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ACR Sept. 1942

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

September 1942 as
Advance Confidential Report

STALLING CHARACTERISTICS OF THE SUPERMARINE SPITFIRE VA AIRPLANE

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WASHINGTON

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ADVANCE CONFIDENTIAL REPORT

STALLING CHARACTERISTICS OF THE SUPERMARINE SPITFIRE VA AIRPLANE

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SUMMARY

An investigation of the stalling characteristics of the Supermarine Spitfire was made as part of the flying-qualities measurements of this airplane. The results of the tests are presented as time histories of the motions of the airplane and the controls during stalls in various conditions of flight.

The Spitfire possessed good stall warning in the form of buffeting. Very little stick travel was required to reach the start of the stall flow breakdown, but the stick could be moved well back before lateral instability occurred.

The motion of the Spitfire in stalls was not violent; in slow angle-of-attack changes or in steeply banked turns, the nose tended to ease down at the start of the stall and, even beyond maximum lift, no violent motions occurred. In steeply banked turns with the gun ports open, however, uncontrollable rolling instability was noted after an unmistakable warning in the form of buffeting occurred.

The maximum lift coefficients obtained in all conditions of flight were considerably lower than are normally reached by airplanes of comparable type.

INTRODUCTION

The stalling characteristics described in this report were determined as part of a program covering the flying-qualities tests made on the Supermarine Spitfire VA airplane at the request of the Army Air Forces, Materiel Division. The stalling characteristics were studied more thoroughly than usual because they were considered to be more desirable in some respects than those of any of the pursuit-type airplanes formerly tested in a similar manner. This paper was originally issued as a memorandum report to the Materiel Division, Army Air Forces.

APPARATUS AND TESTS

The Supermarine Spitfire is a single-engine, single-place, low-wing cantilever monoplane with retractable landing gear and partial-span split flaps. (See figs. 1, 2, 3, and 4.)

Throughout these tests of stalling characteristics the gross weight of the airplane was maintained at approximately 6184 pounds and the center of gravity was at approximately 31.4 percent of the mean aerodynamic chord.

NACA recording instruments were used to record the following items:

1. Airspeed.
2. Positions of the rudder, elevators, and ailerons.
3. Angular velocity in roll.
4. Angle of sideslip.
5. Normal, longitudinal, and transverse accelerations.
6. Elevator force or rudder force (in some cases only).

These instruments recorded photographically and were synchronized by means of a timer.

The airspeed recorder in the Spitfire was calibrated by flying in formation with another airplane. The airspeed recorder in the other airplane was calibrated by means of a trailing airspeed head. The calibration of the pilot's airspeed meter is shown in figure 5.

For most of the stall measurements, the angle of sideslip was measured by means of a yaw vane attached to a boom extending a chord length ahead of the left wing tip. In order to determine whether any error was introduced by angularity of local flow at this point, some stalls were made with yaw vanes attached to both wing tips. The true angle of sideslip of the thrust axis was assumed to be midway between the angles recorded by the two yaw vanes.

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Wool tufts attached to the upper surface of the wings allowed the pilot to observe the development of the flow breakdown at the stall.

The variation of elevator angle with control-stick position is shown in figure 6 and the variation of aileron angle with control-stick position is shown in figure 7.

RESULTS AND DISCUSSION

The results of the measurements are presented as time histories of the control motions and motions of the airplane in typical stalls made in various conditions of flight (figs. 8 to 19). Diagrams of the behavior of the tufts indicating the progression of the stalled region across the wing are also shown. Stalls were made with the gun ports open and also with them covered with doped fabric in each of the following conditions of flight:

Condition	Manifold pressure (in. Hg)	Engine speed (rpm)	Radiator shutter position	Hood position	Flap position	Landing gear position
Gliding	throttle closed	----	closed	closed	up	up
Cruising	36.9(3¾ lb/sq in. boost)	2650	flush	closed	up	up
Landing	throttle closed	------	closed	open	down	down
Landing approach	21.4(-4 lb/sq in. boost)	2300	open	open	down	down

In each condition, stalls were made by very gradually reducing the airspeed while the wings were held laterally level and the heading was kept constant. In some stalls, an attempt was made to hold all controls fixed in the positions required at the first sign of the stall; whereas in others, the elevator was continuously raised after the start of the stall in order to keep the speed from increasing, and the other surfaces were moved in an attempt to maintain control.

The results of the measurements in the various flight conditions are summarized as follows:

Stalling characteristics in the gliding condition of flight.- In the gliding condition with the gun ports covered, the airplane showed no tendency to roll off. Figure 8 shows a stall in which the controls were held approximately in the positions required at the first sign of the stall. At speeds of about 10 miles per hour above the minimum speed, the tufts at the trailing edge of the left wing root were observed to reverse and buffeting was felt in the elevator and rudder controls. This buffeting caused a fairly violent and unmistakable shaking of the airplane. In figure 8 and the following time histories, the buffeting is indicated on the figure by an oscillation of the normal acceleration record. Actually all the instrument records showed vibrations, but it was thought unnecessary to indicate this fact on the time histories. The approximate amplitude of the variation in normal acceleration is shown by the plotted curve, but no attempt has been made to reproduce the frequency of the oscillation that was recorded.

At approximately 6 miles per hour above the minimum speed, the tufts fluctuated above the entire left side of the center section and some right aileron motion was needed to maintain trim. A mild pitching and yawing oscillation developed, but no tendency to roll was observed. In no case did the flow ahead of the ailerons separate from the wing surface.

The shaking of the airplane caused some movement of the controls, in spite of the efforts of the pilot to hold them fixed. The uncontrolled stalls may be distinguished from the controlled stalls by the fact that a large amount of up elevator was applied during the controlled stalls.

Figure 9 shows a gliding stall with the gun ports covered in which the stick was moved far back after minimum speed was reached. Use of the ailerons finally resulted in the development of a rolling oscillation and the violent buffeting continued throughout the stall. As in the previous stall, the only portions of the wing from which the flow separated were the left side of the center section and the extreme tips. Lateral and longitudinal control sufficient to prevent any violent motions were still available beyond the stall, though there was some lag in response to the controls.

The effect of uncovering the gun ports in the gliding condition is shown in figures 9 and 10. In this case, the stall progressed symmetrically outward from each side of the fuselage at the wing root; a very mild lateral and pitching oscillation was observed to accompany the fairly violent buffeting. If the stick were held all the way back, a lateral oscillation would develop which eventually led to a complete loss of lateral control.

The aileron control after the start of the stall in the gliding condition was investigated by abruptly deflecting the ailerons. The rolling velocities thus obtained were greater than those occurring for the same aileron deflection above the stall, probably because of the reduced damping in roll of the stalled portion of the wing. An interval of about 0.7 second elapsed between the time the ailerons were deflected and the time maximum rolling velocity was reached. The rolling velocity was always in the correct direction.

In the gliding condition, as in most other conditions of flight, the buffeting preceding the stall served as a desirable stall warning. The rearward motion of the stick required to start the stall was small, but a large rearward motion of the stick could be made without causing violent motions of the airplane.

<u>Stalling characteristics in the cruising condition of flight</u>.- In the cruising condition, there was essentially no difference in the types of stall that occurred with gun ports open or covered, as shown on figures 12 and 13. The wing tips beyond the ailerons stalled first, apparently because the slipstream prevented separation of flow from the center section. Slight buffeting and rearward motion of the stick started about 5 miles per hour above minimum speed, though the tufts at the center section did not reverse. A considerable amount of left sideslip was necessary to hold the wings level near the stall. This sideslip did not occur in the power-off condition. When the minimum

speed was reached, both wings stalled almost simultaneously, and a relatively mild right roll occurred. The pilot noted that the elevator was rather ineffective in pitching the airplane down after the stall.

Figures 12 and 13 show that the rolling velocity was not checked until approximately one-half second had elapsed after the application of down elevator. This time interval is longer than has been measured in tests on other airplanes.

Stalling characteristics in the landing condition of flight.- A time history of a stall in the landing condition is shown on figure 14. The development of the stall was the same with gun ports open or covered. At a speed of about 10 miles per hour above the minimum speed, the tufts reversed in a region on the left side of the center section near the leading edge, but the tufts at the trailing edge did not reverse.

Buffeting set in when this separation took place. Figure 14 shows that a lateral and pitching oscillation of increasing amplitude developed if the controls were held fixed. With elevator full up, however, some measure of lateral control could be maintained by means of the rudder and ailerons.

Stalling characteristics in the landing approach condition of flight.- During actual landing-glide approaches with the Spitfire, control of the angle of attack was more difficult than in some other pursuit airplanes because of its lack of longitudinal stability. The unmistakable stall warning in the form of buffeting and the extremely mild stall itself, however, permitted the pilot to make tail-first landings without difficulty. A noticeable stall flow breakdown did occur, which could be felt as air blasts on the left side of the pilot's face, just at the three-point contact. The Spitfire did not exhibit any marked rolling or yawing tendencies either at contact or in the landing run.

In the landing-approach condition, with gun ports covered, the stall was similar to that in the landing condition, with the exception that considerable rudder and aileron deflections were required to maintain trim near minimum speed. Figure 15 shows the time history of a stall in this condition.

With gun ports open, the flow separated from the outboard wing panels before the center section stalled. Figure 16 shows that control was maintained in this condition for several seconds after the stall, but a mild right roll eventually occurred.

MAXIMUM LIFT COEFFICIENTS FOR VARIOUS FLIGHT CONDITIONS

The maximum lift coefficients as measured in various conditions of flight are shown in the accompanying table.

Condition	Flap position	Gear position	Manifold pressure (in. Hg)	Engine speed (rpm)	Gun ports covered: Indicated stalling speed (mph)	Gun ports covered: Maximum lift coefficient	Gun ports open: Indicated stalling speed (mph)	Gun ports open: Maximum lift coefficient
Gliding	up	up	throttle closed	----	90	1.18	91	1.15
Cruising	up	up	36.9 ($3\frac{3}{4}$ lb/sq in. boost)	2650	77	1.63	76	1.68
Landing	down	down	throttle closed	----	80	1.51	81	1.46
Landing approach	down	down	21.4 (-4 lb/sq in. boost)	2300	69	1.99	75	1.72
Take-off	up	down	43.9 (7 lb/sq in. boost)	2850	80	1.49	--	----
Climbing	up	up	43.9 (7 lb/sq in. boost)	2850	76	1.64	--	----

The maximum lift coefficients obtained are considerably lower than normal. Apparently the desirable stall warning is obtained at the expense of high maximum lift.

STALLING CHARACTERISTICS IN MANEUVERS

The stall warning possessed by the Spitfire was especially beneficial in allowing the pilot to reach maximum lift coefficient in accelerated maneuvers. Because of the neutral static stability of this airplane, the pilot obtained no indication of the lift coefficient from the motion of the control stick. Nevertheless, he was able to pull rapidly to maximum lift coefficient in a turn without danger of inadvertent stalling.

Figure 17 shows a time history of a 180° turn in which the stall was reached. The stall in accelerated maneuvers was very similar to that in the gliding condition. With gun ports closed, the pilot was able to pull the stick far back without losing control or interrupting the turn. The airplane tended to pitch down when stalled and to recover by itself if the stick were not pulled back. It would be possible for a pilot pursuing an enemy in a turn to bring his sights on him momentarily by pitching beyond the stall without fear of rolling instability.

With gun ports open, a right roll occurred if more than about 10° up elevator were applied. This reaction caused the airplane to roll out of a left run and into a right turn. Time histories of these maneuvers are shown on figures 18 and 19. In spite of the lateral instability that occurred in turns with gun ports open, the pilot was able to approach maximum lift coefficient closely because of the desirable stall warning. The maximum lift coefficient reached in turns from level flight with flaps up was 1.22. The airplane could be flown beyond the stall at even lower lift coefficients.

This value of maximum lift coefficient is closer to that reached from stalls in straight flight with power off than the value reached with power on because the slipstream effects in high-speed turns are relatively small. The low value of the maximum lift coefficient offsets, to some extent, the benefit gained by the Spitfire from its low wing loading in making turns of small radius. Good stall-warning characteristics appear to be essential on an airplane with neutral static stability. In airplanes tested previously, which had neutral static stability and poor stall warning, inadvertent stalling in rapid maneuvers was practically unavoidable. The stalling characteristics of the Spitfire are therefore its redeeming feature. It would be desirable, however, to obtain these characteristics without sacrificing a high value of the maximum lift coefficient.

CONCLUSIONS

The Supermarine Spitfire airplane possessed stalling characteristics essentially in compliance with the requirements for satisfactory stalling characteristics given in reference 1. These characteristics may be summarized as follows:

1. Warning of the complete stall was provided by the occurrence of buffeting that set in at speeds several miles per hour above the minimum speed and by the rearward movement that could be made with the stick after the start of the stall flow breakdown without causing violent motions of the airplane.

2. Stall recovery could be made by application of down elevator, although the recovery from a roll was somewhat slower than has been measured on some previously tested airplanes.

3. The airplane exhibited no dangerous ground-looping tendencies in landing. Tail-first landings could be readily made without the occurrence of either lateral or directional instability due to stalling.

The airplane possessed some unusual characteristics in stalls that are not required in reference 1. The motion beyond the stall was not violent and an unusual amount of lateral control was available in many flight conditions, even when full up elevator was applied. The good stalling characteristics allowed the airplane to be pulled rapidly to maximum lift coefficient in accelerated maneuvers in spite of its neutral static longitudinal stability.

The maximum lift coefficients available in maneuvers with flap up and in all conditions of flight tested were considerably lower than are normally reached by airplanes of similar type.

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National Advisory Committee for Aeronautics,
Langley Field, Va.

REFERENCE

1. Gilruth, R. R.: Requirements for Satisfactory Flying Qualities of Airplanes. NACA A.C.R., April 1941.

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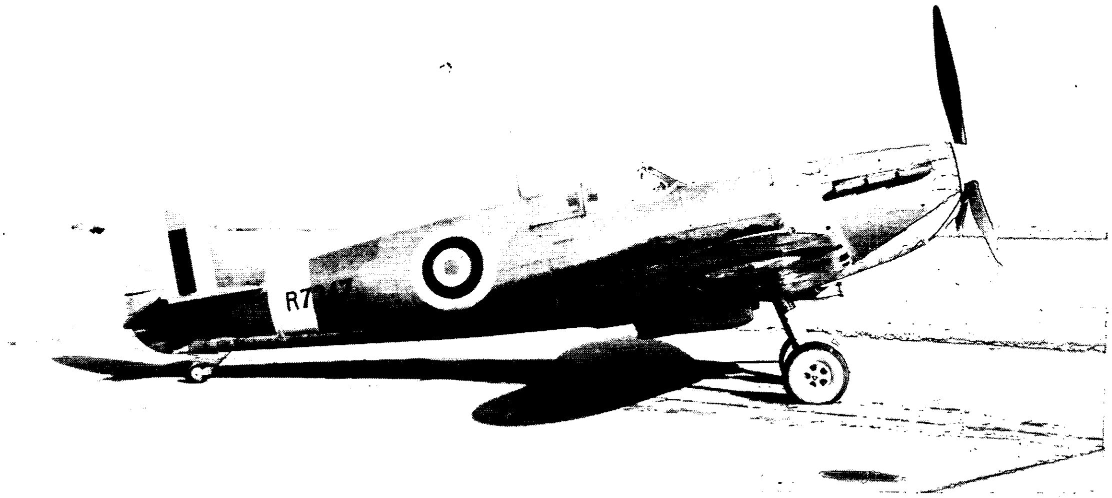

Figure 1.- Side view of the Supermarine Spitfire airplane.

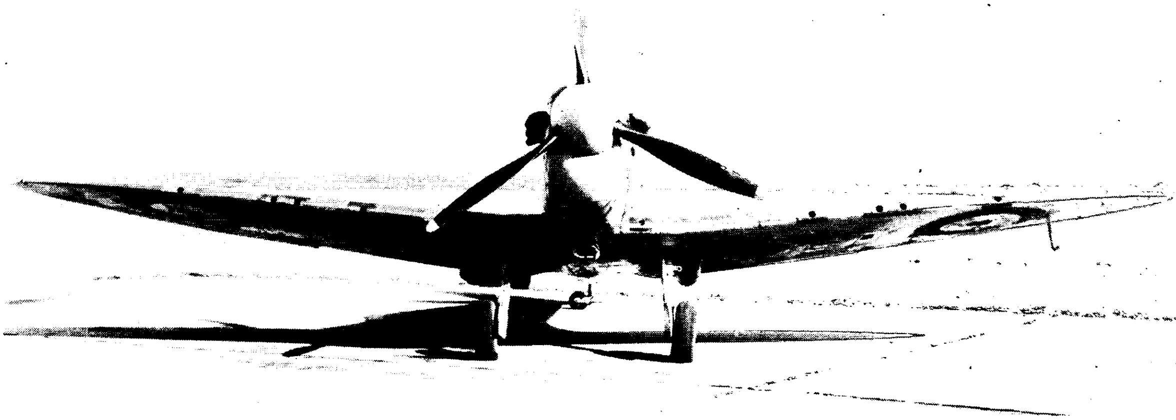

Figure 2.- Front view of the Supermarine Spitfire airplane.

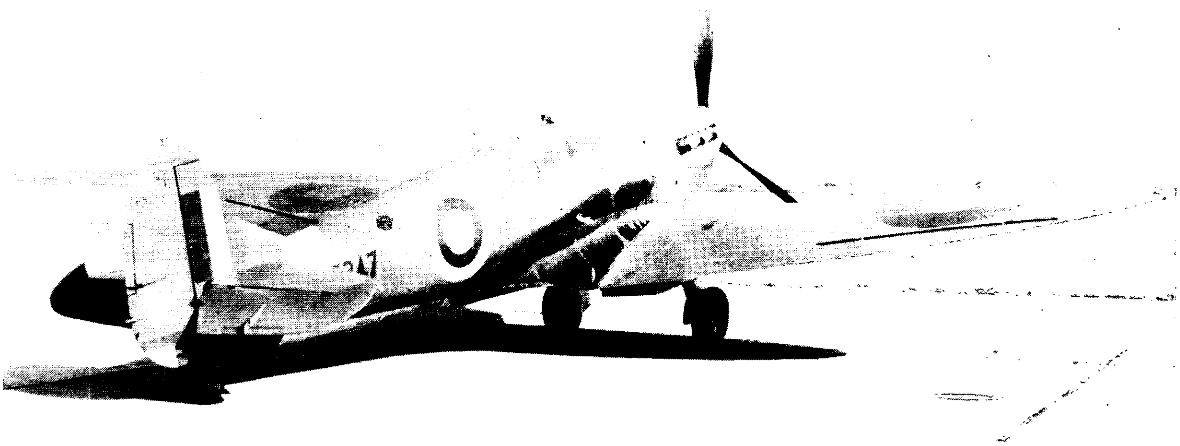

Figure 3.- Three-quarter rear view of the Supermarine airplane.

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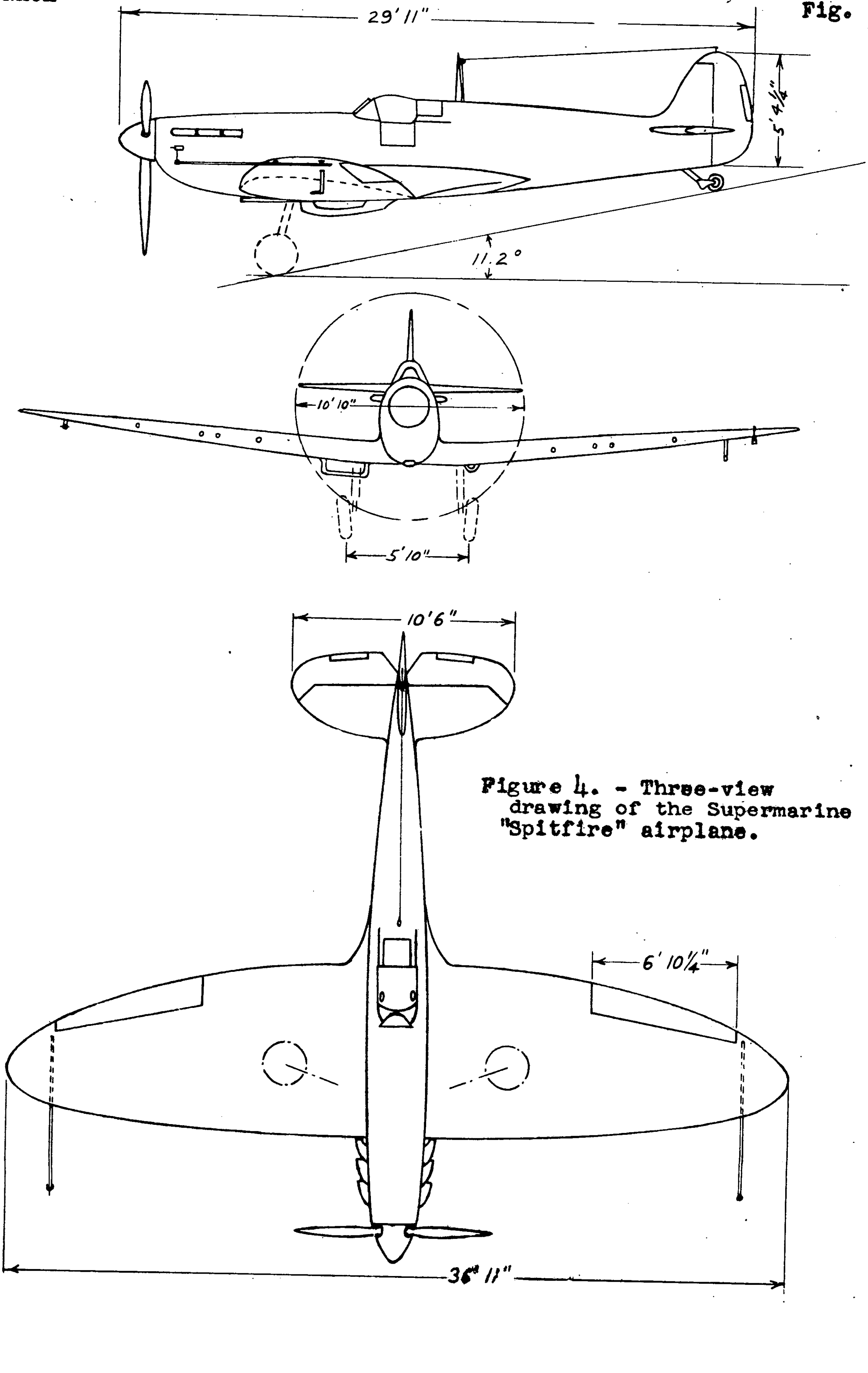


Figure 4. - Three-view drawing of the Supermarine "Spitfire" airplane.

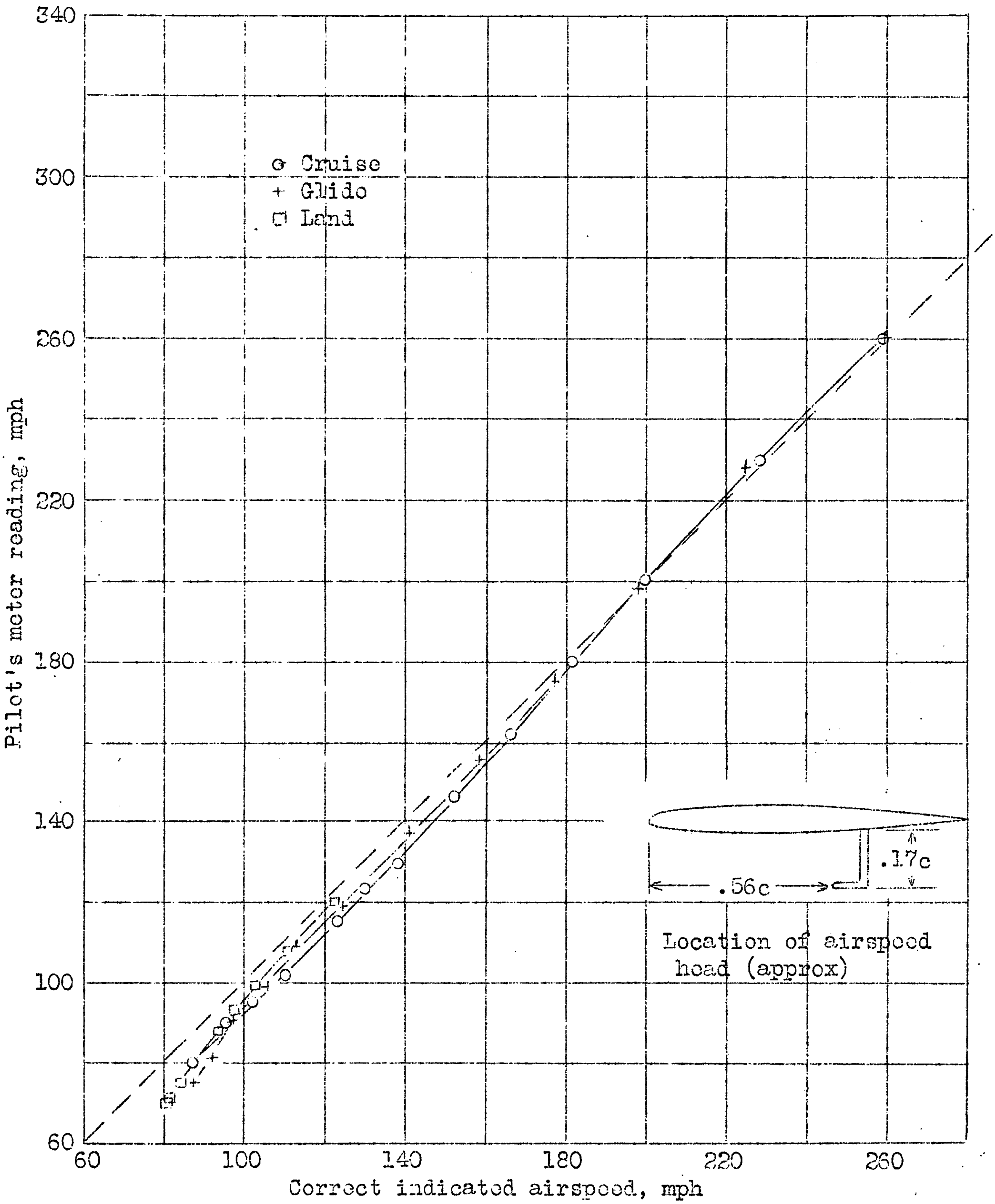


Figure 5.- Calibration of the pilot's airspeed indicator in the Supermarine Spitfire airplane.

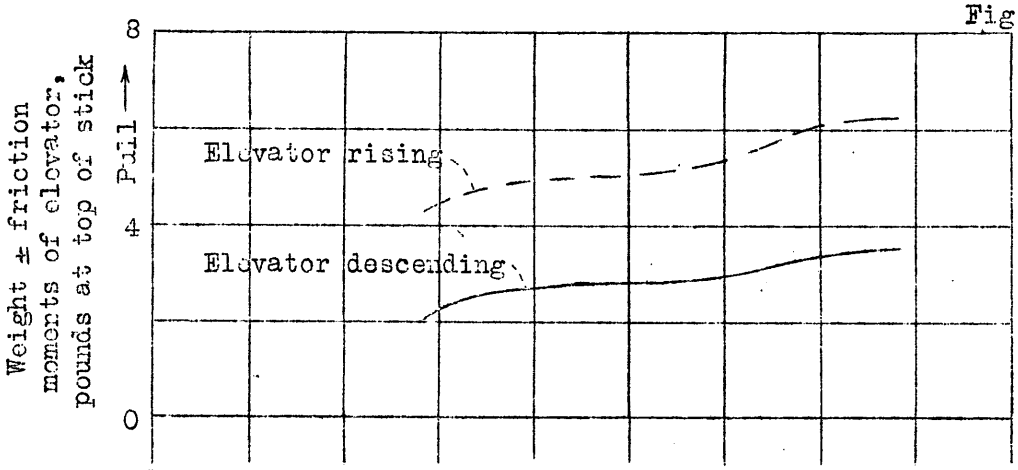
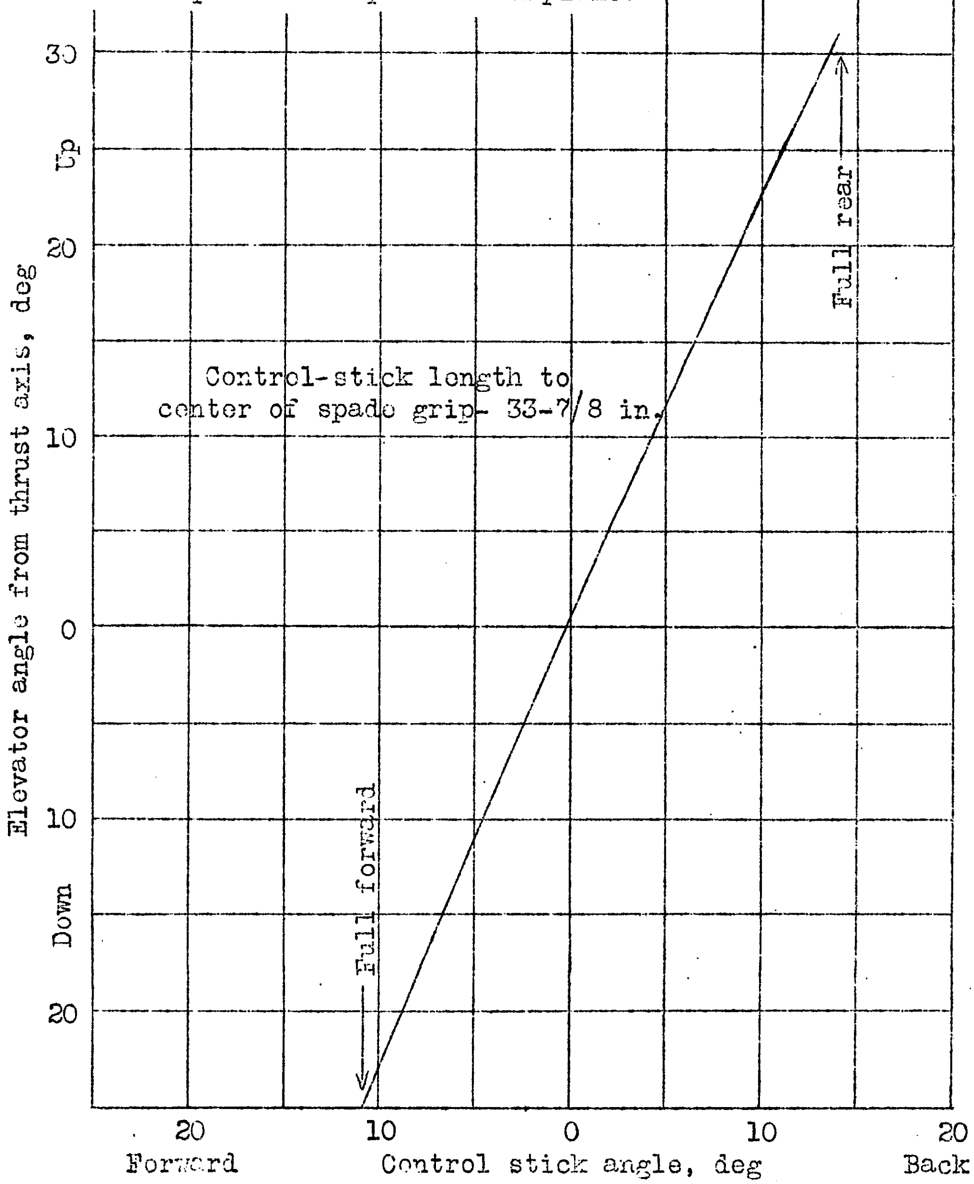


Figure 6.- Variation with control-stick angle of elevator angle and stick force caused by elevator friction and unbalance. Supermarine Spitfire airplane.



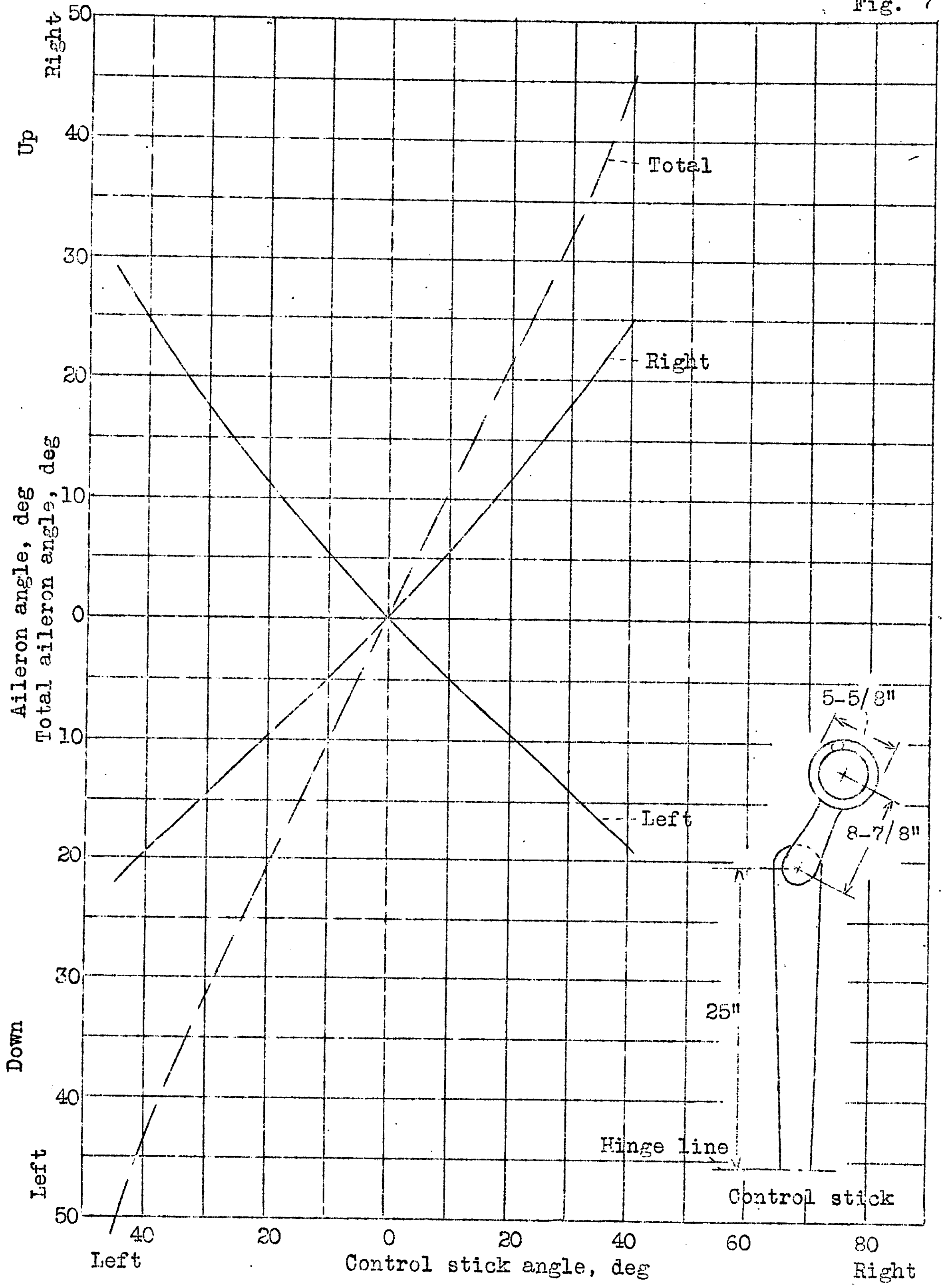


Figure 7.- Variation of left, right, and total-aileron angles with control stick angle. Supermarine Spitfire airplane.

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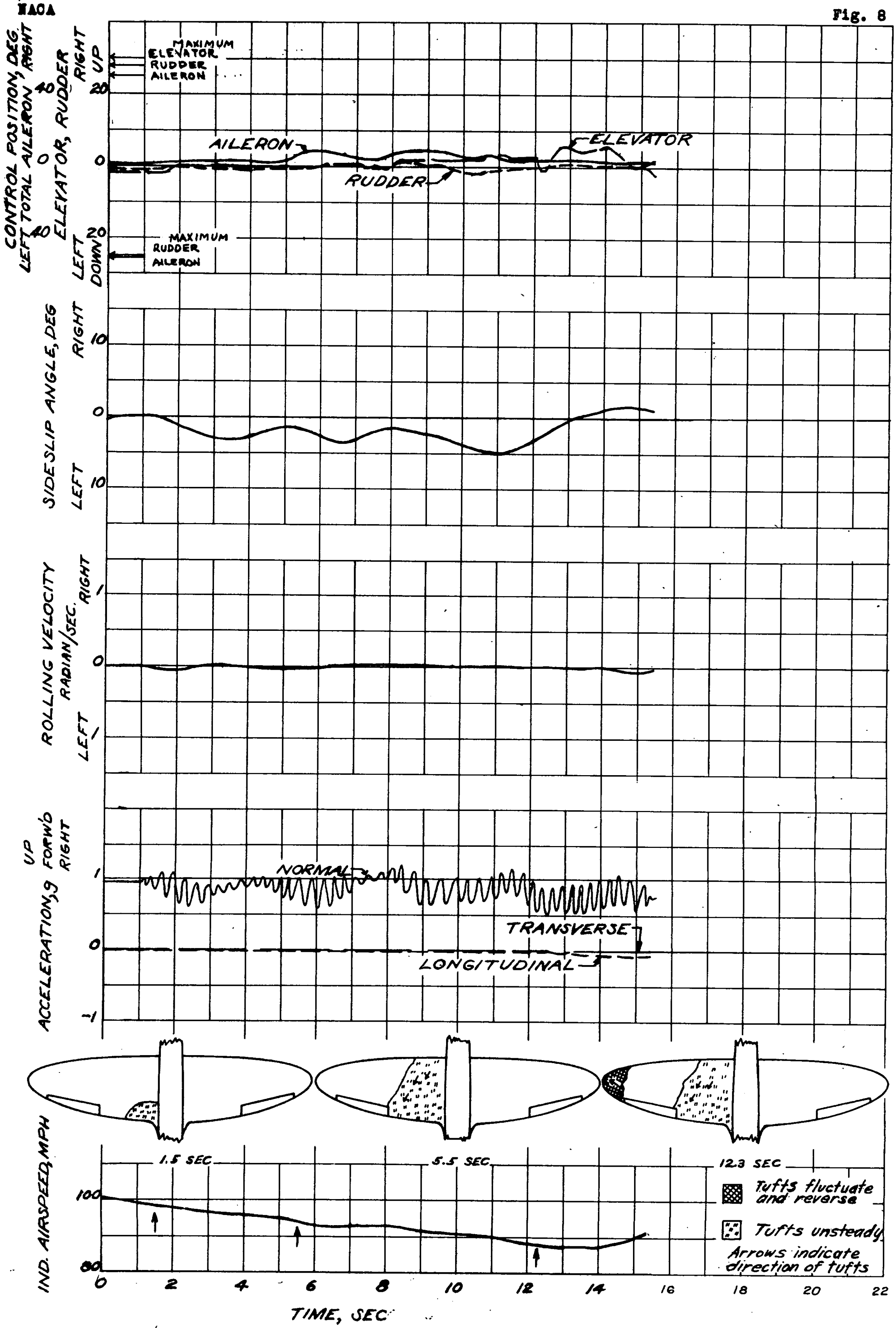

Figure 8. - Time history of a stall in the gliding condition, gun ports covered. Controls were held approximately in the positions required at the start of the stall. Supermarine Spitfire airplane.

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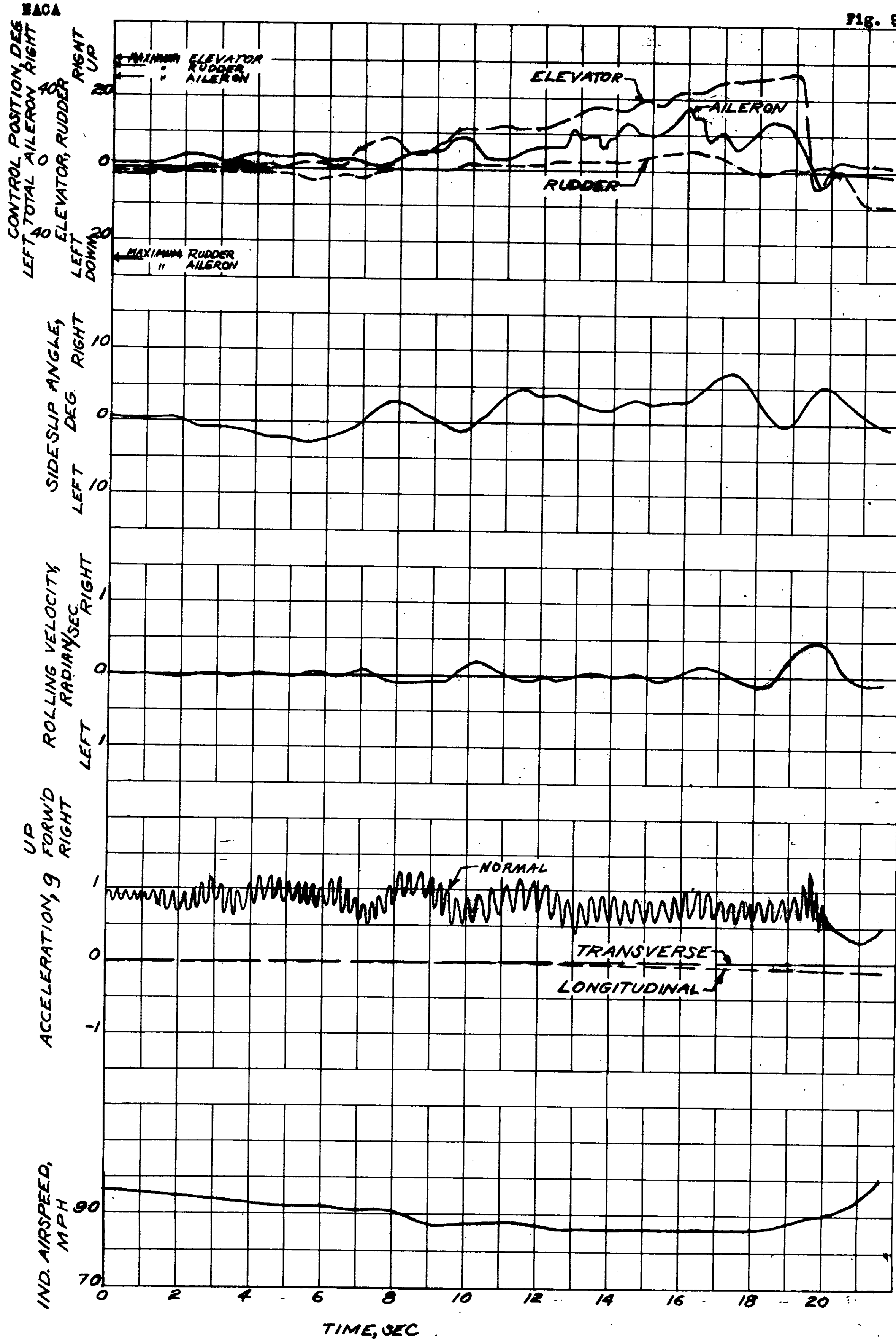

Figure 9. - Time history of a stall in the gliding condition with gun ports covered. Nearly full up elevator was applied and control was maintained with ailerons and rudder. Supermarine Spitfire airplane.

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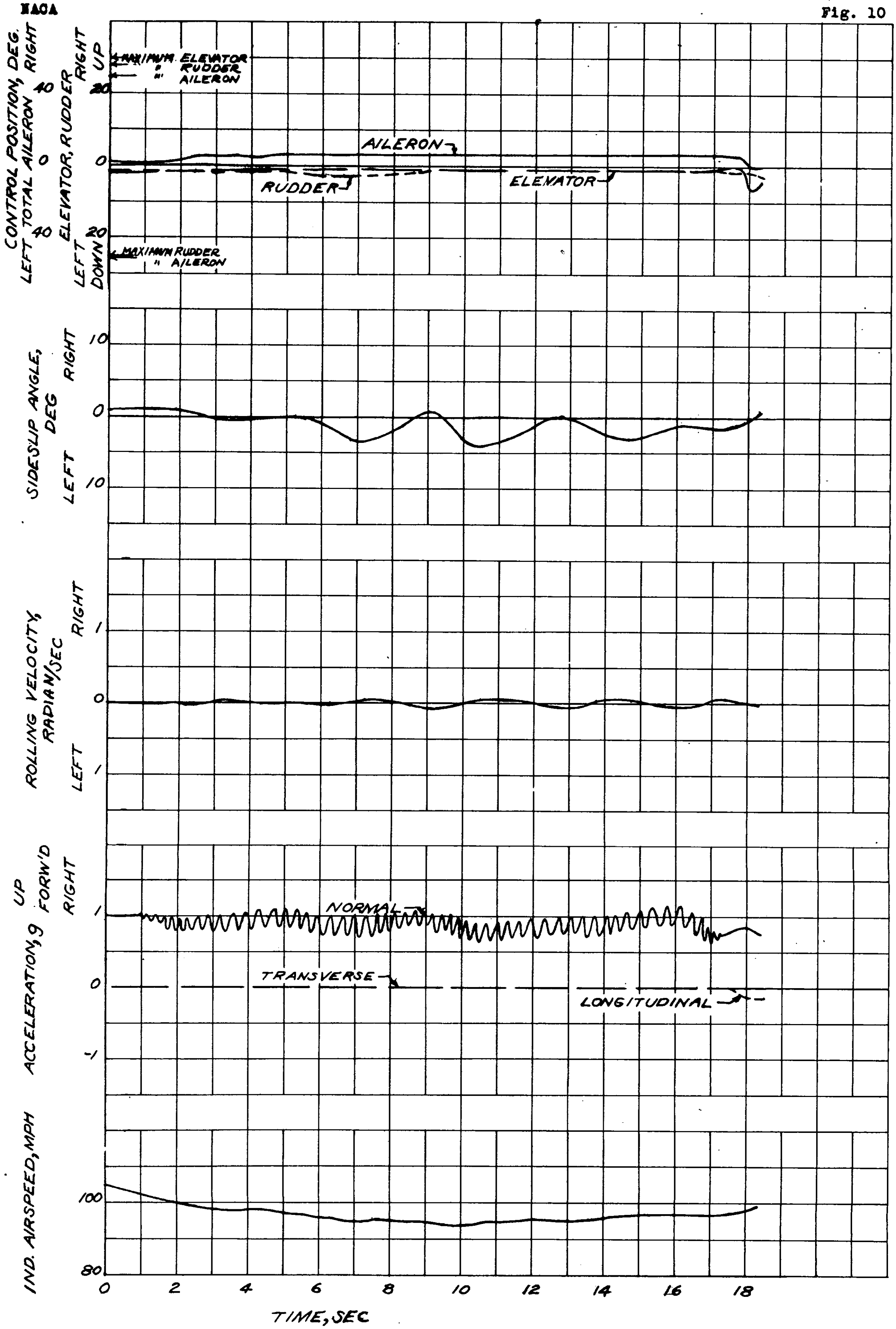

Figure 10. - Time history of a stall in the gliding condition with gun ports open. Controls were held in the positions required at the start of the stall. Supermarine Spitfire airplane.

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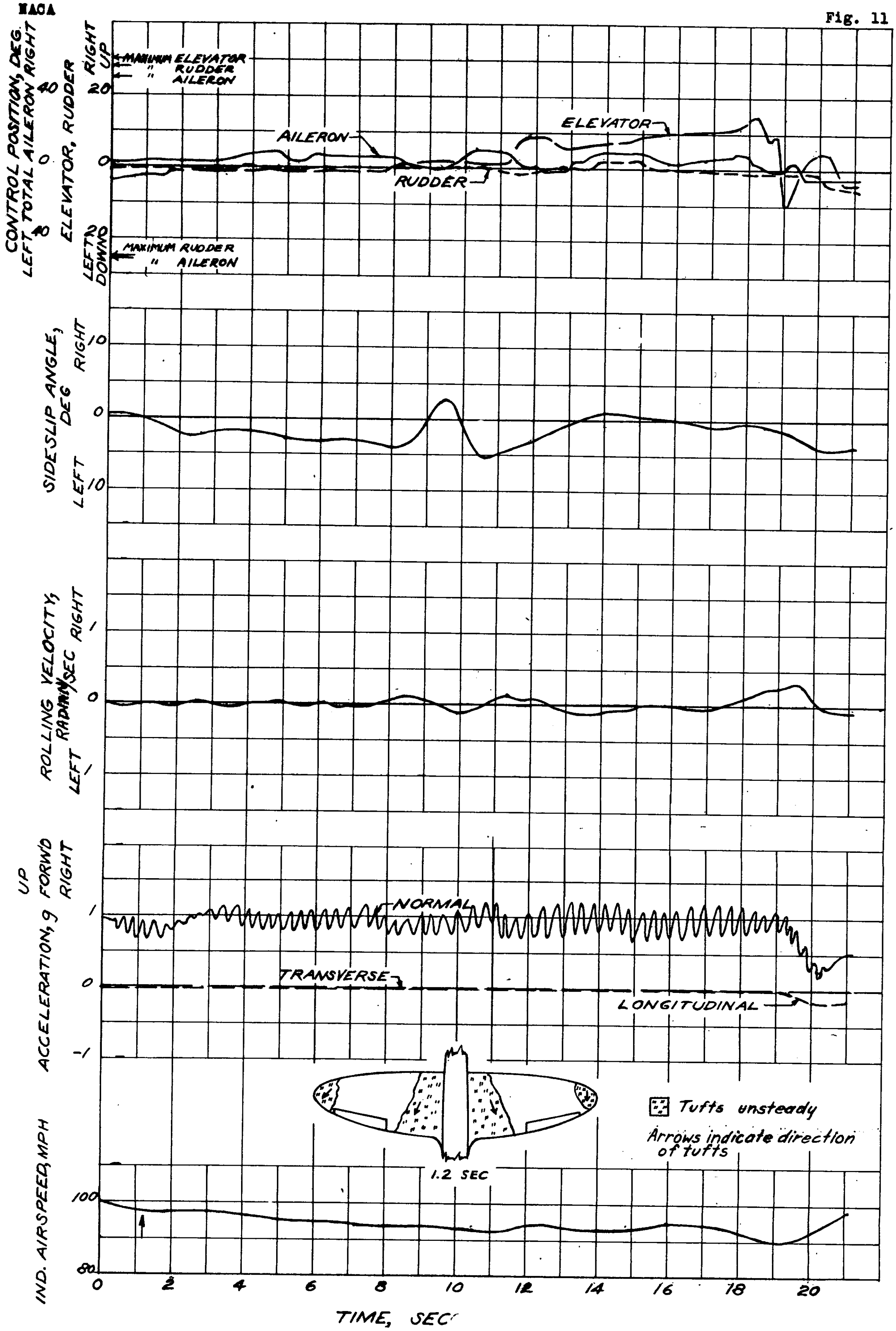

Figure 11. - Time history of a stall in the gliding condition with gun ports open. Airplane was controlled by ailerons and rudder beyond the stall. Supermarine Spitfire airplane.

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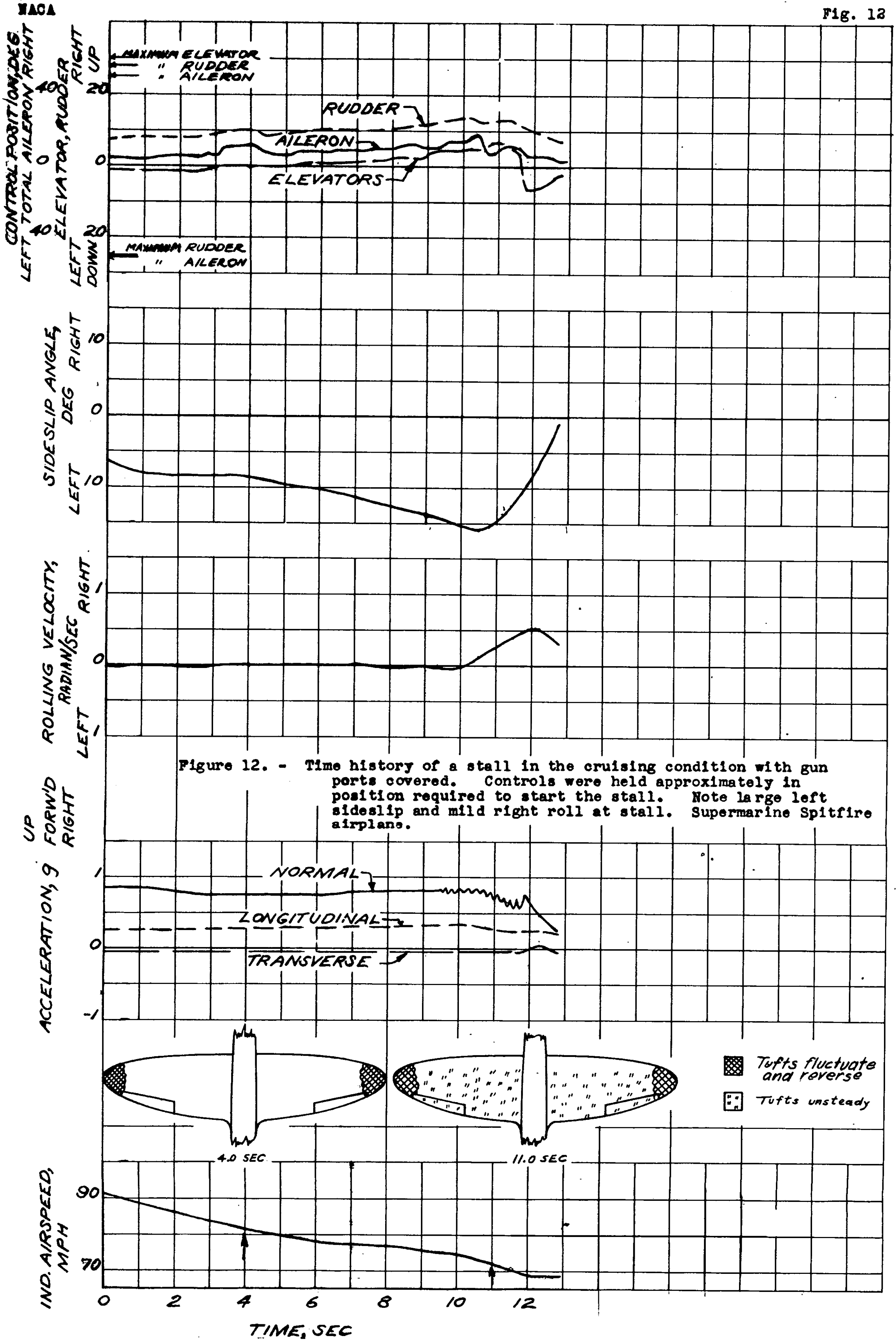

Figure 12. - Time history of a stall in the cruising condition with gun ports covered. Controls were held approximately in position required to start the stall. Note large left sideslip and mild right roll at stall. Supermarine Spitfire airplane.

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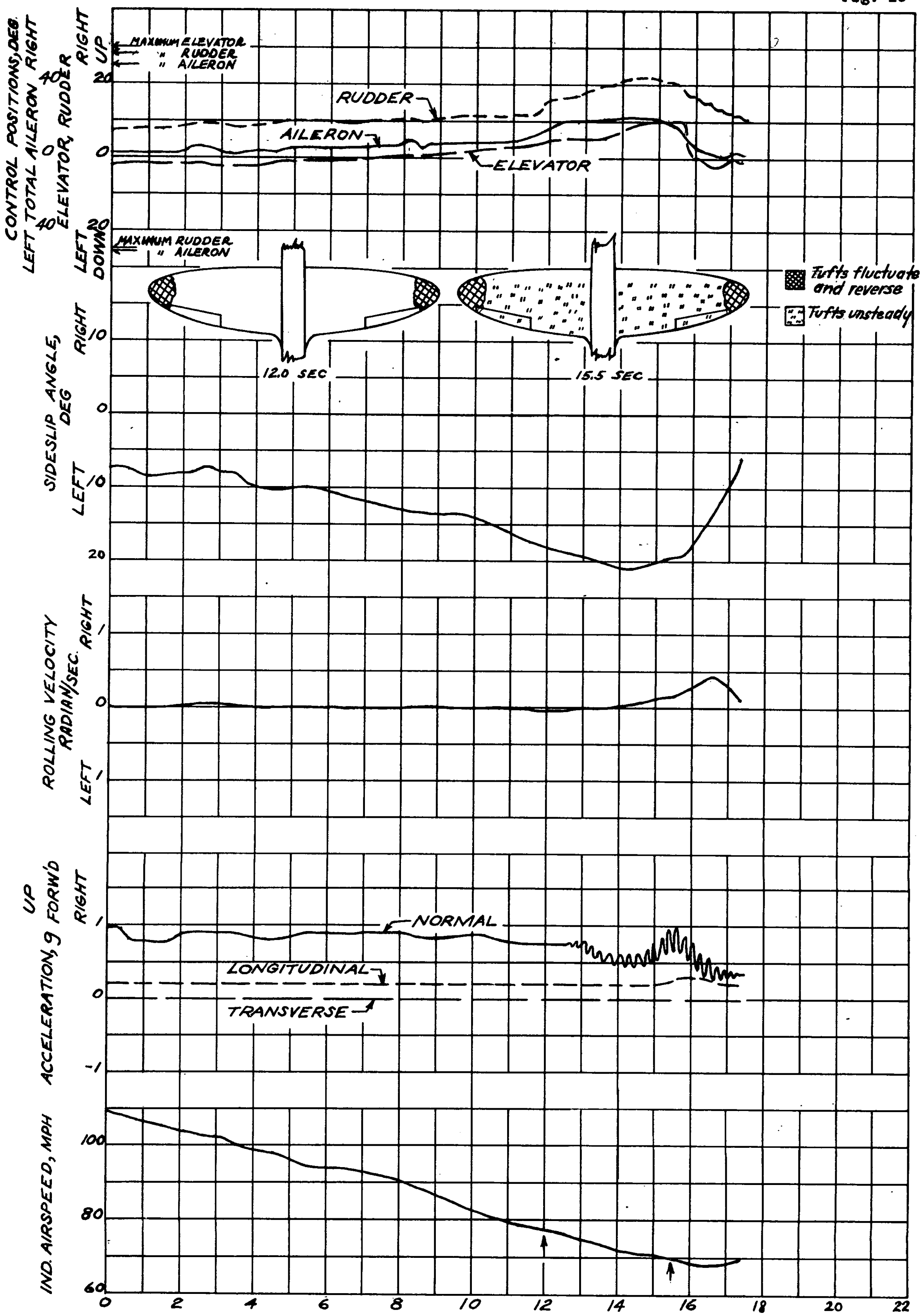

Figure 13. - Time history of a stall in the cruising condition with gun ports open. Note similarity to stall with gun ports closed (fig. 11). Supermarine Spitfire airplane.

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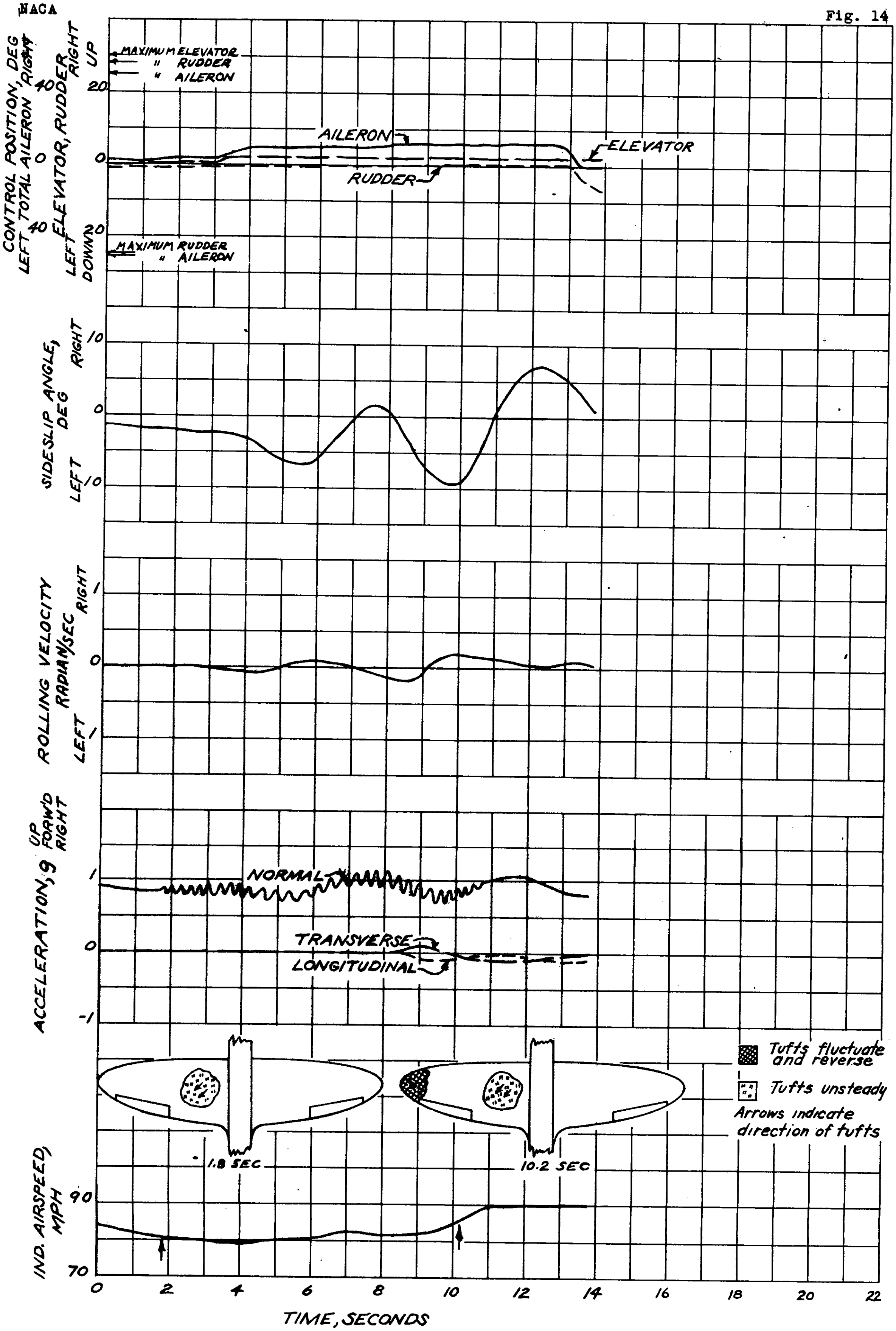

Figure 14. - Time history of a stall in the landing condition with gun ports covered. Controls were held in the positions required to start the stall. Note lateral and pitching oscillation. Supermarine Spitfire airplane.

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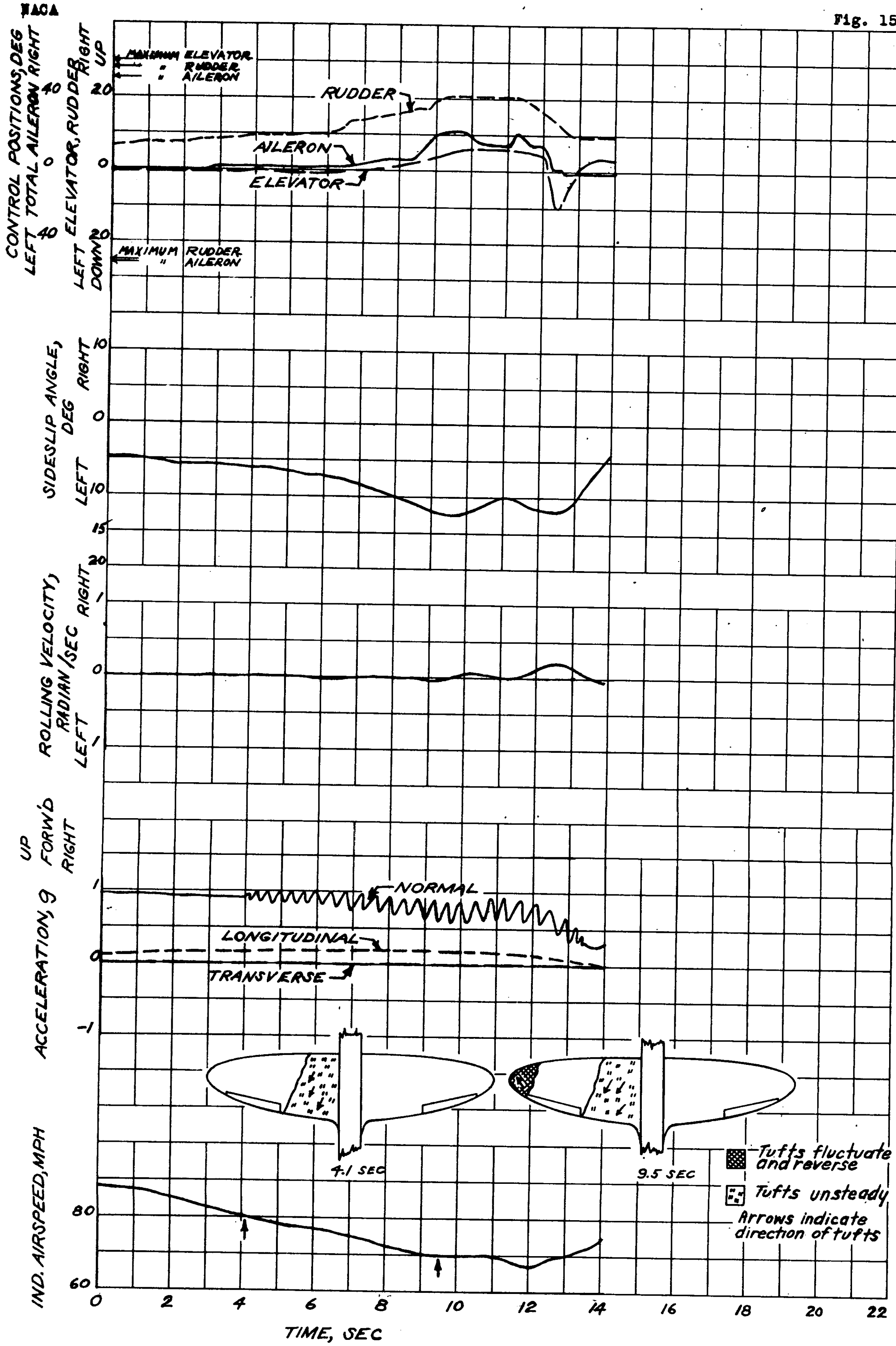

Figure 15. - Time history of a stall in the landing-approach condition with gun ports covered. Supermarine Spitfire airplane.

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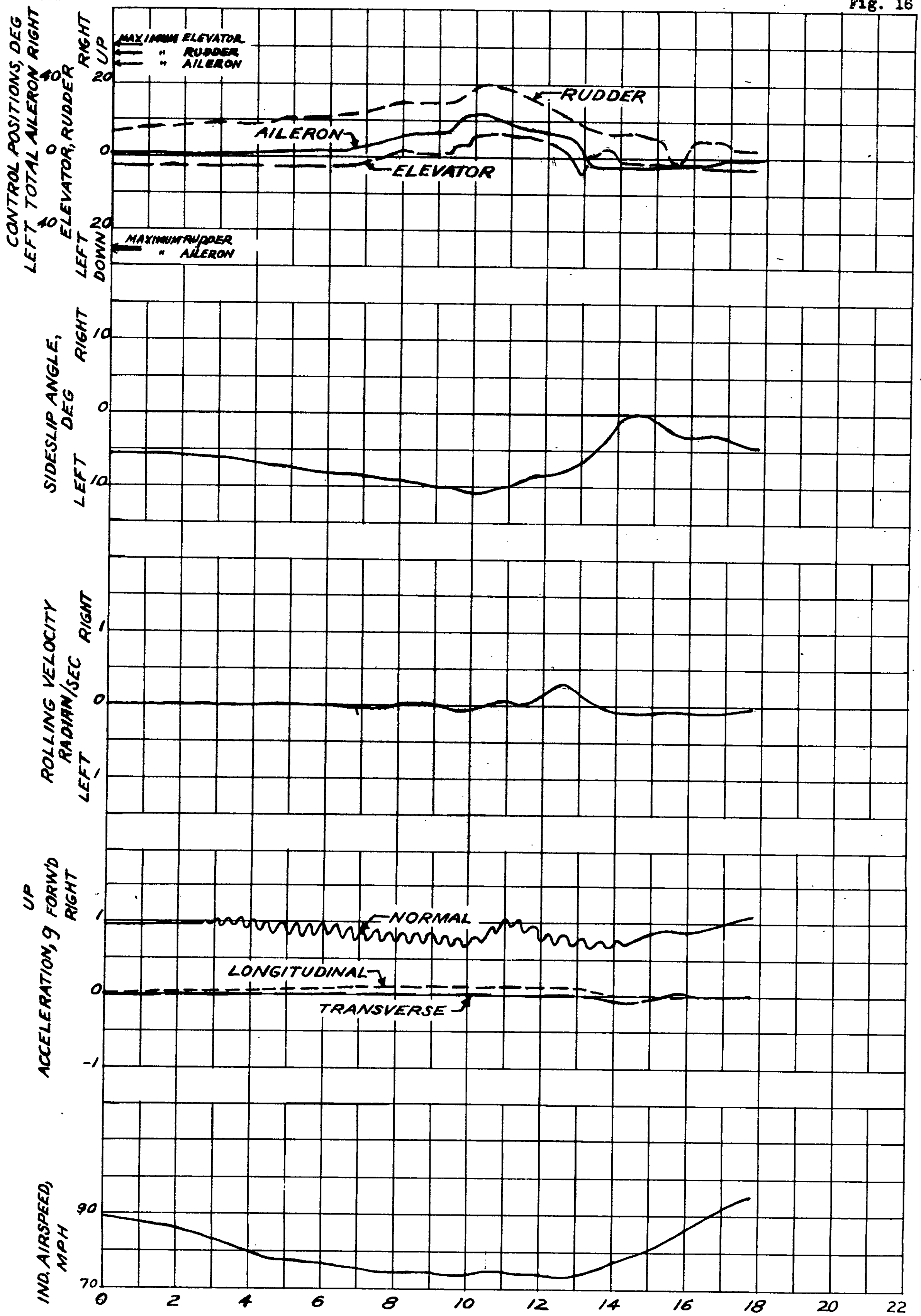

Figure 16. - Time history of a stall in the landing approach condition with gun ports open. Note slight right roll. Supermarine Spitfire airplane.

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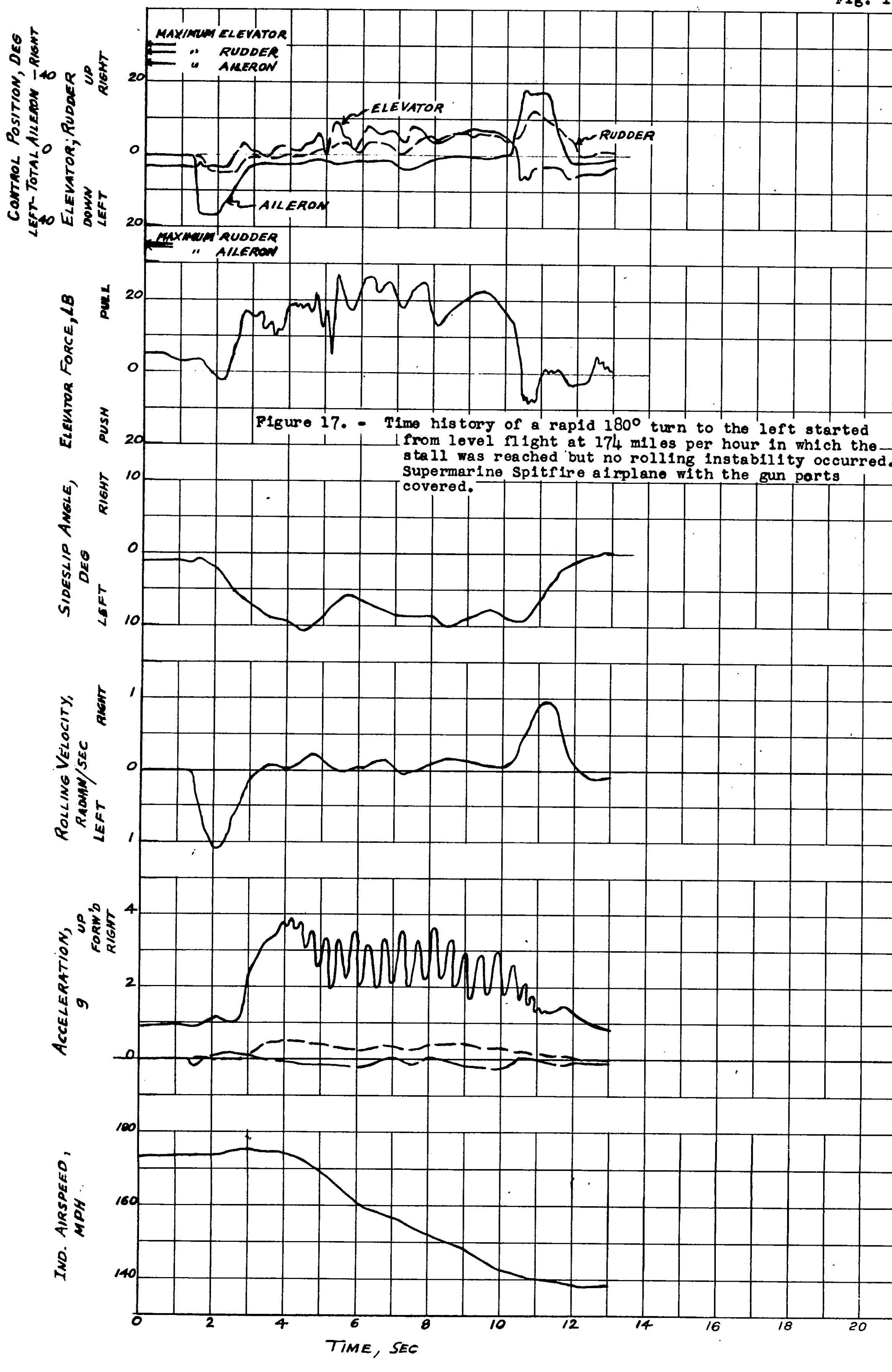

Figure 17. - Time history of a rapid 180° turn to the left started from level flight at 174 miles per hour in which the stall was reached but no rolling instability occurred. Supermarine Spitfire airplane with the gun ports covered.

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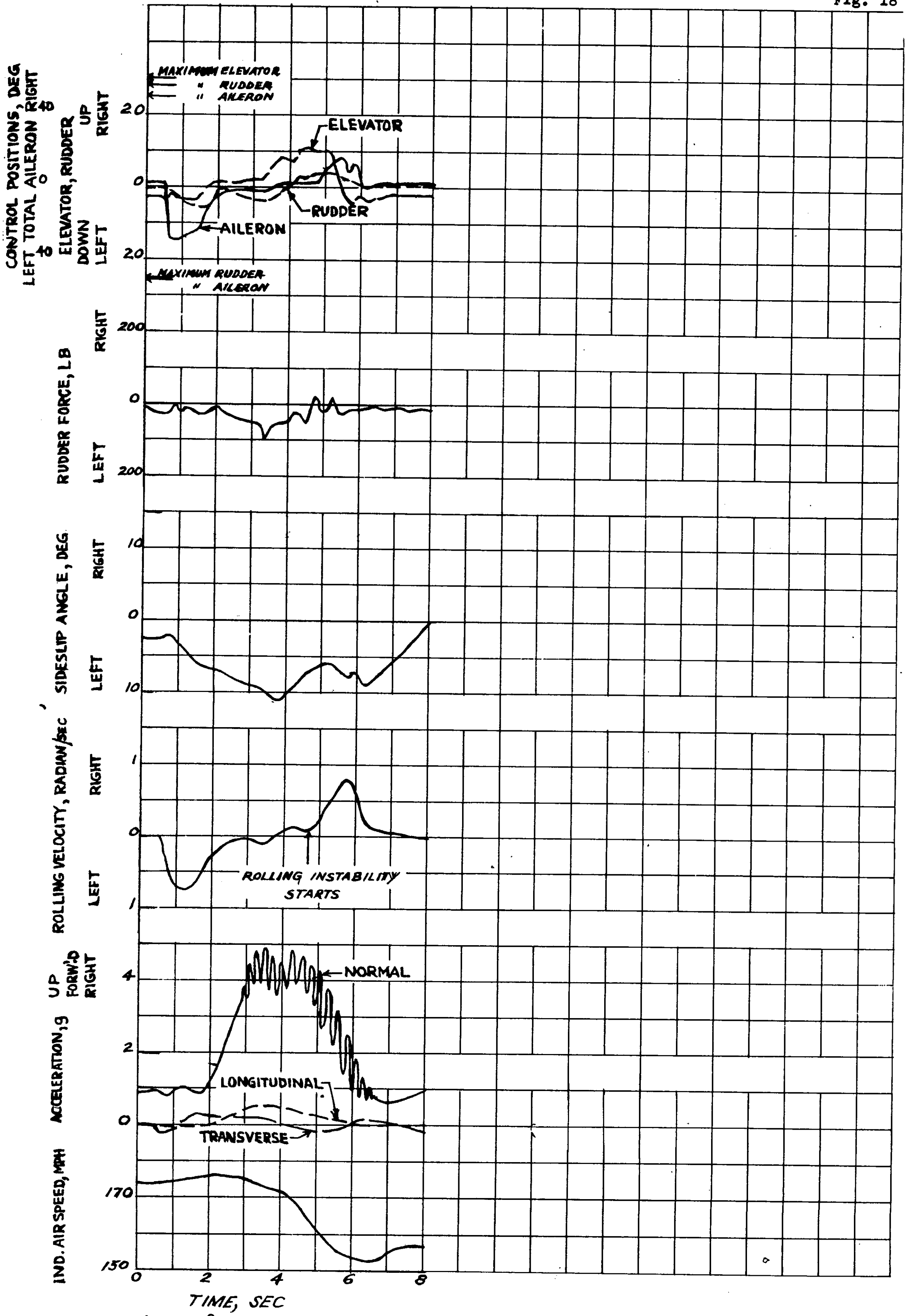

Figure 18. - Time history of a rapid turn to the left started from level flight at 174 miles per hour in which the stall was reached followed by a roll out of the turn. The aileron motion that occurred during the roll resulted from the floating tendency of the ailerons. Supermarine Spitfire airplane with gun ports open.

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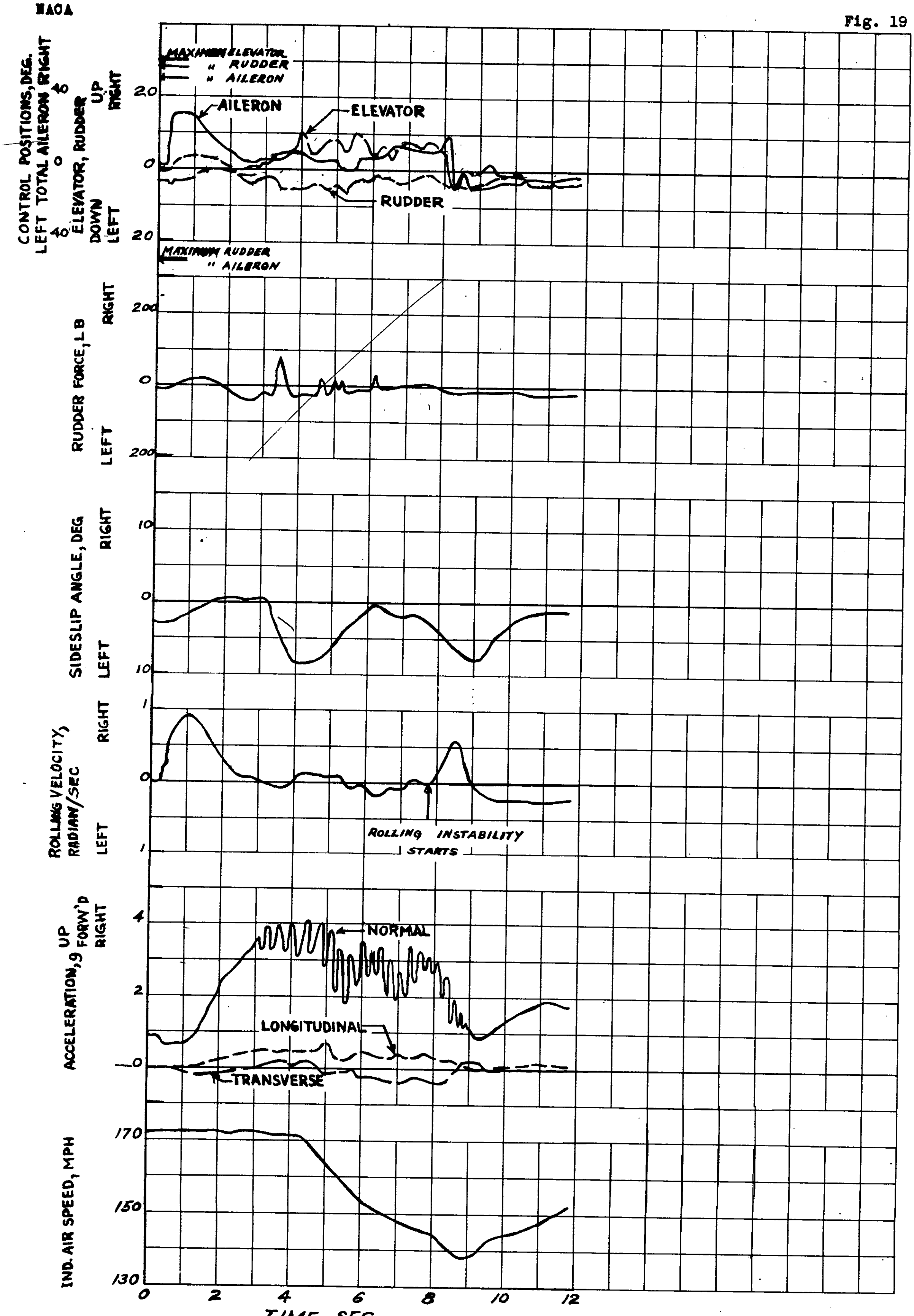

Figure 19. - Time history of a rapid turn to the right started from level flight at 172 miles per hour in which the stall was reached. The airplane subsequently rolled into the turn. The aileron motion that occurred at the start of this roll resulted from the floating tendency of the aileron. Supermarine Spitfire airplane with gun ports open.