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AIRCRAFT AND ARMAMENT EXPERIMENTAL ESTABLISHMENT

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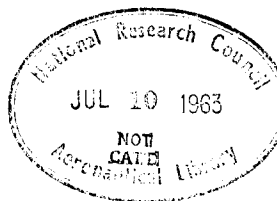
Spitfire IX. BS.139
(Merlin 61)

C. A. E.
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Spitfire Vs. AA.937 & AB.186. Spitfire XII's. EN.221 & EN.222.
(Merlin 45 and 46) (Griffon IIB)

The effect of 'clipping' Spitfire wings.
by F/Lt. D.R.H. Dickinson. F.R.Ae.S.

A. & A.E.E. Ref:- 4493/-A.S.56.
Item No:- 2E/5/42.



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1. Introduction.

Each of the following aircraft have been flown at this Establishment with and without wing tips:-

Spitfire Vs. A.A.937 and A.B.186.
Spitfire IX B.S.139.
Spitfire XII's. E.N.221 and E.N.222.

In addition a Seafire III has been flown with and without wing tips.

This report sums up the principal features of the two conditions, and includes remarks on both handling and performance. Some performance results have already been issued (see 44th part of Report No. A. & A.E.E./692,i.) but are reiterated again to complete the comparison.

2. Condition of aircraft relevant to tests.

2.1. General. The main features of the aircraft tested are given in the following table.

| Mark | Vb | Vb | IX | XII | XII |
|------------------|-----------------------------|--|----------------------------|---------------------------|----------------------------|
| Number | A.A.937 | A.B.186 | B.S.139 | E.N.221 | E.N.222 |
| Engine | Merlin 45 | Merlin 46 | Merlin 61 | Griffon II | Griffon II |
| Propeller | D.H.45/4 | Rotol RX5/10 | Rotol R3/4F5/3 | Rotol R13/4F5/6 | Rotol R13/4F5/6 |
| Wings | Normal Vb. | Normal Vb. | Universal | Universal | Universal |
| Armament | 2x20 mm.guns 4x 0.303" " | 2x20mm.guns 4x 0.303" " | 2x20mm.guns 4x 0.303" " | 2x20mm.guns 4x0.303" " | 2x20mm.guns 4x 0.303" " |
| Unusual features | - | Modified horn bal- anced elev- ator | - | - | - |

Each of these aircraft were flown with normal and clipped wings. When clipped, the wing span was reduced from 37 ft. to 32 ft. 6 in., and the wing area from 242 sq.ft. to 231 sq.ft. A plan form and photographs of the clipped wings were given in the 46th part of Report No. A. & A.E.E./692,i.

2.2. Loadings. The aircraft were flown at the following loadings:-

| Aircraft | Mk. No. | Weight lb. | Dist. of C.G. aft of datum point -ins. |
|----------|---------|---------------|---|
| A.A.937 | Vb | 6,540 | 8.2 |
| A.B.186 | Vb | 6,535 | 8.2 |
| B.S.139 | IX | 7,445 | 4.4 |
| E.N.221 | XII | 7,400 | 5.7 |
| E.N.222 | XII | 7,335 | 5.4 |

2.3. Aileron rigging. The aileron droop was measured on Mk.Vb A.A.937 on arrival, when it was found to be zero. This was then adjusted to give the correct droop of $\frac{3}{8}$ in.

/On

On the two Mk.XII aircraft the ailerons were rigged with the correct droop.

3. Description of tests.

The first Spitfire aircraft with clipped wings to be tested by this Establishment was A.A.937, a Mk.Vb. This aircraft carried out comparative performance and handling tests with normal and clipped wings. The aileron control on this aircraft was above the average in that it was light and effective at high speed. Accordingly, further comparative handling tests were made on Spitfire IX B.S.139 which was known to have rather poor aileron control in that it was heavy and sluggish. At the same time arrangements were made to send A.A.937 to the R.A.E. for stiffness tests of the aileron circuit, to ensure that it was not abnormal.

At this time a proposal that all Mk.XIIs should be fitted with clipped wings was under discussion, and to obtain data on this point, and also to obtain further general information on handling qualities, two Spitfire XII aircraft, E.N.221 and E.N.222, were flown by a number of pilots both with and without wing tips. A few attempts to measure times to bank were made on these aircraft.

The handling tests included not only a qualitative assessment of the rate of roll, but also observations of the characteristics in dives, medium and tight turns, at the stall, during aerobatics and at take-off and landing.

In order to check the effect on the indicated airspeeds on a given aircraft due to changes in position error when the wings were clipped, a further aircraft, A.B.186 (Mk.Vb) was fitted with a special A.S.I. system, the pitot-static head being fitted on the front of one of the 20 mm. gun barrels. Readings of this A.S.I. together with the normal A.S.I. were taken over a range of speeds, stalling speeds being noted in particular.

In addition to these tests, take-off tests with normal and clipped wings have been made on the Vb A.B.186, and also on a Seafire aircraft on which 18° of flap were available for take-off.

The tests were made between November, 1942 and February, 1943.

4. Results of tests.

4.1. Handling. Initially handling tests were made on A.A.937, special attention being paid to rolling characteristics. It was found that there was little appreciable difference between the rolling characteristics of this aircraft with tips on and off. The aileron control on this aircraft was, however, above the average for the type, although subsequent stiffness tests at the R.A.E. showed the aileron circuit to be normal. It was thought that any difference in rolling qualities might be more obvious on an aircraft with poor ailerons and hence tests were made on the Mk.IX B.S.139. Here again, however, little appreciable difference could be discerned between the qualities with tips on and off.

More thorough tests were subsequently made on the two Mk.XII aircraft. An attempt was made to obtain some quantitative indication of the rolling qualities by measuring the time to roll from 30° of bank on one side to 30° of bank on the other side, the pilot applying as much aileron as he could as quickly as possible.

The results are plotted in Fig. 1, and they indicate that on E.N.221, which had poor ailerons, there was quite an appreciable decrease in the time to bank when the tips were removed. On E.N.222 the ailerons were better than those of E.N.221 with normal or clipped wings, and in this case there was no appreciable difference in the qualities. The pilot's impressions were that the weight of the controls was not changed when the tips were removed, but a given control movement was slightly more effective.

In general manoeuvres the normal wings were very much superior. With clipped wings the aircraft could not turn as fast or as tight, and in mock combat was easily out-turned by the aircraft with normal wings. The stalling speed in turns was considerably higher with the clipped wings and this aircraft also tended to become unsteady at a higher speed above its stall.

The Mk.V A.B.186, and one of the Mk.XII aircraft were dived to 450 mph. A.S.I. when fitted with clipped wings. The aircraft remained steady in the dive, /and

and no signs of buffeting developed.

4.2. Stalling speeds. The following stalling speeds were observed:-

| Aircraft | All-up weight | Wings | Stalling speeds- mph, ASI. | |
|-----------------|---------------|---------|----------------------------|------------------|
| | | | Flaps & u/c up | Flaps & u/c down |
| Mk.V. A.B.186 | 6,535 lb. | Normal | 72 | 62 |
| | | Clipped | 80 | 66 |
| Mk.XII. E.N.221 | 7,400 lb. | Normal | 75 | Not obtained |
| | | Clipped | 93 | 72 |
| Mk.XII. E.N.222 | 7,335 lb. | Normal | 76 | 63 |
| | | Clipped | 90 | 74 |

As already explained some tests were made with a special additional A.S.I. system fitted to A.B.186, the position error of which would be unaffected by the change in tip shape. These tests indicated that the difference between the equivalent air speeds with and without wing tips would be about 2 m.p.h. less than the difference between the normal A.S.I. readings.

It will be seen that removing the wing tips produced a much larger change in stalling speed on the Mk.XII than on the Mk.V. We can offer no satisfactory explanation of this discrepancy, but merely record the results obtained. The only features which appreciably differed were the additional stubs and bulges for the 20 mm. guns on the Mk.XII wings, and the difference in design and direction of rotation of the propeller.

It is pointed out that the change in stalling speed that might be expected due to the reduction in wing area is only about 2 m.p.h.

The stalling characteristics with and without wing tips were very similar in each case.

4.3. Take-offs and landings. The take-off and landing characteristics were unaffected by removing the wing tips. No change in the length of the runs was apparent to the pilots, but there was a noticeable change in A.S.I. at take-off (see table below) which may be a position error affect aggravated by the proximity of the ground. Analysis of the films taken during measured take-offs show only a small change in true air speed.

The results of measured take-offs corrected to zero wind and standard atmospheric conditions are summarised below:-

| | Spitfire V A.B.186 | | Seafire III A.M.970 | |
|-------------------------------------|-----------------------|---------|------------------------|---------|
| | Normal | Clipped | Normal | Clipped |
| Flaps | Nil | Nil | 18° | 18° |
| Take-off run - yards. | 262 | 270 | 229 | 252 |
| Distance to 50 ft. screen - yards. | - | - | 500 | 530 |
| A.S.I. at take-off - m.p.h. | - | - | 70 | 75 |
| True air speed at take-off - m.p.h. | 89 | 89 | 88. | 89 |

The above Seafire III results were given in the 2nd part of Report No. A. & A.E.E./785, b.

4.4. Performance. The performance results obtained on A.A.937 are summarised in the following table. The results were given fully in the 46th part of Report No. A. & A.E.E./692, i.

| | Normal wings | Clipped wings |
|--|--------------|---------------|
| Maximum rate of climb (at 15,200 ft) | 2840 ft/min. | 2670 ft/min. |
| Time to 10,000 ft. | 3.7 mins. | 3.9 mins. |
| Time to 20,000 ft. | 7.4 " | 7.9 " |
| Time to 30,000 ft. | 13.6 " | 15.0 " |
| Service ceiling | 38,000 ft. | 36,200 ft. |
| Maximum speed at 17,000 ft. | 342 m.p.h. | 343 m.p.h. |
| Maximum speed at 19,800 ft. (F/T height) | 353 " | 353 " |
| Maximum speed at 25,000 ft. | 346 " | 342 " |

5. Conclusions.

From the foregoing paragraphs the advantages and disadvantages of removing the wing tips appear to be:-

Advantages.

- (i) A small increase in the rate of roll of aircraft with originally poor ailerons, but little effect on aircraft with good ailerons.
- (ii) A slight increase in speed at heights below about 20,000 ft.

Disadvantages.

- (i) An inability to turn as fast or tight as an aircraft with normal wings due to an increased stalling speed in the turn, thereby detracting considerably from the fighting efficiency of the aircraft.
- (ii) A small increase in take-off run (only serious on ship-borne aircraft).
- (iii) A loss in maximum rate of climb at any height of 160 - 200 ft/min.
- (iv) A lowering of the Service ceiling by 1,800 ft.
- (v) A decrease in speed above 20,000 ft.

In view of these facts, and in particular of disadvantage (i), it is recommended that the wing tips are not removed from Spitfire aircraft.

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Number, capacity, air-space, disposition,
material and construction.

3. FILTERS.
Type, number and disposition.

4. COOLING SYSTEMS.
Method of control.
Degree of control.
Maximum permissible
oil temperature.

5. TYPE OF OIL USED ON TEST.

6. COOLERS.
Type and number of coolers
and disposition.