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Flight Tests of a Falcon Fitted with an Irving Flap

By

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AERODYNAMIC SYMBOLS

1. GENERAL

m	Mass
t	Time
V	Resultant linear velocity
Ω	Resultant angular velocity
ρ	Density, σ relative density
ν	Kinematic coefficient of viscosity
R	Reynolds number, $R = lV/\nu$ (where l is a suitable linear dimension)

Normal temperature and pressure for aeronautical work are 15° C and 760 mm.

For air under these conditions $\begin{cases} \rho = 0\cdot002378 \text{ slug/cu. ft.} \\ \nu = 1\cdot59 \times 10^{-4} \text{ sq. ft./sec.} \end{cases}$

The slug is taken to be 32·2 lb.-mass.

α	Angle of incidence
ϵ	Angle of downwash
S	Area
b	Span
c	Chord
A	Aspect ratio, $A = b^2/S$
L	Lift, with coefficient $C_L = L/\frac{1}{2}\rho V^2 S$
D	Drag, with coefficient $C_D = D/\frac{1}{2}\rho V^2 S$
γ	Gliding angle, $\tan \gamma = D/L$
L	Rolling moment, with coefficient $C_l = L/\frac{1}{2}\rho V^2 bS$
M	Pitching moment, with coefficient $C_m = M/\frac{1}{2}\rho V^2 cS$
N	Yawing moment, with coefficient $C_n = N/\frac{1}{2}\rho V^2 bS$

2. AIRSCREWS

n	Revolutions per second
D	Diameter
J	V/nD
P	Power
T	Thrust, with coefficient $k_T = T/\rho n^2 D^4$
Q	Torque, with coefficient $k_Q = Q/\rho n^2 D^5$
η	Efficiency, $\eta = TV/P = Jk_T/2\pi k_Q$

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Flight Tests of a Falcon Fitted with an Irving Flap

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Reports and Memoranda No. 1863
5th September, 1938*

SUMMARY.—Reasons for enquiry.—It has been stated that flaps for landing a clean, heavily loaded aeroplane, should provide a range of settings over which the lift is constant but the drag variable within wide limits, with low operating forces. The Irving flap aims to do this and it was decided to test it in flight, to see how nearly it approached the ideal and to gain experience of the landing technique to be employed with such a flap.

Range of investigation.—The flap was fitted right across the span of a standard Falcon inboard of the ailerons; the changes in gliding angle and trim due to the flap, together with its contribution to maximum lift were determined.

Measurements were made of the operating force, and the linkage and chord ratio varied with a view to reducing this to a minimum.

By means of a " gate " the flap movement could be kept within the constant lift range, when making landings, and the effect of variable drag explored.

Handling trials were made by a large number of service and firms' pilots.

Results.—The lift due to the flap increased uniformly until the half open position and thereafter remained constant, whilst the drag increased steadily. The total gliding angle change was $3\frac{1}{2}°$, and trim change was negligible.

The aerodynamic hinge moment was not as low as calculation suggests is possible for this type of flap. Tests indicated that it would be reduced were the chord ratio of the upper to the lower member increased from 1 to 2. Nevertheless, the present flap was quickly and easily operated and enabled pilots to reach a given point at a given speed, without sideslipping, S-turns or use of engine.

Pilots who tested the flap, generally considered it a definite help in facilitating the landing approach, but suggested that much more drag could be used with advantage.

Conclusions.—It is feasible in the landing technique, to control the gliding angle with a rapidly adjustable flap, which gives variable drag at constant lift.

With the present Irving mechanism, quick movements of the flap are possible for aeroplanes up to about 3,000 lb. weight. With the Falcon, the flap was sufficiently large to show its advantage over the non-variable flap, but not large enough to enable the pilot to take full advantage of the landing technique used.

A modification to the flap suggested by Mr. W. E. Gray, considerably reduces the operating load, and makes it applicable to larger and more heavily loaded aeroplanes.

* R.A.E. Report, July, 1938.

1. *Introduction.*—In the problem of balancing trailing edge flaps, it is now commonly accepted that, save in a small aeroplane, the use of springs to balance the aerodynamic forces is unsound, on account of the change of load with speed. Some patented mechanisms which bear their inventors' names, such as Zap, Irving, Youngman, are ingenious attempts at the solution, and have been discussed elsewhere.[1] The ideal to be aimed at is the close balance of the flap weight at any deflection, by springs, and the elimination of aerodynamic loads by pure aerodynamic balancing.

If, in addition to requiring a low operating force, a flap could produce a constant lift but variable drag for a good part of its range, then the landing technique described in §6 could be tested. Some interim notes on this subject have already been issued.[2] For this purpose, modification of the Zap flap on the Parnall Parasol was considered, but rejected in favour of a test of the Irving flap on the Falcon, a typically representative low-wing monoplane. The wing loading of both aeroplanes was about 12 lb./sq. ft. It would have been better to try the variable drag technique on a more heavily loaded type, say over 25 lb./sq. ft., but none was available.

This report is concerned both with the principle and piloting technique of the rapid flap operation, and with the Irving flap itself and its suitability for practical use. It may be stated at the outset that there were no model results available for the lift, drag or pitching moments of this flap, and that it was entirely fortuitous that the qualities on the Falcon turned out to be reasonably close to the ideals set out above. Model tests of operating loads had been made and were used to design the flap control layout.

2. *Scope of tests.*—Flight tests to determine the characteristics of the flap so far as it affected the lift, drag and pitching moment of the aeroplane, were made during June-August, 1937. Measurements of the operating force and its variation with the linkage of the system were also included. A large number of civil and service pilots flew the aeroplane up till January, 1938 ; summaries of these pilots' opinions are included in §6 of this report.

3. *Descriptions.* 3.1. *Flap.*—The Irving flap consists of two articulated members, the lower hinged to the upper which in turn is hinged to the wing near the trailing edge. Fig. 1 is a forward view of the fully open flap on the aeroplane. The aerodynamic balance of hinge moments for this flap is, roughly speaking, obtained by partially cancelling the closing moment on the lower member with the opening moment on the upper member. Wind tunnel tests at the National Physical Laboratory[3] showed that this flap arrangement produced relatively small moments for medium openings, but overbalance of the fully open flap could not be eliminated.

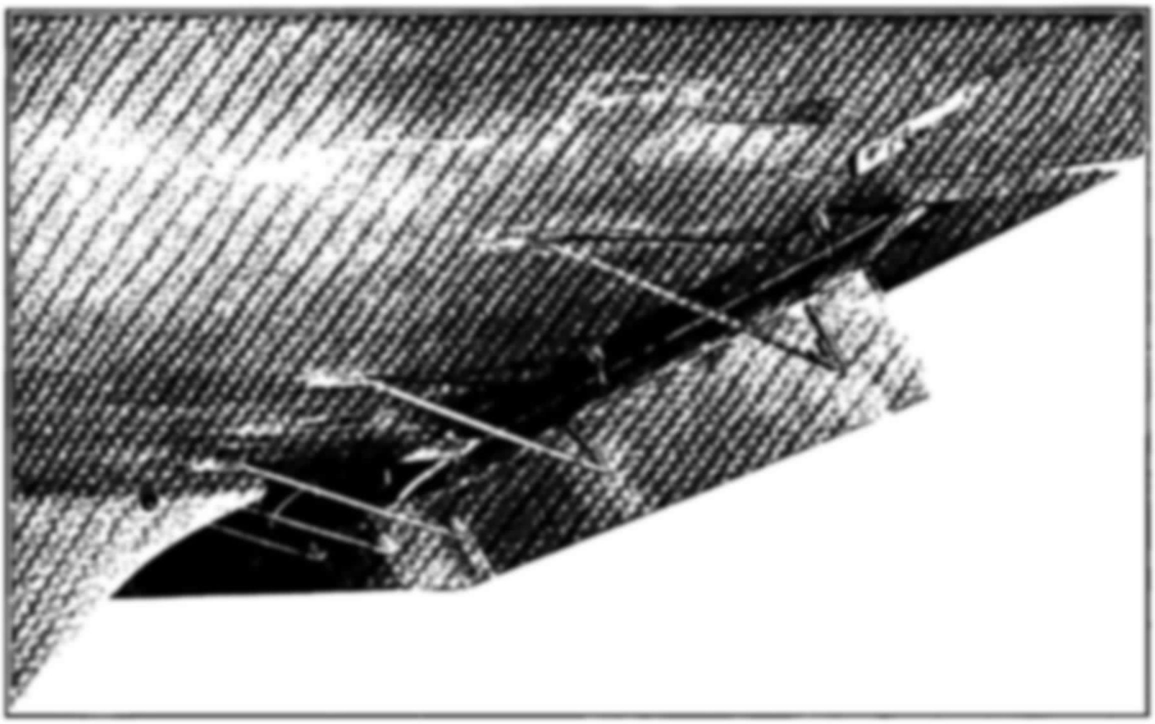

FIG. 1.—A Forward View of the Fully Open Irving Flap.

A general layout of the linkage and flap as fitted to the Falcon is shown in Fig. 2. The flap handle H is connected to the master bell crank K fitted to the rear spar in the cockpit, and thence to the torque tube T which is connected by a series of

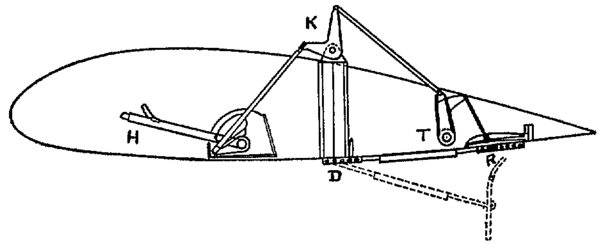

FIG. 2.—A Diagrammatic Layout, showing Position of Handle and Linkage to the Irving Flap.

bent levers and rods to the lower member. The drag rods DR (twelve for the complete flap span) pivoted to points D on the rear spar determine the motion of the flap members. Moving the flap handle through 60° opens the flap fully in the manner shown in Fig. 3.

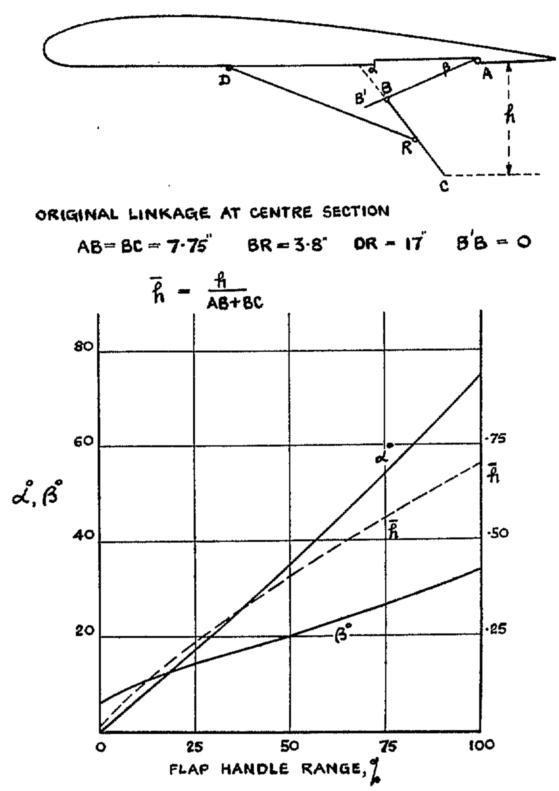

FIG. 3.—Irving Flap on Falcon. Angles and Linkage.

The flap extended inboard of the ailerons across the underside of the fuselage and tapered with the local chord. The torque tube had universal joints where the dihedral in the wing commenced. At the corresponding positions in the flap, sliding plates (included in the flap area) were fitted on the lower member so as to maintain an unbroken span for all angles of opening. Dimensions are given in Table 1.

3.2. *Flap handle gate.*—In subsequent tests it was found that this flap possessed properties approaching the ideal, as explained in §6. For the first half of the flap travel the lift increased uniformly; for the second half the lift remained constant and drag only increased.

The flap handle was therefore fitted with a double control. By the master control A, *see* Fig. 4, the handle could be moved through the whole of its range LMN, whilst the auxiliary lever control B allowed the handle to be moved through the constant lift range only, MN.

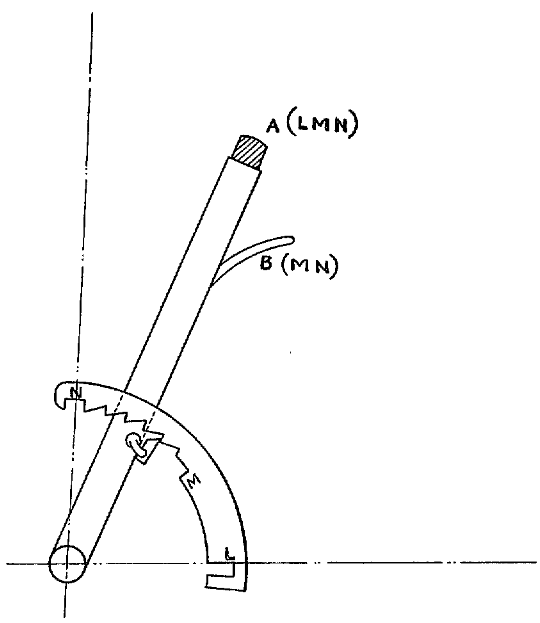

FIG. 4.—Diagrammatic Sketch of Flap Handle showing Master Trigger and Auxiliary Lever.

This arrangement facilitates the landing technique considerably. At the start of the approach glide the pilot depresses control A and moves the handle past the " gate " M, setting his air speed slightly above the constant stalling speed for the range MN. For the rest of the landing he operates the handle with lever B thereby varying the drag and adjusting the glide to enable him to touch down at a particular spot on the aerodrome. Use of the lever B ensures that the flap handle is operated within the gated range MN, so that the margin of speed above the stall remains constant.

4. *Discussion of tests and results.* 4.1. *Flap effect on aeroplane's characteristics.*—Time did not permit a complete series of lift and drag curves at various flap settings to be obtained; measurements were therefore confined to the variation with flap

setting of stalling speed, gliding angle at constant speed, and elevator angle to trim. The glides and trimming tests were made at 70 m.p.h. which pilots had found from preliminary tests to be the best all round gliding speed.

The results are shown in Fig. 5. The gliding angle γ increases by less than 1° over the first half of the flap range, and by a further $2\frac{1}{2}$° for the last half of the range reaching $9\frac{1}{2}$° at full flap deflection. The trimming curve at 70 m.p.h., seen

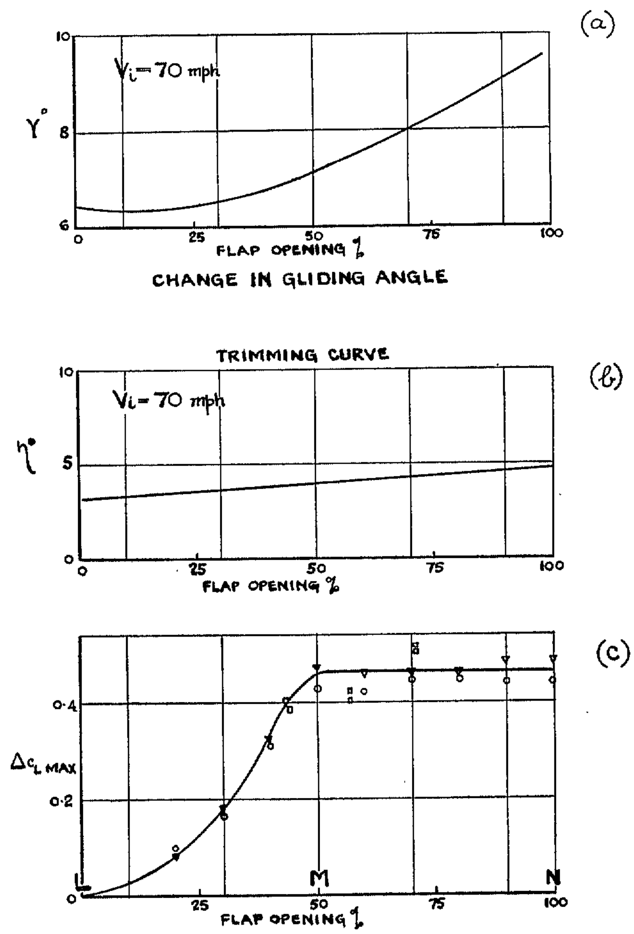

FIG. 5.—Change in $\Delta C_{L\ max.}$ ($C_{L\ max.}$ = 1·77 at 50-100 per cent. flap opening).

in Fig. 5*b*, shows that the elevator movement η is only 2° for the whole flap range. The stalling speed falls from 61 m.p.h. to 51 m.p.h. for the first half of the flap range, and thereafter remains constant (absolute $C_{L\ max.}$ is 1·77). Fig. 5*c* shows this as the change of $\Delta C_{L\ max.}$ due to flap. Accurate measurements of incidence at constant lift (*i.e.* constant speed) were not made, but the available evidence suggests that the lift curves are substantially coincident for all flap settings in the last half of the range.

4.2. *Hinge moments.*—The investigation into the flap aerodynamic hinge moment was hampered by the limited variations possible to the linkage, and by the very high frictional force in the system. The friction was smaller in flight than on the ground, due to the better alignment of the torque tube, owing to wing flexing. In tests its effect was eliminated by taking the mean of force readings required to move the flap open and closed.

The linkage variations followed results deduced from wind tunnel data.[4] In Fig. 6 the force curves *a*, *b* and *c* show roughly that increased overbalance for the fully open position is produced by moving the aft end of the drag rod towards the

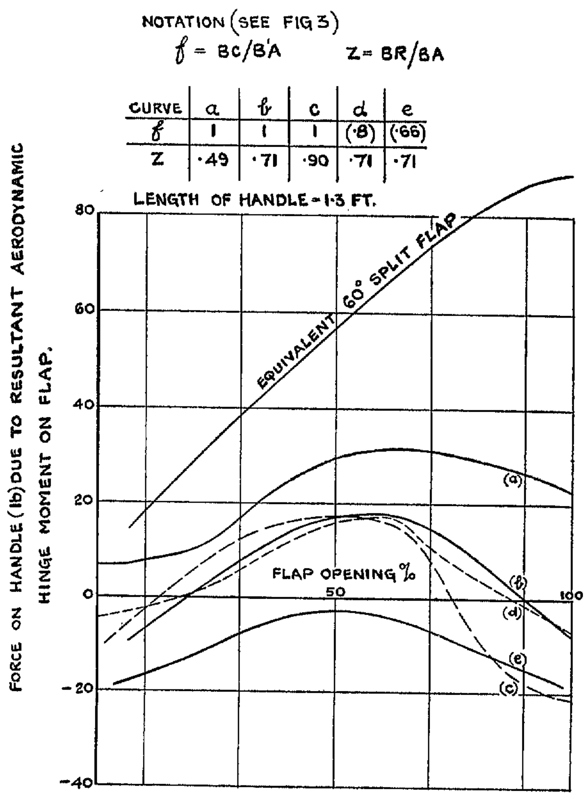

FIG. 6.—Handle Force (due to aerodynamic load) Variation with Flap Linkage, at $V_i = 70$ m.p.h.

flap trailing edge (*i.e.* increasing *z*). The ratio *f*, of the chords of the upper and lower members could not be varied directly, without extensive alterations. Instead a false nose strip was attached to the upper member, producing an increasing opening moment and partially shielding the lower member. This resulted in a ratio denoted by (*f*) ; and *d* and *e* of Fig. 6 show that the force curve is moved bodily by this means, but there seems to be no reduction of the tendency to overbalance at the end of the range. In the same Fig. 6, the force required to open an ordinary unbalanced 60° split trailing edge flap,[4] is shown for comparison. The chord of this flap is such that its projection perpendicular to the lower wing surface is equal to that of the hinged flap when fully open.

4.3. *General.*—The results of the pilots' tests (*see* Part II) need to be considered in relation to the measured characteristics of the aeroplane.

With regard to changes in fore and aft trim it appeared that some pilots previously thought that a change of trim when putting down a flap was inevitable ; experience with the Irving-Falcon disposed of this belief but the necessity of attaining zero change of trim in any design incorporating a quickly variable flap was stressed. The principles governing the balance of pitching moments with flaps are generally understood but it is not always easy to avoid changes of elevator angle to trim, especially with large tail planes, without some sacrifice in flap lift ; in such cases interconnection between the flap and an elevator trimming tab can be used to maintain trim with elevator free.

With regard to the amount of drag required, one pilot out of each group of about ten thought there was enough available on this Falcon ($\gamma = 10°$ at $1 \cdot 4$ V_s) and two of these forty-four pilots did not think there was any advantage to be gained from drag variation. It is conceivable that these pilots would have appreciated both the higher drag and its variability if this Falcon had had a wider range of gliding angles. The fact that 90 per cent. of the pilots wanted more drag and four out of the six who were not confident about " spot landings " thought they would be if more drag were available, points to the desirability of having an available gliding angle, without excessive speed, of considerably more than 10°.

It must be recollected that the aeroplane which first convinced the Royal Aircraft Establishment pilots of the desirability of high drag for landing was the Parasol with Zap flap[1] which had a gliding angle of 16° at $1 \cdot 4$ V_s ; moreover its gliding angle increased fairly rapidly with speed, reaching 20° at $1 \cdot 7$ V_s which was not considered an excessive speed except for the last stage of the approach. It is probable that a pilot appreciates gliding angle principally in terms of the horizontal distance covered for a given height drop, in other words his impression of gliding angle is linear with cot γ, and when discussing gliding angles from the pilot's point of view it is probably better to express them as gradients. The Falcon and Zap Parasol are compared on this basis below :—

Aeroplane.	γ	Gradient (tan γ).
Irving-Falcon flap up	6·4°	1 in 8·9 } at $1 \cdot 4$ V_s
,, ,, ,, at gate ..	7·1°	1 in 8·0 } at $1 \cdot 4$ V_s
,, ,, ,, full down ..	9·6°	1 in 5·9 } at $1 \cdot 4$ V_s
Zap-Parasol flap full down ..	16°	1 in 3·5 } at $1 \cdot 4$ V_s
,, ,, ,, ,, ,, ..	20°	1 in 2·7 at $1 \cdot 7$ V_s

It will be seen from the above table that the $2\frac{1}{2}°$ range of gliding angle in the "gated" range of flap movement on the Falcon corresponds to a range of 700 yards variation in landing spot when starting an approach glide from 1,000 ft. height in still air. Extension of the gliding angle range to $\gamma = 16°$ would add another 800 yards to the range of possible landing spots. All the pilots who flew the Falcon were skilled pilots and it is easy to see that the majority should be capable of keeping their errors of judgment within the limits actually set by the aeroplane's range of gliding angle; with comparatively unskilled pilots the range of gliding angle must be increased and it may be accepted that, for wing loadings of the order tested, the upper limit of gliding angle needs to be set by the degree of skill of the pilots who are to use the aeroplane; for average pilots, it might well be extended to the Zap Parasol figure of 1 in 3·5, *i.e.* 16°.

The problem of whether the above figures are applicable to aeroplanes of more than double the wing loading is one which can only be solved by direct test. The view has been expressed in a paper on landing flaps, [5] and is indeed commonly held that rate of descent in the final stages of an approach glide (*i.e.* below about 200 ft.) cannot be allowed to rise indefinitely without causing anxiety to the pilot and upsetting his judgment. Unless Fowler flaps or some other device giving a maximum lift coefficient of the order of $C_L = 3 \cdot 0$ are used, the stalling speed and consequently the gliding speed, at loadings in the neighbourhood of 30 lb./sq. ft. becomes very high; as a result the vertical component of the forward speed on the glide, even at moderate gliding angles, also becomes very high. For example if an aeroplane, geometrically similar to the Falcon with Irving flap were loaded to 30 lb./sq. ft. the rates of descent would be approximately as follows:—

Flap.	γ	V_c ft./sec.	
Up	6·4°	18	at 110 m.p.h. gliding speed = 1·4 times stalling speed with flap down.
At gate	7·1°	20	
Full down ..	9·6°	27	

As mentioned in the introduction an aeroplane of wing loading about 25 lb./sq. ft. was to have been tested with a fairly high drag flap to throw some light on this point but it has not become available; until some such test is made, it cannot be certain how much drag can usefully be employed near the ground at wing loadings of 25–30 lb./sq. ft., but there seems no reason to believe that a gliding angle of 1 in 3·5 would not be useful in the early stages of an approach, just as with light wing loading.

5. *Conclusions.*—The Irving flap as fitted to the Falcon is a good approach to the ideal required by pilots. At speeds near the stall the lift increases with flap opening until half way, after which it remains constant; only the drag increases

in the second half of the flap range. The total change in gliding angle is rather small, $3\frac{1}{2}°$; the gliding angle with flap fully down at $1 \cdot 4\ V_s$ might well be increased from the present value of 10° to about 15°. The change in trim due to the flap is negligible.

Although the flap is quickly operable in its present condition, the aerodynamic hinge moment is not as small as might be. Restricted tests show that a hinged flap with an upper to lower chord ratio of about 2, would produce a much smaller moment.

When operated over the last half of its range the flap behaves as a variable air brake, and enables the landing technique to be employed in which the gliding angle can be adjusted by a fairly skilled pilot, to make a spot landing without sideslips, S turns or use of engine. An extension of the range of gliding angle available is needed if full use is to be made of this technique.

6. *Pilots' reports.* 6.1. *Introductory.*—When the Zap flap[6] was tested at the Royal Aircraft Establishment in 1935 pilots were impressed with the very low standard of accuracy needed in judging the approach. On the other hand a considerable increase in skill was necessary in flattening out, and moreover with full throttle the aeroplane would not maintain level flight with flap fully down. The nett result of very high drag was, therefore, that an increase of skill was necessary.

It was realised, however, that the extreme ease with which the aerodrome could be approached, and the large errors in judgment of height and distance that were permissible, would have a revolutionary effect upon the skill required to land, if only the dangers of flattening out from a steep glide at a high approach speed could be decreased.

The obvious thing to do was to make the flap quickly operable so that all the advantages of a steep glide would be available during the approach, while at some safe height the drag could be reduced quickly and so allow the final approach to be flat enough to avoid the necessity of an increase of skill in flattening out, thereby obtaining a considerable overall reduction in the skill required in landing.

After further examination and experiment it was found that, unless variation of drag could be separated from variation of lift, the danger of sinking on reducing the drag, resulting from an associated loss of lift, made it inadvisable for an inexperienced pilot to alter his flap setting during the final stages of the approach.

The scheme as it finally crystallised is that variable drag must be supplied without alteration of lift, and without alteration of trim.[2] If, therefore, the variable drag is to come from the wing flap it can only be obtained by varying the flap through a range where the lift remains constant.

The original idea was that the variable drag now to be provided by an air brake should take the place of that obtainable by sideslipping and " S " turning in order to prevent an increase in the standard of skill required. (The ability to side-slip is fast disappearing, and a long straight approach is necessary on new types.)

Remembering, however, that training time in war is a vital factor, and that a disproportionate amount of that time is spent in learning to land, the variable air brake idea has now gone much further than merely replacing, by other means, the ability to vary the glide which was originally done by sideslipping. It now aims at revolutionising the whole landing technique. The ideal is that the aeroplane should be flown well up to the aerodrome, and then just pointed at the near boundary, the rate of descent in the glide being kept at the desired value by an air brake. It should not, in fact it does not, require much skill to bring the aeroplane over the near boundary at the correct height and within a few m.p.h. of the correct speed when using this technique.

A new factor has arisen. It is understood that most future aeroplanes will have not less than two engines and that they are likely to be so reliable that forced landing from engine failure will be very rare. Assuming that this hypothesis can be accepted it should be taken advantage of to the full by providing a large amount of fixed flap drag, so that a pilot can come well up to the aerodrome without any danger of overshooting. He can then point the aeroplane at the aerodrome and control his speed by the throttles. This is in effect exactly the same technique as was suggested for the variable air brake, with the exception that the pilot cannot get rid of the drag quickly and safely if he finds, for some reason, that he has to go round again just before landing. This consideration is the only limit to the amount of drag (fixed) that can be usefully employed. Subject to this limitation the more drag the better. Modern aeroplanes vary in this respect : some have high flap drag which gives the pilot a wide selection of approach angles, while others are deficient in flap drag and require a higher standard of skill to approach than is advisable, or should be necessary. Even accepting the supposition that forced landings can be disregarded it must not be assumed that any kind of flap and a power approach make landing easy : there is one, and only one thing, that will keep down the skill required in judgment of the approach and that is a large *difference between the steepest possible gliding angle and the flattest possible gliding angle.* This may be obtained with a fixed high drag flap and the use of the throttle, or by a powerful variable air brake. Whichever is used it is *high drag* that ultimately makes for ease of approach. Thus looking to the future care should be taken that aeroplanes are provided with adequate drag for landing, be it variable or fixed.

This discussion would not be complete without a reference to the reliability of engines and the relative unlikelihood of forced landings. No attempt is made to assess the absolute importance of the points mentioned below ; they are mentioned merely as points for consideration in determining whether or not to disregard the forced landing.

(1) In war time engines will be more severely used than now.

(2) Modern engines have greatly varying petrol consumptions with varying throttle openings and, in the stress and excitement of war, the pilot may run out of petrol before he can find a suitable landing ground.

(3) Weather conditions may prevent a pilot from returning to any of the aerodromes he anticipated being able to reach, and he may run out of petrol in searching for landing ground.

(4) Petrol tanks or petrol pipes may be shot through.

(5) Damage to engines or airscrews from gun fire may also occur.

Thus even if pure mechanical failure of the engines is eliminated there are other factors to consider. Due weight must also be given to the moral effect on the personnel of having a reasonable chance of forced landing successfully if the occasion arises. The War Manual lays stress on this point, saying that confidence in technical equipment is a vital factor making for high morale.

There are thus weighty considerations on both sides ; the reduction in the standard of skill, the saving of aircraft and personnel, and the moral factor on the one ; constructional complications, added weight, extra cost and possible slight loss of performance and load carrying capacity on the other. Nice judgment will be necessary to assess these opposed factors in their true relation and to arrive at the best compromise.

It is earnestly hoped that due consideration be given to the pilot's aspect as well as the aircraft constructor's in deciding these matters. Too much importance cannot be attached to this question of high drag and variable air brakes, and it should be remembered that if the latter prove impossible the former should not be lost sight of.

6.2. *Summary of pilots' test reports.*—With the flap linkage in its original condition (*see* Curve (*a*) of Fig. 6) the aeroplane was flown by forty-four pilots drawn from the Royal Aircraft Establishment, Aeroplane and Armament Experimental Establishment, Central Flying School, and firms' test pilots. They were supplied with a brief note on the flap and on its uses as an air brake, together with a series of questions, on the general principle. Their replies, which were collective from the official establishments, and individual from firms' pilots, are given in the following tables. In addition, their criticisms are briefly summarised with occasional comments in parentheses by S/L Fraser.

Forty-four pilots have flown the Falcon and answered the questionnaire. This table shows the results numerically

Question.	R.A.E.		A. & A.E.E.		C.F.S.		Firms.		Total.	
(*a*) Do you like the principle of operation? . .	*Yes.* 11	*No.* 0	*Yes.* 9	*No.* 1	*Yes.* 13	*No.* 1	*Yes.* 9	*No.* 0	*Yes.* 42	*No.* 2
(*b*) Do you prefer to land with the flap up or down?	*Down* 11	*Up.* 0	*Down.* 10	*Up.* 0	*Down.* 14	*Up.* 0	*Down.* 9	*Up.* 0	*Down.* 44	*Up.* 0
(*c*) Do you think there is enough drag with the flap fully down or could you use more?	*More.* 10	*Enough.* 1	*More.* 9	*Enough.* 1	*More.* 13	*Enough.* 1	*More.* 8	*Enough.* 1	*More.* 40	*Enough.* 4
(*d*) Do you think there is too much drag with the flap down?	*No.* 11	*Yes.* 0	*No.* 10	*Yes.* 0	*No.* 14	*Yes.* 0	*No.* 9	*Yes.* 0	*No.* 44	*Yes.* 0
(*e*) Do you think there is any advantage to be gained by being able to vary the drag?	*Yes.* 11	*No.* 0	*Yes.* 9	*No.* 1	*Yes.* 14	*No.* 0	*Yes.* 8	*No.* 1	*Yes.* 42	*No.* 2
(*f*) Can you by using the flap as a variable air brake come in on a straight glide and feel certain you will neither overshoot nor undershoot?	*Yes.* 11	*No.* 0	*Yes.* 8	*No.* 2	*Yes.* 11	*No.* *3	*Yes.* 8	*No.* *1	*Yes.* 38	*No.* 6
(*g*) Do you think it is an advantage to be able to lose as much drag as possible without losing lift if you have to go round again?	*Yes.* 11	*No.* 0	*Yes.* 10	*No.* 0	*Yes.* 14	*No.* 0	*Yes.* 9	*No.* 0	*Yes.* 44	*No.* 0

* Become " Yes " if more drag available.

A summary of points raised by various pilots not covered by direct answers to questionnaire

Pilot A.—Suggests that same results could be obtained by split flap. While agreeing that a certain advantage is gained in a forced landing it is considered that change in trim resulting from varying the drag would make approaches difficult. (Yes, but zero change of trim would have to be aimed at.)

Pilot B.—States that the advantage to a pilot during the approach glide of being able to vary the drag cannot be over-estimated provided there is no change of lift. Also he states that the effect of the flap as a pure air brake, independent of lift, is remarkable.

Pilot C.—Likes the possibility of using the flap to change gliding speed and angle, with a stop to prevent the stalling speed being increased. The associated firm are making an aeroplane with the flap controlled by throttle.

Pilot D.—Says there is a grave danger of stalling if the brake is applied without the nose being depressed. (So there is if the throttles are closed with the flap down.)

Pilot E.—While agreeing that the variable air brake is an advantage, is of opinion that on twin engined aircraft engine failure is unlikely and no brake is therefore needed.

Pilot F.—While agreeing that the air brake has great advantages he regards it as impracticable on twin engined aircraft.

Pilot G.—Agrees that brake is a considerable advantage but wants more variation of drag.

Pilot H.—While agreeing that the air brake has advantages, prefers the slot and slotted flap as an easy method of getting in over obstacles.

Pilot K.—Considers that the air brake has advantages as the objections to depending on the use of the engine will hold for some time yet.

Central Flying School.—Are in general agreement with the principle of an air brake, but differ regarding the operation of the flap; two pilots do not like the idea of connecting the flap to the throttle.

Aeroplane and Armament Experimental Establishment.—Like the variable air brake if it can be connected to the throttle with a separate lever for lift.

Royal Aircraft Establishment.—Are most emphatic regarding the advantages of a variable air brake.

6.3. *Conclusions.*—Neglecting for the moment constructional considerations, a fair estimate of the general conclusions of pilots regarding an air brake appears to be as follows. It is considered to be a distinct advantage because less accuracy is needed in the approach, as overshooting as well as undershooting can be checked (the latter is of course done by the throttle). Drag can be lost quickly without lift in the event of having to go round again. It gives the pilot control over his gliding angle and speed in the event of a forced landing, thus reducing the skill required in such an event more nearly to the level necessary on the types of aeroplanes now being replaced.

Some disappointment was expressed regarding the absolute value of the change of gliding angle, and it was generally felt that to be really effective, and to allow a substantial reduction in the skill required in the approach, the variation of gliding angle should be much greater. If it can be reduced quickly, as much drag as possible should be provided—very much more than on the Falcon.

Several firms' pilots, while agreeing with the principle of the air brake as an ideal, suggest that it has serious limitations in practice. The principal objections are :—

(1) constructional complication entailing additional weight ;

(2) in view of (1) its not being really necessary on twin-engine or multi-engine aeroplanes as forced landings from engine failure are unlikely, and

(3) the difficulty of providing variable drag without introducing changes of trim which would neutralise the advantages of the former.

One firm, whose designer is also a test pilot, is arranging for the variable air brake to be connected to the throttle so that it may be tried in practice and a true estimate be made of the advantages from a piloting point of view as against the disadvantages from a constructional point of view.

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5	S. B. Gates	Trailing edge flaps in relation to take-off and landing of landplanes. R. & M. 1707. June, 1935.
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TABLE 1

Principal dimensions

Aeroplane	
Weight	2,200 lb.
Wing area (including centre section) S	182 sq. ft.
Wing loading (w)	12·1 lb./sq. ft.
Span $2s$	35 ft.
Mean chord $\bar{c}$	5·2 ft.
Sweep forward of trailing edge of wing	6·5°
C.G. with respect to leading edge $\bar{x}$	1·72 ft.
C.G. with respect to leading edge $\bar{z}$	0·71 ft.
Irving hinged flap	
Total span	20 ft.
Mean chord (both members combined)	1·23 ft.
For linkage in Fig. 3	
Max. proj. to wing surface (mean for span) " h "	0·9 ft.
Max. angle of lower member " α "	76°
Flap span/$2s$	0·57
Max. flap proj./$\bar{c}$	0·175
Flapped area/S	0·71
Flap handle	1·3 ft.
Flap handle range	60°

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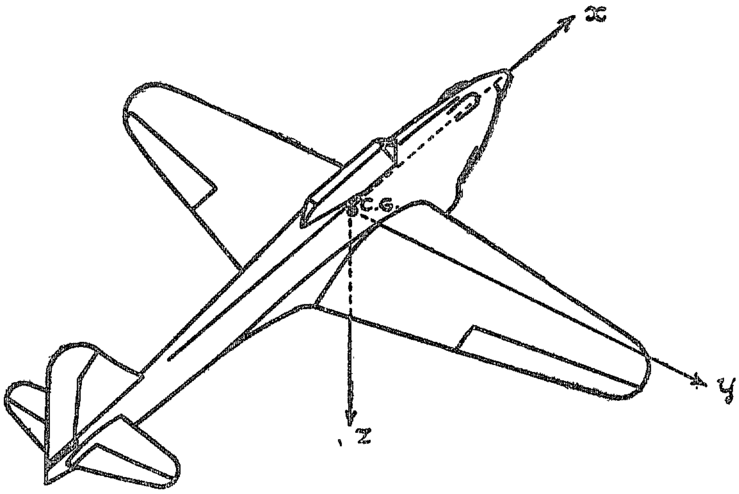
SYSTEM OF AXES



Axes	Symbol Designation Positive direction	x longitudinal forward	y lateral starboard	z normal downward
Force	Symbol	X	Y	Z
Moment	Symbol Designation	L rolling	M pitching	N yawing
Angle of Rotation	Symbol	ϕ	θ	ψ
Velocity	Linear Angular	u p	v q	w r
Moment of Inertia		A	B	C

Components of linear velocity and force are positive in the positive direction of the corresponding axis.

Components of angular velocity and moment are positive in the cyclic order y to z about the axis of x, z to x about the axis of y, and x to y about the axis of z.

The angular movement of a control surface (elevator or rudder) is governed by the same convention, the elevator angle being positive downwards and the rudder angle positive to port. The aileron angle is positive when the starboard aileron is down and the port aileron is up. A positive control angle normally gives rise to a negative moment about the corresponding axis.

The symbols for the control angles are :—

ξ aileron angle
η elevator angle
η_T tail setting angle
ζ rudder angle

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