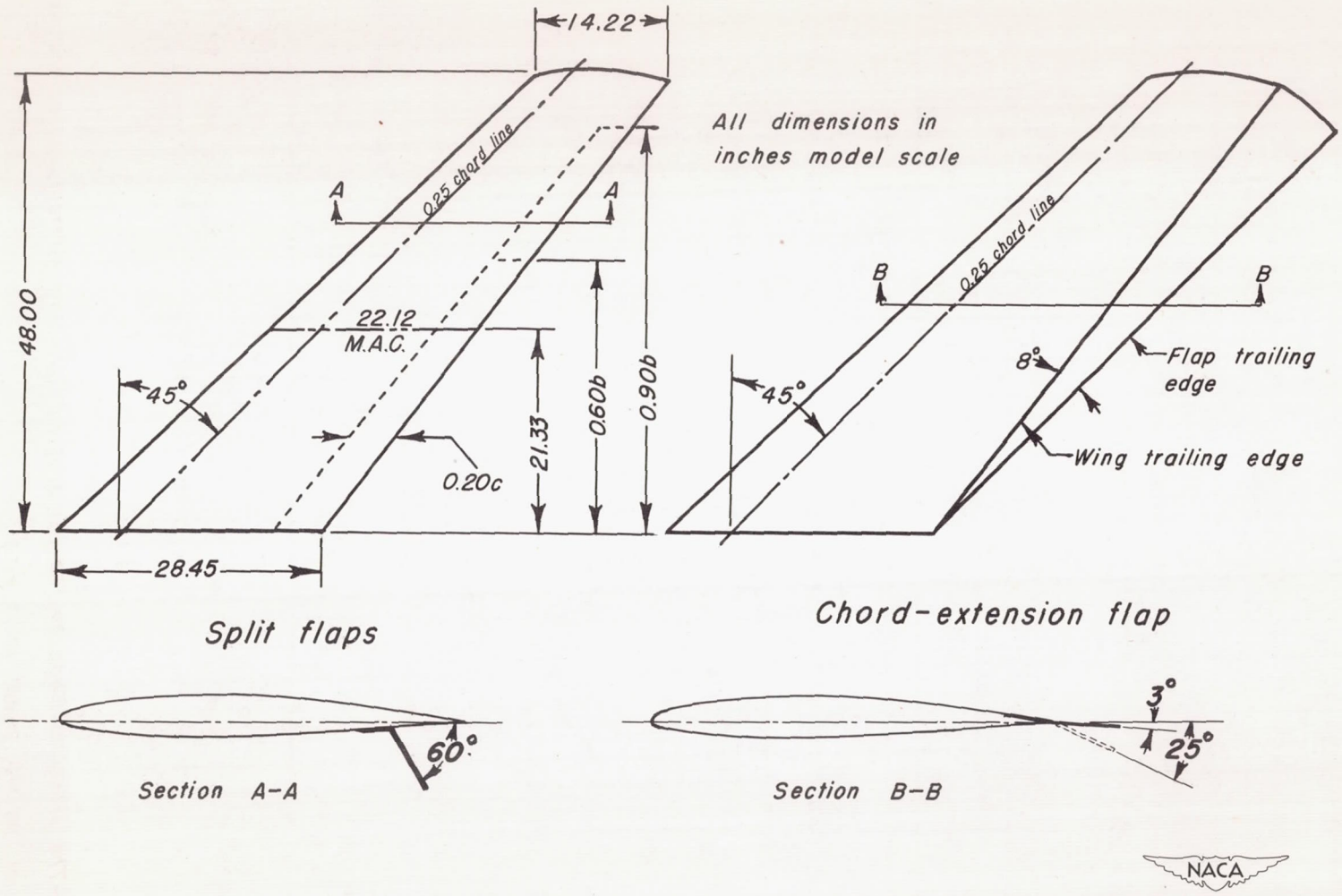


Figure 2.- The 45° swept-back wing model and flap geometry.

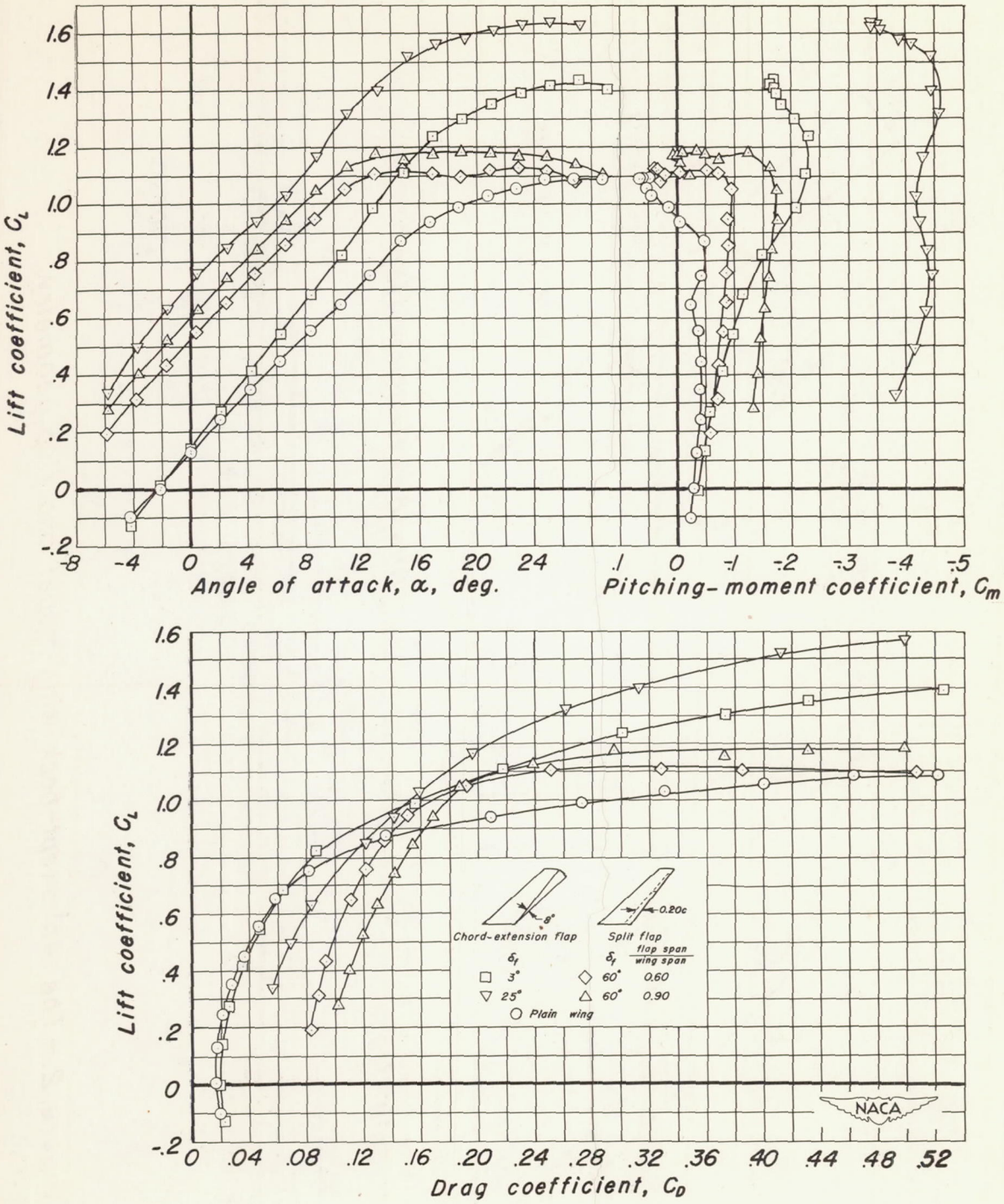


Figure 3.- The effect of flaps on the lift, drag, and pitching-moment characteristics of the 45° swept-back wing.