R. & M. No. 2614
(5979)
A.R.C. Technical Report

MINISTRY OF SUPPLY

AERONAUTICAL RESEARCH COUNCIL
REPORTS AND MEMORANDA

A Résumé of Aerodynamic Data on Air Brakes

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LONDON: HIS MAJESTY'S STATIONERY OFFICE
1951
SIX SHILLINGS NET

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Communicated by the Principal Director of Scientific Research (Air),
Ministry of Supply

Reports and Memoranda No. 2614*

June, 1942

Summary.—A collection has been made of aerodynamic data on air brakes. The characteristics of wing brake flaps have been analysed, including the effect of venting or perforating the flaps. In particular, the design of brake flaps so as to have no appreciable effect on lift or trim is discussed, and in this connection the relative merits of double split trailing-edge flaps, Youngman flaps, air brakes behind the tail, etc., are compared. A brief description of some methods of balancing brake flaps is given. The small amount of data available on wing and tail buffeting due to brake flaps has also been analysed.

1. *Introduction.*—The development of clean aerodynamic design and high wing loadings has led to very high terminal velocities in dives, high speeds in glides, and low rates of deceleration in level flight. There is, therefore, a growing need for the development of air brakes, not only for dive bombing, but for glide path control, torpedo dropping, and as a means for providing rapid deceleration on fighters. There are of course a number of dive bombers fitted with brake flaps already in existence, the most well known being the Ju.87 and 88 (Fig. 1a, b). Air brakes have also been used to some extent on gliders for glide-path control[2]. The possible applications to torpedo aircraft and fighters have only been realised comparatively recently, but a considerable amount of experimental work has been done in this connection. The purpose of this report is to summarise the aerodynamic data available on the subject.

2. *Design Requirements.*—In designing air brakes the aim should be to produce the required drag with, as far as possible, no other effects on the aeroplane.

For dive bombers, the drag should reduce the terminal velocity sufficiently to enable the aeroplane to be pulled out of the dive at a reasonably low height. It is clearly impossible to specify this requirement exactly, but it is probable that a terminal velocity of about between 300 and 350 m.p.h. in a 50-deg. dive should be aimed at. The terminal velocity of the Ju.88, for example, is about 350 m.p.h. (50-deg. dive, weight 26,200 lb). Fig. 2a shows very roughly the size of the flaps needed to fulfil these conditions on a typical modern aeroplane.

Brake flaps on fighters should if possible provide a deceleration of about 1*g* at 400 A.S.I. This again is an arbitrary figure representing a compromise between desirable and practicable decelerations. It will be seen from Fig. 2a that the size of flap needed to fulfil this condition is approximately the same as that needed for the dive bombing requirement.

It is difficult to specify a requirement for glide-path control, but it would probably be considered reasonable if the glide angle could be doubled without an increase in speed. Fig. 2b shows that this can be done with considerably smaller flaps than those needed for dive bombers and fighters.

* R.A.E. Report Aero 1756—received 20th July, 1942.

For torpedo aircraft, the air brakes must enable the aeroplane to lose speed as rapidly as possible in level flight after a dive from, say, 6,000 ft. It has been suggested that the speed should drop to 150 knots within about 9 secs after flattening out. Fig. 3 shows that this is impracticable on a modern torpedo aircraft, such as the Beaufort, but flaps of reasonable size do produce a very great improvement, the speed dropping to 150 knots in about 20 secs, compared with over 2 minutes without flaps.

Brake flap installations, whether for dive bombers, torpedo aircraft, or fighters, should have as little effect as possible on lift and trim. This is most important on fighters, since in this case the flaps are likely to be operated very quickly at high flight speeds, and quite small changes of lift and trim would cause large deviations from the flight path. A strengthened landing flap used as a brake flap on the Spitfire, for example, was found to be unacceptable because of the large change of lift involved[3]. Brake flaps mounted on the underwing surface near the front spar have also been found unacceptable owing to the large changes of trim involved. On dive bombers, a small change of trim may be allowed since it can be corrected by means of a trimmer coupled to the flaps, as on the Ju.88. It is desirable, however, to avoid a change of lift; a loss of lift would imply an increase in the attitude of the aeroplane for a given speed and angle of dive, and hence a detrimental effect on field of view; a large increase in lift due to the flaps would mean greater difficulty in pulling out of the dive, assuming the flaps are closed either before or during the pull-out.

The effect of brake flaps on wing moment must be kept small (expecially if the moment due to the flap is nose-down) as otherwise the tail loads are likely to become excessive at high speeds.

In general, brake flaps must be capable of quick operation at high speeds, and this is especially so for fighters. On dive bombers and torpedo-carriers, quick retraction is essential. For glide-path control the flaps should be capable of being snapped on and off very rapidly, though in this case the flight speed will be low.

Finally, it is essential that any form of wing or tail buffeting, or any vibration of ailerons or other control surfaces, must be avoided.

3. *Discussion*.—3.1. *Drag.—Effect of Location and Type of Flap on Drag*.—The drag of a wing brake flap depends on its frontal area, fore-and-aft position on the wing and angular setting; on the wing thickness, and wing incidence, and to a lesser extent on its spanwise position and aspect ratio.

The variation in drag with chordwise position for a part-span flat-plate flap on a rectangular wing is shown in Fig. 4. The drag is a maximum in the region of the $1/4\ c$ point, where the drag coefficient is more than twice that of a flat plate of the same aspect ratio. This high drag is due to the fact that the flap spoils the flow over the wing behind it, so that it has approximately the same effect as a flat plate extending down to the chordline. In fact the drag of a flat plate brake can be estimated roughly by assuming a drag coefficient of about $1 \cdot 3$ over an effective area extending to the chordline, as suggested in Ref. 6.

The effect of wing incidence on drag is shown in Fig. 5. The drag of an upper-surface flap increases whilst that of a lower-surface flap decreases with incidence. This effect is important in the case of glide-path control where the flaps are used at low speeds.

The increase in drag with wing thickness is shown in Fig. 6, for a flap at $0 \cdot 3c$ from leading edge. The drag of a trailing-edge flap is practically independent of wing thickness.

The variation in drag with flap angle is shown in Fig. 7. For most purposes, a sufficiently accurate estimate of this variation can be obtained by assuming the drag coefficient based on the projected area to be proportional to the sine of the flap angle (*see* Ref. 4).

These examples serve to illustrate the effect of the main variables involved. A more complete analysis will be found in Ref. 4, 5.

Effect of Venting on Drag.—The effect on drag of perforating or slatting the flaps, deduced from Ref. 7 and from the results of recent Royal Aircraft Establishment tests (unpublished), is given in detail in Table 1.

It will be seen that with round perforations giving an open area of about one-third the total flap area, the drag is reduced by only about 15 per cent. Horizontal slatting of the flap, as on the Ju.88, reduces the drag nearly in the same proportion as the open area. On the other hand, chordwise slots in trailing-edge flaps at 60 deg. did not affect the drag of the flaps, but this result was obtained at a rather low Reynolds number and is probably unreliable.

3.2. *Effect of Brake Flaps on Lift and Trim. Lift.*—The effect of wing brake flaps on lift is shown for some typical cases in Figs. 8, 9. An under-surface flap alone always increases the lift, the increment being a maximum for a flap at the trailing edge and falling to zero at the leading edge. Upper-surface flaps in general cause a decrease in lift. For a given flap position, the change of lift is very roughly proportional to the projected area of the flap[4].

When upper and lower flaps are used together their effects on lift are not always additive, the lift curve of the combination sometimes collapsing as shown in Fig. 9, giving a larger loss of lift than that due to the upper flap alone. The effect on lift of upper and lower-surface flaps at the trailing edge are approximately additive, equal flaps on upper and lower surfaces giving no appreciable change of lift (Refs. 7, 8, 9).

Trim.—The change of trim due to wing brake flaps can be divided into two components :—

1. The change in pitching moment on the wing itself.
2. The change in pitching moment associated with the change in downwash at the tail.

The former depends mainly on the span, chord, angle to wing, and chordwise position of the flaps. Flaps on the under surface of the wing give a pitching moment varying from a nose-up moment for forward positions of the flaps to a nose-down moment at the trailing edge. On the upper surface, the effect is similar but of reversed sign (*see* Fig. 10). The change in moment is very roughly proportional to the span of the flaps, but the variation with chord and angle is more complicated (*see* Ref. 4).

The change in downwash at the tail depends mainly on the change in lift and on the spanwise position of the flaps. For a given flap position, $\Delta \varepsilon$ is roughly proportional to ΔC_L (Ref. 4). The change in downwash, and hence the change in pitching moment associated with it, is greatest for inboard positions of the flap decreasing and changing sign as the flap is moved outwards; for outboard flap positions the change is always small. (*See* Fig. 11.)

The contributions of wing and tail to the total change in pitching moment may add together or tend to offset each other, depending on the position of the flaps. For flaps mounted near the fuselage, the two effects are additive if the flaps are forward of about $0 \cdot 7c$. For aft positions, the two effects are of opposite sign, and it is sometimes possible to find a position at which the total effect is zero. With flaps mounted well outboard, the effect on the tail plane is always small and the wing component generally predominates.

The effect of combining upper and lower-surface flaps is not additive (Fig. 14), and as in the case of lift, the change in pitching moment may be greater than with one flap alone.

Methods of Avoiding Changes of Lift and Trim.—As mentioned in Section 2 it is essential in designing brake flaps for fighter and torpedo aircraft to avoid appreciable changes of lift or trim, and the change of moment on the wing itself must also be kept small. It is usually difficult to fulfil these three conditions at the same time. A possible solution in some cases is to use a combination of upper and lower-surface flaps, *e.g.* equal split flaps at the trailing edge. Fig. 16 shows the effect of double-split trailing-edge flaps on the lift, drag and moment characteristics of a tapered aerofoil[8]. The changes in lift and moment are negligible at small lift coefficients.

The main problem in designing double-split flaps, however, is in avoiding tail buffeting. Figs. 17, 18 show two ways in which the tail can be kept clear of the wake from the flaps. In the first of these examples advantage was taken of the fact that the flaps could be placed sufficiently far outboard for the wake to pass outside the tail plane. This was also found possible on the Beaufighter. In the example of Fig. 18 advantage was taken of the comparatively high tailplane position on the Spitfire, together with the fact that the upper edge of the wake can be lowered slightly (for the same drag) by using an upper-surface flap of larger chord, but at a smaller angle as shown (*see* Ref. 9).

Another method of avoiding lift and trim changes suggested by Mr. Youngman of Messrs. Fairey Aviation Co. and used on the Barracuda, is illustrated in Figs. 19, 20. This consists of a flap rather like a Fowler flap but capable of being turned upwards to a negative angle behind the wing, as shown in Fig. 20. This flap can certainly be arranged to have no effect on lift, trim, or wing moment, but the wake behind it is very disturbed, and it is only applicable to aeroplanes having high tail positions. The minimum tail height practicable is of the order of half the wing chord. In applying this type of flap to fighters, the main disadvantage would be that the flap can only get into the drag position by passing through other positions for which there are large changes of lift and trim. A somewhat similar flap proposed by Mr. L. C. Williams of General Aircraft, is mounted on the top surface of the wing and open to a drag position behind the wing at right angles to the chord[10]. It has the same disadvantages as the Youngman flap.

Before discussing more novel arrangements mention should be made of methods of reducing trim and lift changes associated with single flaps on the wing surface. It is sometimes possible, for example, to find a position for a single flap such that there is no change of trim. This position would be near the trailing edge and well outboard, so that the wing moment offsets the downwash effect. There would, however, still be a large change of lift. The brake flap on the Skua (Fig. 1) is an example of this; the change of trim is small but the change in lift would preclude its use on a fighter.

Several attempts have been made to reduce the change of lift due to an under-surface flap by modifying the flap itself, *e.g.* by inclining it forward, hinging the flap at its midpoint, etc. None of these modifications have given an appreciable improvement (*see* Table 2).

The effect of leaving a gap between the flap and the wing surface, and of latticing the flap as on Ju.88, is shown in Fig. 21 (from Ref. 4). The gap reduces the change in moment appreciably, whilst with latticed flaps the change of trim for forward positions becomes slightly nose down instead of nose-up. For flaps near the trailing-edge latticing seems to have little effect. Changes in lift are not appreciably affected either by gaps or by latticing[4].

Engine Gills used as Air Brakes.—The large spoiling drag usually associated with air-cooled engine gills suggests the possibility of using them as air brakes. Wind-tunnel tests on the Beaufighter showed that with the gills opened to 90 deg., a deceleration of 1g at 400 m.p.h., A.S.I. would be obtained. At high speeds the loss of lift will be small. The change of trim has not been measured but it is likely to be small, at any rate if the engine thrust line is on the wing chord.

Body Flaps.—A series of flaps can be mounted round the fuselage of an aeroplane so that they have no effect on lift or trim. It has not, however, been found possible as yet to arrange these flaps in such a way that their wake passes clear of the tail plane.

Air Brakes Behind the Tail.—An apparently obvious way of automatically avoiding changes of lift and trim and all forms of buffeting is to mount an air brake behind the tail. Some versions of the Dornier 217 are fitted with a flap of this type. The exact details of the installation are not known, but the main principles involved are shown in Fig. 1f, taken from a German Patent Specification[1]. The flaps open in the form of a cross behind the tail, and the complete installation can be jettisoned if necessary.

Wind-tunnel tests at the R.A.E. on a similar arrangement designed to give a deceleration of $1g$ at 400 m.p.h., A.S.I., on the Mosquito, showed that the effect on trim may not be negligible (*see* Fig. 22). The arrangement is large and cumbersome, the overall length of the arms being 14 ft. The size could perhaps be reduced by filling in the space between the arms with fabric, which could be made to fold neatly in the closed position. This, however, results in considerable shielding of the tail plane, with consequent large changes in trim and stability (Fig. 22).

Tail Parachutes.—The use of a tail parachute as a brake is particularly applicable to torpedo aircraft, or for any other purpose where the brake is only required once during a flight. Flight tests are being made at the R.A.E. to establish the technique of this method and experimental installations are being designed for the Beaufort, Hudson, Sunderland and Catalina. It is outside the province of this report to discuss this method in detail.

3.3. *Operation of Brake Flaps.*—With the application of brake flaps to fighters the problem of operation has become much more difficult, since the flaps have to be operated very quickly at high speeds. Thus an unbalanced split flap large enough to produce a deceleration of $1g$ at 400 A.S.I., on say the Beaufighter would need an operating moment of the order of 10,000 lb ft at 400 m.p.h.[18]

Several methods of balancing brake flaps have been suggested, and some of them are illustrated in Fig. 23. The Irving flap, for example, using a double-hinge system as shown in Fig. 23a, reduces the operating force to about an eighth of that required for an unbalanced split flap having the same projected area. Flight tests on a Falcon fitted with this flap showed considerable promise[13]. Details regarding the best hinge positions, etc., are given in R. & M. 1864[14]. The Gray flap is another ingenious application of the double-hinge system in which a small auxiliary flap is added at the trailing edge of the lower main flap, and the opening and closing of the system is controlled simply by adjusting the angular setting of the auxiliary flap. The work done in operating this arrangement is less that 1 per cent that for an equivalent split flap. Further details will be found in Refs. 15, 16.

When brake flaps are fitted on both upper and lower wing surfaces, they can sometimes be balanced against each other by hinging them so that one flap closes forward and the other backwards, as shown in Fig. 23c. The main disadvantage of this arrangement is that a high peak moment may occur on the forward-closing flap as it begins to open (*see* R. & M. 1864[14]. This effect becomes negligible if the flaps are latticed, and flaps of this type are in fact in use on the aeroplane shown in Fig. 1(*l*).

Another possible method of balancing is to open the flap in such a way that it turns about its centre of pressure. The Youngman flap mentioned previously (Figs. 19 to 20) uses this idea.

Bellows Flaps.—A flap operated entirely aerodynamically has been developed by Mr. Youngman of Messrs. Fairey Aviation Co. and is showing considerable promise. The flap is constructed on the bellows principle, and consists of four plates hinged together and covered with doped fabric, as illustrated in Fig. 23d. The arrangement is made to open or close by applying pressure or suction internally from a venturi or any other means. The simplest source of pressure and suction is a venturi with a butterfly valve at the rear; with the valve closed the venturi supplies full total head to open the flap; with the valve open the venturi sucks the flap shut. It is doubtful whether these bellows flaps can be designed to open much beyond 60 deg. as the length of the rear arms of the bellows tend to become too long (*see* Ref. 12).

The main advantage of these bellows flaps is their extreme lightness and the fact that they can be installed without major internal modification to the aeroplane, and without having to supply extra hydraulic or pneumatic power. Moreover the operation can be made as rapid as desired at the highest flight speeds, provided the ducts supplying air to the flaps are large enough. The main disadvantage of the flaps is the possibility of difficulty in ensuring simultaneous opening and closing. A direct mechanical connection is not possible owing to the light construction of the flaps. Flight tests have indicated, however, that provided the opening and closing are made sufficiently rapid any trouble of this sort is unlikely, unless the flaps are actually damaged.

The pressure distribution on a bellows flap is given in Figs. 24a, b.

3.4. *Buffeting Due to Brake Flaps.*—(*a*) *Wing Buffeting.*—The flow behind a brake flap is necessarily very disturbed, and if the flap is mounted well forward on the wing, there is a considerable chance of wing buffeting. Two cases have occurred recently (on Beaufighter and Spitfire) in which flaps of the Youngman bellows type, mounted under the front spar, caused severe wing vibration. It has been established that the vibration was not inherently associated with the bellows construction, but was due entirely to the disturbed flow passing over the wing surface behind the flaps.

An attempt has been made to investigate the problem in the wind tunnel, using an inductance pressure cell*, which enables a continuous record to be made of the pressure fluctuations at any point on the wing surface. Some examples of the records obtained are given in Figs. 26, 27, which show the fluctuations in static pressure behind the solid and perforated flaps shown in Fig. 25. The amplitude of the fluctuations behind the solid flap represents about $\pm 0 \cdot 1 \ \frac{1}{2} \rho v^2$. The fluctuations were considerably reduced by each of the types of venting tried, chordwise slots giving probably the best result. (All the vented flaps had approximately the same drag. The drag of the solid flap was about 15 per cent higher, but this should not appreciably affect the comparisons involved). This effect of venting in smoothing out the flow behind flaps has been confirmed in flight[2].

(*b*) *Tail Buffeting.*—In most brake-flap designs, tail buffeting is avoided by keeping the disturbed wake† from the flaps clear of the tail plane. It is usual, however, to go as near the limit as possible, owing to difficulty in getting enough drag, and the determination of the widths of wakes at the tail plane is, therefore, of considerable importance. The data at present available is not sufficient to enable wake widths to be predicted with any confidence and a tunnel test is necessary to check the wake position on any new design. This, however, is now a very simple test, since it has been found that wind-tunnel explorations with silk tufts give a reasonably reliable indication of the disturbed wake intensity.

The width of a wake can often be reduced by venting the flaps. Thus chordwise slots giving an open area of about 27 per cent of the total flap area may reduce the wake width in a vertical plane by as much as 20 per cent, and the width in a horizontal plane is also reduced (for the same drag). Advantage was taken of this fact in the case illustrated in Fig. 17. Horizontal slatting, as on the Ju.88 does not reduce the wake to the same extent as chordwise slatting.

In some cases it is impossible to find a wing flap arrangement in which the wake is clear of the tail, whilst at the same time keeping lift and trim changes negligible. It is important, therefore, to investigate whether the wake can be made comparatively harmless by perforating or slatting the flaps. Wind-tunnel tests, using the inductance pressure cell mentioned in the preceding section, have shown that venting of trailing-edge flaps reduces the amplitude of the fluctuations in static pressure on the surface of the tail plane. Owing to lack of full-scale experience it is impossible to say whether the improvement obtained will be sufficient to prevent tail buffeting in any particular case. Severe tail buffeting on the Bermuda, due to double-split flaps at the trailing edge, is said to have been cured by copious perforation, but the extent of the perforations needed is not known.

When brake flaps are mounted well forward on the wing, venting has little effect on the flow at the tail, the amplitude of fluctuation on both pressure and direction being unaffected by any form of venting. The flow at the tail may, however, be much improved by leaving a sufficiently

* Developed by J. S. Thompson and J. Bekassy.

† The disturbed wake is somewhat wider than the total-head wake.

large gap between the flap and the wing, but the width of the gap has to be of the same order as the wing thickness, and the drag of the flap is consequently very much reduced. Tail buffeting on the Vengeance due to upper and lower-surface flaps on the front spar is said to have been cured in this way.

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TABLE 1

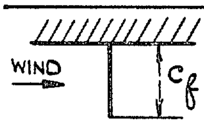
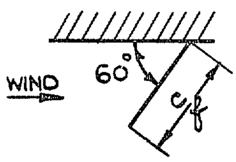
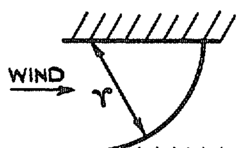
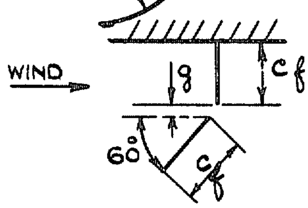
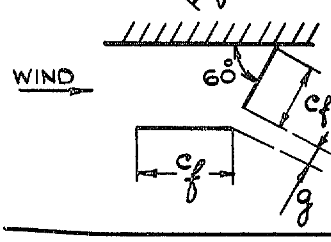
Effect of Venting of Brake Flaps on Drag

Test	Detail of flap	Type of venting	C_F based on total area	C_F based on blocked area
1. N.A.C.A. tests on rectangular A.R.C. 5334.	Double split at T.E. (a) Full span	Round perforations (33 per cent of total area)	0·95	1·42
		Solid	1·1	1·1
	(b) Part span	Round perforations	0·88	1·31
		Solid	1·0	1·0
2. R.A.E. tests on rectangular wing B.A. 1685.	Part span. 09 deg rectangular flap at 0·3c (a) On lower surface	Latticed as Ju.88	1·28	2·16
		Solid	2·18	2·18
		Solid with 0·05c gap between flap and wing.	1·92	2·01
	(b) Upper surface	Latticed	1·22	2·04
		Solid	2·80	2·80
	(c) Upper and lower	Latticed	1·29	2·16
		Solid	2·55	2·55
3. R.A.E. tests on a high wing monoplane (S.24/37) B.A. 1685.	Part span. 90 deg rectangular flap at 0·4c on both wing surfaces.	Latticed as Ju.88	1·35	2·26
		Solid	2·45	2·45
4. R.A.E. tests on a low wing fighter (unpublished).	Double split at trailing edge. (a) At 60 deg	Chordwise slots	0·89	1·29
		Solid	0·89	0·89
	(b) At 90 deg	Chordwise slots	1·05	1·52
		Solid	1·17	1·17

TABLE 2

Effect of lift and drag of various lower-surface brake flaps on a high mid-wing single-engined aeroplane (Wind-Tunnels Note Number 535)

All flaps on front spar $0 \cdot 465c$ *from leading edge and approximately mid-way between fuselage and wing tip. Flap span* $= 0 \cdot 5b$.

DESCRIPTION OF FLAP	ΔC_L DUE TO BRAKE FLAP AT $\alpha = 0$	ΔC_D DUE TO BRAKE FLAP AT $\alpha = 0$	ΔC_D BASED ON PROJ. AREA AT $\alpha = 0$
 $c_f = 0{\cdot}14$ LOCAL CHORD	0·58	0·112	1·52
 $c_f = 0{\cdot}14c$	0·51	0·088	1·31
 $r = 0{\cdot}14c$	0·63	0·119	1·45
 $c_f = 0{\cdot}14c$ $g = 0{\cdot}1\,c_f$	0·79	0·190	1·38
 $c_f = 0{\cdot}14c$ $g = 0{\cdot}3\,c_f$	0·50	0·116	1·81

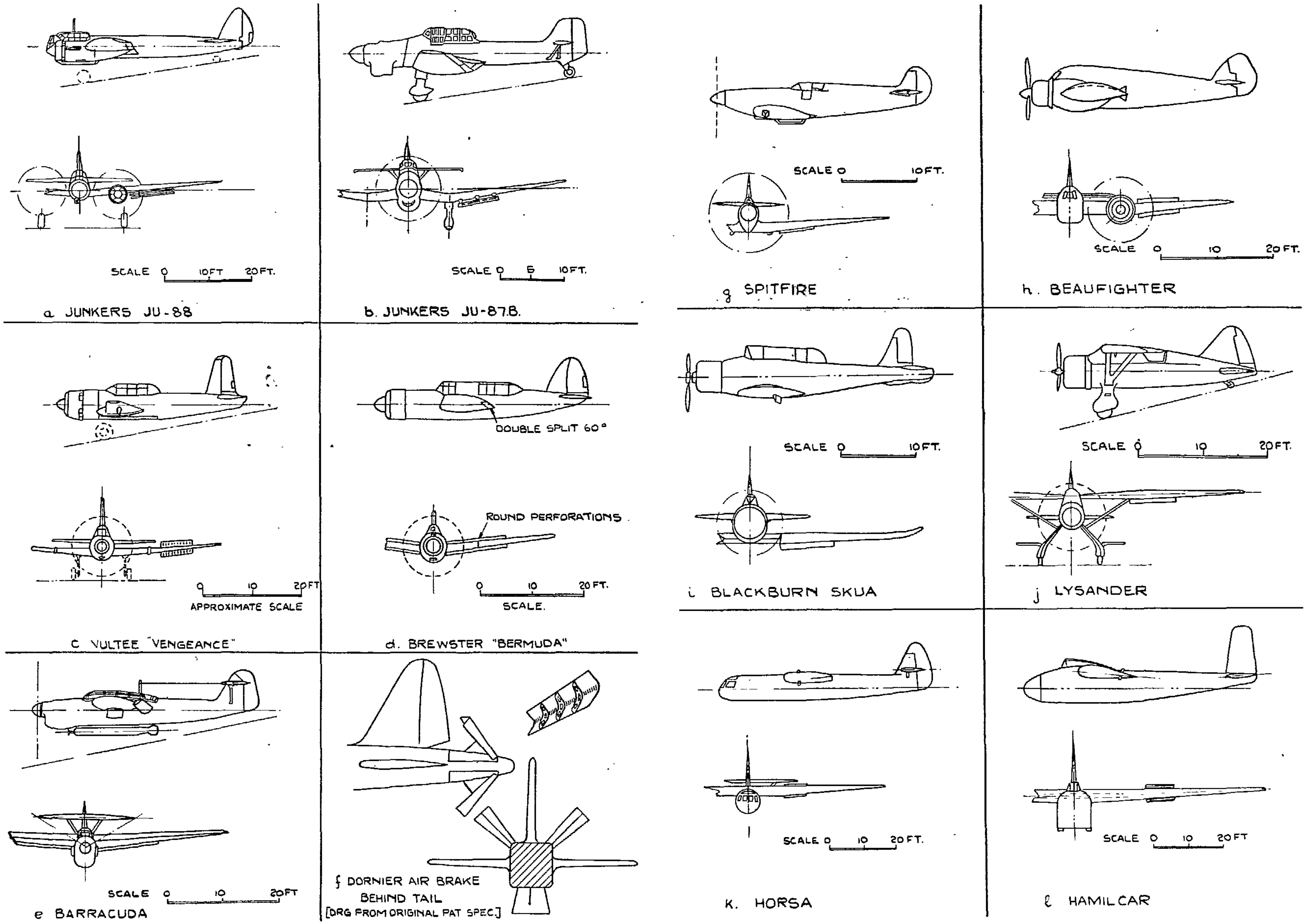

SCALE 0 10FT 20FT.
a JUNKERS JU-88
SCALE 0 5 10FT.
b. JUNKERS JU-87B.
SCALE 0 10FT.
g SPITFIRE
SCALE 0 10 20 FT.
h. BEAUFIGHTER
0 10 20FT
APPROXIMATE SCALE
c VULTEE "VENGEANCE"
DOUBLE SPLIT 60°
ROUND PERFORATIONS
0 10 20 FT.
SCALE.
d. BREWSTER "BERMUDA"
SCALE 0 10FT.
i BLACKBURN SKUA
SCALE 0 10 20FT.
j LYSANDER
SCALE 0 10 20FT
e BARRACUDA
f DORNIER AIR BRAKE
BEHIND TAIL
[DRG FROM ORIGINAL PAT SPEC]
SCALE 0 10 20 FT.
k. HORSA
SCALE 0 10 20 FT
l HAMILCAR

FIG. 1.

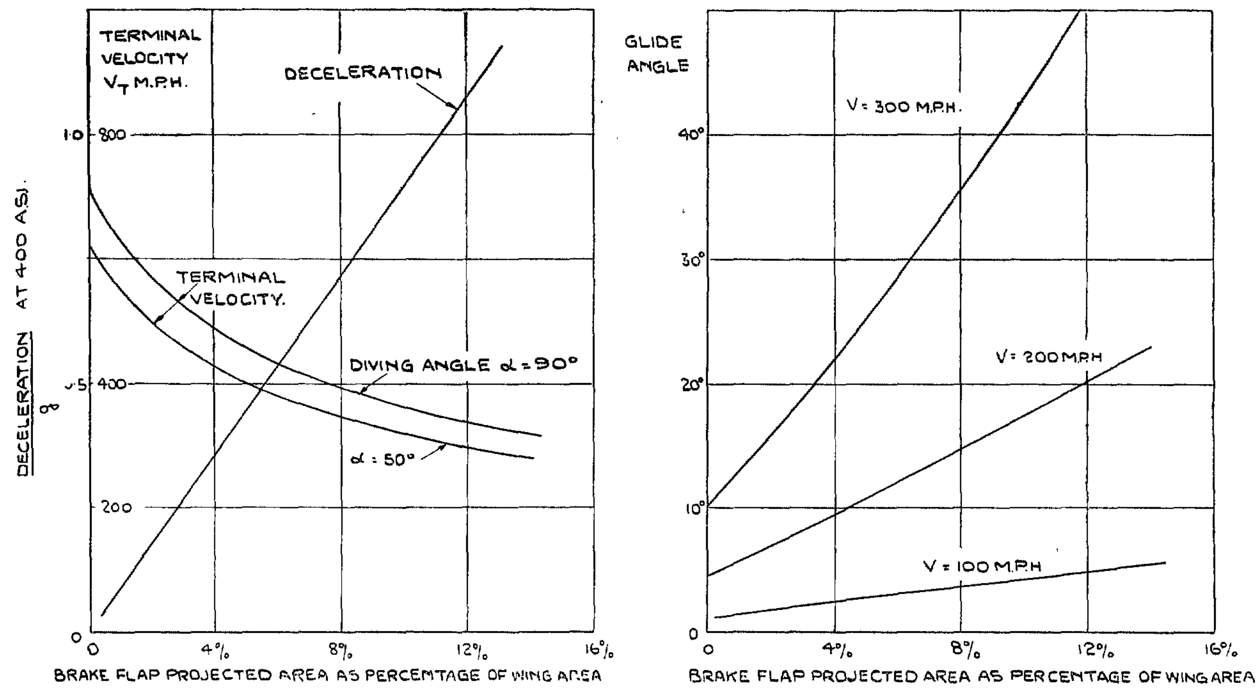


FIG. 2. Effect of Double-split Trailing-edge Brake Flaps on Terminal Velocity, Deceleration and Glide Angle for a Typical Two-engined Fighter (Wing Loading 40 lb./sq ft).

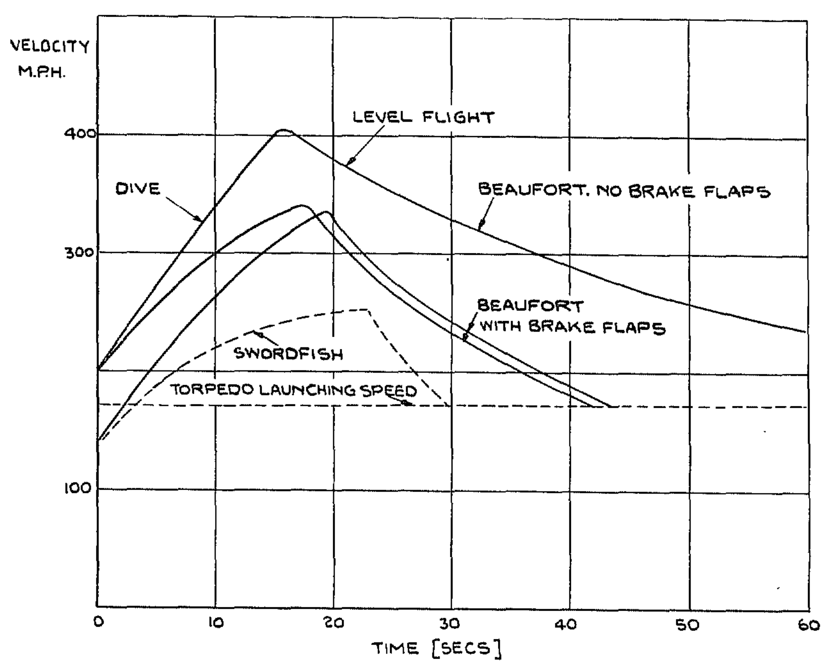


FIG. 3. Application of Brake Flaps to Torpedo Dropping.

(Descent from 6,000 ft in a 50 deg dive, flattening out before dropping the torpedo. Dive commenced at (*a*) 140 m.p.h., (*b*) 200 m.p.h.)

(Brake flaps assumed on Beaufort are double-split flaps at trailing edge with projected area about 5 per cent wing area.)

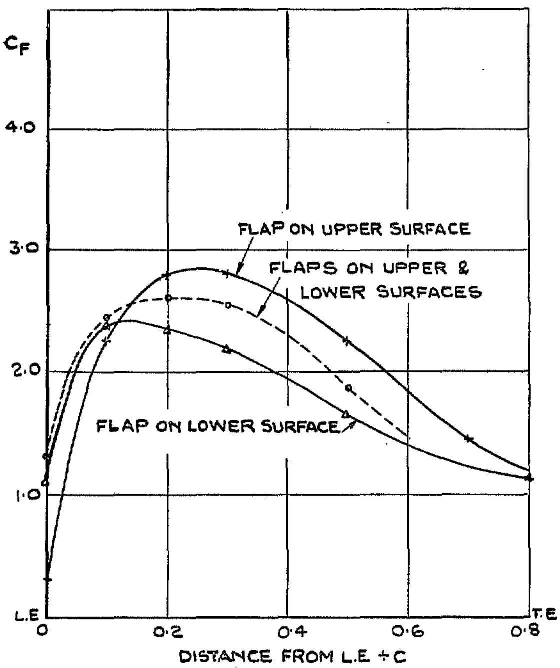


FIG. 4. Variation of Brake-flap Drag Coefficient with Chordwise Position on Wing ($C_L = 0$). Solid Brake Flap at 90 deg on Rectangular Wing RAF 48. Chord $0 \cdot 1c$, Span $= 0 \cdot 42s$

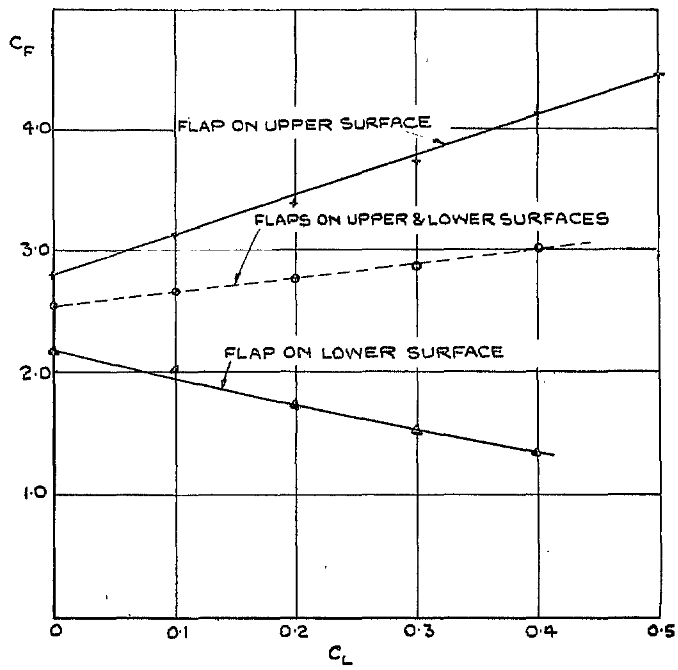


Fig. 5. Variation of Brake-flap Drag Coefficient with Lift. Flap at $0 \cdot 3c$ from Leading Edge. Solid Brake Flap at 90 deg on Rectangular Wing RAF 48. Chord $0 \cdot 1c$, Span $0 \cdot 42s$

(Report No. BA.1685)

C_F Drag coefficient, based on projected area of flap at constant lift.

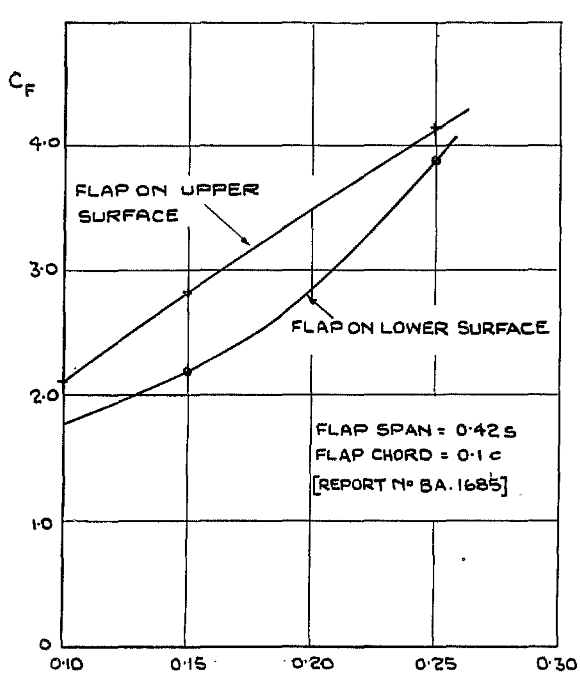


FIG. 6. Variation of Brake-flap Drag Coefficient with Wing Thickness for a Solid 90 deg Flap, $0 \cdot 3c$ from Leading Edge.

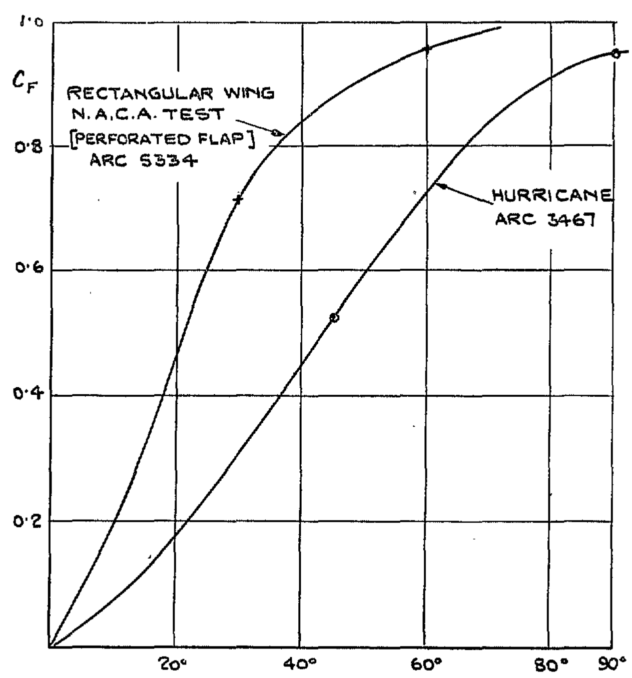


FIG. 7. Variation of Brake-flap Drag Coefficient with Flap Angle for Double-split Flap at Trailing Edge.

C_F Drag Coefficient, based on projected area of flap, at constant lift.

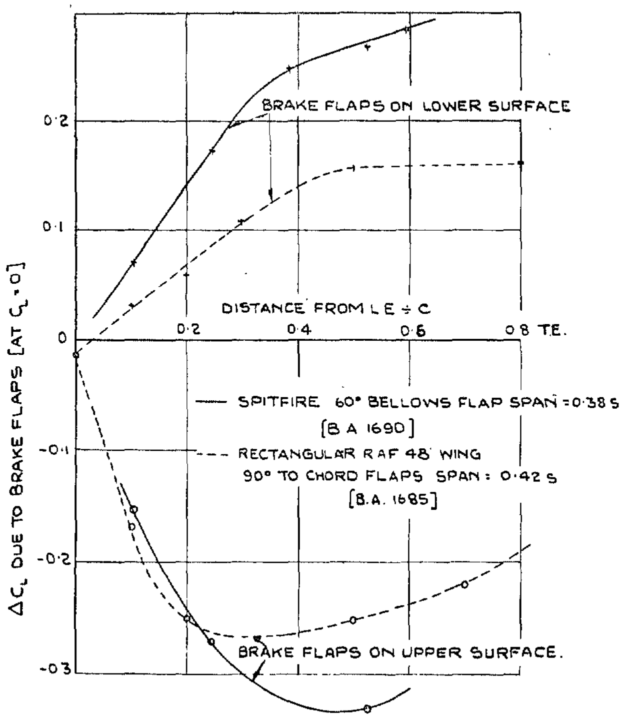


FIG. 8. Effect of fore-and-aft position of Brake Flaps.

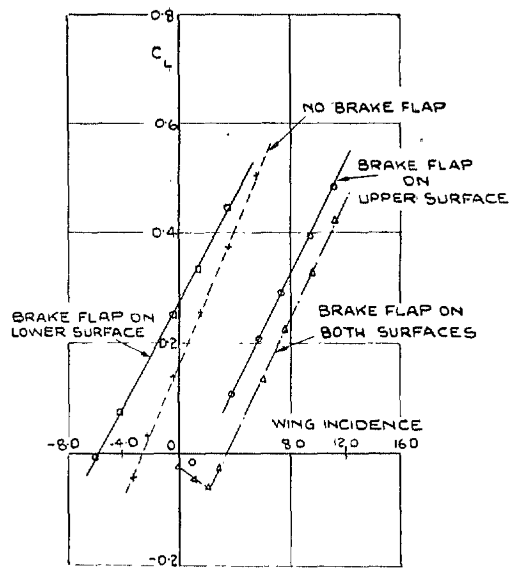
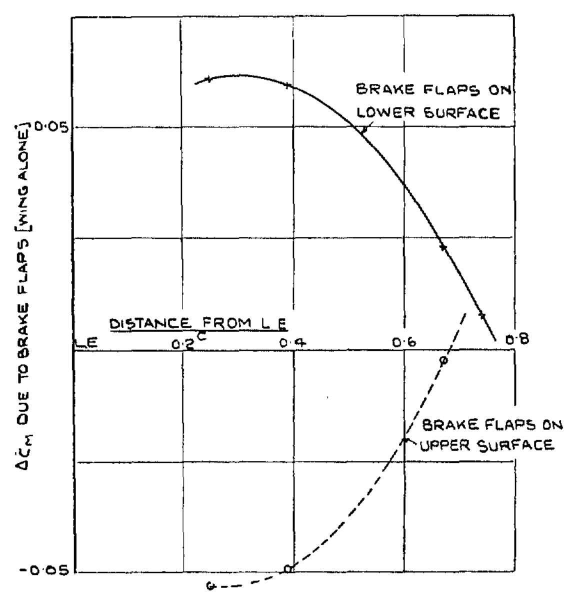


FIG. 9. Effect of Combining Upper and Lower Flaps. (Part-span 90 deg Flap Set at $0 \cdot 3c$ from Leading Edge on Rectangular Wing RAF 48). (Report No. B.A. 1685).

Effect of Wing Brake Flaps on Lift.



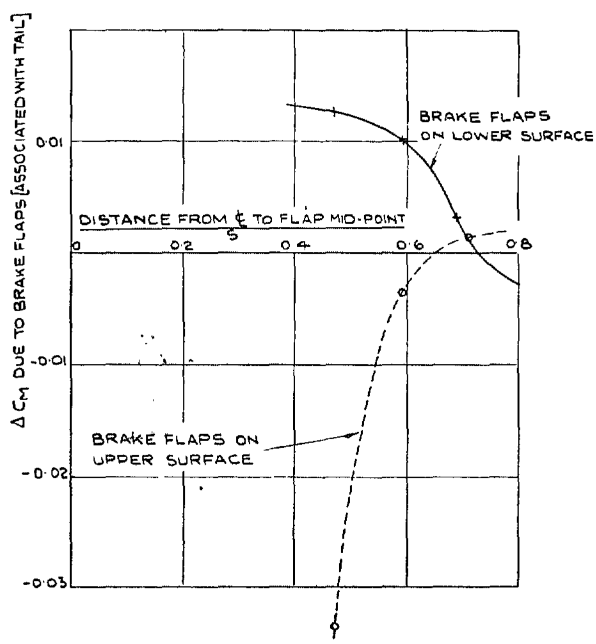


FIG. 10. Effect on Pitching Moment without Tail.

FIG. 11. Tail Contribution to Change of Pitching Moment.

(Bellows Brake Flap at 60 deg, Chord $= 0 \cdot 146\bar{c}$, Span $= 0 \cdot 38s$.)
Effect of Brake Flaps on Pitching Moment (Spitfire).
(Report No. B.A. 1690.)

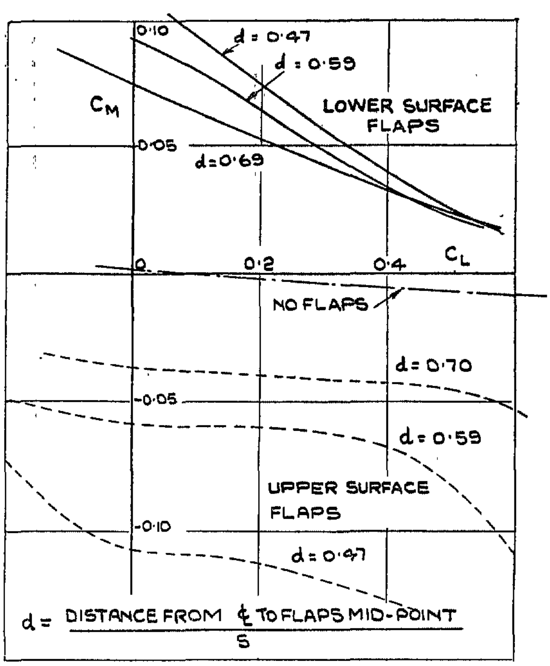


FIG. 12. Effect of Spanwise Position of Flaps. (Bellows Brake Flaps at $p = 0 \cdot 25c$.)

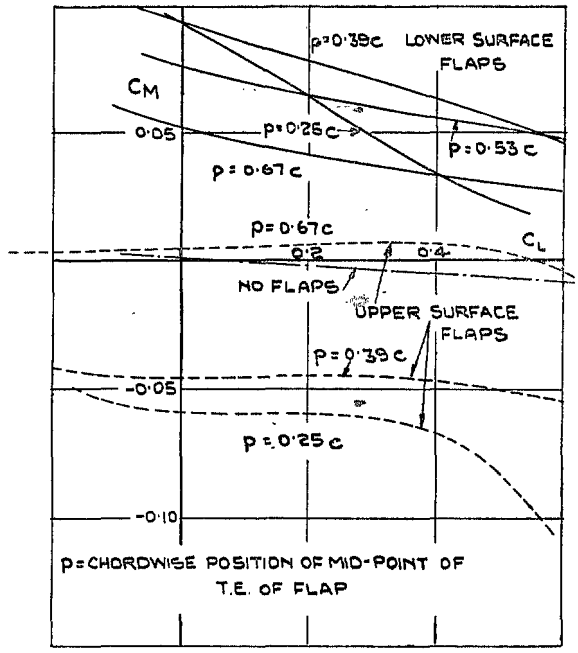


FIG. 13. Effect of Chordwise Position of Flaps. (Bellows Brake Flaps at $d = 0 \cdot 59c$.)

Overall Effect of Brake Flaps on Pitching Moment.

(Spitfire Report No. B.A. 1690.)

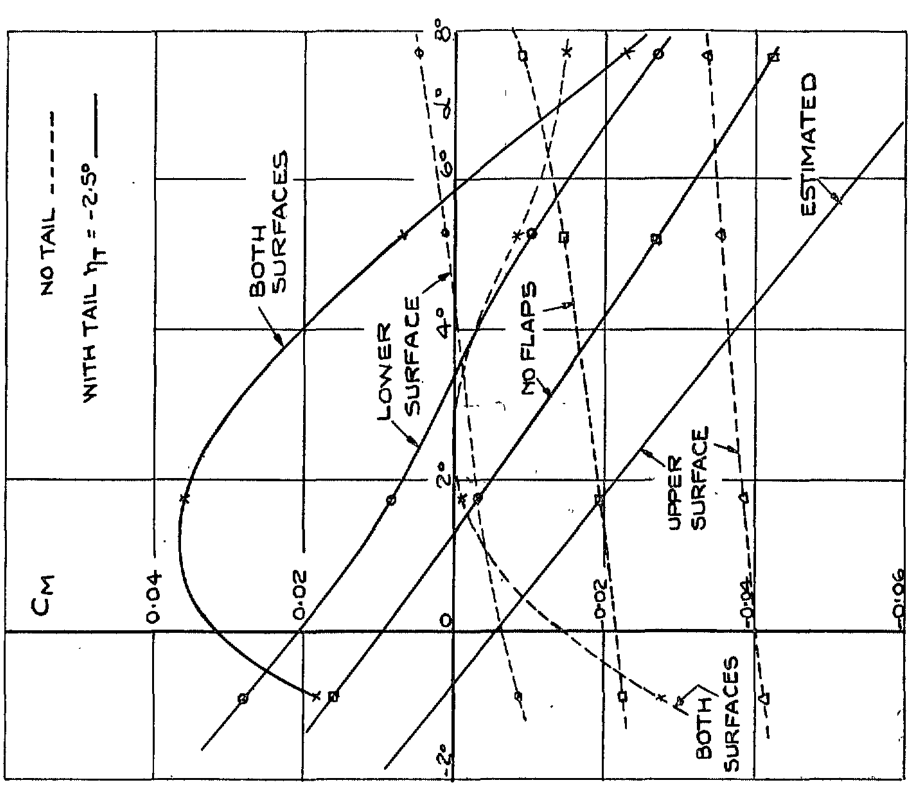


FIG. 14. Effect of Combining Upper and Lower Flaps on a High Wing Glider (Hamilcar).

(Solid 90 deg Flaps Chord = $0 \cdot 087\bar{c}$, Span = $0 \cdot 236s$, Chordwise Position $0 \cdot 22c$ behind Leading Edge.)

(Report No. Aero 1744.)

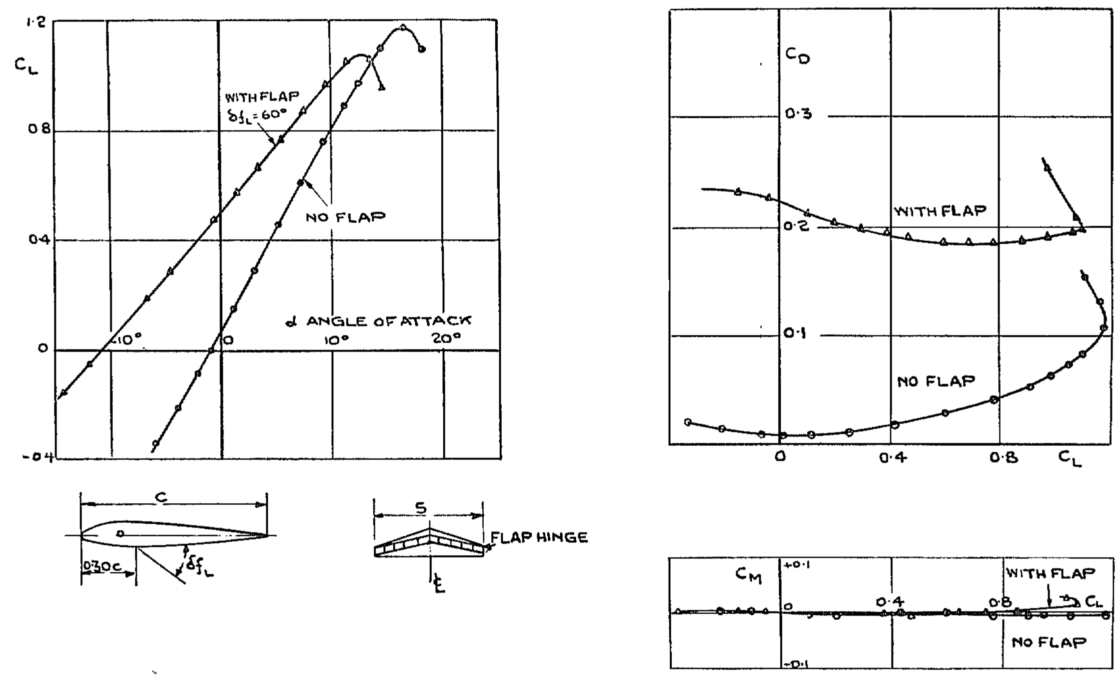


Fig. 15. Effect of a $0 \cdot 2c$ Full-span Lower-surface Perforated Single-split Flap Located on a Line through the 30 per cent Chord Stations of the Aerofoil Sections of a 3 : 1 Tapered NACA 23012 Aerofoil.

(N.A.C.A. Advance Report A.R.C. 5711.)

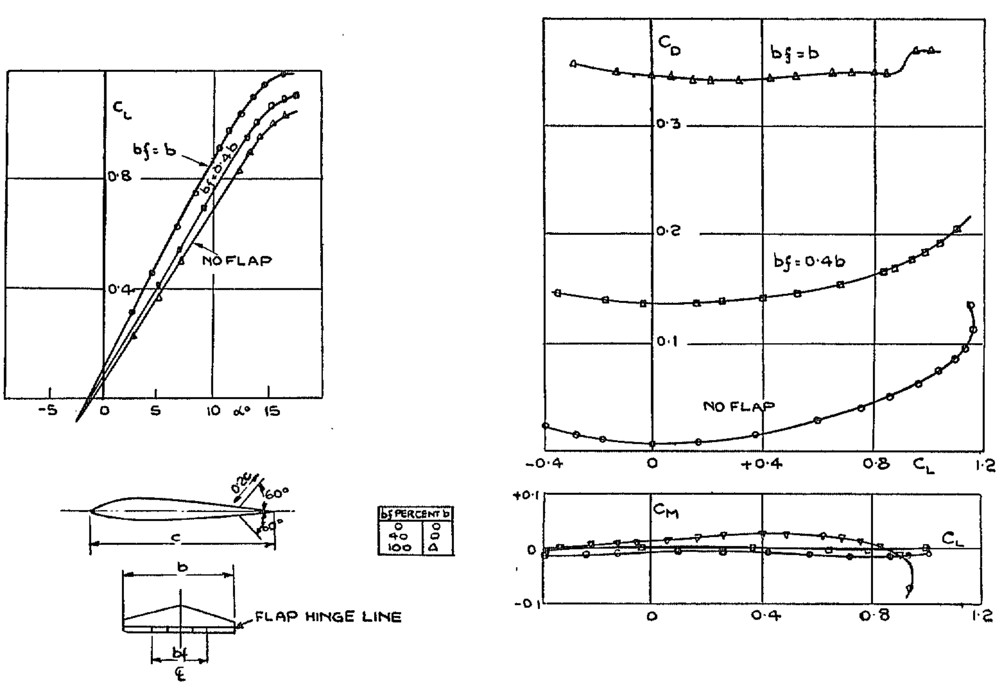


Fig. 16. Effect of $0 \cdot 2c$, Partial-span Perforated Double-split Flap at Trailing Edge of a 3 : 1 Tapered Aerofoil (NACA 23012).

(N.A.C.A. Advance Report A.R.C. 5711.)

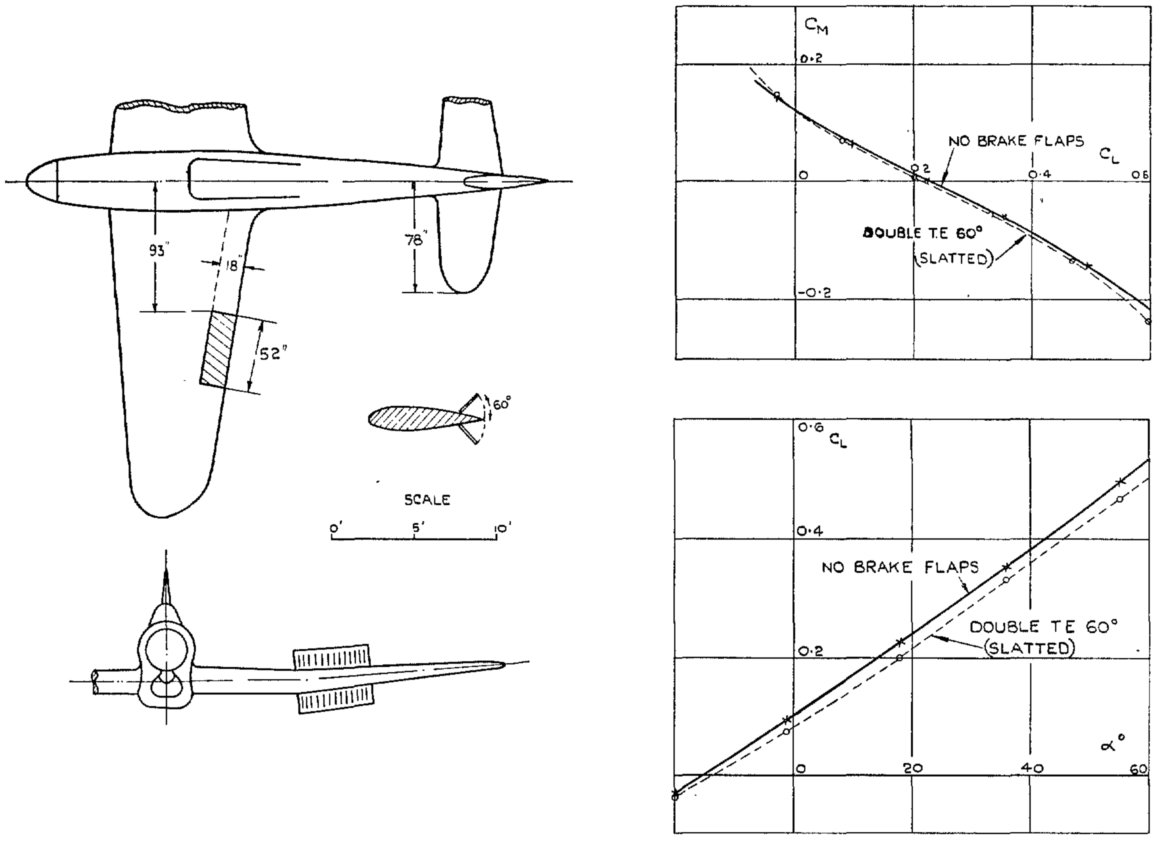


FIG. 17. Double-split Trailing-edge Brake Flaps on the Typhoon.

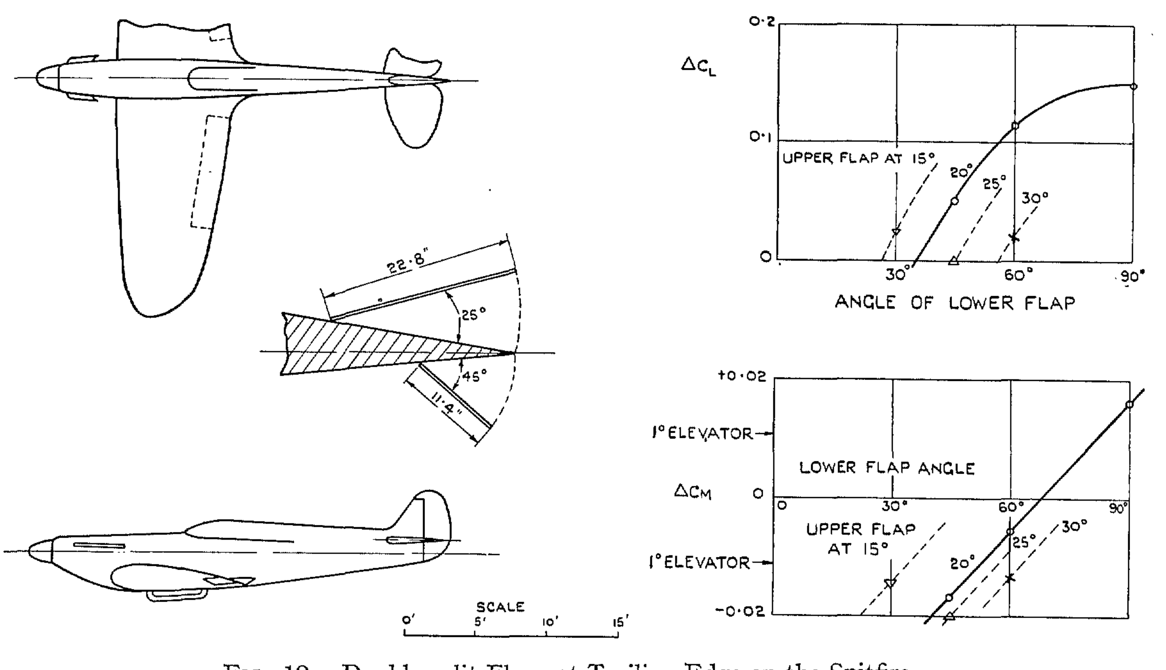


FIG. 18. Double-split Flaps at Trailing Edge on the Spitfire.

(Report No. Aero 1722.)

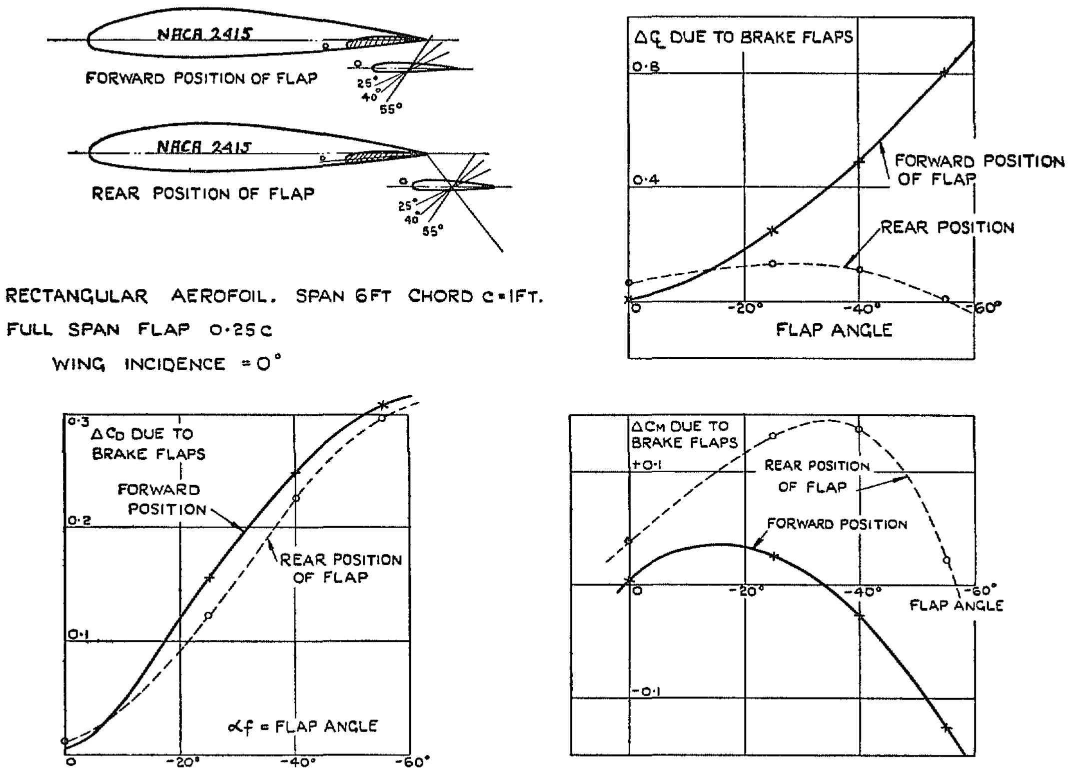


FIG. 19. Youngman Flap on Rectangular Aeıofoil. (N.P.L. Unpublished Data.)

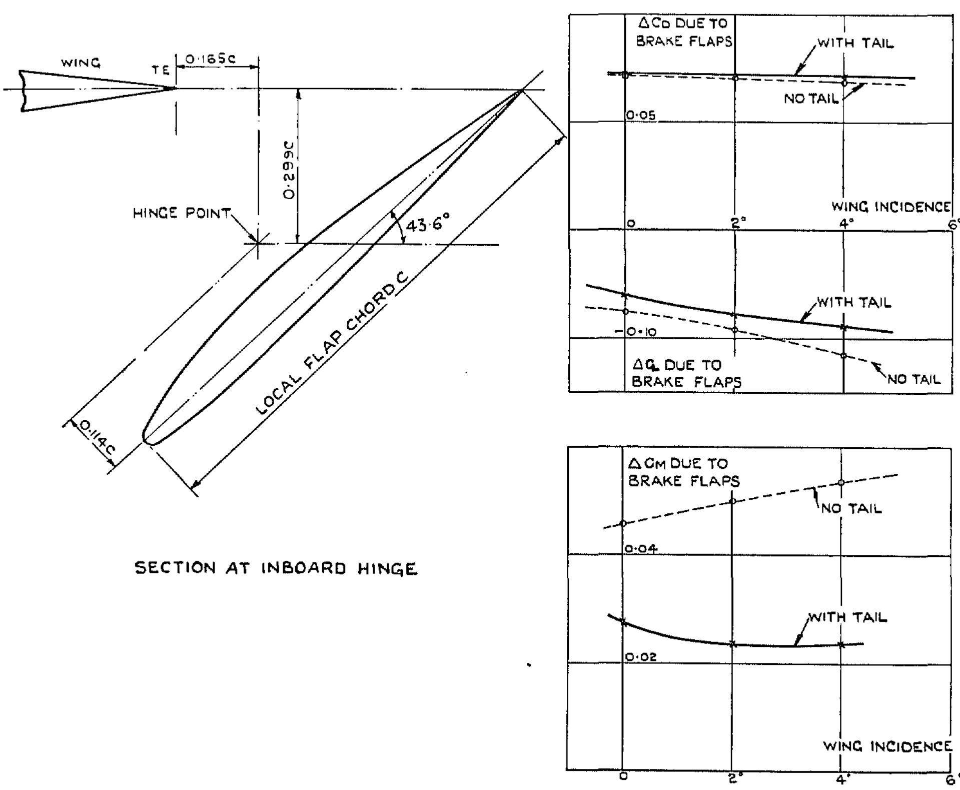
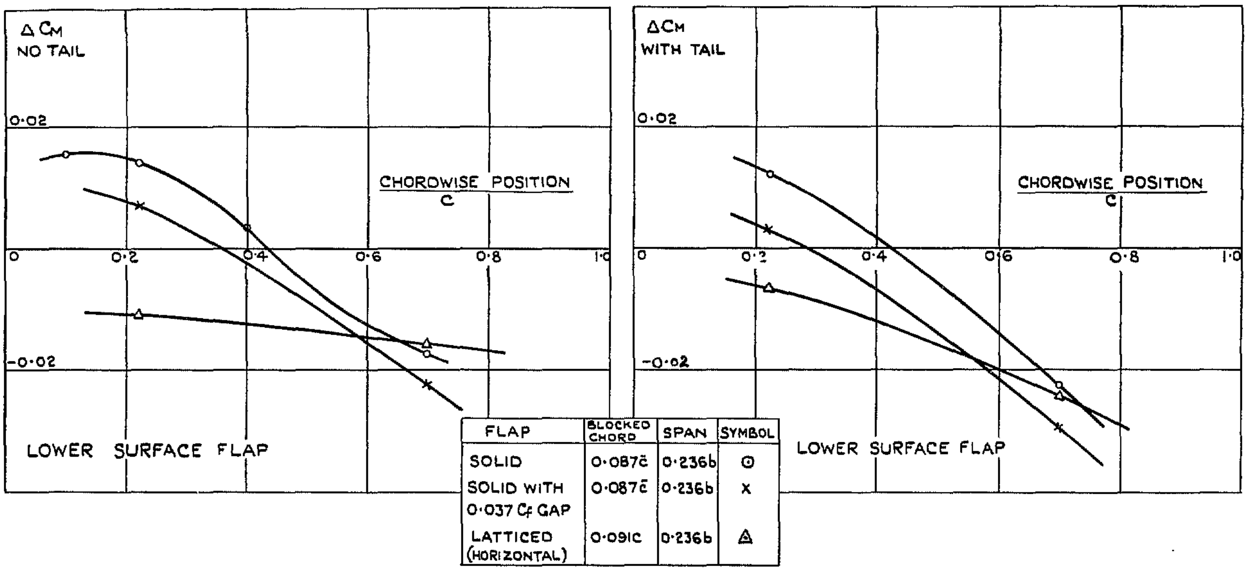


FIG. 20. Youngman Brake Flaps on the Barracuda (Firms Tests).
(*See* Fig. 1 for General Layout of Aircraft.)



FLAP	BLOCKED CHORD	SPAN	SYMBOL
SOLID	0·087c̄	0·236b	⊙
SOLID WITH 0·037 C_f GAP	0·087c̄	0·236b	x
LATTICED (HORIZONTAL)	0·091c	0·236b	△

FIG. 21. Effect of Latticing Flap on Change of Trim.
(Test on a High Wing Glider (Fig. 1(*l*)) Report No. Aero 1744.)

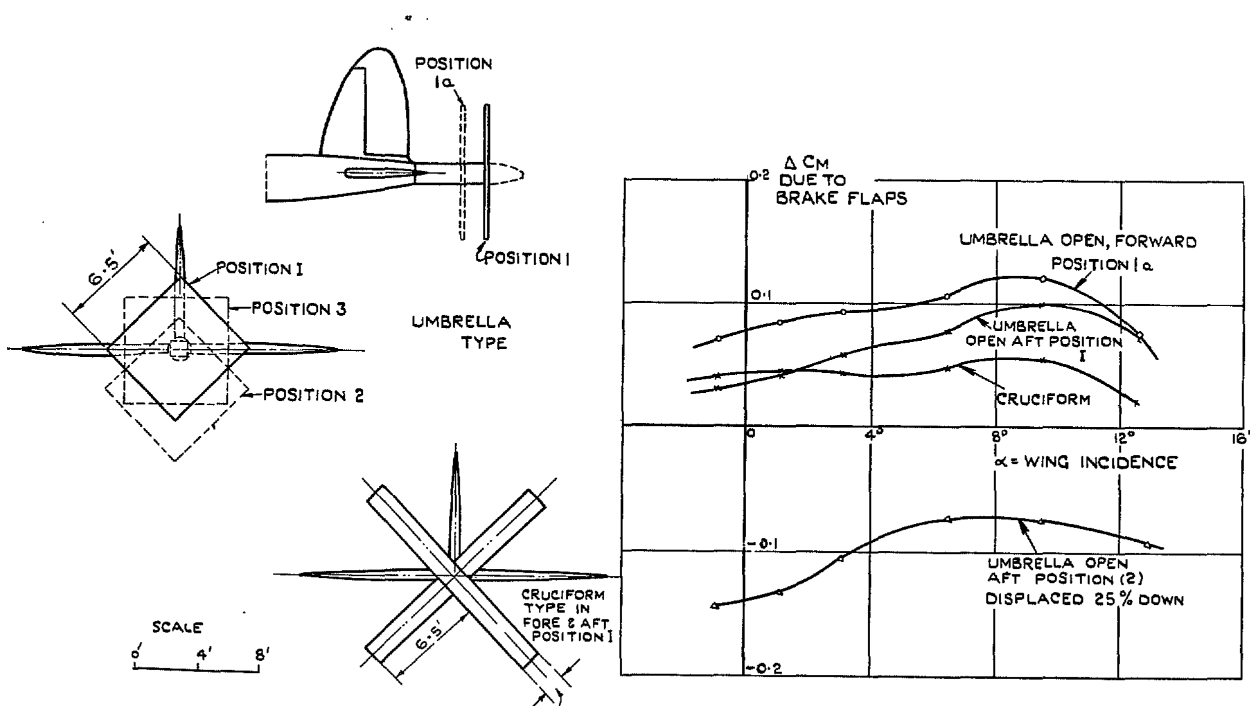


FIG. 22. Umbrella Brake Flaps on Mosquito.

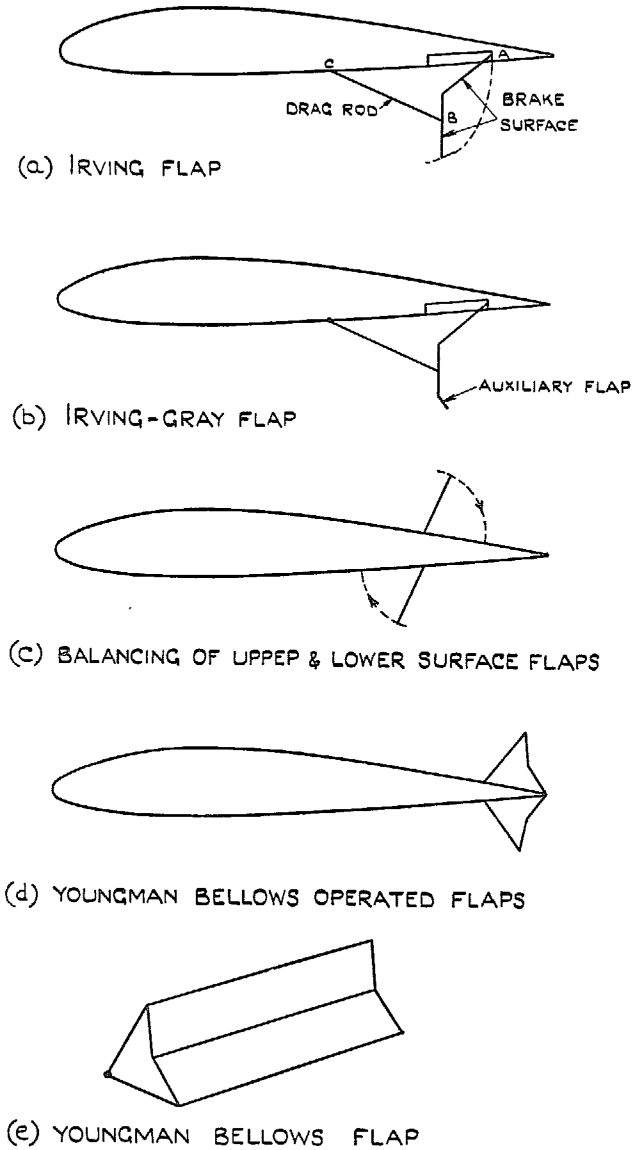


FIG. 23. Some Methods of Balancing Brake Flaps.

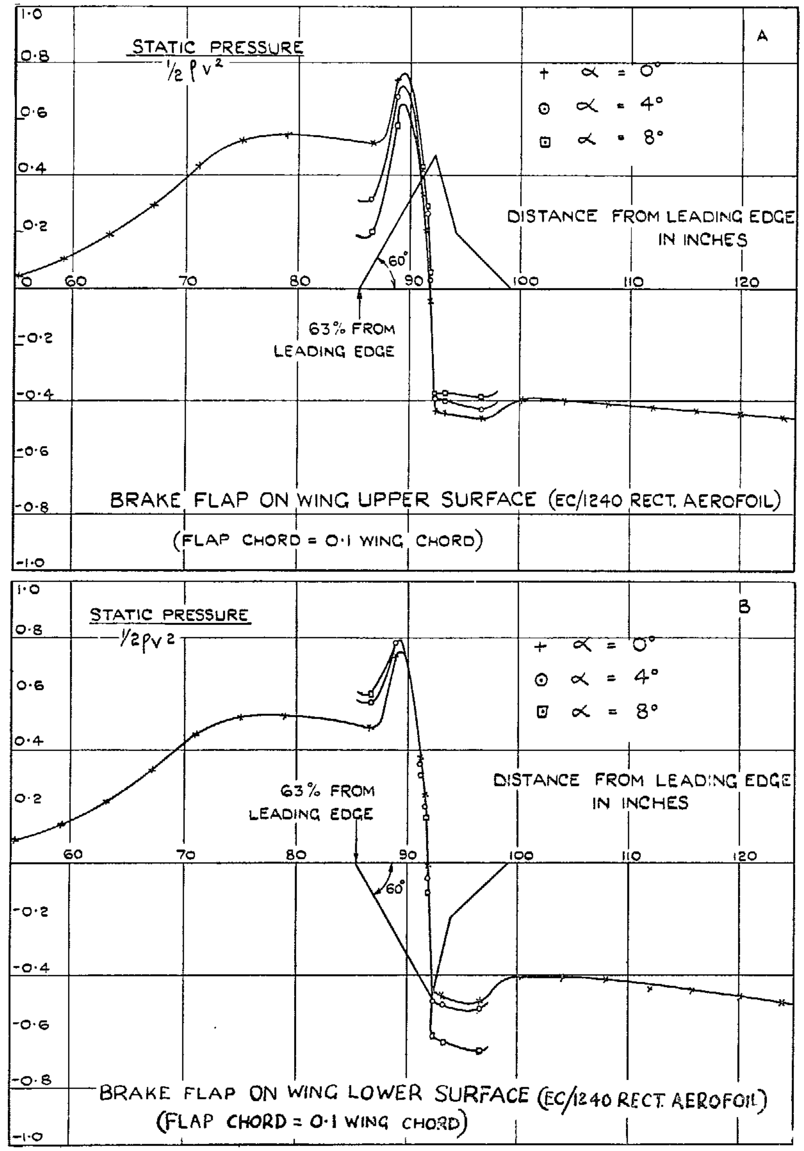


FIG. 24. (A and B). Pressure Distribution on a Bellows Flap.

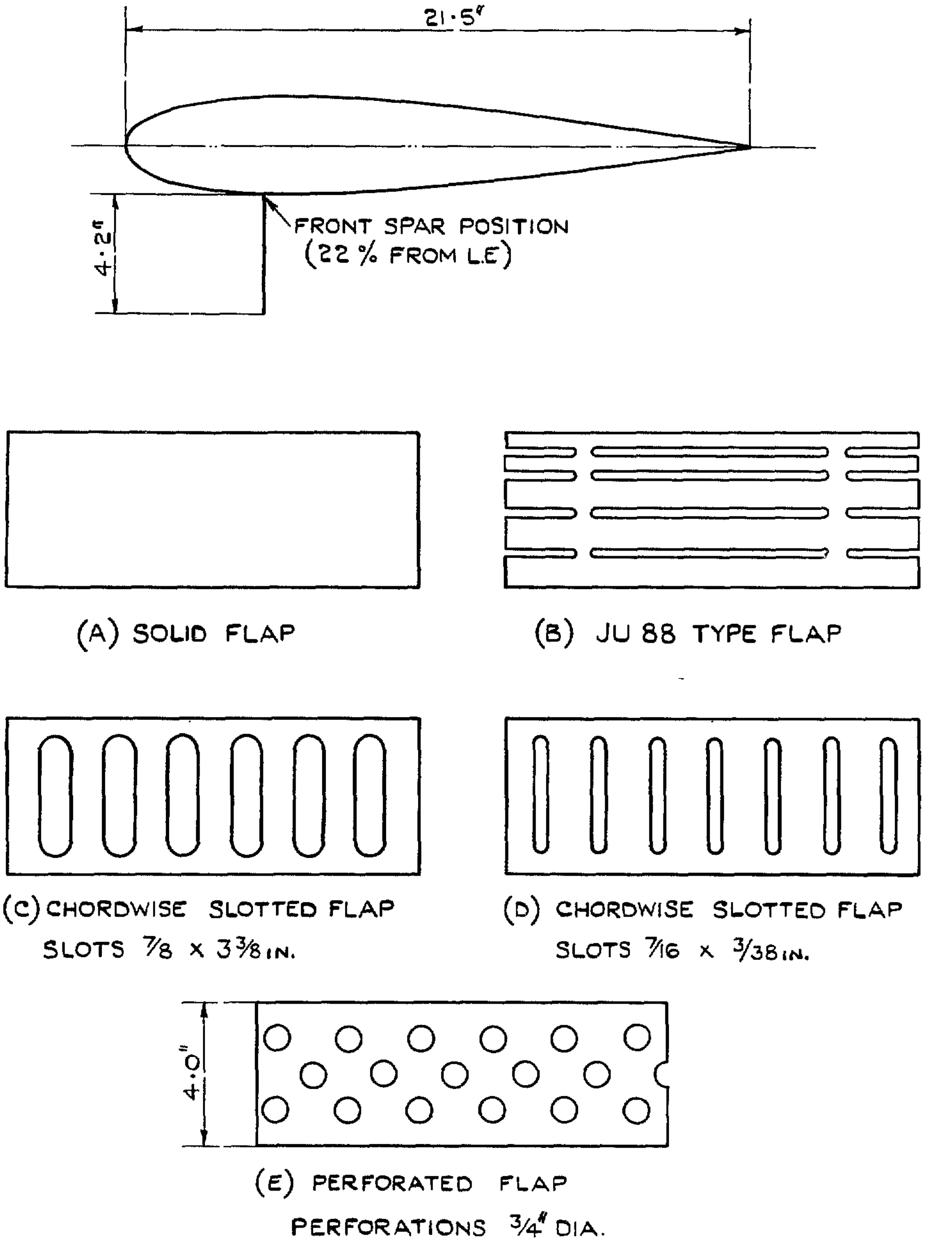
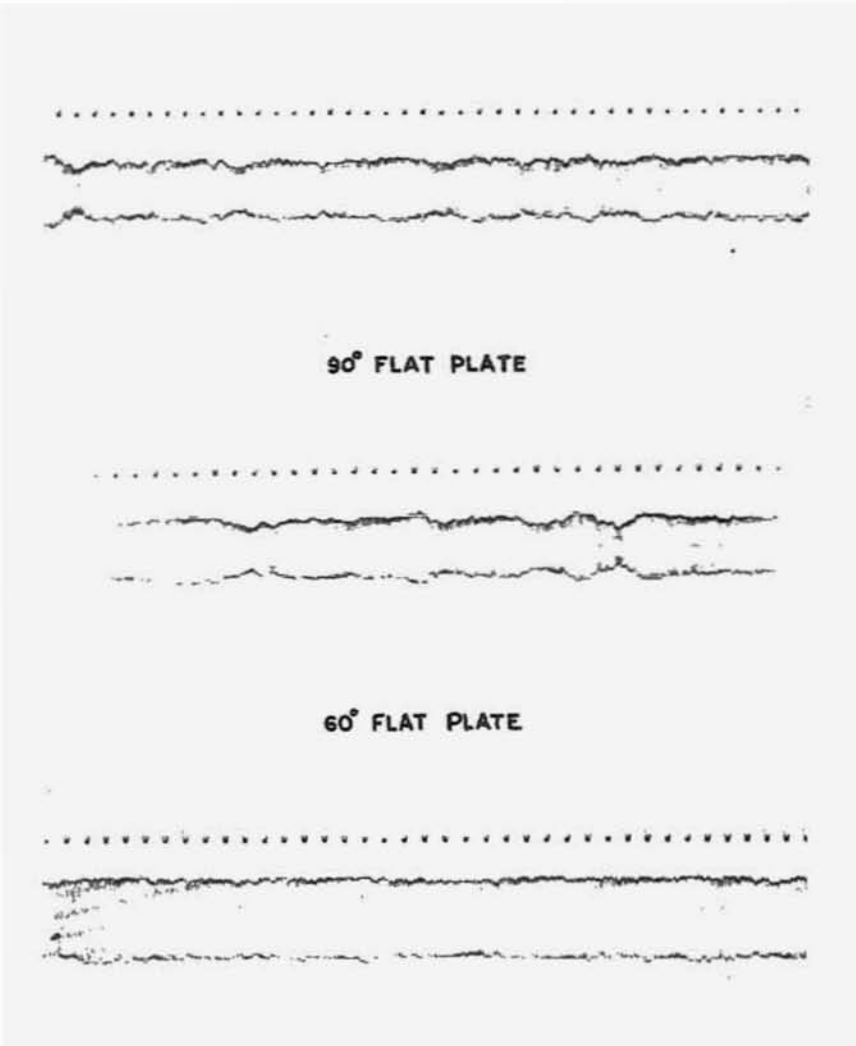


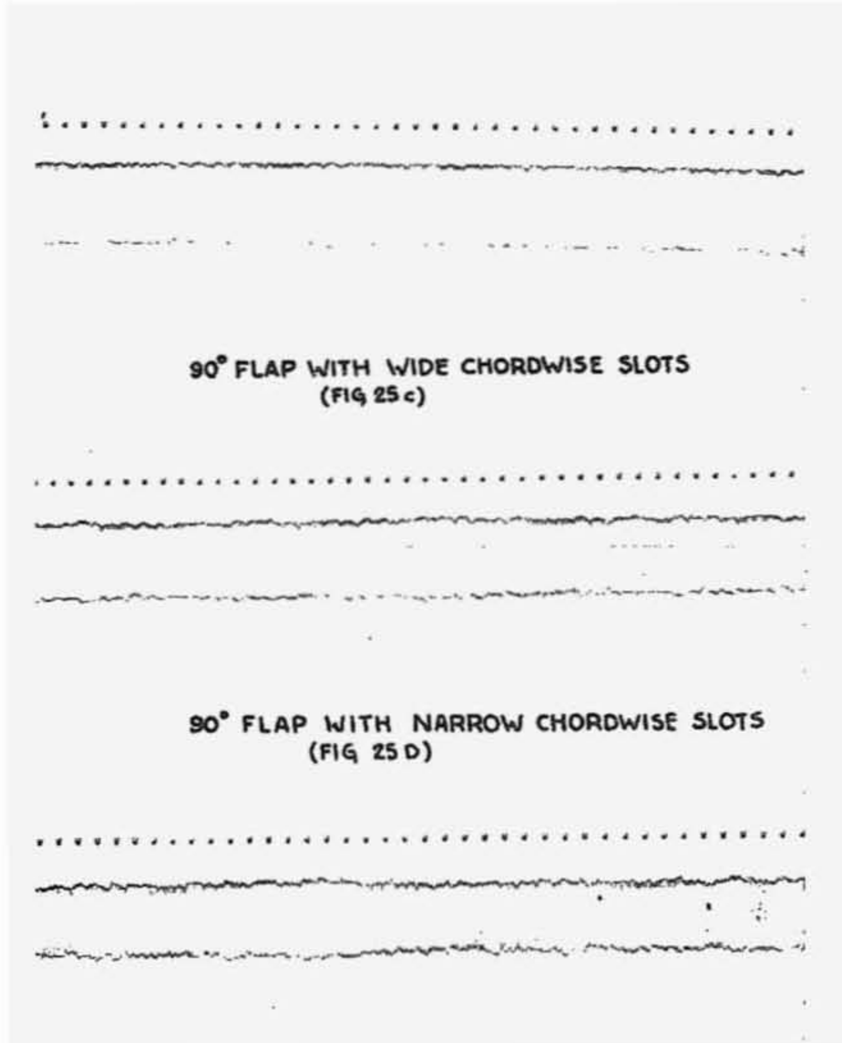
FIG. 25. Model Tests on Wing Buffeting due to Brake Flaps.

(98515) Wt.14/865 K.5 6/51 Hw.



90 deg Flap with Round Perforations (Fig. 25e)

Fig. 26. Pressure Fluctuation on Wing Surface behind Brake Flaps.



Ju.88 Type (Fig. 25b)

Fig. 27. Pressure Fluctuation on Wing Surface behind Brake Flaps.

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