Messerschmitt Me. 109
Handling and Manœuvrability Tests

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Summary.—Reasons for Enquiry.—Comprehensive handling and manœuvrability tests were required on the Me. 109, for comparison with similar tests already made on other modern single-seater fighters[6,7,8,9]. The performance of a captured Me. 109 was measured in France[2], and the aircraft then flown to England for these further tests.

Range of Investigation.—The handling tests covered the following ground :—ease of take-off and landing ; trim and stability ; " one control " tests, flat turns and sideslips ; stalling tests, including a determination of $C_{L\,max}$; high-speed dive ; harmony and " feel " of the controls.

An investigation of the fighting qualities of the Me. 109 included dog fights with Hurricanes and Spitfires, measurement of aileron forces and times to bank at speeds up to 400 m.p.h., and an analysis of the turning performance of the aircraft.

Pilots' views on cockpit layout, comfort and view are given in an Appendix to the report.

Conclusions.—(i) Take-off is fairly straightforward. Landing is difficult until the pilot gets used to the aircraft.

Longitudinally the aircraft is too stable for a fighter. There is a large change of directional trim with speed. No rudder trimmer is fitted ; lack of this is severely felt at high speeds, and limits a pilot's ability to turn left when diving.

Fin area and dihedral are adequate. The stall is not violent, and there is no subsequent tendency to spin. $C_{L\,max}$ is 1·4, flaps up and 1·9, flaps down. No vibration or " snaking " develop in a high speed dive.

Aileron snatching occurs as the slots open. All three controls are far too heavy at high speeds. Aerobatics are difficult.

(ii) The Me. 109 is inferior as a fighter to the Hurricane or Spitfire. Its manœuvrability at high airspeeds is seriously curtailed by the heaviness of the controls, while its high wing loading causes it to stall readily under high normal accelerations and results in a poor turning circle.

At 400 m.p.h. a pilot, exerting all his strength, can only apply 1/5 aileron, thereby banking 45 deg. in about 4 secs. From the results Kb_2 for the Me. 109 ailerons was estimated to be $-$ 0·145.

The minimum radius of turn without height loss at 12,000 ft., full throttle, is calculated as 885 ft. on the Me. 109 compared with 696 ft. on the Spitfire.

The cockpit is too cramped for comfort.

1. *Introduction.*—The Messerschmitt Me.109 single seater fighter has, since the outbreak of war, been the most extensively used fighter type of the German Air Force, and corresponds roughly to our Hurricane or Spitfire.

A number of crashed Me.109s fell into French hands at various times, and two aircraft were captured intact. Examination of these aircraft enabled the Aeronautical Technical Service of the French Air Ministry to prepare a very thorough descriptive report[1]. In addition, performance tests were made, and the flying qualities of the aircraft were briefly examined; the results of the flight tests are contained in two further French reports [2,3].

One of the aircraft was crashed during the performance tests, and the work was completed on the other. This second aircraft was then flown to England. After several weeks at the A. & A.E.E., Boscombe Down[4], it arrived at the Royal Aircraft Establishment for a comprehensive investigation of its handling qualities. The results of this investigation form the subject of the present report.

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The aircraft was available for flight tests at the R.A.E. during May and June, 1940. It was flown by all three pilots of the Aerodynamic Flight, the total flying time being 35 hours.

2. *Description of the Aircraft.*—2.1. *History.*—Since the Me.109 first appeared the design has undergone a number of major modifications. The following are believed to be the main stages in the development of the aircraft to its present form; the list of types is that given in the French descriptive report[1], and is not an official German classification.

Type 1.—The first version (1938) had a 670 b.h.p. Jumo 210 engine, fixed-pitch wooden airscrew, and two nose machine guns firing through the airscrew disc.

Type 2.—In the second version the Jumo 210 engine was retained, but a twin-bladed variable-pitch airscrew was fitted, and four machine guns were carried, two in the nose and one in each wing.

Type 3 (*a*).—A much more powerful engine was next installed, the Jumo 210 being replaced by a 1,100 b.h.p. direct injection D.B.601 driving a three-bladed variable pitch airscrew. The wing structure was considerably stiffened up, and about 60 lb. of permanent ballast was inserted in the rear of the fuselage to get the C.G. back. Four machine guns were still carried.

Type 3 (*b*).—This version only differs from type 3 (a) in that the wing armament consists of two 20 mm. cannon instead of the two machine guns.

The aircraft tested at the R.A.E. was of type 3 (b).

2.2. *Performance.*—As a matter of interest a summary of the performance results obtained during the French tests[2] is included below. The weight of the aircraft during these tests was 5,600 lb. It is stated in the French report that the speeds quoted depend on an estimate of the position error curve, and that in consequence there might be an inaccuracy of 2 to 3 per cent. on speed, i.e. ± 9 m.p.h. on top speed.

Top level speed

355 m.p.h. at 16,400 ft., 2,400 r.p.m. + 2·3 lb./sq. in. boost pressure. Radiators closed.
330 m.p.h. at 14,800 ft., 2,400 r.p.m. + 2·1 lb./sq. in. boost pressure. Radiators open.

Rate of Climb and Time to Height

Height ft.	r.p.m.	Boost lb./sq. in.	Rate of climb ft./min.	Measured time to height	German published time to height
				m. sec.	m. sec.
3,280	2,430	+3·9	2,740	1 16	1 0
6,560	2,430	+3·7	2,530	2 31	1 54
9,850	2,430	+3·6	2,900	3 50	3 0
13,150	2,430	+3·5	2,990	5 03	3 48
16,450	2,430	+2·0	2,600	6 20	4 54
19,750	2,400	+0·2	1,860	8 01	6 18
23,000	2,400	−1·8	1,450	10 02	
26,300	2,400	−3·6	820	13 35	

Owing to cooling difficulties the radiators were open up to 13,000 ft. and then gradually closed up to 26,000 ft. This may account for the discrepancy between the measured times to height and those published in Germany. The top level speed agreed well with the published figure.

Absolute ceiling.—32,000 ft

2.3. *General.*—The aircraft is a low-wing monoplane of fairly clean design. A list of aerodynamic data is given in Table 1, a three view general arrangement drawing in Fig. 1, while photographs of the aeroplane are reproduced in Fig. 2. The cockpit layout is shown in Fig. 3, and a photograph of the windscreen is given in Fig. 4.

In size, the aircraft is smaller than the Hurricane and Spitfire, and the wing loading is high—about 32 lb./sq. ft. compared with the 25 lb./sq. ft. of the Hurricane and Spitfire. From landing considerations the designer has thus found it expedient to incorporate high lift devices, and the aircraft is equipped with slots, slotted flaps and slotted ailerons which come down 10 deg. when the flaps are lowered; the ground attitude has been made large, 17 deg. at the wing root, in order to utilise a large proportion of the available $C_{L\,\max}$.

The structure is fully described in Ref. 1. The aircraft is of all metal construction except for the movable control surfaces and the flaps; these are fabric covered. The general standard of surface finish is good, the entire metal covering being flush riveted. Throughout the design it is obvious that great attention has been paid to ease of maintenance and inspection, and care has been taken to ensure that damaged components can be readily and quickly replaced by new parts.

During the R.A.E. tests the aircraft was flown with tanks full at its full service load. Ballast weights were added at the appropriate places in lieu of equipment which had been removed (ammunition, wireless, etc.), so the C.G. position should also be representative. The all-up weight was 5,580 lb. with the C.G. 24·8 in. aft of the leading edge at the root ($h = 0{\cdot}302$). This loading agrees well with the value of 5,600 lb. quoted for the all-up weight by the Germans.

2.4. *Engine.*—The engine is a 1,100 b.h.p. direct injection D.B.601. This is a 12-cylinder 60-deg. inverted V liquid-cooled engine with spar reduction gear. Provision is made to install a cannon firing along the axis of the reduction gear through the airscrew hub, but the French have no evidence that the Me.109 has yet been equipped in this way. Bosch injection pumps are used to meter the fuel.

The engine is glycol cooled. There are two radiators, one under each wing near the trailing edge. Each radiator is provided with a flap, operated from a wheel in the cockpit, which enables the cooling to be regulated. An oil cooler is carried in a duct underneath the fuselage. The air intake to the supercharger is from a scoop protruding from the engine cowling on the left side of the aircraft. An interesting feature is that the supercharger is driven through a hydraulic coupling; the advantages of such a system are discussed in Ref. 1.

2.5. *Airscrew.*—A 10·2-ft. diameter three-blade variable-pitch metal airscrew is fitted. It is of V.D.M. design, the pitch being controlled electrically. This type of airscrew is used very widely on German military aircraft.

The pilot can set the pitch at any value between 22·5 deg. and 90 deg., i.e. the airscrew is fully feathering. A stationary electric motor fixed to the crankcase just behind the airscrew hub is used to alter the blade setting through a flexible drive and a differential reduction gear. A pitch indicator is provided in the cockpit; this is coupled mechanically to the electric motor, and takes the form of a clock face with hour and minute hands, about ten minutes on this " clock " being equivalent to 1 deg. change of pitch. There is no provision for governing the r.p.m. and the pilot must set the pitch to give the r.p.m. desired for any condition of flight.

2.6. *Fuselage.*—A drawing of the fuselage, including a number of cross-sections, is given in Fig. 5. There is only a very small fillet at the wing-body junction, and the side of the fuselage is roughly normal to the upper surface of the wing. The under surface of the fuselage remains flat, flush with the under surface of the wing, for more than 3 ft. to the rear of the trailing edge; the fuselage cross-section then gradually assumes an ovoid form, and finally becomes pear shaped near the tail unit, the fin being merged very gradually into the fuselage.

About 60 lb. of permanent ballast is carried at the rear of the fuselage; this had to be installed because of the added weight forward when changing from the Jumo 210 to the D.B. 601 engine.

The undercarriage is attached to the fuselage at the wing root, and retracts sideways into the wings. The aircraft can thus be left standing on its undercarriage when the wings are removed, a useful maintenance feature.

2.7. *Wings*.—2.71. *Wing Form*.—In plan the wings have a straight taper, with a sweepback of 1 deg. at the quarter-chord line. The wing tips are fairly square cut, and the ratio root chord/tip chord is 2·06 1.

The thickness/chord ratio is 0·148 at the root and 0·105 at the tip; all along the span the aerofoil section has a 2 per cent. camber with the maximum thickness at about 30 per cent. of the chord, so the root and tip sections resemble NACA 2315 and 2310 respectively. There is no wing twist. The dihedral angle, 5·75 deg., is fairly high.

The surface finish is good; the metal skin is flush riveted and all inspection doors, etc., are flush and well fitting when closed.

2.72. *Slots*.—The slots occupy 46·2 per cent of the span and extend well inboard of the ailerons (Fig. 1). Sections of the wing with slat open and closed are given in Fig. 6. The slat is articulated to two transmission rods which run straight out of the wing and are linked together by a robust system of rigid rods and bell-crank levers; it opens and closes very freely, and when closed the fit between wing and slat is very good. A surprising feature is the absence of any form of damping device in the mechanism.

The slat chord and gap are considerably smaller than those suggested in A.D.M. 253 for the guidance of British designers.

2.73. *Flaps*.—The 25 per cent. c slotted flaps are fairly large, occupying 51·8 per cent. of the wing span. The ratio flap area/gross wing area is 0·14, and the maximum angle is 42½ deg. A plan and sections of the flap are given in Fig. 7. An interesting point is that the portion of the slotted flap immediately behind the wing radiator is thickened in section, as shown in Fig. 7. This is probably done to prevent the radiator flap stalling when fully open at low climbing speeds; it will be seen that the bulge on the flap considerably reduces the very large expansion at the rear of the radiator duct with radiator flap open.

The slotted flaps are operated mechanically from a 11·7-in. diameter wheel on the pilot's left; four complete turns are required to fully lower the flaps. They may be set in any intermediate angle.

2.74. *Pitot-static Head and Estimated Position Error*.—A drawing of the pitot-static head is given in Fig. 8. It is situated underneath the port wing at 0·68s, and in terms of the local wing chord is 0·32c from the local leading edge and 0·155c below the under surface of the wing.

For some of the tests (trim curves and aileron forces) it was desirable to convert pilots' A.S.I. to indicated airspeed so that C_L could be deduced. Accordingly the position-error correction curve was estimated from A. & A.E.E. generalised curves[5]; the estimated position error curve is plotted in Fig. 8.

2.8. *Control Surfaces*.—The relations between movements of the top of the stick or centre of a rudder pedal, in inches, and the corresponding angular movements of the appropriate control surface are illustrated in Fig. 9.

When tested on the ground all three controls showed remarkably little friction and no appreciable backlash. Each control surface is mass-balanced, and even the control column is statically balanced for fore-and-aft movement by means of a counterweight incorporated in the elevator control circuit. Transmission between the cockpit controls and the control surfaces is by a mixed system of rods and wires.

2.81. *Ailerons.*—Drawings of the slotted ailerons are given in Fig. 10. It will be seen from the sections that the slot width is very small. The ailerons have a 21·6 per cent. balance and the hinge position is well below the under surface. Each aileron has a mass balance weight of streamlined form carried on an arm projecting downwards; an aileron was removed and it was found that its centre of gravity coincided with the hinge line, i.e. complete static mass balance is achieved.

When the flaps are up the ailerons have a droop of 1·2 deg. and a 2:1 differential (maximum angles 13·5 deg. down and 25 deg. up). As the flaps are lowered both ailerons come down progressively, and when the flaps are fully lowered (42·5 deg.) both ailerons come down 11 deg.; the differential is now slightly less. Fig. 9 shows the aileron-stick gearings for three flap settings (0 deg., 20 deg. and 42·5 deg.).

A small fixed trimming tab is attached to each aileron (Fig. 10). These tabs are of metal sheet, and can be bent when on the ground to adjust lateral trim.

2.82. *Tail Unit.*—Drawings of the fin and rudder, including sections are given in Fig. 11a, and similar drawings are given for the tailplane and elevator in Fig. 11b. Both these controls are horn balanced; the percentage balance is 10·35 per cent. for the elevator and 8·5 per cent. for the rudder. The mass-balance weights are carried in the horns, and it is believed that static mass balance is achieved in each case.

The tailplane is high; a large portion of the rudder comes below it, and thus remains unshielded at high incidences, a useful anti-spin feature.

No rudder trimmer is provided which can be operated in flight. When on the ground directional trim may be adjusted by bending a portion of the trailing edge of the rudder.

Longitudinal trimming is effected by means of an adjustable tailplane having a 12 deg. incidence range and operated mechanically from a handwheel on the pilot's left; this wheel is mounted concentrically with the flap-actuating wheel, and by winding both wheels together the pilot automatically compensates for the change of trim due to flaps.

3. *Programme of Tests.*—A number of modern aircraft have been put through a standard series of handling tests at the R.A.E. The aircraft tested have included such single-seater fighters as the Spitfire[6], Hurricane[7], Gloster F5/34[8] and Curtiss H-75[9]. As a first step it was thus thought of comparative value to put the Me.109 through the same series of tests, which covered the following points;—pilots' impressions of ease of take-off and landing; longitudinal and directional trim; control with rudder and ailerons alternately held fixed, flat turns and sideslips; behaviour at and near the stall (ADM 293—issue 2); harmony and " feel " of the controls.

In addition to the above standard programme, $C_{L\,\max}$ was determined with a trailing static, and the behaviour in a high-speed dive was investigated. Rough measurements were also made of aileron stick forces and rates of roll, for comparison with the results of similar aileron tests[9] on the Spitfire, Gloster F5/34 and Curtiss H-75.

The fighting qualities of the aircraft were next examined by staging a series of dog fights and diving attacks between the Me.109 and a Spitfire, both flown by pilots of the Aerodynamic Flight. Later a number of service pilots who had recently seen active service were invited to the R.A.E. with their Spitfires and Hurricanes in order to practice aerial combat against the Me.109. Information of considerable interest was gained from these mock fights.

Finally the R.A.E. pilots were asked to give their opinions on cockpit layout, comfort, view, etc.; these are summarised in Appendix I at the end of the report.

4. *Handling Tests.*—4.1. *Take-off and landing.*—4.11. *Take-off.*—All the take-off tests were done with the slotted flaps set at the recommended position of 20 deg. The throttle can be opened very quickly, for as the engine is of the direct injection type it responds almost instantaneously to throttle movement without choking. The initial acceleration is very good, and there is no tendency to swing or bucket; during the ground run the aircraft rocks slightly from side to side, but this feature is not sufficiently pronounced to worry the pilot.

On opening the throttle the stick must be held hard forward. The tail comes up fairly quickly, and the stick can then be eased back. It is advisable for the pilot to hold the aircraft on the ground for a short while after he feels that flying speed has been gained, as if the aircraft is pulled off too soon the left wing will not lift, and on applying opposite aileron the wing comes up, then falls again, with the ailerons snatching a little. If no attempt is made to pull the aircraft off quickly, the take-off is quite easy and straightforward.

The take-off run is remarkably short, and the initial rate of climb is exceptionally good. In these respects the Me.109 is definitely superior to those Spitfires and Hurricanes having two-pitch airscrews, and compares well with the Curtiss H-75.

4.12. *Approach.*—The stalling speeds when gliding are 75 m.p.h.* with flaps and undercarriage up and 61 m.p.h. with flaps and undercarriage down. Lowering the flaps makes the ailerons heavier and very slightly less effective, and gives rise to a fairly large nose-down pitching moment which can, however, be readily corrected owing to the juxtaposition of the flap and tailplane adjustment operating wheels; the attitude of the aircraft at constant airspeed changes by about 10 deg. when the flaps are put down. Lowering the undercarriage causes only very slight nose-heaviness.

If the engine is opened up when the flaps are down, as for a mislanding in which the pilot decides to go round again, the aircraft becomes slightly tail heavy, but can easily be held with one hand while trim is adjusted.

The effect of varying the approach speed on rate of descent was measured when gliding with flaps and undercarriage down. The results are given in the following table.

TABLE 3

Gliding Angles—Flaps and Undercarriage Down

A.S.I. m.p.h.	V_i† m.p.h.	Rate of descent $V_c\sqrt{\sigma}$ ft./sec.	Gliding angle γ approx.	Pilot's rough estimate of gliding attitude
			deg.	deg.
60	80	26·5	13·0	+ 3
70	86	22·5	10·3	0
80	93	23·3	9·8	− 5
90	100	24·5	9·6	−12
100	108	29·2	10·5	−18

Attitude when cruising level = − 5 deg.

Approaching with flaps and undercarriage down the pilot has an impression of sinking at speeds below 80 m.p.h. and of diving at speeds above 100 m.p.h. The normal approach speed is about 90 m.p.h.

Gliding at 90 m.p.h. with flaps and undercarriage down the glide path is fairly steep and the view is reasonably good owing to the nose-down attitude of the aircraft. Longitudinally the aircraft is markedly stable, stick free, and the elevator is heavier and more responsive at this speed than is usual on single-seater fighters, comparing well with that of the Curtiss H-75[9]; these features add considerably to the ease of the approach. Lowering the ailerons 11 deg. with the flaps detracts little from their effectiveness, but makes them feel much heavier; the rudder is rather sluggish for small movements.

Normal gliding turns can be made at 90 m.p.h. flaps down, without any signs of stalling or undue loss of height.

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* Throughout this report speeds quoted are pilots' A.S.I. unless otherwise stated.

† Position error estimated from A.A.E.E. generalised curves as described in § 2.74.

4.13. *Landing.*—This is definitely more difficult than on the Hurricane or Spitfire, mainly owing to the high ground attitude of the aircraft. The aircraft must be rotated through a large angle before touch down, and this requires a fair amount of skill on the part of the pilot, and tempts him to do a wheel landing. If a wheel landing is made there is a strong tendency for the left wing to drop just before touch-down, and when the ailerons are used quickly to bring the wing up they snatch a little, causing the pilot to over-correct. By holding off a little high the aircraft can be made to sink slowly to the ground on all three wheels, and there is then no tendency for a wing to drop. A pilot quickly becomes accustomed to the landing technique required on this aircraft, and should have no difficulty after a few practice landings.

The centre of gravity is unusually far behind the main wheels, and the brakes can be applied fully immediately after touch-down without fear of lifting the tail. The ground run is very short, and there is no tendency to swing or bucket. Owing to the large ground attitude, and the consequent high position of the nose, the view ahead during the hold-off and ground run is extremely bad. Landing at night would probably be difficult.

4.14. *Ground Handling.*—Because of the large weight on the tail the aircraft can be taxied very fast without bouncing or bucketing, but is difficult to turn quickly; an unusually large amount of throttle is necessary, in conjunction with harsh use of the differential brakes, when manoeuvring in a confined space. Apart from turning performance, the ground handling qualities are good. The brakes are powerful and can be used harshly without lifting the tail; they are foot operated, and the pilots expressed a strong preference for the hand-operated system universal on British aircraft.

4.2. *Trim.*—4.21. *Lateral.*—A small fixed tab is fitted to each aileron; these tabs can be adjusted when on the ground to correct any tendency to fly one wing low. No means are provided for trimming the ailerons in flight.

There is no pronounced change of lateral trim with speed or throttle setting if care is taken to fly without sideslip. As no trimmer is fitted to the rudder, a small amount of sideslip is quite probable, particularly at high speeds when the rudder is fairly heavy; owing to the large wing dihedral any such inadvertent sideslip gives rise to a pronounced rolling moment, necessitating use of the ailerons for its correction.

4.22. *Directional.*—The absence of a rudder trimmer is a bad feature, since there is a large change of directional trim with speed. A rudder angle indicator was fitted, and rudder angles necessary to fly straight and level with no sideslip were measured at various speeds when gliding and at full throttle, with flaps and undercarriage in turn up and down. The resulting curves of rudder angle to trim plotted against pilot's A.S.I. are given in Fig. 12. It will be seen that when flying at full throttle there is a very rapid variation of directional trim with speed. The practical consequences are not quite as alarming as the curves might suggest, because the rudder is light at low speeds, and very little force is needed to hold on the 5 deg. of right rudder necessary when climbing at 150 m.p.h.; the French report[2] that it is difficult to turn to the right when climbing was not confirmed, and is thought to be misleading; on the aeroplane tested at the R.A.E. climbing turns could be done with equal facility to both left and right.

It is at high speeds that lack of a rudder trimmer most seriously inconveniences the pilot. At 215 m.p.h. the aircraft is trimmed directionally, no rudder being required. At higher speeds left rudder must be applied, and at 300 m.p.h. about 2 deg. of left rudder are needed. The rudder is very heavy at high speeds, and a large force is necessary to apply even such a small amount; this becomes very tiring, and affects the pilot's ability to put on more left rudder to assist a turn to the left. Consequently at high speeds the Me.109 turns more readily to the right than to the left.

4.23. *Longitudinal.*—The adjustable tailplane is controlled from a 11·7-in. diameter wheel on the pilot's left (Fig. 3); 5·75 turns are required to move the tailplane through its full angular range (+ 3·4 deg. to − 8·4 deg.) and the wheel rotation is in the natural sense, i.e. winding forward pushes the nose of the aircraft down.

Tailplane angles to trim were measured at various speeds when gliding with (i) flaps and undercarriage up, (ii) flaps up and undercarriage down, (iii) flaps and undercarriage down and at full throttle with flaps and undercarriage up. The centre of gravity was at $h = 0{\cdot}302$ with undercarriage down; raising the undercarriage has little effect on the fore-and-aft C.G. position as wheels retract sideways.

The curves so obtained are given in Fig. 13b, where tailplane angles to trim are plotted against A.S.I. For ease of interpretation in terms of stick-free stability some of the curves are replotted against C_L in Fig. 14b; the estimated position error curve of Fig. 8 was used in obtaining C_L from pilots' A.S.I.

During the measurement of tailplane angles to trim, simultaneous readings were taken of the corresponding elevator angles (from a stick-position indicator). The measured elevator angles were thus obtained with the tailplane setting varying, whereas, in order to obtain a picture of the stick-fixed stability of the aircraft, elevator angles to trim with the tailplane at a constant setting are necessary. By estimating the ratio of the change in tail lift per degree elevator movement to that per degree tailplane movement (a_2/a_1) it is possible to convert the measured elevator angles to those corresponding to a fixed tailplane setting. This has been done and the resultant elevator angles to trim tailplane fixed, are plotted against A.S.I. in Fig. 13a, and some of the curves are replotted against C_L in Fig. 14a.

The nose-down change of trim due to lowering the flaps and undercarriage is large, but readily corrected. It will be seen that the aircraft is very stable when gliding at low speeds with flaps down, while Fig. 14 shows that the stability of the aircraft with flaps and undercarriage up is greater than is customary on single seater fighters; this curtails manoeuvrability in the looping plane, and contributes to the heavy " feel " of the elevator, particularly at high speeds. Fig. 14 also shows that slipstream does not cause a large change of trim, flaps up, and only slightly decreases the stability.

4.3. *" One Control " Tests, Fat Turns and Sideslips.*—This group of tests is designed to provide information for assessing the relative degrees of static directional stability (N_v) and lateral stability (L_v).

The aircraft was trimmed longitudinally to fly straight and level at 230 m.p.h. at 10,000 ft., 2,200 r.p.m. At 230 m.p.h. under these conditions the aircraft is not in trim directionally, and a slight pressure is required on the left rudder bar to keep the aircraft flying straight with no sideslip; this should be borne in mind when considering the results given below.

	Directional (ailerons fixed)	Lateral (rudder fixed)
4.31. Sudden application and release of one control, the other being held fixed.	If the rudder is suddenly displaced through half its maximum travel, ailerons fixed, the aircraft swings through about 8 deg. in yaw and at the same time banks about 5 deg. in the direction of the applied rudder; as the rudder is applied the nose pitches down a little. On releasing the rudder the nose swings back fairly quickly and the aircraft does an oscillation in yaw and roll which gradually dies out; during this oscillation the aileron control cannot be prevented from moving slightly from side to side. To the left, the left wing then slowly comes up, the right wing falls, and the aircraft enters a right hand spiral; to the right the wing stays down, and the aircraft turns to the right with bank slowly increasing.	When the ailerons are displaced smartly, rudder fixed, the aircraft banks with no appreciable opposite yaw. On releasing the stick it returns immediately to its central position. To the left, the left wing slowly comes up and the aircraft then slowly banks and turns to the right; if right aileron has been applied, the right wing stays down and the bank slowly increases. The behaviour of the aircraft on releasing the ailerons is extremely sensitive to rudder position, and the spiral stability of the aircraft with rudder fixed cannot thus be assessed with any degree of certainty. Use of rudder alone will raise the wing. A considerable amount of rudder must be applied in order to raise the wing from a 30 deg. bank, ailerons free, and the resultant sideslip is accompanied by a marked nose-down pitching moment.

	Directional (ailerons fixed)	Lateral (rudder fixed)
4.32. Steady banked turn with one control, the other being held fixed.	Good banked turns can be done in either direction on rudder alone, ailerons fixed central. Only about ¼ rudder is required to initiate the turn, and there is very little sideslip on entry. In order to recover from the turn at the same rate over ½ rudder is needed, and there is considerable sideslip. If the rudder is used harshly there is more sideslip on entry and recovery, and this is accompanied by a pronounced nose down pitching moment which must be corrected by pulling the stick back. If the rudder is released when in a 30 deg. banked turn to the left, ailerons still fixed central, the aircraft slowly rolls over to the right; when the rudder is released in a 30 deg. banked right hand turn, the bank slowly increases and the turn tightens.	Excellent banked turns are possible in either direction using ailerons alone, rudder fixed. There is very little sideslip on entering or leaving the turn, even if the ailerons are used harshly. When turning steadily there is no appreciable sideslip.

	Flat turns.	Steady sideslip when gliding	
	Flaps and undercarriage up.	Flaps and undercarriage up. Gliding at 100 m.p.h.	Flaps and undercarriage down. Gliding at 90 m.p.h.
4.33. Flat turns and sideslips.	The aircraft was flown at 230 m.p.h. at 10,000 ft. Only half-rudder was used during this test. Although the force needed is considerable, full rudder can be applied, but the accompanying nose down pitching moment is so large that an excessive pull must be applied to the stick to hold the nose up. When flat turning steadily with half-rudder applied, about half opposite aileron is necessary to hold the wings level and the aircraft becomes very nose heavy. Rather more force is needed to hold on half-rudder when turning to the left than when turning to the right. When the flat turn has become steady the speed has fallen to 175 m.p.h. The rate of flat turn is about 110 deg./min.	The maximum angle of bank in a straight sideslip is about 5 deg. Rudder is the limiting control, and about 1/4 aileron is required to hold the wing down against full rudder. The aircraft is fairly nose heavy in the sideslip. During the sideslip the aircraft is vibrating and appears to be a little unsteady, requiring occasional use of the controls to keep the speed constant. If all the controls are released during the sideslip, the nose falls, the aircraft swings smartly into the sideslip path and the bank decreases very quickly. The aircraft then glides straight with wings level and the nose slowly rising to the trimmed position and oscillating slightly in pitch.	The maximum angle of bank in a straight sideslip is again about 5 deg., rudder being the limiting control. About 1/5 aileron is needed in conjunction with full opposite rudder. The aircraft is not quite as nose heavy as when sideslipping with flaps and undercarriage up. The aircraft again vibrates when sideslipping and appears to be a little unsteady. The behaviour on releasing all the controls is similar to that described in the previous column, except that the final pitching oscillation is slightly more pronounced and of a longer period.

4.4. *Stalling Tests.*—4.41. *Determination of* $C_{L\,\max}$.—The aircraft was fitted with a swivelling pitot head and a suspended static head (60-ft. cable) in order to measure the indicated airspeed at and near the stall. Only one flight was made, as operating a suspended static head from a single-seater aircraft with a rather cramped cockpit is difficult. Stalling speeds with engine throttled right back were measured with flaps and undercarriage up and down, and the speed at which the slots opened were also noted; in every case both slots opened almost simultaneously. The following results were obtained:—

TABLE 4

Stalling Speeds and $C_{L\,\max}$

$W = 5{,}580$ lb. $\quad S = 174$ sq. ft.

Condition		Pilots' A.S.I.		Indicated airspeed V_i (from trailing static)		C_L	
Flaps and ailerons	Undercarriage	Speed at which slots open	Stalling speed	Speed at which slots open	Stalling speed	C_L at which slots open	$C_{L\,\max}$
		m.p.h.	m.p.h.	m.p.h.	m.p.h.		
Up	Up	111	75	120·5	95·5	0·865	1·4
Down—Flaps 42·5°	Up	90	61	100·5	81	1·2	1·9
—Ailerons 10°	Down	90	61	100·5	81	1·2	1·9

Lowering the slotted flaps 42·5 deg. and the slotted ailerons 10 deg. thus increases $C_{L\,\max}$ by 0·5. This is roughly the value to be expected from normally designed slotted flaps and ailerons arranged as on the Me.109, but is somewhat less than that attainable with efficiently designed modern slotted flaps.

4.42. *ADM. 293—issue 2.*—The aircraft was subjected to the tests laid down in ADM. 293—issue 2. The all-up weight was 5,580 lb. with the C.G. at $h = 0 \cdot 302$. The results obtained are given in the following tables; speeds quoted are pilots' A.S.I.

	Flaps and undercarriage up.	Flaps and undercarriage down.
Test 1. Determination of the stalling speed, etc.	The aircraft stalls at 75 m.p.h. If the stick is moved slightly forward or backward when gliding trimmed at 1·2 V_s (90 m.p.h.) and then released the aircraft does a very slowly damped pitching oscillation of long period and finally settles to its trimmed speed. About 1-in. backward stick movement, requiring hardly any force, is required to stall from 1·2 V_s. The slots open at about 110 m.p.h., and as they open the ailerons snatch slightly, and there is then slight aileron vibration. At 83 m.p.h. the aircraft becomes unsteady laterally and aileron buffeting sets in which increases in intensity as the stall is approached. There is thus ample warning of the approach of the stall.	The aircraft stalls at 60 m.p.h. If the stick is moved slightly forward or backward when gliding trimmed at 1·2 V_s (72 m.p.h.) and then released, the aircraft does a quickly damped pitching oscillation; it is far more stable than with flaps and undercarriage up. About 1 in. backward stick movement, requiring hardly any force, is required to stall from 1·2 V_s. No aileron snatching occurs when the slots open (at about 90 m.p.h.), and there is no warning of the stall.

	Flaps and undercarriage up.	Flaps and undercarriage down.
Test 2. Slow glide.	The aircraft was trimmed at $1{\cdot}2\,V_s$ (90 m.p.h.) and then put into a steady glide at $1{\cdot}1\,V_s$ (82 m.p.h.). With both ailerons and rudder fixed a fairly quick lateral oscillation of about 10 deg. either way takes place, and some aileron vibration is felt on the stick. If the rudder is fixed and the ailerons are used, these oscillations can be checked, by moving the stick very quickly from side through a small angle. During these corrections the aileron vibration is slightly more marked than with stick fixed. The ailerons are quite effective at $1{\cdot}1\,V_s$. With ailerons fixed, the oscillation can be cut down to about 3 deg. either way by quick use of the rudder, which is effective. Using both ailerons and rudder the wings can be kept level if the controls are used quickly to anticipate the rolling oscillation.	The aircraft was trimmed at $1{\cdot}2\,V_s$ (72 m.p.h.) and then put into a steady glide at $1{\cdot}1\,V_s$ (66 m.p.h.). With both ailerons and rudder fixed the aircraft glides quite steadily, with no lateral unsteadiness and no aileron vibration. Both the ailerons and the rudder are effective at this speed.
Test 3. Straight stall. A slow glide was done at $1{\cdot}2\,V_s$ and the stick then slowly pulled back as far as possible.	If both ailerons and rudder are held fixed the left wing drops suddenly through about 10 deg. at 83 m.p.h. and the aircraft goes into a gentle left-hand spiral. Ailerons alone will lift the wing. If the ailerons are used, rudder fixed, the aircraft becomes laterally unsteady and there is some aileron buffeting at 83 m.p.h.; this increases as the speed is reduced, and below 77 m.p.h. the aircraft cannot be fully controlled on ailerons alone. If the rudder is used, ailerons fixed, the lateral oscillations cannot be checked at speeds below 81 m.p.h. By vigorous use of aileron and rudder control can be retained down to the stalling speed of 75 m.p.h. The aileron buffeting is very marked at the stall and the aircraft is very unsteady laterally; if the stick is pulled further back at the stall the ailerons and rudder are still slightly effective, but the aileron buffeting and lateral unsteadiness are so violent that a sustained stalled glide is impossible. There is no tendency to spin on stalling.	If both ailerons and rudder are held fixed the aircraft remains on a level keel in a straight path down to the stall (61 m.p.h.), when the left wing drops suddenly through about 10 deg. without any warning, the nose falls with it, and the aircraft goes into a left hand spiral. Neither rudder nor ailerons are effective at the stall, and the wing cannot be raised until speed is gained. There is complete control until the stall is reached. There is no tendency to spin after stalling.

	Flaps and undercarriage up.	Flaps and undercarriage down.
Test 4. Slow speed turn. During a gliding turn with 30 deg. bank the pilot reduced the speed by pulling the stick back until the minimum speed was reached at which a steady sustained turn was possible. After turning through 180 deg. at this speed recovery was made on ailerons alone, without use of the rudder, and without allowing the stick to go forward.	The minimum speed for a steady sustained turn is 88 m.p.h. to both left and right. The stick position is very slightly aft of its position in a straight glide at the same speed. Recovery from the turn is normal, with no tendency to stall or spin. A turn can be done at 83 m.p.h. but the aircraft is not under full control as it is very unsteady laterally and there is considerable aileron buffeting. On recovering from a turn at 83 m.p.h. on ailerons alone, the aircraft sometimes stalls, but there is no tendency to spin.	The minimum speed for a steady sustained turn is 64 m.p.h. to both left and right. The stick position is slightly aft of its position in a straight glide at the same speed. On recovering from the turn on ailerons alone, the aircraft stalls; there is no tendency to spin. Turns at a lower speed than 64 m.p.h. cannot be done, as below this speed a wing drops suddenly and cannot be raised by the controls.
Test 5. Turn from a slow glide. Having trimmed at 1·2 V_s a glide was done at 1·1 V_s and the normal control movements made to go into a 30 deg. banked turn at the same speed.	At 1·1 V_s (82 m.p.h.) the aircraft is unsteady laterally, although this can be checked by use of ailerons and rudder. There is no tendency to spin on entering the turn, and, apart from aileron buffeting, response to the controls is normal.	At 1·1 V_s (66 m.p.h.) the aircraft is under full control, response to the controls is normal on entering the turn, and there is no tendency to spin.

4.5. *High-Speed Dive.*—The aircraft was dived at 370 m.p.h. and all three controls were in turn given a slight displacement and then released. No vibration, flutter or " snaking " developed.

If the elevator is trimmed for level flight at full throttle, a moderately large push is necessary to hold the aircraft in the dive, and there is a temptation to wind the trimmer forward. If this is done, recovery is very difficult unless the trimmer is first wound back again, owing to the excessive heaviness of the elevator at high speeds.

At 370 m.p.h. a considerable amount of pressure is needed on the left rudder bar to hold the aircraft straight, and if the rudder is displaced in either direction and released, the aircraft eventually banks and turns to the right. Small rudder displacements, sufficient to yaw the nose about 10 deg., give rise to no appreciable nose-down pitching moment. Large rudder displacements do cause the nose to pitch down, but as the rudder is very heavy at 370 m.p.h. they would not normally be used.

4.6. *Flying Controls.*—4.61. *Ailerons.*—At low speeds the aileron control is very good, being similar to that of the Curtiss H-75; there is a positive " feel ", there being a definite resistance to stick movement, and response is brisk. In these respects the Me.109 ailerons are better than those of the Spitfire, which become so light at low speeds that they lose all " feel ".

As the speed is increased the ailerons gradually become heavier, but response remains excellent. They are at their best between 150 m.p.h. and 200 m.p.h., and are described as " an ideal control " over this speed range. Above 200 m.p.h. they start becoming unpleasantly heavy, and at 300 m.p.h. are far too heavy for comfortable manœuvring. Between 300 m.p.h. and 400 m.p.h. the ailerons are described as " solid "; at 400 m.p.h. a pilot, exerting all his strength, cannot apply more than about fifth-aileron.

More detailed aileron tests (measurement of stick forces and time to bank) were made, and are described in section 5.2. These tests showed that, although the Me.109 ailerons felt much heavier than those of the Spitfire at speeds between 300 m.p.h. and 400 m.p.h., the aircraft could be made to bank at about the same rate as the Spitfire at these high airspeeds. The more " solid " feel of the Me.109 ailerons at high airspeeds is attributed to smaller stick travel (± 4 in. compared with ± 8 in. on the Spitfire), fairly rigid control circuit, and partly to the awkward seating position of the pilot. The matter is more fully discussed in section 5.2.

Throttling back the engine does not alter the effectiveness of the ailerons at any speed. Lowering the flaps at low speeds (the ailerons come down 11 deg. with the flaps) makes the ailerons considerably heavier and slightly reduces their effectiveness, although response is still amply adequate.

Apart from their excessive heaviness at high speeds, the most serious defect of the Me.109 ailerons is a tendency to snatch as the wing tip slots open. This is particularly noticeable when manœuvring. For example, if the stick is pulled back in a tight turn, putting additional *g* on the aircraft, the slots open at quite a high airspeed; as they open, the stick suddenly snatches laterally through several inches either way, sufficiently to upset a pilot's aim in a dog fight. The snatch appears to be associated with the opening of the slots, for once they are fully open a steady turn can be done, with no aileron vibration, until the stall is approached.

As mentioned in section 4.42 (ADM. 293) some aileron snatching also occurs when gliding near the stall with flaps up and slots open; it disappears on lowering the flaps fully, and so does not worry the pilot during the approach glide.

4.62. *Elevator.*—The elevator is an exceptionally good control at low speeds; it is fairly heavy, and is not over sensitive during the approach glide, while response is excellent. Throughout the speed range the elevator is heavier than that of the Hurricane or Spitfire, but up to 250 m.p.h. this is not objected to, since it is very responsive. Above 250 m.p.h. the elevator becomes definitely too heavy for comfort, and between 300 m.p.h. and 400 m.p.h. is so heavy that manœuvrability in the looping plane is seriously restricted; when diving at 400 m.p.h. a pilot, pulling with all his strength, cannot put on enough *g* to black himself out if trimmed in the dive.

At low speeds the elevator is slightly lighter when the engine is throttled back, and is very slightly less responsive. The elevator control is unaffected by lowering the flaps.

4.63. *Rudder.*—The rudder is light but rather sluggish at low speeds, and large displacements are required for quick response. As the speed is increased the range of sluggishness decreases, and at 200 m.p.h. has disappeared, the rudder now being effective for small displacements and still quite light. Between 200 m.p.h. and 300 m.p.h. the rudder is the lightest of the controls for small movements, assisting directional aim for gunnery; but at 300 m.p.h. the absence of a directional trimmer is severely felt, as a small amount of left rudder is necessary to fly without sideslip, and the force required, although not excessive, becomes very tiring. As the speed is increased to 400 m.p.h. the rudder becomes extremely heavy, and at 400 m.p.h. only small displacements can be made; and the force required to hold the aircraft straight is considerable.

Throttling back the engine at low speeds makes the rudder a little more sluggish, and lowering the flaps further reduces the rudder effectiveness, although response is still adequate when large displacements are used. If the speed is increased when gliding with flaps down, the rudder starts juddering slightly at 100 m.p.h.; this juddering increases rapidly as the speed is increased, and at 120 m.p.h. is so pronounced that any further increase of speed is inadvisable. As the normal approach speed with flaps down is 90 m.p.h., this rudder vibration is not normally noticed, and is of little practical importance.

4.64. *Harmony.*—The controls are fairly well harmonised between 150 m.p.h. and 250 m.p.h., although the elevator is somewhat heavy compared with the ailerons and rudder. At low speeds harmony is spoiled by the sluggishness of the rudder, while at high speeds harmony is poor because of the excessive heaviness of the ailerons.

4.65. *General.*—Features particularly liked by the pilots were the positive "feel" of the ailerons and elevator at low speeds, and the excellent response characteristics of all three controls at medium speeds. The control characteristics which were particularly complained of, and which were considered to spoil the aircraft as a fighter, were—

(i) The undue stiffening up of the controls, particularly the ailerons, at high speeds.

(ii) The aileron snatching caused by the slots opening during manœuvres, and

(iii) The absence of a rudder trimmer.

4.7. *Aerobatics.*—Aerobatics are not easy on this aircraft. Loops must be started from about 280 m.p.h., when the elevator is unduly heavy; there is a marked tendency for the slots to open near the top of the loop, resulting in aileron snatching and loss of direction, and in consequence accurate looping is almost impossible.

At speeds below 250 m.p.h. when the ailerons are light and very effective, the aircraft can be rolled very quickly, but there is a strong tendency for the nose to fall in the final stages of the roll, and the stick must be moved well back in order to keep the nose up.

Upward rolls are difficult; the elevator is so heavy at high speed that only a gentle pull-out from the preliminary dive is possible, and a considerable loss of speed is thus inevitable before the upward rolls can be started.

5. *Fighting Qualities of the* Me.109.—5.1. *Dog-fights with Spitfire and Hurricane.*—Mock fights were staged between the Me.109 and a Spitfire, both flown by pilots of the R.A.E. In addition a number of fighter pilots, all of whom had recent experience of operational flying, visited the R.A.E. with their Spitfires and Hurricanes in order to practice combat with the Me.109 ; during these fights the Me.109 was flown by an R.A.E. pilot who had completed the handling tests described earlier in this report, and was thus thoroughly familiar with the aircraft and could be expected to get the best out of it. A brief account of the information provided by these fights has already been published[10]. The following notes summarise the results obtained.

The arrangements were for the aircraft to take off singly and meet at about 6,000 ft. The Me.109 then went ahead and commenced to turn as tightly as possible to see if it would out-turn our own aircraft. After doing three or four tight turns in both directions the Me.109 was put into a dive, followed by a steep climb. The aircraft then changed position and repeated the above programme, after which the pilots engaged in a short general fight.

When doing tight turns with the Me.109 leading at speeds between 90 m.p.h. and 220 m.p.h. the Spitfires and Hurricanes had little difficult in keeping on the tail of the Me. 109. During these turns the amount of normal g recorded on the Me.109 was between $2\frac{1}{2}$ and 4 g. The aircraft stalled if the turn was tightened to give more than 4 g at speeds below about 200 m.p.h. The slots opened at about $\frac{1}{2}$ g before the stall, and whilst opening caused the ailerons to snatch; this upset the pilot's sighting immediately and caused him to lose ground. When the slots were fully open the aircraft could be turned quite steadily until very near the stall. If the stick was then pulled back a little more the aircraft suddenly shuddered, and either tended to come out of the turn or dropped its wing further, oscillating meanwhile in pitch and roll and rapidly losing height; the aircraft immediately unstalled if the stick was eased forward. Even in a very tight turn the stall was quite gentle, with no tendency for the aircraft to suddenly flick over on to its back and spin. The Spitfires and Hurricanes could follow the Me.109 round during the stalled turns without themselves showing any signs of stalling.

The good control near the stall during these turns at full throttle contrasts with the results obtained from the ADM. 293 tests (section 4.42), for when gliding the aircraft becomes unsteady at 10 m.p.h. above the stall. Slipstream thus appears to have a steadying influence on the behaviour of the Me.109 near the stall.

After these turns the Me.109 was put into a steep dive at full throttle with the airscrew pitch coarsened to keep the r.p.m. down. It was found that both the Hurricanes and the Spitfires could keep up with the Me.109 in the dive; the aircraft with constant speed airscrews could do this more readily than those with two-pitch airscrews. The ailerons and elevator of the Me.109 became so heavy in the dive that rapid manœuvring was impossible, while, as explained in section 4.22, banked turns could be done more readily to the right than to the left because of the absence of rudder bias.

The Me.109 was then pulled out of the dive and climbed at a very low airspeed at an unusually steep attitude. The aircraft was under perfect control during the climb, and could be turned with equal facility in either direction. Under these conditions it outclimbed our aircraft in most cases, since most of our pilots climbed at a higher airspeed and a flatter angle, keeping below the Me.109 and waiting for it to come out of the climb.

However, other pilots who chose to climb at very low airspeeds, mainly those with constant-speed airscrews, succeeded in keeping on the tail of the Me.109, although the Me.109 pilot thought they would have difficulty in keeping their sights on him steadily, as he was at a steeper attitude than their sights could " line ".

In most cases this steep climb at low airspeed was the only manœuvre whereby the Me.109 pilot could keep away from the Hurricane or Spitfire. During the general fighting which followed the set programme, one other feature of advantage to the Me.109 emerged. If a negative g is put on the aircraft for a short time, the engine does not cut as it is of the direct injection type; whereas on the Spitfire or Hurricane the engine immediately splutters and stops when negative g is applied, because the carburettor quickly ceases to deliver petrol under these conditions. Hence the Me.109 pilot found that a useful manœuvre when being chased was to push the stick forward suddenly and do a semi-bunt, if our fighters followed him their engines cut giving the Me.109 a chance to get away; this was particularly useful against the Hurricane, as its top level speed is less than that of the Me.109 so that once the Me.109 had escaped in this way it could avoid combat. The Spitfire, on the other hand, soon caught the Me.109 after this manœuvre.

When the Me.109 was following the Hurricane or Spitfire, it was found that our aircraft turned inside the Me.109 without difficulty when flown by determined pilots who were not afraid to pull their aircraft round hard in a tight turn. In a surprisingly large number of cases, however, the Me.109 succeeded in keeping on the tail of the Spitfire or Hurricane during these turning tests, *merely because our pilots would not tighten up the turn sufficiently from fear of stalling and spinning.*

During the general fighting, with the Me.109 chasing a Spitfire or Hurricane, some of our pilots escaped by doing a flick half-roll and then quickly pulling up out of the subsequent dive. The Me.109 pilot found this particularly difficult to counter, for when the Me.109 rolled after his opponent, the speed built up quickly in the steep dive which followed the half roll, and the elevator became so heavy that a quick pull out was impossible; in addition care had to be taken not to pull out quickly when the speed had decreased, because the aircraft stalled so readily under g. As a result 2,000–3,000 ft. may be lost in the manœuvre, and if a Me.109 pilot can be tempted to do this at low altitude a crash is almost inevitable. Conversation with some of the pilots who had had experience in actual combat with the Me.109 revealed that in several cases a Me.109 had, in fact, been observed to crash in this way without a shot being fired.

The Me.109 pilot summed up his general impressions of the aircraft as a fighter in the following manner. " From all this dog-fighting I am certain that if the pilot of a Hurricane or Spitfire finds himself attacked by a Me.109 he can easily out-turn it, and can lose it straight away by doing any violent manœuvre; the Me.109 just cannot be made to do a really quick manœuvre because at high speeds the controls are much too heavy, and at low speeds the slats come out, causing the ailerons to snatch, followed by the aircraft stalling if the manœuvre is done more rapidly."

5.2. *Aileron Forces and Times to Bank.*—Aileron control at high speed is of considerable topical interest. Rough measurements have recently been made[9] of the stick forces necessary to apply about 1/4-aileron at various speeds up to 400 m.p.h., together with the corresponding times to 45 deg. bank, on the Curtiss H-75, Spitfire and Gloster F5/34, three modern single-seater fighters. For comparison with this work, precisely similar tests were done on the Me.109.

The results are presented in Fig. 15 as curves of stick force and times to 45 deg. bank plotted against indicated airspeed V_i; the previous Spitfire results are included in the diagram.

At 400 m.p.h. the Me.109 pilot, pushing sideways with all his strength, can only apply about 1/5 aileron, thereby banking 45 deg. in about 4 secs.; on the Spitfire also, only 1/5 aileron can be applied at 400 m.p.h., and again the time to 45 deg. bank is about 4 secs. Both aircraft thus have their rolling manœuvrability at high speeds seriously curtailed by aileron heaviness. The Spitfire ailerons do not feel as "solid" at 400 m.p.h. as those of the Me.109; this is because there is rather more stretch in the aileron control circuit of the Spitfire.

An interesting point is that the maximum sideways force a pilot can exert on the stick is about 60 lb. on the Spitfire, but only about 40 lb. on the Me.109; the reason for this difference is that the cockpit of the Me.109 is so cramped that a pilot cannot bring his arm round into the position most favourable for applying a large side force to the stick.

The times to 45 deg. bank shown in Fig. 15 are of comparative value only, and do not indicate the variation of time to bank with airspeed when a given amount of aileron is applied in a given time; although the pilot attempted to apply the ailerons in about 1 sec. at all speeds, he could not avoid applying them more slowly at the higher airspeeds, when the stick forces were very large.

A method whereby values of the combined balance and response factor of an individual aileron, Kb_2, can be deduced from the observed stick forces and displacements is given in Appendix II, at the end of the report. At 400 m.p.h. Kb_2 appears to be $-0{\cdot}145$ for the Me.109 ailerons (slotted, 21·6 per cent. balance), and $-0{\cdot}14$ for the Spitfire ailerons (sharp nosed Frise, 27·5 per cent. balance). Comparative data for the Me.109 and Spitfire ailerons are given in Table 2, and drawings of the Me.109 ailerons in Fig. 10.

To show the effect on aileron heaviness of the geometry of the installation (aileron size, stick gearing, etc.), quite apart from aileron balance, the variation of stick force with stick displacement has been calculated for the Me.109 and Spitfire, assuming that the ailerons of both aircraft have exactly the same value of Kb_2 ($-0{\cdot}09$, as this was taken as standard in Ref. 8); the results are plotted in Fig. 16, while details of the calculations are given in Table B of Appendix II. Because of their smaller size the Me.109 ailerons should be only about half as heavy as those of the Spitfire, other things being the same; but this is largely offset, especially for small aileron displacements, by the smaller stick travel of the Me.109, ± 4 in. compared with ±8 in. on the Spitfire.

The following table summarises the most important results emerging from these aileron tests and those described in Ref. 9.

TABLE 5

Aileron Characteristics of Four Modern Fighters

		Me.109	Spitfire	Curtiss H–75	Gloster F5/34
Maximum sideways force an average pilot can apply at stick top.	lb.	40	60	60	60
Time to 45° bank when this force is applied at 400 m.p.h., approx.	sec.	4	4	2	<1
Corresponding aileron displacement, approx.	..	1/5	1/5	3/5	3/4
Kb_2 at 400 m.p.h.	..	$-0{\cdot}145$	$-0{\cdot}14$	$-0{\cdot}105$	$-0{\cdot}035$
Wing span	ft.	32·4	37·0	37·2	38·2
Aileron type	..	Slotted	Frise	Slotted	Frise
% balance (area ahead hinge/total area) ..	..	21·6	27·5	23·0	28·0
Total aileron area/gross wing area	..	0·0655	0·078	0·078	0·100
Max. stick travel	in.	±4	±8	±9·9	±7·2
Max. aileron angles	up	25°	25°	25·5°	18°
	down	13·5°	19°	10°	16·5°

This table brings out very forcibly the wide differences, both in design and performance, between the aileron installations of four typical modern single-seater fighters. Although ability to bank quickly at high airspeeds is of cardinal importance in a fighter, aircraft are still in service whose ailerons are described by the pilots as " almost immovable " at high speeds, and every effort should be and is being made to avoid similar trouble on future designs.

A comprehensive paper on aileron control at high speed has recently been written by Gates and Irving[11], and general model research on the balancing of controls is in progress at the National Physical Laboratory. Steps are being taken to improve the Spitfire ailerons, and an attempt is being made to frame a standard of aileron performance to which all future designs must comply.

5.3. *Comparative Turning Performance of Me.*109 *and Spitfire.*—During the dog-fights against the Hurricane and Spitfire, it became apparent that our fighters could out-turn the Me.109 with ease when flown by determined pilots. Since the minimum radius of turn without height loss depends largely on stalling speed, and hence on wing loading, the poor turning performance of the Me.109 may be ascribed to its high wing loading, 32·2 lb./sq. ft. compared with 24·8 lb./sq. ft. on the Spitfire. It was thought of interest to go into the matter a little more deeply, and to calculate the relative performances of these aircraft in circling flight, so that the sacrifice of turning performance entailed by the Me.109's high wing loading could be assessed qualitatively.

In a recent report on the dog-fight[12] Gates gives an analysis whereby the performance of an aircraft in steady spiral flight at full throttle can be estimated from its measured full throttle performance in straight flight (partial climbs and top speed); the analysis leads to a compact diagram from which the radius and time of turn, and the corresponding rate of ascent or descent can be obtained at any given airspeed and normal g.

Such diagrams have been constructed for the Spitfire and Me.109, and are given in Fig. 17, together with an explanation of their use. The turning performance of the Hurricane is probably little different from that of the Spitfire, these aircraft being roughly similar in wing loading and level performance. The " stall boundary " depends on an estimate of $C_{L\,\max}$ at full throttle. In the case of the Spitfire this has been measured in flight, while the Me.109 figures were based on the Spitfire results; tables of the assumed values of $C_{L\,\max}$ are given in Fig. 17. $C_{L\,\max}$ falls off as g is increased, because the stalling speed increases as g gets larger, thus lessening the slipstream effect.

It will be seen that the minimum radius of turn without height loss is obtained by flying as near the stall as possible at a comparatively small g. For ease of comparison the radius of turn has been plotted against speed for both aeroplanes in Fig. 18, (i) for turns at the stall, and (ii) for turns without height loss. The advantage of the Spitfire over the Me.109 at once becomes apparent, the minimum radius of turn without loss of height being about 696 ft. on the Spitfire as against 885 ft. on the Me.109. The characteristics of these turns are summarised in the following table:—

TABLE 6

*Spitfire and Me.*109

Turns at Minimum Radius without Height loss. Both Aircraft at Full Throttle at 12,000 *ft.*

	Spitfire	Me.109
Minimum radius of turn without loss of height ft.	696	885
Corresponding time to turn through 360° sec.	19	25
Indicated airspeed V_i m.p.h.	133	129
Pilots' A.S.I. approx. m.p.h.	126	118
g	2.65	2·1
Angle of bank	68°	62°

The turning performances of both aircraft would undoubtedly be improved by use of a flap giving an appreciable reduction of stalling speed thereby shifting the stall boundaries of Fig. 17 to the left. Calculations and flight tests are now being done on the use of flaps for improving manœuvrability at low airspeeds and a report giving the results of the investigation is in preparation.[13]

5.4. *Discussion.*—The tests have shown that as a fighter the Me.109 is in general inferior to the Hurricane or Spitfire. Its fighting qualities, good and bad, may be briefly set out as follows :—

Good points.

(i) High top speed and excellent rate of climb.
(ii) Good control at low speeds.
(iii) Gentle stall, even under g.
(iv) Engine does not cut immediately under negative g.

Bad points.

(i) Controls, particularly the ailerons, far too heavy at high speeds.
(ii) Owing to high wing loading, the aeroplane stalls readily under g and has a poor turning circle.
(iii) Aileron snatching occurs as the slots open.
(iv) Quick manœuvres are difficult, at high speed because of (i) above, at low speed because of (ii) and (iii).
(v) Absence of a rudder trimmer, curtailing ability to bank left at high speeds.
(vi) Cockpit too cramped for comfort when fighting.

The gentle stall and good control under g are of some importance, as they enable the pilot to get the most out of the aircraft in a circling dog-fight by flying very near the stall. As mentioned in section 5.1, the Me.109 pilot succeeded in keeping on the tail of the Spitfire in many cases, despite the latter aircraft's superior turning performance, because a number of the Spitfire pilots failed to tighten up the turn sufficiently. If the stick is pulled back too far on the Spitfire in a tight turn, the aircraft may stall rather violently, flick over on to its back, and spin. Knowledge of this undoubtedly deters the pilot from tightening his turn when being chased, particularly if he is not very experienced.

The most serious defect of the Me.109 is its inability to roll fast in a high-speed dive because of its heavy ailerons. Some of our own fighters are not free from this defect, the Spitfire being about as bad as the Me.109 in this respect, and, as mentioned in section 5.2, energetic action is now being taken to improve the aileron control of our existing single-seater fighters. Measures are also being considered to ensure that future designs will comply with an agreed high standard of rolling manœuvrability.

Recent discussions with the Fighter Command have made it clear that this provision of adequate lateral control at high speed is at present the most pressing control problem of fighter design. Next to this, the most important feature desired is ability to decelerate quickly, so as to avoid overshooting when making a diving attack on a much slower machine. To meet this requirement the design of a quickly operable high-drag flap for single-seater fighters is being considered.

Compared with the above, turning performance in the circling slow speed dog-fight is now considered of minor importance. The tactical situation may, however, change, and this aspect of fighting manœuvrability should not be pushed too far into the background. As shown in section 5.3, we have in the Spitfire and Hurricane, fighters considerably superior to the Me.109 in slow speed turning performance. Nevertheless, work on the effect of flaps on manœuvrability at low speeds is desirable, since the need for making our aircraft still better in this respect may arise.

6. *Conclusions.*—6.1. *Handling.*—(i) Take-off is fairly straightforward. The controls have an exceptionally good " feel " and the aircraft is very stable during the approach glide, but the actual touch down can be " tricky " until one gets used to the aircraft. Taxying characteristics are good.

(ii) Absence of a rudder trimmer is a severe handicap at high speeds, since there is a large change of directional trim with speed. Longitudinally the aircraft is too stable for a fighter.

(iii) Good banked turns are possible on ailerons or rudder alone. Sideslip produces a large nose-down pitching moment.

(iv) The stall is not violent and there is no tendency to spin. $C_{L\ max}$ when gliding is $1 \cdot 4$ with flaps up and $1 \cdot 9$ with flaps down.

(v) No vibration or " snaking " develops when the controls are displaced slightly and released in a high-speed dive.

(vi) Aileron snatching occurs as the slots open. All three controls are far too heavy at high speeds. Aerobatics are difficult.

6.2. *Fighting Qualities.*—(i) In general the Me.109 is inferior to the Hurricane or Spitfire as a fighter because its manoeuvrability at high speed is seriously curtailed by control heaviness, while its high wing loading causes it to stall readily under g and results in a poor turning circle at low speeds.

(ii) At 400 m.p.h. a pilot, pushing sideways with all his strength, can only apply 1/5 aileron, the time to bank 45 deg. being 4 secs. The Spitfire is as bad as the Me.109 in this respect. Kb_2 for the Me.109 ailerons is $-0 \cdot 145$.

(iii) The minimum radius of turn without height loss is 885 ft. on the Me.109 compared with 696 ft. on the Spitfire.

(iv) The cockpit is far too cramped for comfort.

APPENDIX I

Pilots' Opinions on Cockpit Layout and View

1. *Cockpit Layout.*—A photograph of the cockpit interior is given in Fig. 3. The two instruments with white dials at the top of the dash-board are stick and rudder position indicators, fitted for the R.A.E. tests; a reflector sight normally occupies this space. It will be seen that the German A.S.I. has been replaced by an English A.S.I. and English oxygen equipment has been fitted. Apart from these alterations the layout is standard.

All three pilots gave their opinions on cockpit layout, comfort and convenience, based on their experience during the handling tests, and their views are summarised below.

Cockpit size.—The cockpit is unquestionably too cramped for comfort. It is too narrow, the headroom is insufficient, and the seating position is tiring. When wearing a seat-type parachute a pilot of normal size finds that his head touches the hood roof.

Noise.—With the side windows open the noise in the cockpit is very considerable. It is lessened by closing the side windows, but even then the cockpit is far noisier at full throttle than that of the Hurricane or Spitfire.

Main Flying Controls.—The control column position is good, and the slight offset of the grip is convenient (*see* Fig. 3). The position of the rudder pedals makes for too reclining an attitude, putting extra weight on the small of the back. A bad feature is the absence of any fore-and-aft adjustment of the rudder pedals.

Trimming and Flap Controls.—These are particularly well placed on the pilot's left. The flap gear is very good, for it is easy to operate and, being manual, is not likely to go wrong. From the Service point of view this system should be noted, as it might easily save more serious accidents when the hydraulics are punctured. The juxtaposition of the tailplane-adjusting wheel and the flap-control wheel was also considered an excellent feature, as the wheels may be operated together with one hand and the change of trim due to flaps thereby automatically corrected.

Throttle.—The throttle arrangements were described by one pilot as " marvellously simple, there just being one lever with no gate or over-ride to worry about ". It may be mentioned here that, while the pilots were not greatly impressed with the Me.109 as an aircraft, the D.B.601 direct injection engine came in for very favourable comment. The response to throttle opening is particularly good, it is apparently impossible to choke the engine, and there is no tendency to splutter and stop when the aircraft is subjected to a negative g by suddenly pushing the stick forward.

Airscrew Control.—This works well, no difficulty being experienced during the tests. The pitch control lever would be better placed alongside the throttle than on the dash-board.

Undercarriage Control.—The undercarriage selector is free from complication and cannot be criticised. The absence of an undercarriage warning hooter seems strange to British pilots.

Brakes.—These are foot operated. They work well, but the standard Dunlop system operated from a toggle on the stick is thought to provide a more sensitive control.

Instrument Panel.—Except for the absence of a blind flying panel, the instruments present are adequate and the grouping is good, flying instruments being on the left and engine instruments on the right. The absence of a gyro horizon is severely felt when flying in cloud. The instruments are clear to read. No flying was done at night, but the lighting arrangements appeared to be rather inadequate.

Ancillary Equipment.—Guns, sights, wireless, etc., were not tested. The wireless layout appears to be well placed, and the machine gun and cannon firing switches, mounted in the grip of the stick, come readily to hand. The electrical panel on the lower right of the dash-board would be difficult to use until the pilot became familiar with it, as the various press buttons cannot readily be distinguished.

An interesting feature is the jettison arrangement for the Verey cartridges, designed to enable a pilot to quickly jettison the cartridges before a forced landing in enemy territory, so that he does not give away the signal of the day.

2. *View.*—Fig. 4 shows the general windscreen layout. The flat front panel is inclined at about 55 deg. to the horizontal when the aircraft is in flying attitude; the large corner panels are also flat, in contrast to the curved panels of the Spitfire and Hurricane. The port corner panel is divided into two parts vertically, and the forward portion hinges inward about its leading edge, forming a direct vision opening about 9 in. high by 3 in. wide at the top and 6 in. wide at the bottom; this opening is inclined at 26 deg. to the direction of flight so that the width of forward vision is about 2 in.

The cockpit hood does not slide back. It is hinged at the starboard side for entry and exit, and cannot thus be opened in flight. Sliding windows are fitted, one in each side panel of the hood. The hood jettisoning arrangements for emergency exit are interesting. The hood is spring loaded, and on pushing the jettison lever the whole of the hood and the wireless mast behind it are flung clear backwards.

The view forward when taxying is very bad, partly owing to the high ground attitude of the aircraft, and partly because the hood cannot be slid back to enable the pilot to look round the edge of the windscreen.

When in flight, the view forward and sideways is normal, being similar to the Hurricane; the windscreen framework members are sufficiently narrow, and do not catch the pilot's eye nor create blind spots. Sideways and rearwards the view is about the same as the Spitfire and Hurricane, but the cramped position of the pilot in the cockpit makes it difficult to look downward or upward to the rear, and the tailplane can only be seen with an effort.

The direct vision opening gives a large field of view and is completely draught free at all speeds. A high speed can thus be maintained in bad weather conditions, whereas on the Hurricane or Spitfire the pilot must slide back the hood and look round the edge of the windscreen to obtain a view forward in rain or cloud, and can only do this by flying at fairly low speed. The direct vision opening also assists landing, as the high position of the nose obstructs the view forward during the hold off, and the opening is in the correct position to give a view of the ground. The direct vision opening obviously satisfies a very real need, for the early Me.109s were not fitted with this device.

The windscreen panels are clear and free from distortion, and do not oil up in flight. The hood sliding panels are difficult to open, particularly at high speeds.

APPENDIX II

Analysis of Aileron Control Forces

The following approximate formula may be used to express the aileron stick force in terms of the geometry of the aileron system and the balance characteristics of the individual aileron; the analysis whereby this equation is derived is set out fully in Ref. 8.

$$\frac{P}{\frac{1}{2}\rho V^2 S_\xi c_\xi} = -Kb_2\left[\xi_u \frac{d\xi_u}{dx} + \xi_d \frac{d\xi_d}{dx} - \xi_f\left(\frac{d\xi_u}{dx} - \frac{d\xi_d}{dx}\right)\right] \quad \dots \quad (1)$$

Where	P	force at stick top.
	x	movement of stick top from its central position.
	ξ_u	corresponding angular movement of upgoing aileron.
	ξ_d	corresponding angular movement of downgoing aileron.
	ξ_f	upfloating angle of the ailerons.
	S_ξ, c_ξ	area and mean chord of each aileron.
	$b_2 = \frac{\partial C_H}{\partial \xi}$	slope of hinge-moment curve of the aileron.
	K	" response factor ", explained in Ref. 8; introduced to allow for the effect on aileron hinge moments of the changes in wing incidence due to the rolling of the aircraft which accompanies aileron displacement.

The above equation enables the combined balance and response factor Kb_2 to be evaluated from the stick force measurements described in section 5·2, and plotted out in Fig. 15. The values of Kb_2 so obtained are given below, similar figures for the Spitfire ailerons[8] are included for comparison.

TABLE A

	Me.109	Spitfire
Droop	1·2°	0°
ξ_f (estimated)	+2·7°	+1·5°
Kb_2 at $Vi = 300$ m.p.h. ..	−0·125	−0·095
Kb_2 at $Vi = 400$ m.p.h. ..	−0·145	−0·14

In order to show the effect on aileron control forces of the geometry of the aileron installations, quite apart from the aerodynamic balance of the individual ailerons, control forces at 400 m.p.h. have been calculated from equation (1) for the Me.109 and Spitfire, assuming a uniform value of − 0·09 for Kb_2 for the ailerons of both aircraft.

These calculated stick forces are plotted against stick displacement in Fig. 16, while Table B below gives details of the calculation; a study of Table B enables the relative effects of size, stick gearing, differential, etc., to be clearly seen.

TABLE B

$Vi = 400$ m.p.h. $b_2 = -0{\cdot}09$. $K = 1{\cdot}0$

	Me.109		Spitfire	
	Up	Down	Up	Down
$\frac{1}{2}\varrho V^2 S_\xi c_\xi b_2 \times 12 \times \left(\frac{\pi}{180}\right)^2 = X$	−0·77		−1·76	
1/4 aileron				
ξ deg.	5·2	4·4	5·0	4·9
$\frac{d\xi}{dx}$ deg./in.	5·75	4·1	2·80	2·44
$\xi_u \frac{d\,\xi_u}{dx} + \xi_d \frac{d\,\xi_d}{dx} = A$ ..	47·9		26·0	
$-\,\xi_f \left(\frac{d\,\xi_u}{dx} - \frac{d\,\xi_d}{dx}\right) = B$ ..	− 4·5		− 0·5	
$A + B$	43·4		25·5	
$P = X\,(A + B)$ lb. ..	−33·4		−44·9	
1/2 aileron				
ξ deg.	11·3	9·2	11·3	9·8
$\frac{d\xi}{dx}$ deg./in.	6·25	3·22	3·17	2·45
$\xi_u \frac{d\,\xi_u}{dx} + \xi_d \frac{d\,\xi_d}{dx} = A$ ..	100·2		59·4	
$-\,\xi_f \left(\frac{d\,\xi_u}{dx} - \frac{d\,\xi_d}{dx}\right) = B$ ..	− 8·2		− 1·1	
$A - B$	92·0		58·3	
$P = X\,(A + B)$ lb. ..	−70·7		−102·7	
3/4 aileron				
ξ deg.	18·0	11·1	17·9	14·2
$\frac{d\xi}{dx}$ deg./in.	7·0	2·5	3·50	2·45
$\xi_u \frac{d\,\xi_u}{dx} + \xi_d \frac{d\,\xi_d}{dx} = A$ ..	143·8		97·5	
$-\,\xi_f \left(\frac{d\,\xi_u}{dx} - \frac{d\,\xi_d}{dx}\right) = B$ ..	−12·2		− 1·5	
$A + B$	131·6		96·0	
$P = X\,(A + B)$ lb. ..	−101		−169	
Full aileron				
ξ deg.	25·0	13·2	25·0	19·5
$\frac{d\xi}{dx}$ deg./in.	7·25	1·8	3·63	2·45
$\xi_u \frac{d\,\xi_u}{dx} + \xi_d \frac{d\,\xi_d}{dx} = A$ ...	205·0		138·6	
$-\,\xi_f \left(\frac{d\,\xi_u}{dx} - \frac{d\,\xi_d}{dx}\right) = B$ ..	−14·7		− 1·8	
$A + B$	190·3		136·8	
$P = X\,(A + B)$ lb. ..	−147		−241	

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TABLE 1

Messerschmitt Me. 109—Aerodynamic Data

General	
Mean Weight (lb.)	5,580
S (gross wing area) sq. ft.	174
Engine	D.B. 601
Rated H.P. at 2,400 r.p.m. at 3·75 lb./sq. in. boost pressure at 15,000 ft.	1,100
Power Loading (lb./B.H.P.)	5·07
Wing Loading (lb./sq. ft.)	32·1
Span Loading (lb./sq. ft.)	5·32
C.G. h (mean chord = s/span)	0·302
Airscrew diameter (ft.)	10·2
Gear Ratio	14/9

Wings	
Area (gross) S sq. ft.	174
Span $2s$ ft.	32·4
Mean chord c ft.	5·36
Aspect Ratio	6·05
Dihedral deg.	5·75
Sweepback of 1/4 c line	1°
Chord—	
Root (ft.)	7·03
Tip (ft.)	3·42
Section—	
t/c Root	0·148
t/c Tip	0·105

Slots	
Slot Length/Wing Span	0·462
Slot chord/Local chord	0·118

Flaps	
Type	Slotted
Maximum Angle deg.	42·6
Flap Area/S	0·1425
Flap chord/Local chord	0·246
Flap span/$2s$	0·518

Longitudinal Control	
Tail surface area (Total) S' sq. ft.	24·46
Elevator area/S'	0·371
l'/c (l' = distance C.G. to 1/3 T.P. chord)	3·23
S'/S	0·140
Tail volume coeff. $K = S'l'/Sc$	0·454
Elevator Angles (Max. T.P. 0°)—	
Down	31·6°
Up	31·6°
Type of Balance	Horn
% Balance	10·35
Stick Gearing $d\eta/dx$ deg./in.	5·64
Range of T.P. Movement deg.	+3·4 −8·4

Directional Control	
Area (Fin and Rudder) S'' sq. ft.	12·61
Rudder area/S''	0·58
l''/s (l'' = distance C.G. to centroid of S'')	1·13
Fin and Rudder Vol. coeff. $S''l''/Ss$	0·082
Range of Rudder Angle	±33·8°
Type of Balance	Horn
% Balance	8·47
Pedal Gearing $d\xi/dx$ deg./in.	5·63

Lateral Control	
Aileron Area (Total) sq. ft.	11·0
Aileron Area/S	0·0655
Aileron chord/Local chord	0·235
Aileron span/$2s$	0·352
Aileron Angles (Max. Flaps at 0°)—	
Down	13·6°
Up	25·0°
Stick Gearing $d\xi/dx$ deg./in.	Non Linear
Droop (deg.)	1·2
% Balance	21·6

TABLE 2

Comparative Aileron Data: Me. 109 and Spitfire

		Me.109	Spitfire
Weight during tests	lb.	5,580	6,000
Wing loading	lb./sq. ft.	32·1	24·8
Wing area (gross)	S sq. ft.	174	242
Span	$2s$ ft.	32·4	37·0
Aspect ratio		6·05	5·7
Dihedral	deg.	5·75	6·0
Wing section N.A.C.A.	Root	2,315	2,213
	Tip	2,310	2,205
Aileron type		Slotted	Frise
Percentage balance		21·6	27·5
Area of each aileron	S_ξ sq. ft.	5·7	9·45
Mean chord	c_ξ ft.	1·0	1·38
Maximum angles	deg. Down	13·6	19
	Up	25·0	25
Maximum stick travel	in.	±4·0	±8·0
Droop	deg.	1·2	0
Aileron area/wing area		0·0655	0·078
Aileron chord/local chord		0·24	0·235
Aileron span/$2s$		0·352	0·37
Wing thickness/chord	Inboard end of aileron.	0·122	0·106
	Outboard end of aileron.	0·110	0·075
Kb_2 at 400 m.p.h. estimated from stick-force measurements.		−0·145	−0·14

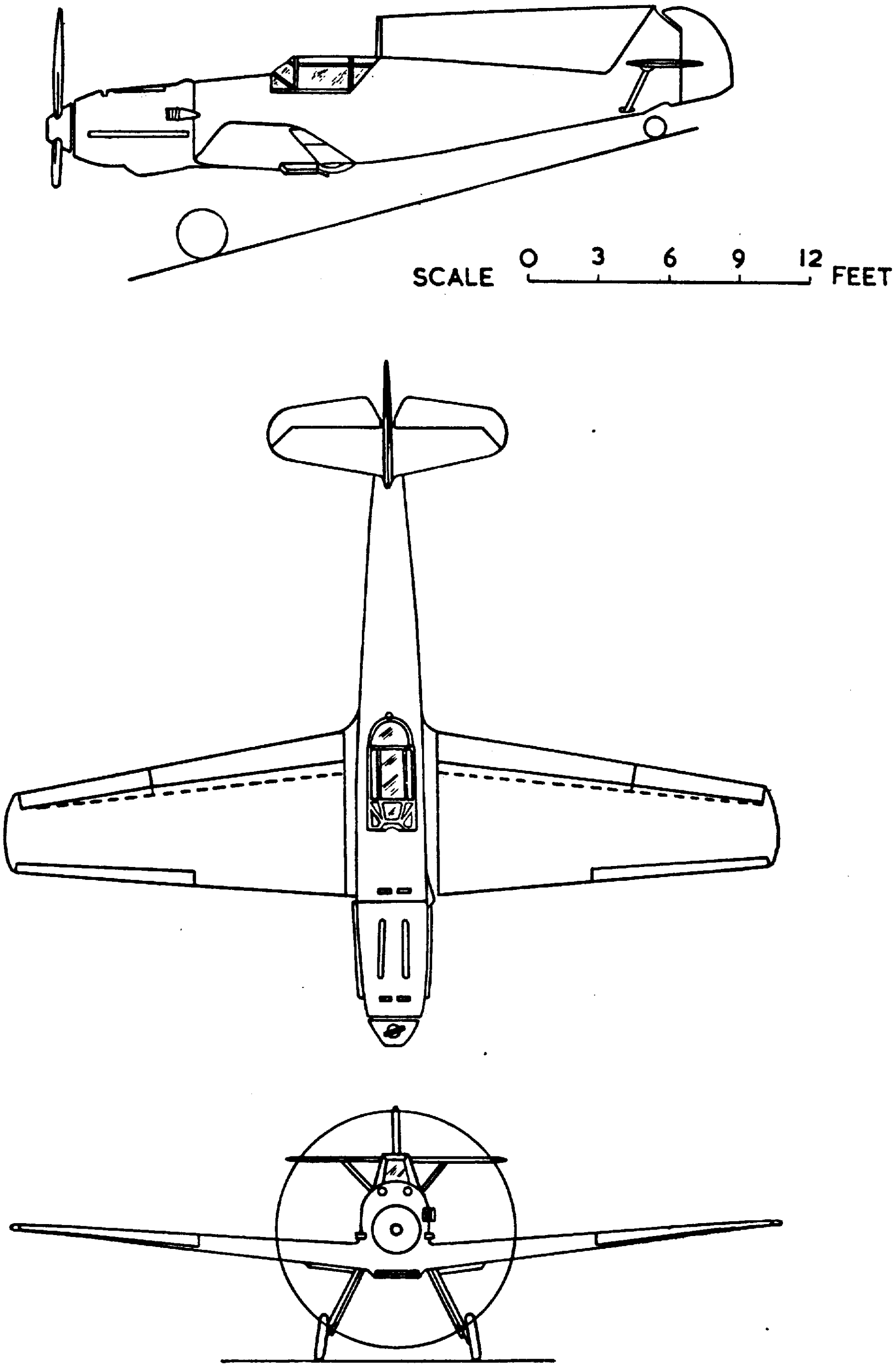


FIG. 1. Messerschmitt Me.109.
(D.B. 601).

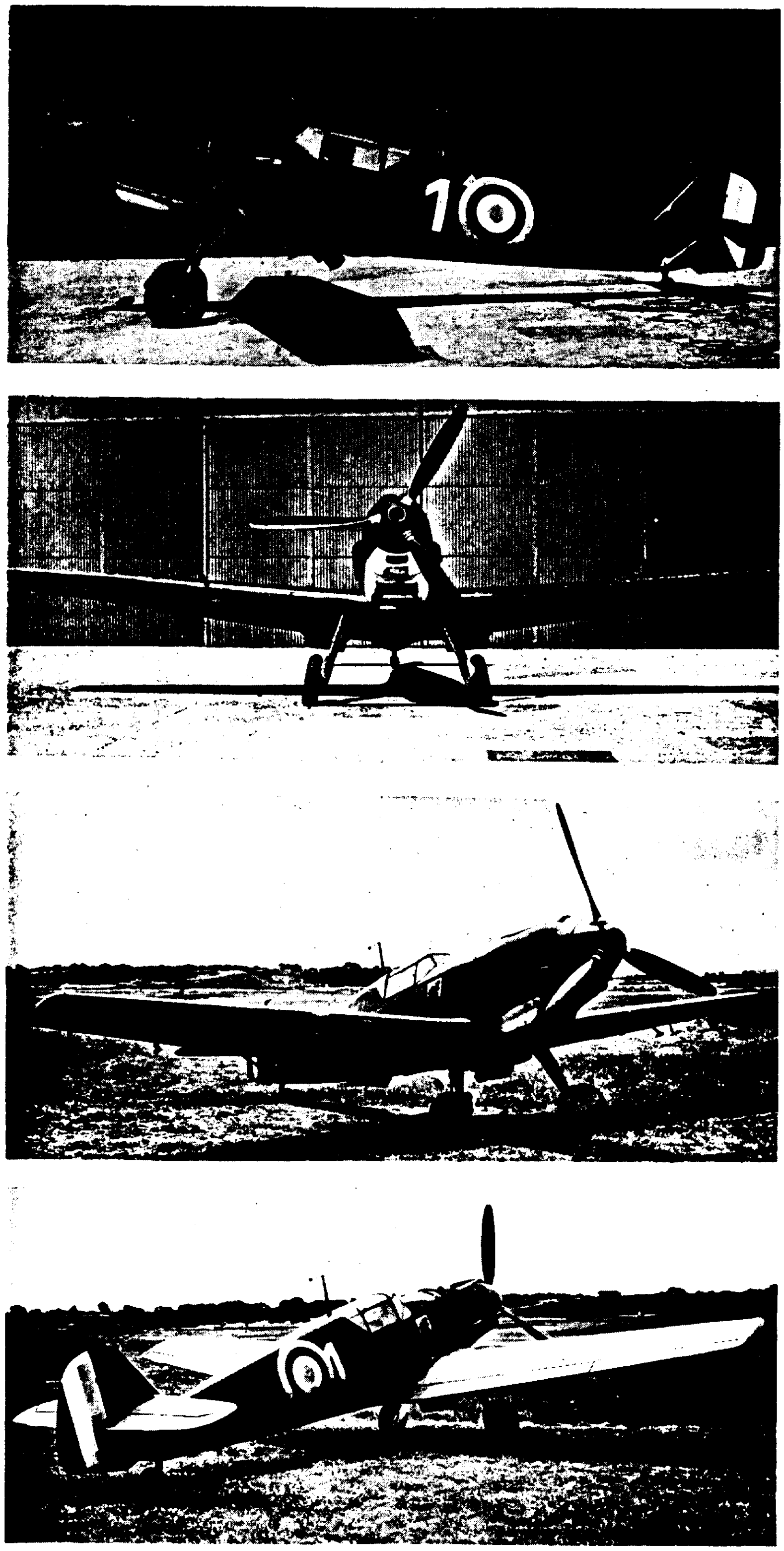


FIG. 2.

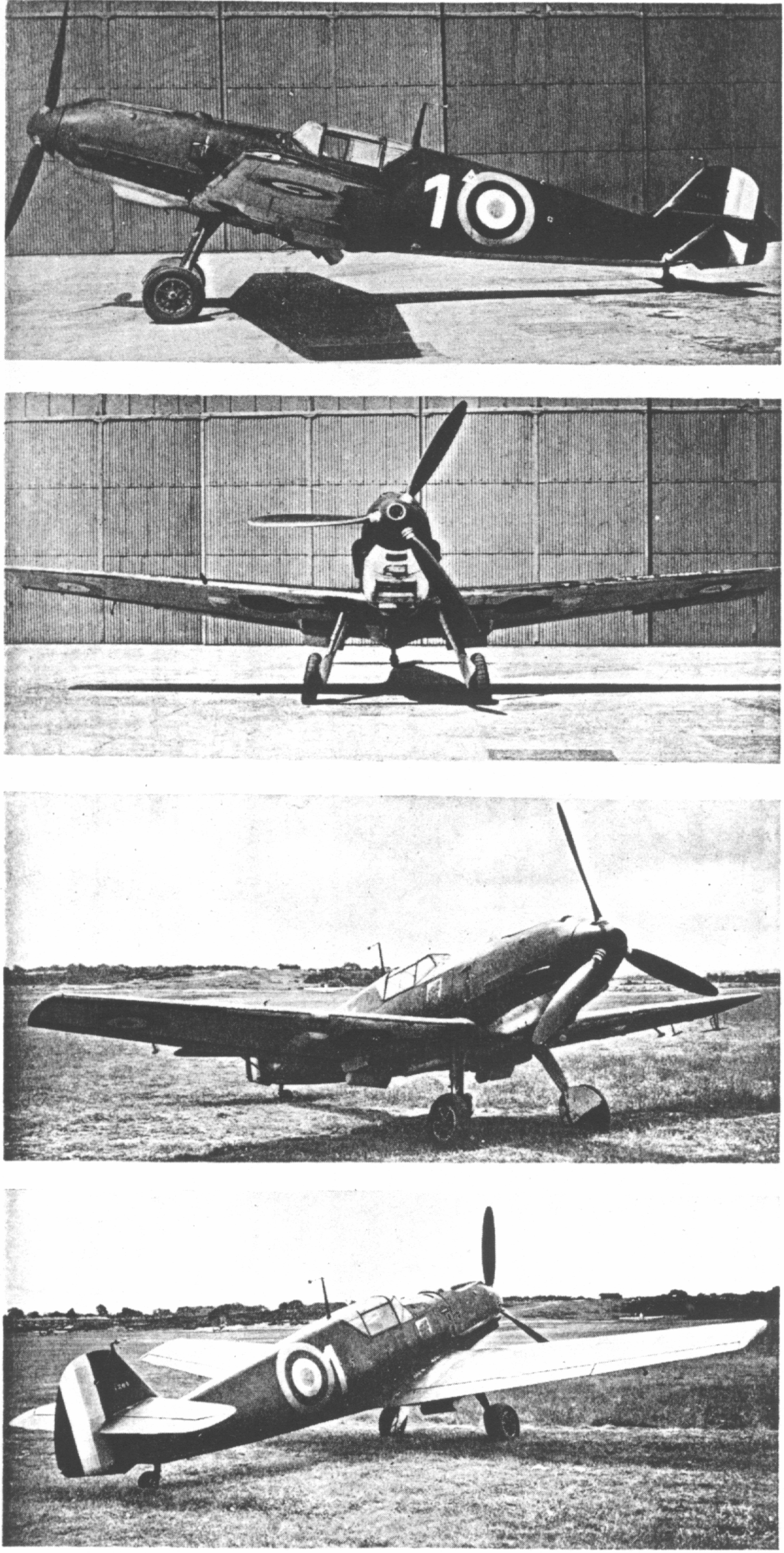


FIG. 2.

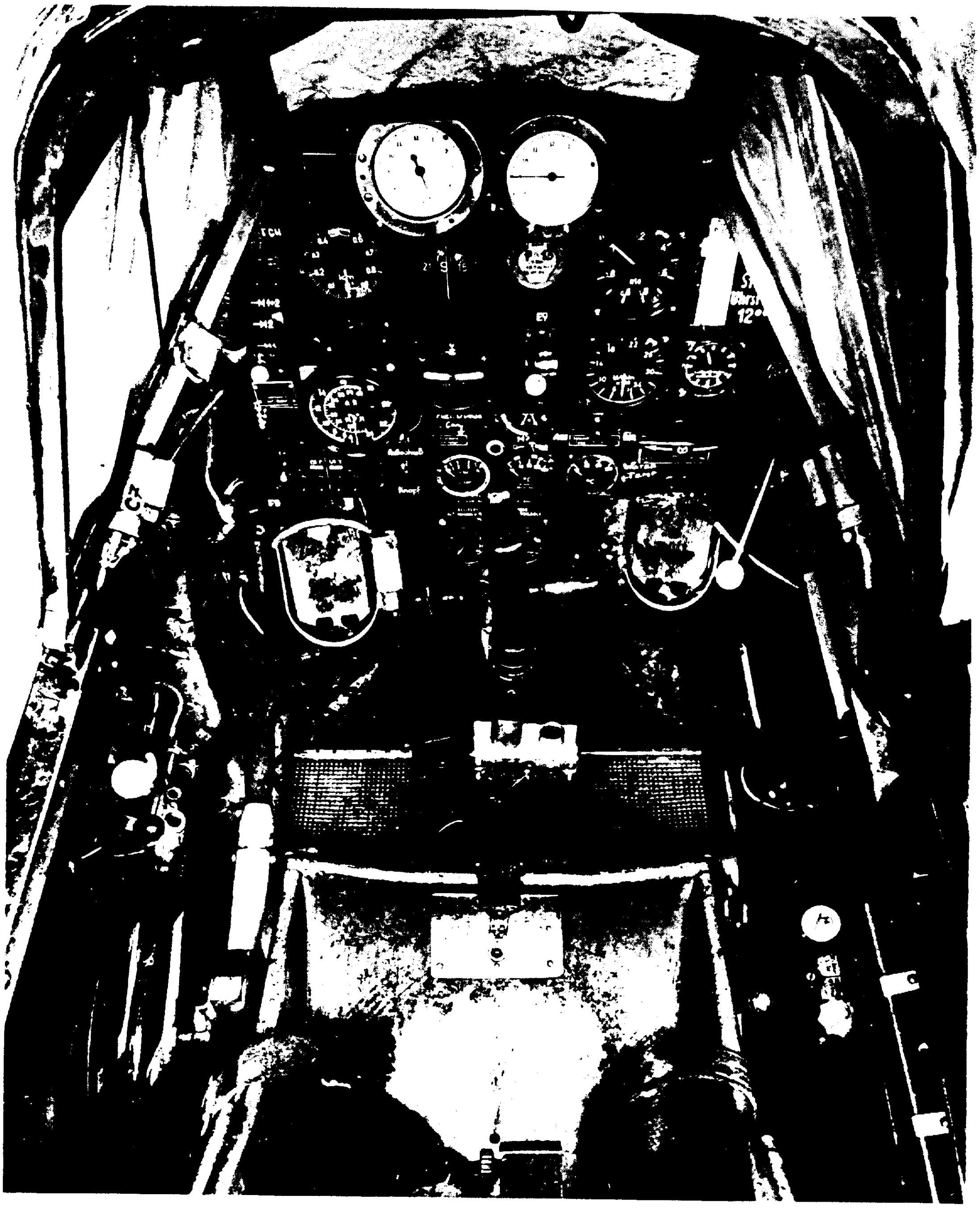


FIG. 3. Cockpit.

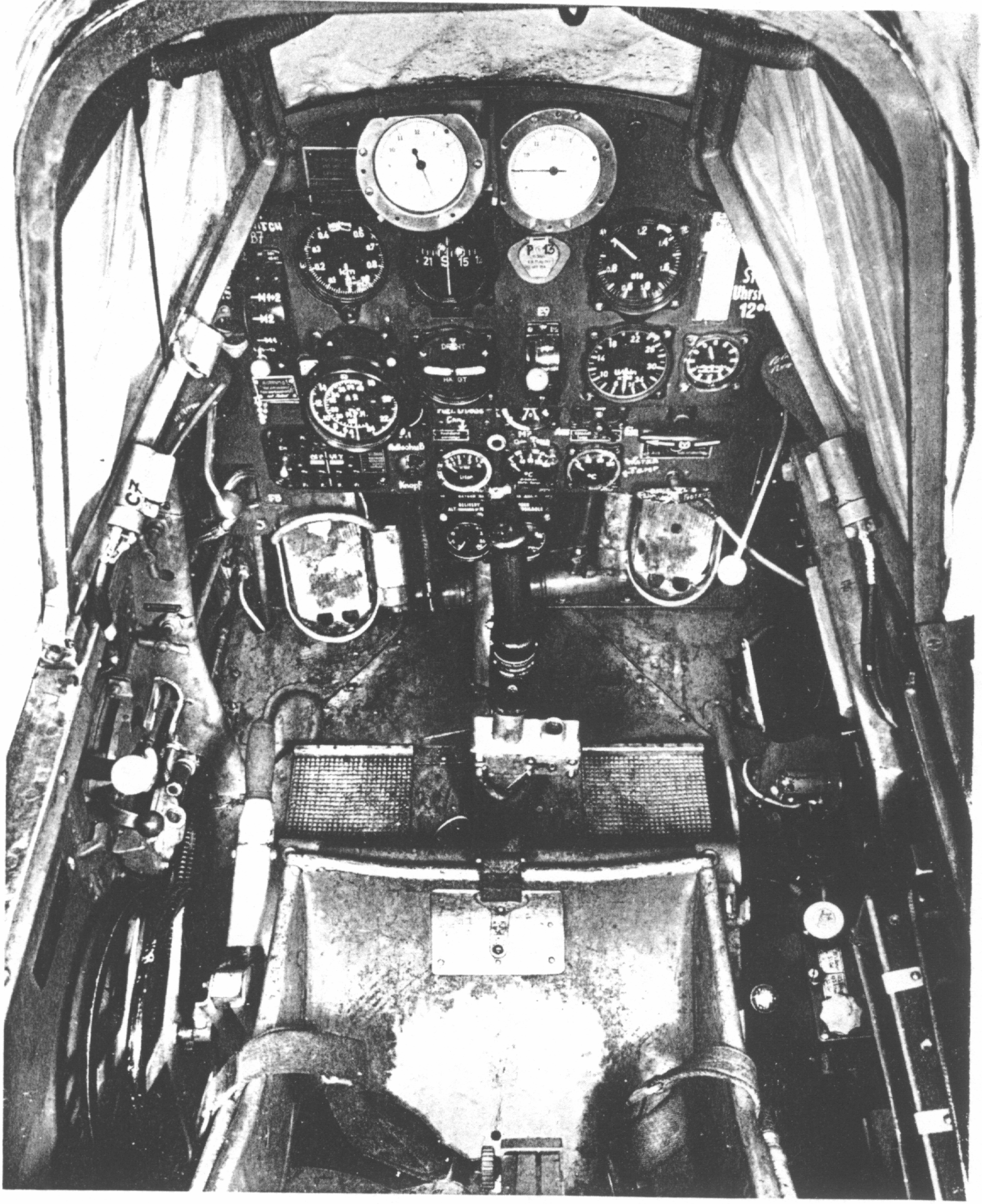


FIG. 3. Cockpit.

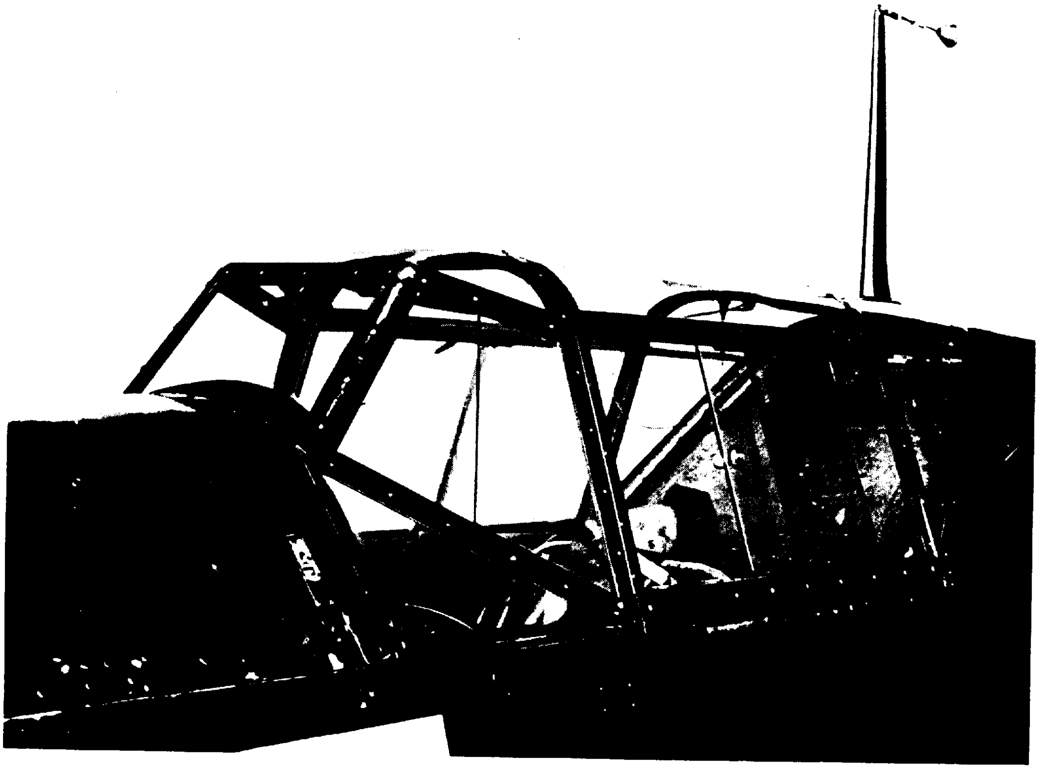


Fig. 4. Windscreen.

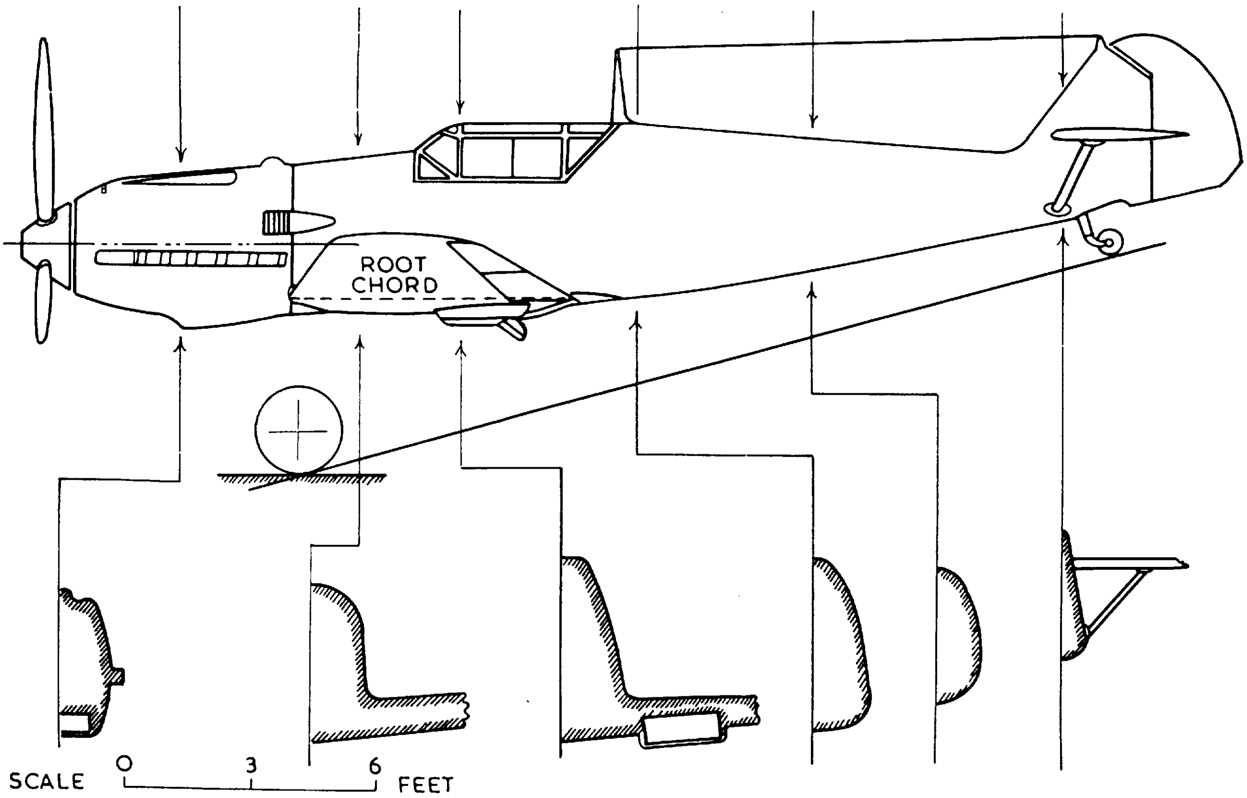


Fig. 5. Fuselage Sections.

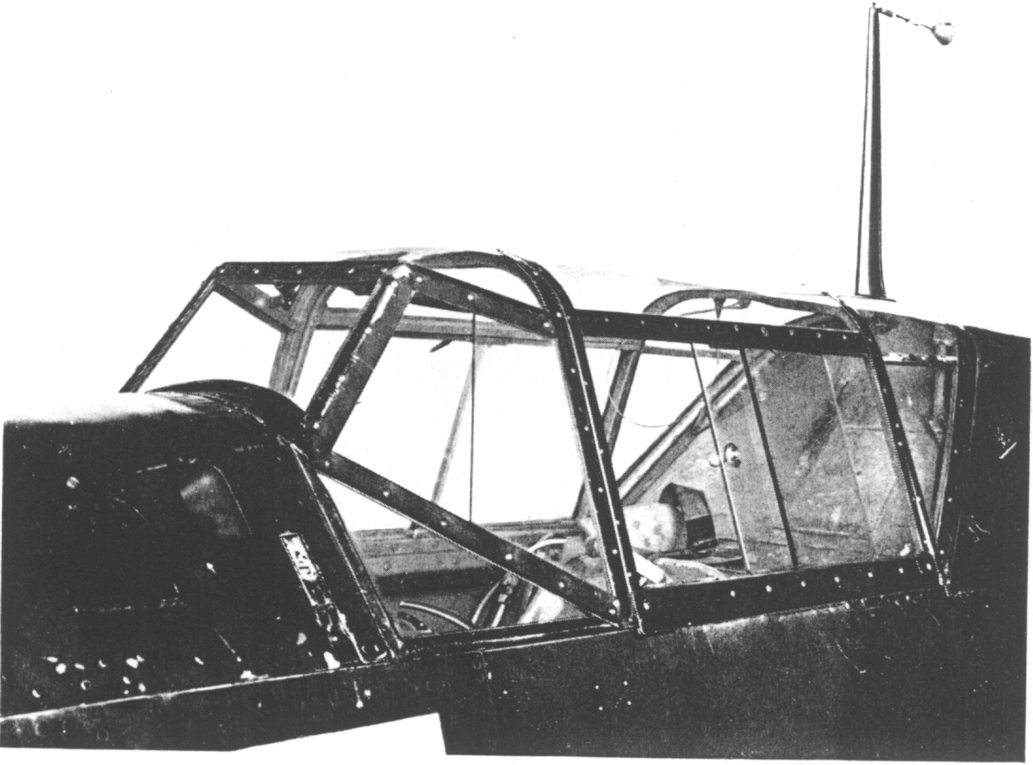


FIG. 4. Windscreen.

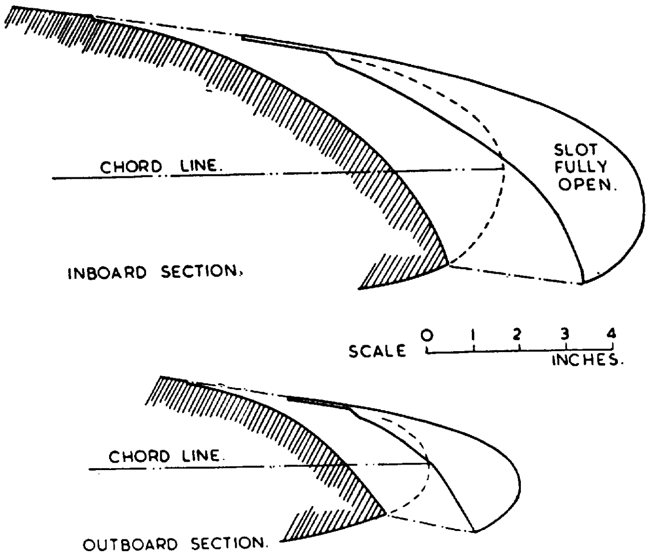


FIG. 6. Slot Sections.

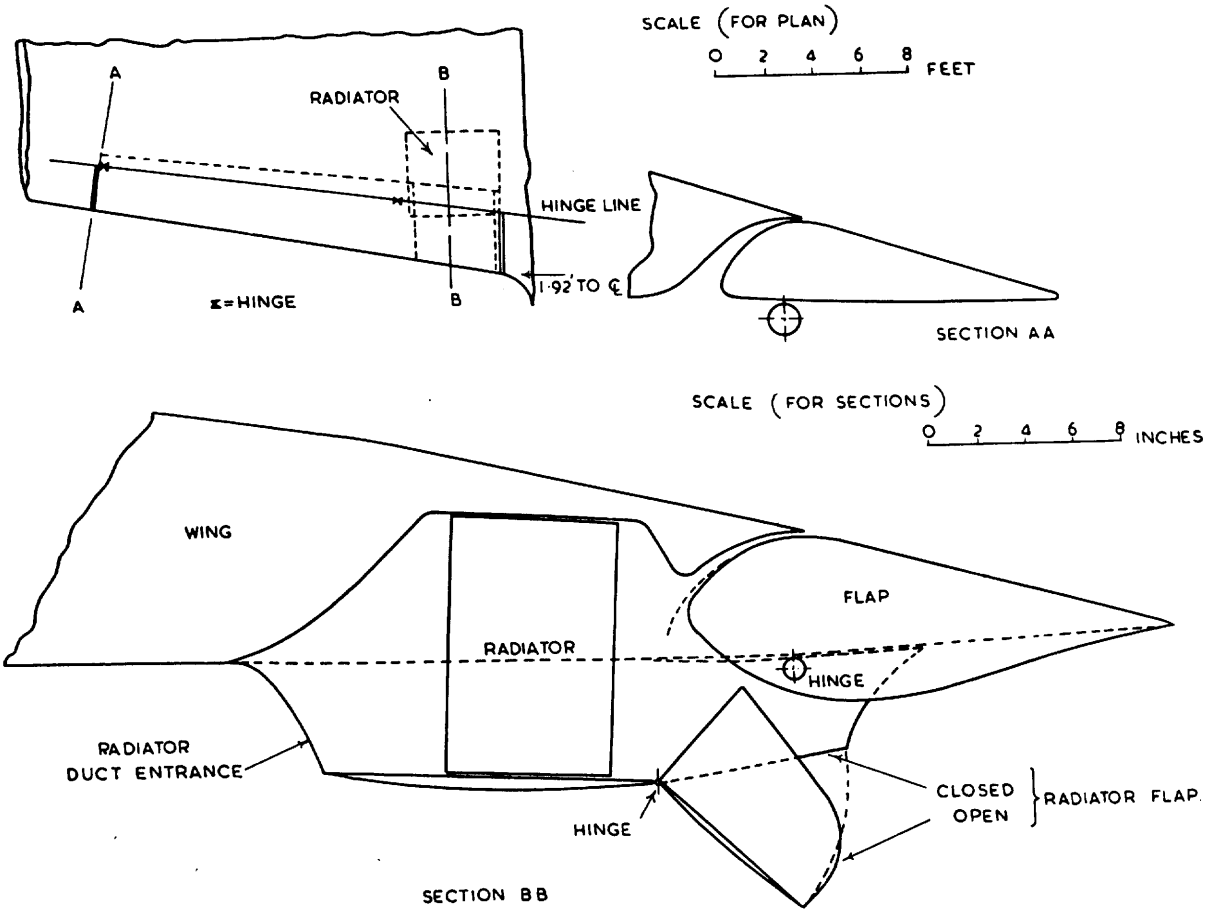
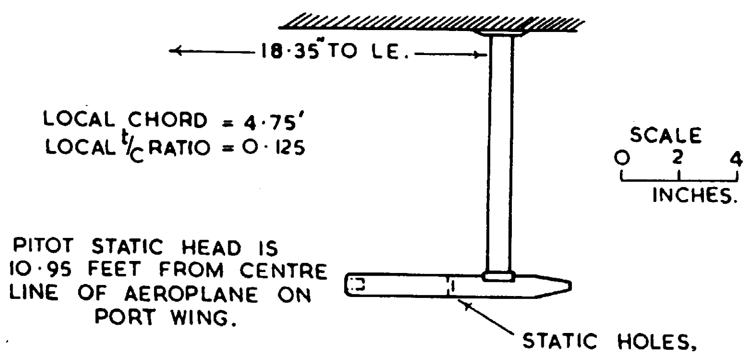


FIG. 7. Plan and Sections of Flap.

PITOT STATIC HEAD.



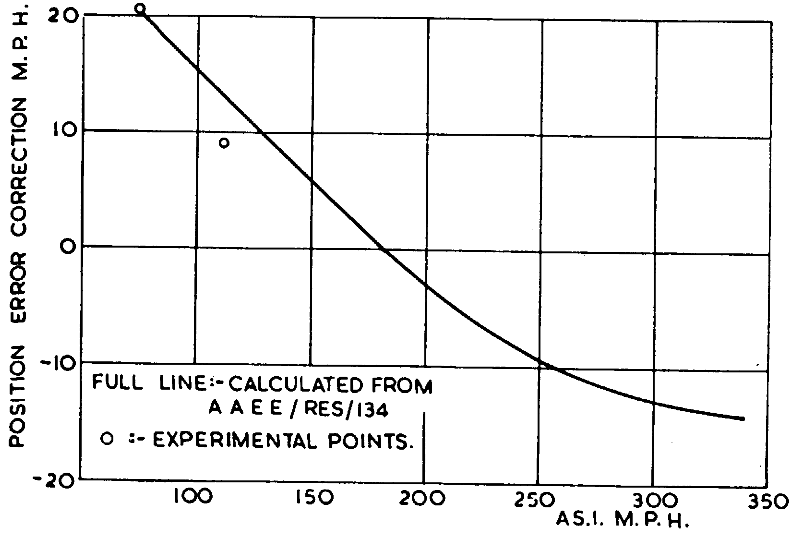


FIG. 8. Position Error Correction Curve.

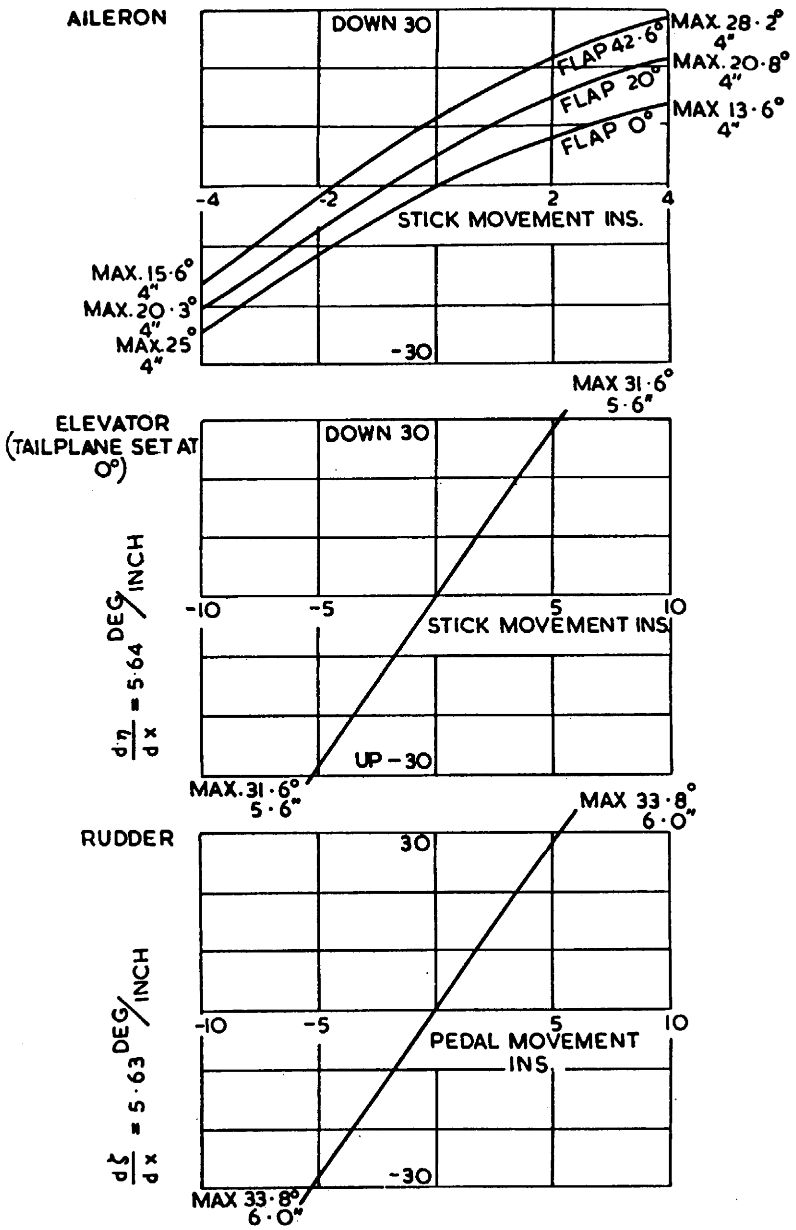


FIG. 9. Gearing between Pilot's Controls and the Control Surfaces.

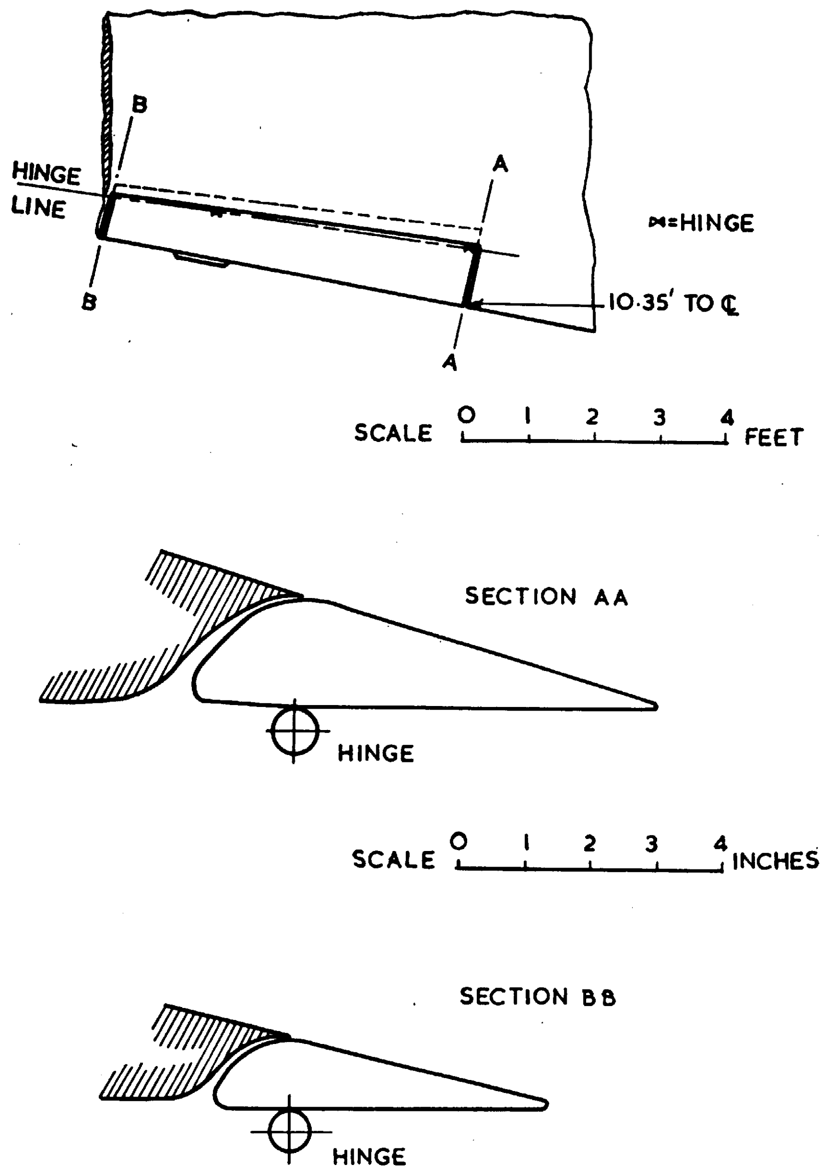


FIG. 10. Aileron—Plan and Sections.

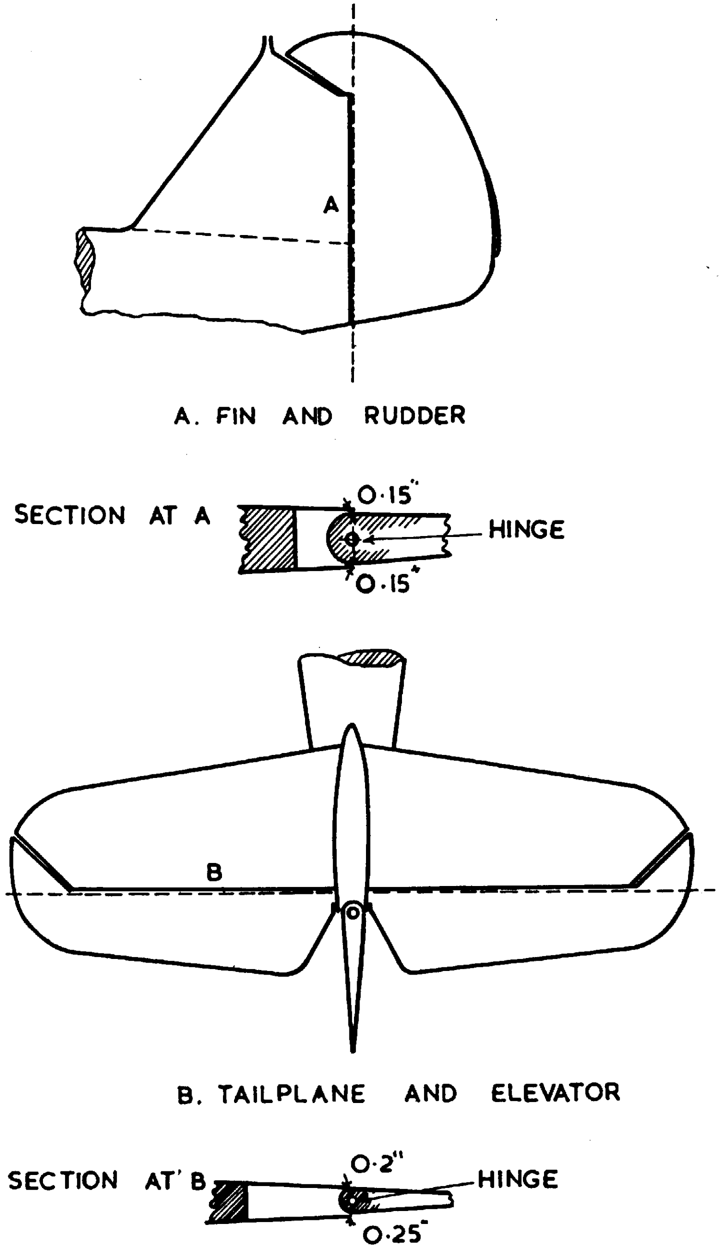


FIG. 11. Control Surfaces.

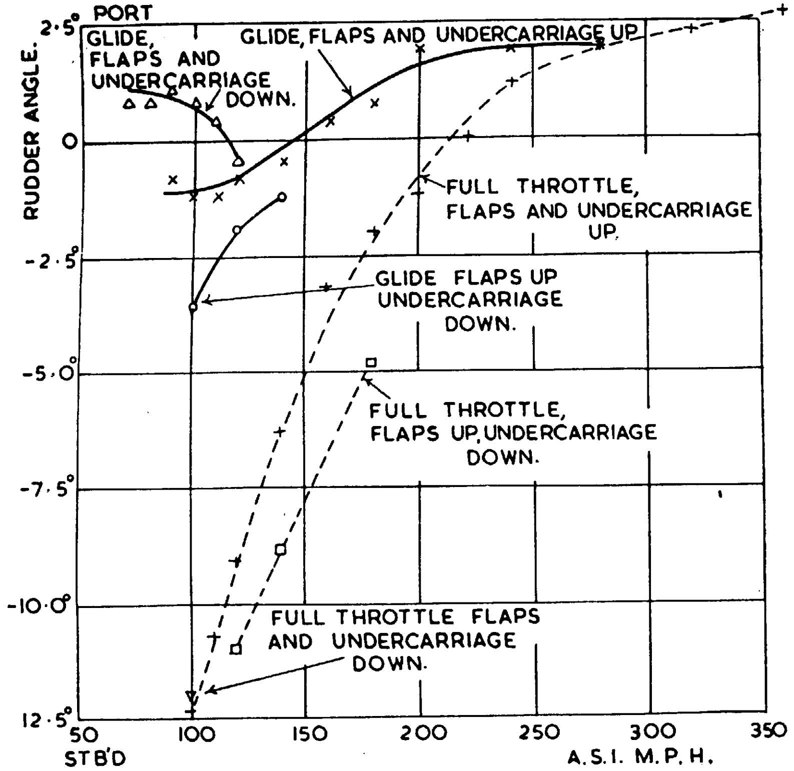
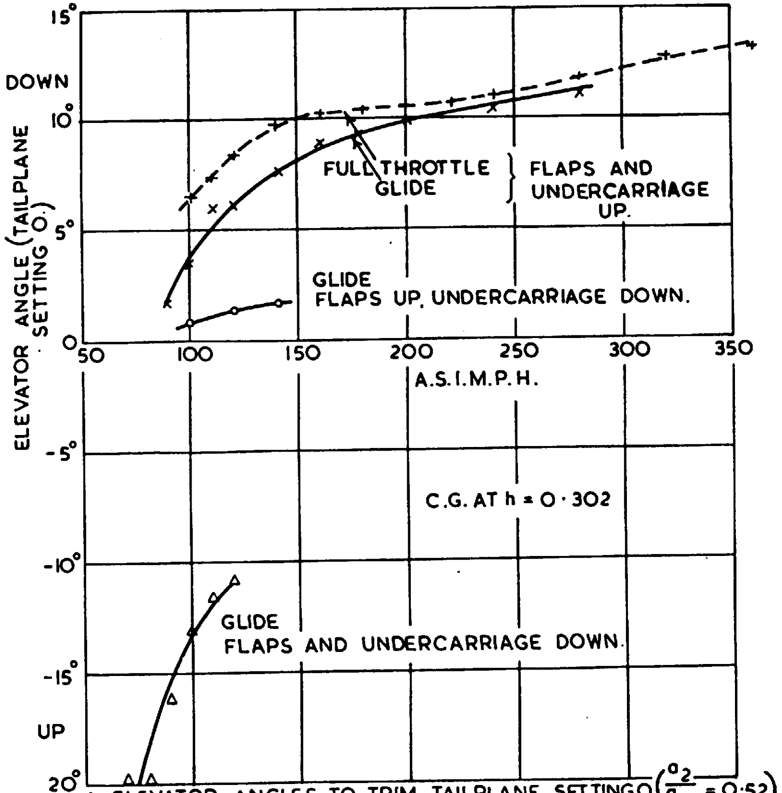
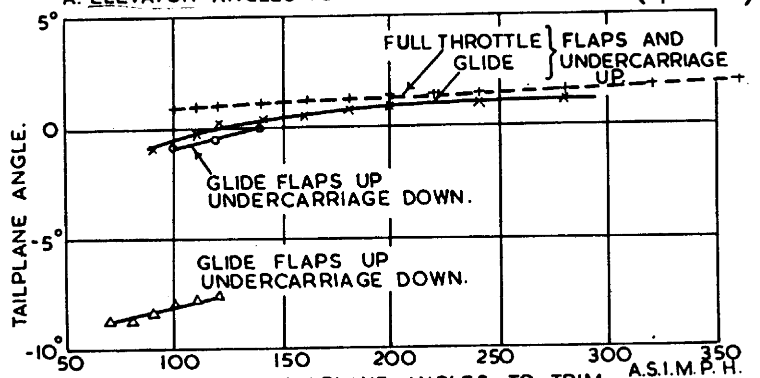


FIG. 12. Rudder Angles to Trim.

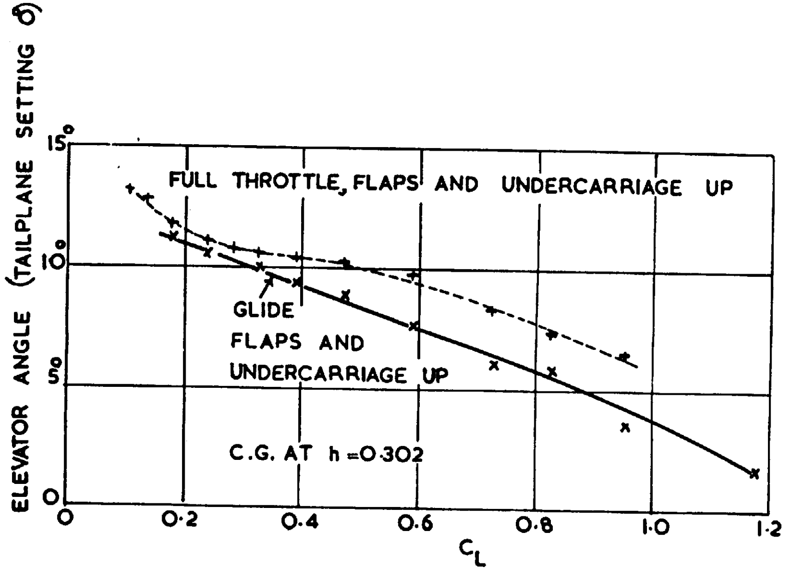


A. ELEVATOR ANGLES TO TRIM TAILPLANE SETTING O $\left(\frac{a_2}{a_1} = 0{\cdot}52\right)$

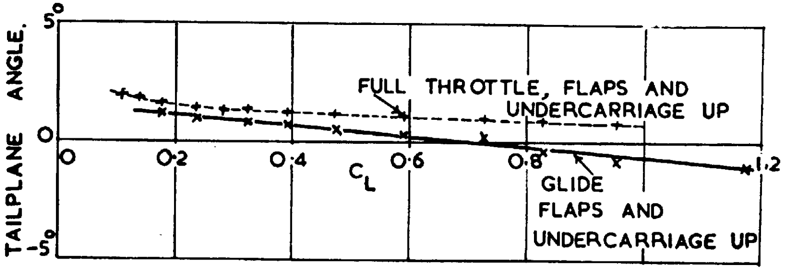


B. TAILPLANE ANGLES TO TRIM.

FIG. 13.

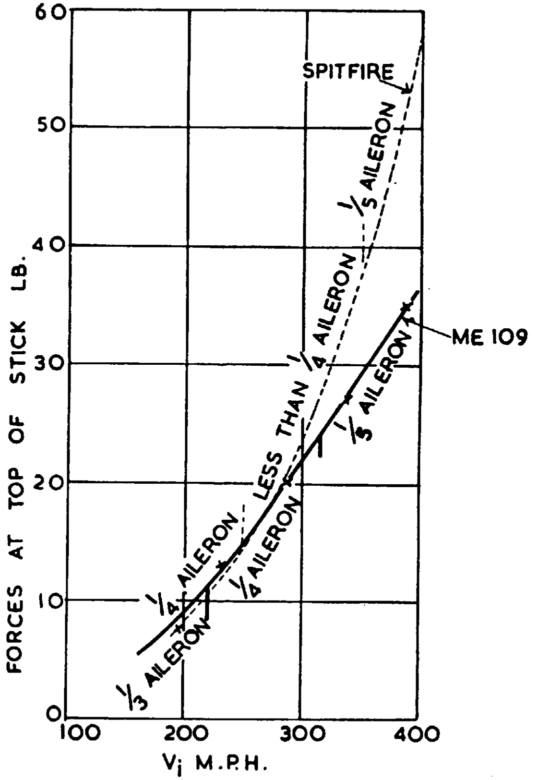


(A) Elevator Angles to Trim, Tailplane Setting 0.

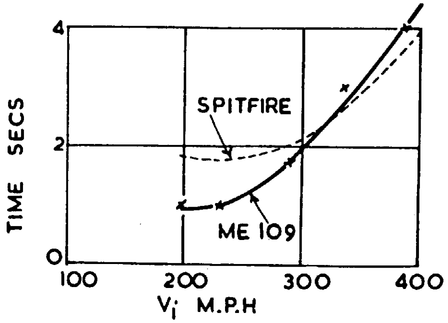


(B) Tailplane Angles to Trim.

FIG. 14.

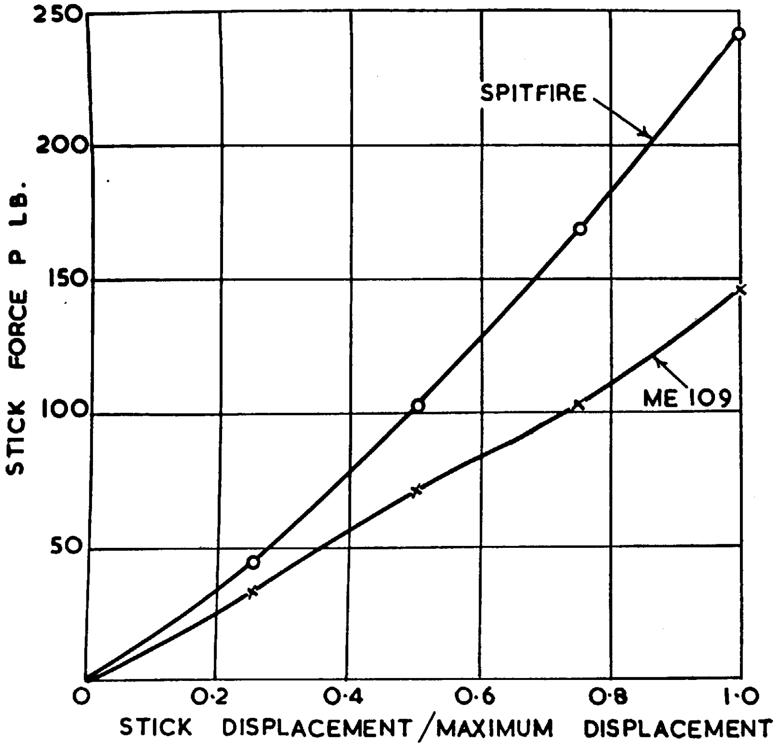


AILERON CONTROL FORCES FOR GIVEN AILERON DISPLACEMENTS



CORRESPONDING TIMES TO 45° BANK

FIG. 15. Me.109 and Spitfire.



V_i = 400 M.P.H.

b_2 = ASSUMED—0·9 FOR BOTH AEROPLANES

K = 1·0

FIG. 16. Me.109 and Spitfire—Effect on Aileron Stick Forces of Aileron Dimensions, Stick Gearing and Differential.

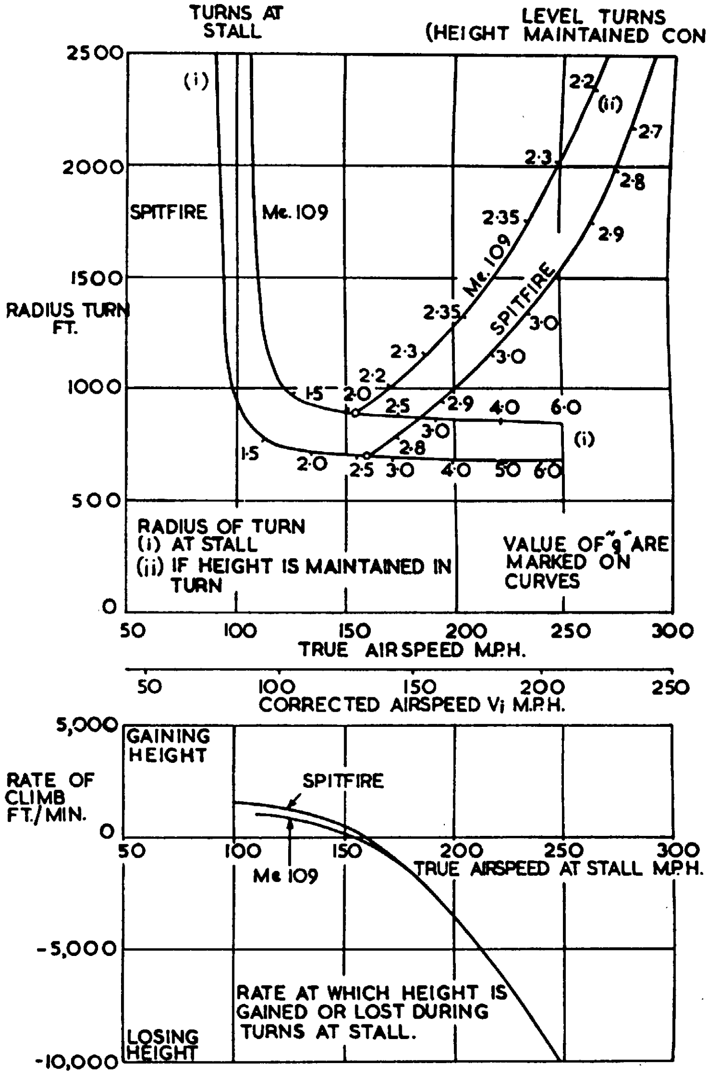


FIG. 18. Me.109 and Spitfire—Comparison of Turning Circles at Full Throttle at 12,000 ft.

(89047) Wt. 13/306 K.5 9/50 Hw.

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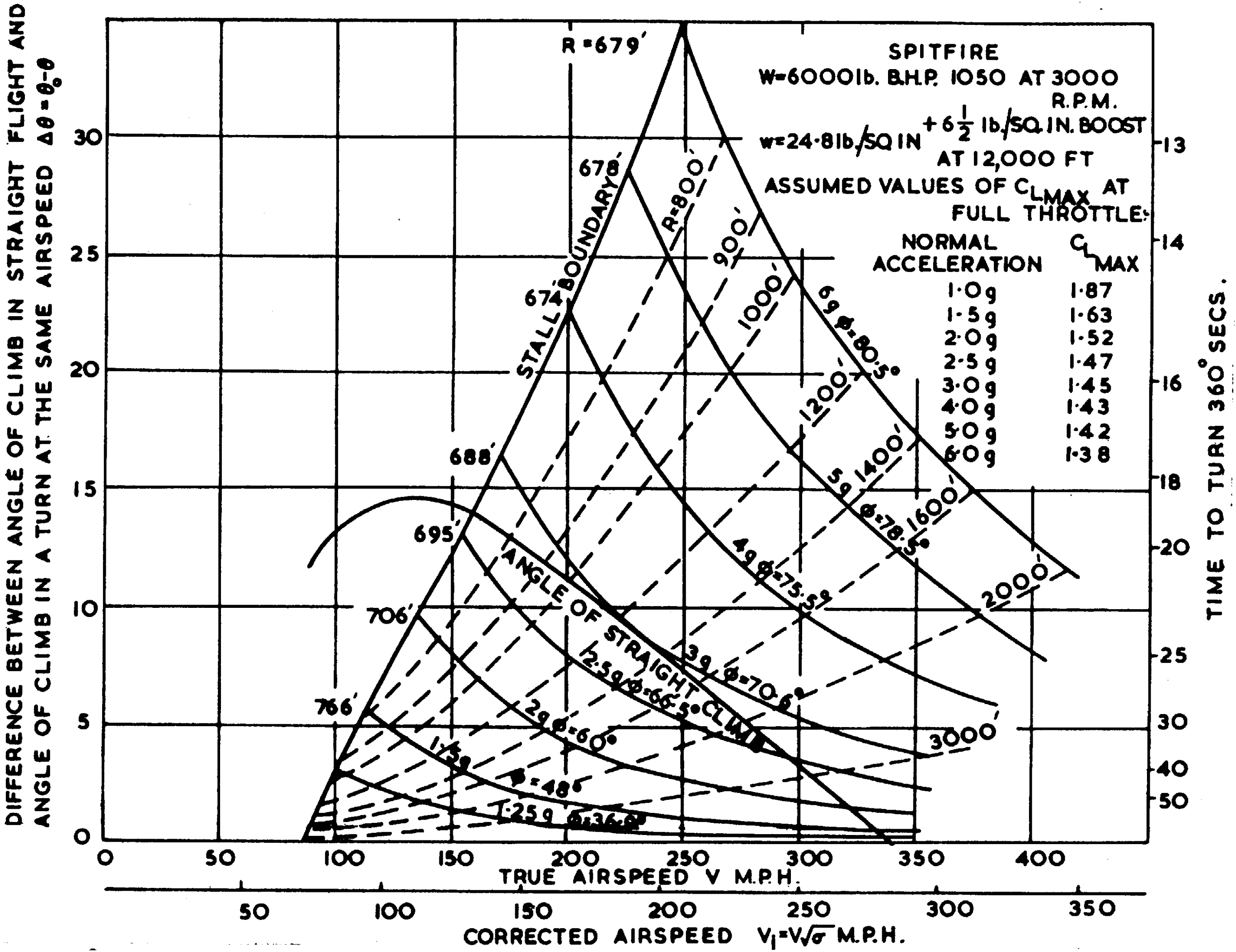

TAILPLANE ANGLE.

ELEVATOR ANGLE (TAILPLANE SETTING δ)

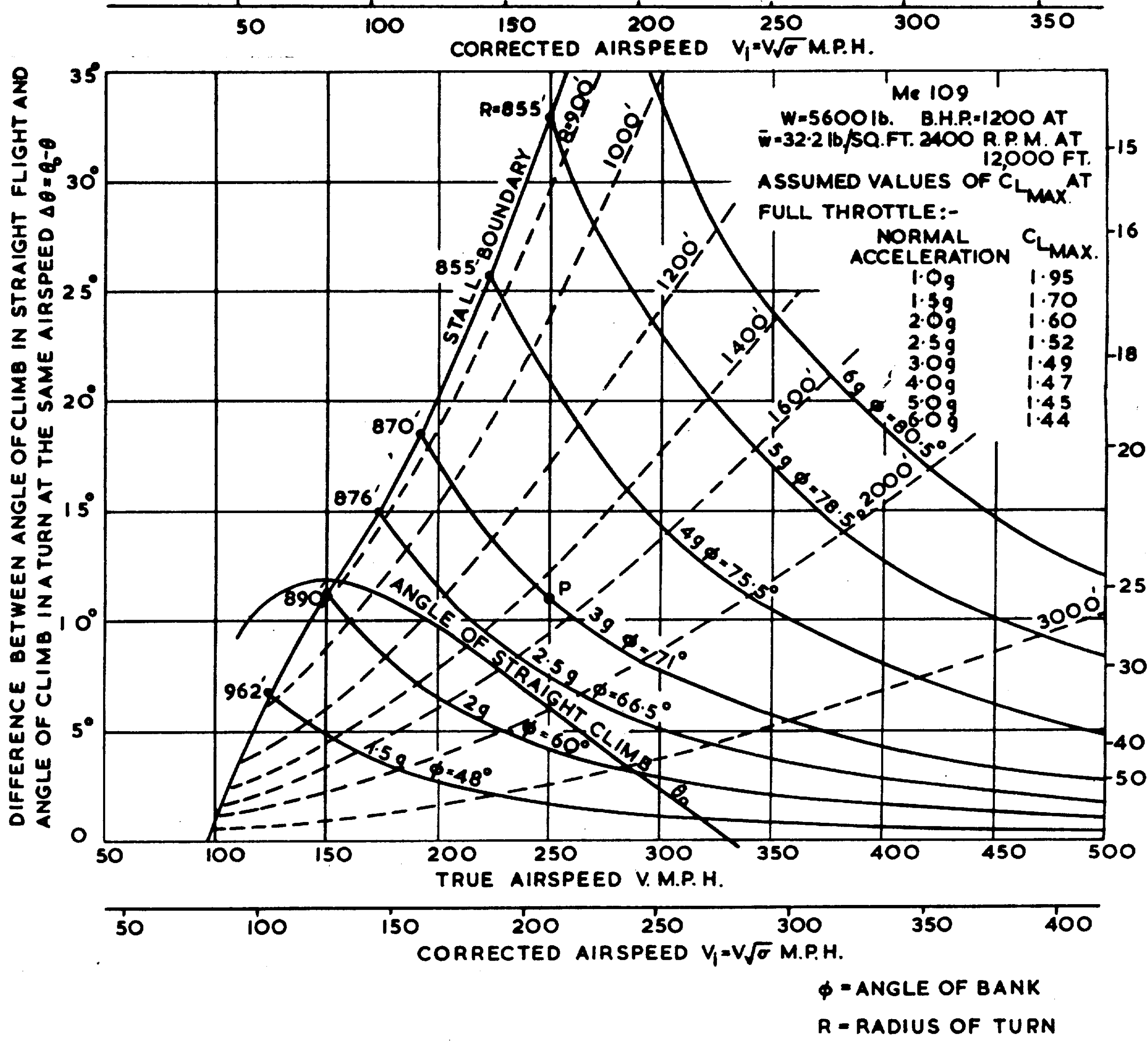

FIG. 17. Spitfire and Me 109. Diagrams of Turning. Performance at Full Throttle at 12,000 ft.

Method of use:- Suppose the Turning Performance of the Me 109 is required at a true Airspeed of 250 m.p.h. when the normal acceleration is 3g. Run along the 3g line until 250m.p.h. is reached (point P.) the radius of turn, from the position of P with respect to the dotted lines of constant radius, is seen to be 1480 ft. while the time to turn through 360° is read off as 25·5 secs. from the right hand scale. The angle of descent is given by the height of the point P above the basic performance curve (marked "angle of straight climb") 5·2° in the example chosen, corresponding to a rate of descent of 2000 ft./min. If P lies on the basic performance curve the aeroplane is turning at a constant height, and if P is below the basic curve, height is being gained. The stalling speed in the turn is obtained by running up the appropriate constant "g" line until the stall boundary is reached. Thus at 3g the Me 109 stalls at 192 m.p.h. true Airspeed.