NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED
February 1946 as
Advance Restricted Report L5I20

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By Paul A. Hunter and John P. Reeder

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

WASHINGTON

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FLIGHT MEASUREMENTS TO DETERMINE EFFECT OF A SPRING-LOADED TAB ON LONGITUDINAL STABILITY OF AN AIRPLANE

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SUMMARY

In conjunction with a program of research on the general problem of stability of airplanes in the climbing condition, tests have been made of a spring-loaded tab, which is referred to as a "springy tab," installed on the elevator of a low-wing scout bomber. The tab was arranged to deflect upward with decrease in speed, which caused an increase in the pull force required to trim at low speeds and thereby increased the stick-free static longitudinal stability of the airplane.

It was found that the springy tab would increase the stick-free stability in all flight conditions, would reduce the danger of inadvertent stalling because of the definite pull force required to stall the airplane with power on, would reduce the effect of center-of-gravity position on stick-free static stability, and would have little effect on the elevator stick forces in accelerated flight. Another advantage of the springy tab is that it might be used to provide almost any desired variation of elevator stick force with speed by adjusting the tab hinge-moment characteristics and the variation of spring moment with tab deflection. Unlike the bungee and the bobweight, the springy tab would provide stick-free static stability without requiring a pull force to hold the stick back while taxying. A device similar to the springy tab may be used on the rudder or ailerons to eliminate undesirable trim-force variations with speed.

INTRODUCTION

The National Advisory Committee for Aeronautics has initiated a program of research on the general problem of the stability of airplanes in the climbing condition. In conjunction with this program, a member of the NACA staff suggested a device that increases the stick-free stability at low speeds and yet does not affect the stick-free stability at high speeds. This device consists of a spring-loaded tab on the elevator. This tab is arranged to deflect upward with respect to the elevator and to cause an increased pull force for trim at low speeds. As the speed is increased, the upward tab deflection, and therefore the increment of pull force, is decreased until at high speed the tab reaches a stop in its neutral position and has no further effect on the elevator forces.

A tab of this type, referred to herein as a "springy tab," was built and installed on the right elevator of a low-wing scout bomber. Eight flight tests were made of the airplane with the springy-tab installation. The data obtained in these flights are compared herein with data previously obtained for the same airplane with the production tab locked.

APPARATUS

A side view of the airplane used in this investigation is shown in figure 1. The production models of the airplane tested incorporate a tab on the right elevator that is designed as a balancing tab but is usually locked. This tab was utilized for the springy-tab installation. The springy tab was statically and dynamically overbalanced by moving its hinge line rearward 0.25 inch and by adding weight to its leading edge. For the springy-tab installation, the elevator mass balance was increased to obtain the original mass overbalance of the elevator. A plan view of the stabilizer, elevator, and tab is shown in figure 2.

A spring was installed as shown in figure 3 to provide a moment about the tab hinge line. The link connecting the spring to the tab was pivoted on the tab at a point behind the hinge line so that the gradient of tab hinge moment with deflection could be made either stable or unstable by adjusting the geometry of the system and the spring characteristics. A small subtab was attached to the trailing edge of the springy tab in order to adjust the floating angle of the tab, and stops were provided to limit the upward deflection of the springy tab to 21° and the downward deflection to 0°. Photographs of the springy-tab installation are given as figures 4 and 5. Unless otherwise noted, the variation of springy-tab hinge moment with springy-tab angle (as measured on the ground) was as shown in figure 6 and the angle of the subtab upward from the springy-tab center line was approximately 6.5°.

The relation between the elevator angle, measured from the stabilizer, and the stick position is shown in figure 7. The friction in the elevator system is indicated in figure 8 to be of the order of $\pm 2\frac{1}{2}$ pounds. The airplane was fitted with a bobweight that required a stick pull force of approximately 5 pounds. The bobweight, which was installed for the tests of the airplane with the original tab and with the springy tab, is a production installation and had no effect on the relative stability of the two configurations. Elevator angle, elevator stick force, springy-tab angle, velocity, acceleration, and time were determined from standard NACA recording instruments. Elevator angles were measured from the stabilizer in all cases. The airspeed used throughout, called correct service indicated airspeed, is the airspeed that would be given by a standard AN airspeed meter if it were connected to a pitot-static system free from position error and is defined by

$$V_{i_s} = 45.08\, f_o \sqrt{q_c}$$

where

V_{i_s} correct service indicated airspeed, miles per hour

f_o standard sea-level compressibility correction factor

q_c measured difference between total and static pressures corrected for pitot-static position error, inches of water

The elevator-system mechanical advantage was changed between the time that the tests of the airplane with the original tab and the tests of the airplane with the springy tab were made. The stick forces for the airplane with the original tab, however, have been corrected to correspond to the mechanical advantage of the airplane with the springy tab installed.

RESULTS AND DISCUSSION

Static Longitudinal Stability

The first several flights were made to adjust the characteristics of the springy tab to give the desired effects on the static longitudinal stability. In these flights, the speed range over which the tab operated was found to be too small and the friction in the tab system, too large. These faults were corrected by adjusting the tension in the spring, by adjusting the angle of the subtab, by changing the position of the link joint on the tab, and by installing ball bearings in all moving joints of the springy-tab system. Unless otherwise noted, the data on static longitudinal stability are from flights made subsequent to these changes.

Figures 9(a), 10(a), 11(a) and (b), and 12(a) show the static longitudinal stability characteristics of the airplane at both forward and rearward center-of-gravity positions with the springy tab installed. The test flight conditions are defined in table I. Comparable data previously obtained with the airplane having the original tab locked at zero deflection are shown in figures 9(b), 10(b), 11(c) and (d), and 12(b). The stick-free stability characteristics of the airplane with the original tab and of the airplane with the springy tab are compared in figure 13 for the climbing and gliding conditions at the rearward center-of-gravity position. The points indicated as spot runs were obtained from short records taken while the airplane was in equilibrium in a given flight condition. The points designated continuous runs were read from longer records during which the speed was slowly decreased.

The effects of the springy tab on the static longitudinal stability of the airplane as compared with the effects of the original tab (figs. 9 to 13) may be summarized as follows:

(1) The springy tab increased the stick-free stability in all flight conditions as manifested by larger negative

slopes of the curves of elevator stick force against airspeed. In power-on flight with the center-of-gravity position at approximately 32 percent of the mean aerodynamic chord - a condition in which the airplane with the original tab had a large degree of instability both stick fixed and stick free - the variation of stick force with airspeed became stable throughout the speed range. In the power-off conditions, for which the airplane with the original tab was stable, the pull forces required to trim at low speed were increased by the springy tab to an extent that was considered somewhat objectionable by the pilots, although the pull force never exceeded 30 pounds. Some lightening of the pull force at the stall occurred in cases in which the springy tab reached its maximum deflection a few miles per hour above the stalling speed but stick-force reversal occurred only in the landing condition at the rearward center-of-gravity position. Because the springy tab reached its stop at zero deflection at approximately 280 miles per hour, the highest speed of the springy-tab tests, it would be expected to have no effect on the stability at higher speeds.

(2) The springy tab tended to reach maximum deflection at a speed near the stalling speed for all flight conditions despite the variation of stalling speed with flight condition. The increased dynamic pressure on the tail in power-on conditions probably accounts for the fact that the tab reached its maximum deflection at a lower speed in these conditions.

(3) The springy tab reduced the effect of center-of-gravity position on the stick-free static stability. The curves of elevator stick force against airspeed, with the springy tab installed, almost coincide in the low-speed range at the two center-of-gravity positions tested. The increased up-elevator deflections required for trim with the more-forward center-of-gravity positions resulted in smaller upward deflections of the tab because of the aerodynamic hinge moment, due to elevator deflection, acting on the tab.

(4) The stick-fixed static longitudinal stability was slightly decreased by the action of the springy tab, as shown by the smaller up-elevator or larger down-elevator deflections required for trim at low speeds with the springy tab in operation.

Dynamic Longitudinal Stability

The results of the static-stability measurements indicated that the airplane with the springy tab installed was stable with the stick free in all flight conditions. For conditions in which a large amount of stick-fixed instability existed, it was considered desirable to investigate whether the airplane with the springy tab installed would tend to return to its trim speed if the speed were changed slightly and the control stick released. The results of tests made in the climbing and gliding conditions in which the stick was released at a speed slightly above the trim speed are given in figure 14. In the climbing condition (fig. 14(a)), the airplane did not tend to return to its trim speed but instead the speed increased slightly at first. The stable variation of stick force with speed in this condition (fig. 9(a)) would give a change in stick force of less than 2 pounds for this change in trim speed. This amount of change in stick force is less than the friction in the elevator control system. The elevator therefore remained essentially fixed during this maneuver and the initial divergence from the trim speed was caused by the stick-fixed instability in this flight condition. Some slight up-elevator motion occurred near the end of the maneuver and prevented the speed from continuing to increase; in fact, the speed apparently began to decrease slightly.

In the gliding condition (fig. 14(b)), the airplane initially tended to return to its trim speed. That this stable tendency was due largely to the action of the springy tab may be seen from the motion of the elevator when the stick was released. The airplane also had a small amount of stick-fixed stability in this condition (fig. 10(a)). Some lag in the action of the tab is indicated in figure 14(b) and may have been caused partly by the small amount of friction in the tab system and partly by the elevator motion. Because the airplane was not in steady flight, the elevator angles in these tests did not bear the same relation to airspeed as in the static-stability tests (fig. 10(a)). The lag in the action of the tab may have caused the instability of the long-period oscillation shown in this figure. The stability of the oscillation for the airplane with the original tab was not investigated. Since the characteristics of the long-period oscillation have been shown by previous investigations to have no correlation with the handling qualities of an airplane, the oscillation shown in figure 14(b) is not believed to be objectionable.

The failure of the springy tab to cause the airplane to tend to return to its trim speed when disturbed, in flight conditions in which the airplane was very unstable with stick fixed, indicates that this device cannot overcome a deficiency in stick-fixed stability, at least not with the same amount of friction as was present in the control system during these tests. The pilots did not consider the characteristics of the airplane to be satisfactory for any flight condition in which it was unstable with stick fixed, although they believed that the control characteristics were improved by the springy tab.

One advantage of the springy tab is the reduced danger of inadvertent stalling. With the springy tab in operation, a definite pull force was required to stall the airplane; whereas, with the original tab, a large push force was required to prevent the stall in power-on conditions.

Accelerated Flight

The variation of elevator stick force and springy-tab angle with normal acceleration in turns at 196 miles per hour is shown in figure 15. Comparable data for the airplane with the original tab are given in figure 16. The springy tab appeared to have little effect on the elevator stick forces in accelerated flight. For the springy-tab system, the test results showed a slightly lower slope of the curve of elevator stick force with normal acceleration at rearward center-of-gravity positions, as may be seen by comparing figures 15 and 16. The effect of the tab on the force per g normal acceleration would be expected to be greater with the more-forward center-of-gravity positions because a larger change in elevator angle would be required to produce a given acceleration and a greater tendency for the tab to float down would exist. The slight friction in the tab system may have caused the flight measurements to differ from the expected tendency.

Take-Offs

Time histories of take-offs of the airplane with a forward center-of-gravity position are given in figures 17(a) and (b) for the springy-tab installation and for the original tab installation, respectively. The time history of a take-off with a rearward center-of-gravity position and the springy-tab installation is given in figure 17(c). With the springy tab, the airplane was said to exhibit a tendency toward automatic take-off. Several of the pilots stated that at the start of the take-off the elevator moved down and then at an airspeed of about 80 miles per hour moved up of its own accord and pulled the airplane off the ground. The action of the springy tab that produced this tendency may be seen in figures 17(a) and 17(c). At the start of the take-off the springy tab was at its maximum up deflection, which produced a down-elevator movement; at about 70 miles per hour, the springy tab started to move down and thereby permitted the elevator to move up. Comparison of the elevator stick forces for the springy-tab installation (fig. 17(a)) with those of the airplane with the original tab (fig. 17(b)) shows the forces required for the airplane with the springy tab to be less than those for the airplane with the original tab. Approximately one-half as much push force was required with the springy tab to lift the tail off the ground although the down-elevator deflections were greater with this installation.

Trim-Force Changes

All pilots who flew the airplane with the springy tab commented on the apparently large trim-force change with power. This and other trim-force changes are compared in table II with those for the airplane with the original tab for speeds of 120 and 100 miles per hour. These data were obtained by trimming the airplane first in the climbing condition and making successive changes in configuration and then trimming in the landing condition and making successive changes in configuration, with records taken after each change. The pull forces required to maintain trim on closing the throttle with the flaps up were considerably larger with the springy tab installed (table II). The push forces required, however, on applying full power with the flaps down were smaller with the springy tab installed. The amount of trim-tab deflection for trim is greater by the amount required to offset the effect of the springy tab at trim speed. The minimum speed at which the airplane with the springy tab could be trimmed, when the maximum trim-tab deflection is used in the landing condition (fig. 11(a)) at either center-of-gravity position and in the approach condition (fig. 11(b)) at the forward center-of-gravity position, was rather high, particularly in the landing condition. As shown in figure 11(a), a force of 22 pounds was required for trim in the landing condition at 100 miles per hour, so the trim forces shown in table II for this condition do not correspond to trim-force changes from a trimmed condition. The data given for the airplane with the original tab trimmed at 100 miles per hour in the landing condition were obtained by interpolation from unpublished data for an airplane of the same type as that of this investigation because data for the airplane with the original tab were not available.

Comparison of Springy Tab with Other Devices

Providing Stick-Free Stability

In a discussion of the springy tab, it might be appropriate to compare it with other devices used to improve stick-free static longitudinal stability. One device used for this purpose is a spring in the control system that exerts a moment which tends to depress the elevator. Although this device, called the bungee, will increase the stick-free stability, it has disadvantages: A pull force must be exerted by the pilot to hold the stick back while taxying and the high push forces that may be required in high-speed flight would result in excessive accelerations if the stick were released in an out-of-trim dive. The same disadvantages apply to a bobweight except that it produces an additional increase of stick force with an increase in normal acceleration, which would prevent excessive accelerations in this maneuver. The springy tab will not cause any appreciable pull force while taxying because the dynamic pressure on the tab at taxying speeds is low. In addition, the springy tab will not cause large push forces at high speed because it will then be deflected to its neutral position.

Another advantage of the springy tab over the bungee or bobweight is that the stick-force characteristics may be adjusted to obtain almost any desired elevator stick-force variation with speed. This adjustment may be accomplished by changing the aerodynamic characteristics of the tab, the spring moment at zero tab deflection, and the variation of the moment exerted by the spring with tab deflection. A force increment of almost any value can be applied at any part of the speed range of the airplane. The variation of hinge moment with deflection for the initial springy-tab configuration is shown in figure 18. The static longitudinal stability characteristics of the airplane with the initial springy-tab configuration before the changes indicated on page 4 were made are shown in figure 19. A comparison of figure 19 with figure 9(a) shows the wide variation of elevator stick-force characteristics obtained with the springy tab for the change in hinge moment between that shown in figure 18 and that shown in figure 6. It should be noted that a large increase in stick-free stability in the low-speed range, where adverse effects of power are usually greatest, may be obtained without greatly affecting the stability at higher speeds by the use of a variation of spring moment with tab deflection in which the spring moment that tends to move the tab upward increases for the larger up-tab deflections.

Because a springy tab may be used to adjust the control-force variation with speed within wide limits, it can be used on the rudder or ailerons to eliminate undesirable trim-force changes with speed.

CONCLUSIONS

From flight tests to determine the effect of a spring-loaded tab on the longitudinal stability characteristics of a low-wing scout bomber, the following conclusions were reached:

1. Compared with the original tab installation the springy tab increased the stick-free stability in all flight conditions as manifested by the larger negative slopes of the curves of elevator stick force against airspeed. In the climbing condition at a rearward center-of-gravity position - a condition in which the airplane with the original tab showed stick-free instability throughout the speed range - the airplane with the springy tab exhibited satisfactory stick-force variation with speed.

2. The pilots did not consider the characteristics of the airplane to be satisfactory for any flight condition in which it was unstable with stick fixed, although they believed that the control characteristics were improved by the springy tab.

3. The springy tab reduced the danger of inadvertent stalling because of the definite pull force required to stall the airplane with power on.

4. The springy tab may be used to provide almost any desired variation of elevator stick force with speed by adjusting the tab hinge-moment characteristics and the variation of spring moment with tab deflection.

5. The springy tab tended to reach maximum deflection at a speed near the stalling speed for all flight conditions despite the variation of stalling speed with flight condition.

6. The springy tab reduced the effect of center-of-gravity position on stick-free static stability.

7. The stick-fixed static longitudinal stability was slightly decreased by the action of the springy tab.

8. The springy tab had little effect on the elevator stick forces in accelerated flight.

9. Pull forces required to maintain trim on closing the throttle with flaps up were considerably larger with the springy tab installed than with the original configuration. The push forces required, however, on applying full power with flaps down were smaller with the springy tab installed.

10. The springy tab would provide stick-free static stability without requiring a pull force to hold the stick back while taxying, as would be required by the bungee and the bobweight.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

TABLE I

AIRPLANE CONFIGURATIONS FOR TEST FLIGHT CONDITIONS

Condition	Power		Flaps	Landing gear	Front hood	Cowl flaps
	Engine speed (rpm)	Manifold pressure (in. Hg at 5000 ft)				
Climbing	2400	38	Up	Up	Closed	Closed
Gliding	Power off	Power off	Up	Up	Closed	Closed
Landing	Power off	Power off	Down	Down	Open	Closed
Approach	2400	21	$\frac{1}{2}$ down	Down	Open	Closed
Wave-off	2400	38	Down	Down	Open	Open

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TABLE II

TRIM-FORCE CHANGES

Power: Engine speed (rpm)	Power: Manifold pressure (in. Hg at 5000 ft)	Landing gear	Flaps	Front hood	Cowl flaps	Stick force, lb: 120 mph: Airplane with springy tab; Trim tab, 10.8°; c.g. position, 26.7 (1)	Stick force, lb: 120 mph: Airplane with original tab; Trim tab, 2.8°; c.g. position, 27.0 (1)	Stick force, lb: 100 mph: Airplane with springy tab; Trim tab, 15°; c.g. position, 26.6 (1)	Stick force, lb: 100 mph: Airplane with original tab; Trim tab, 5.2°; c.g. position, 25.4 (1)
2400	38	Up	Up	Closed	Closed	0	0	0	0
Power off	Power off	Up	Up	Closed	Closed	23.0 pull	15.5 pull	24.0 pull	11.0 pull
Power off	Power off	Down	Up	Closed	Closed	24.5 pull	14.0 pull	25.5 pull	15.5 pull
Power off	Power off	Down	Down	Closed	Closed	20.0 pull	12.5 pull	20.0 pull	9.5 pull
Power off	Power off	Down	Down	Open	Closed	19.5 pull	9.5 pull	21.0 pull	10.0 pull
2400	38	Down	Down	Open	Open	2.5 push	2.0 pull	4.5 push	5.0 push
2400	21	Down	$\frac{1}{2}$ down	Open	Closed	9.0 pull	8.0 pull	21.5 pull	6.5 pull

Power: Engine speed (rpm)	Power: Manifold pressure (in. Hg at 5000 ft)	Landing gear	Flaps	Front hood	Cowl flaps	Stick force, lb: 120 mph: Airplane with springy tab; Trim tab, 15°; c.g. position, 26.5 (1)	Stick force, lb: 120 mph: Airplane with original tab; Trim tab, 12.5°; c.g. position, 26.6 (1)	Stick force, lb: 100 mph: Airplane with springy tab; Trim tab, 15°; c.g. position, 26.4 (1)	Stick force, lb: 100 mph: Airplane with original tab; Trim tab, 12.6°; c.g. position, 26.4 (1)
Power off	Power off	Down	Down	Open	Closed	0	0	22.0 pull	0
2400	21	Down	$\frac{1}{2}$ down	Open	Closed	.5 pull	4.5 push	9.5 pull	------------------
2400	38	Down	Down	Open	Open	10.5 push	22.5 push	1.0 push	25.5 push
2400	38	Up	Down	Open	Open	10.5 push	22.5 push	5.0 push	29.0 push
2400	38	Up	Up	Open	Open	9.0 push	20.5 push	.5 pull	26.0 push
2400	38	Up	Up	Closed	Open	9.0 push	20.5 push	1.0 pull	25.0 push
Power off	Power off	Up	Up	Closed	Closed	18.5 pull	------------------	4.0 pull	------------------

[1]Trim-tab deflections are in direction for nose up and c.g. positions are in percent mean aerodynamic chord.

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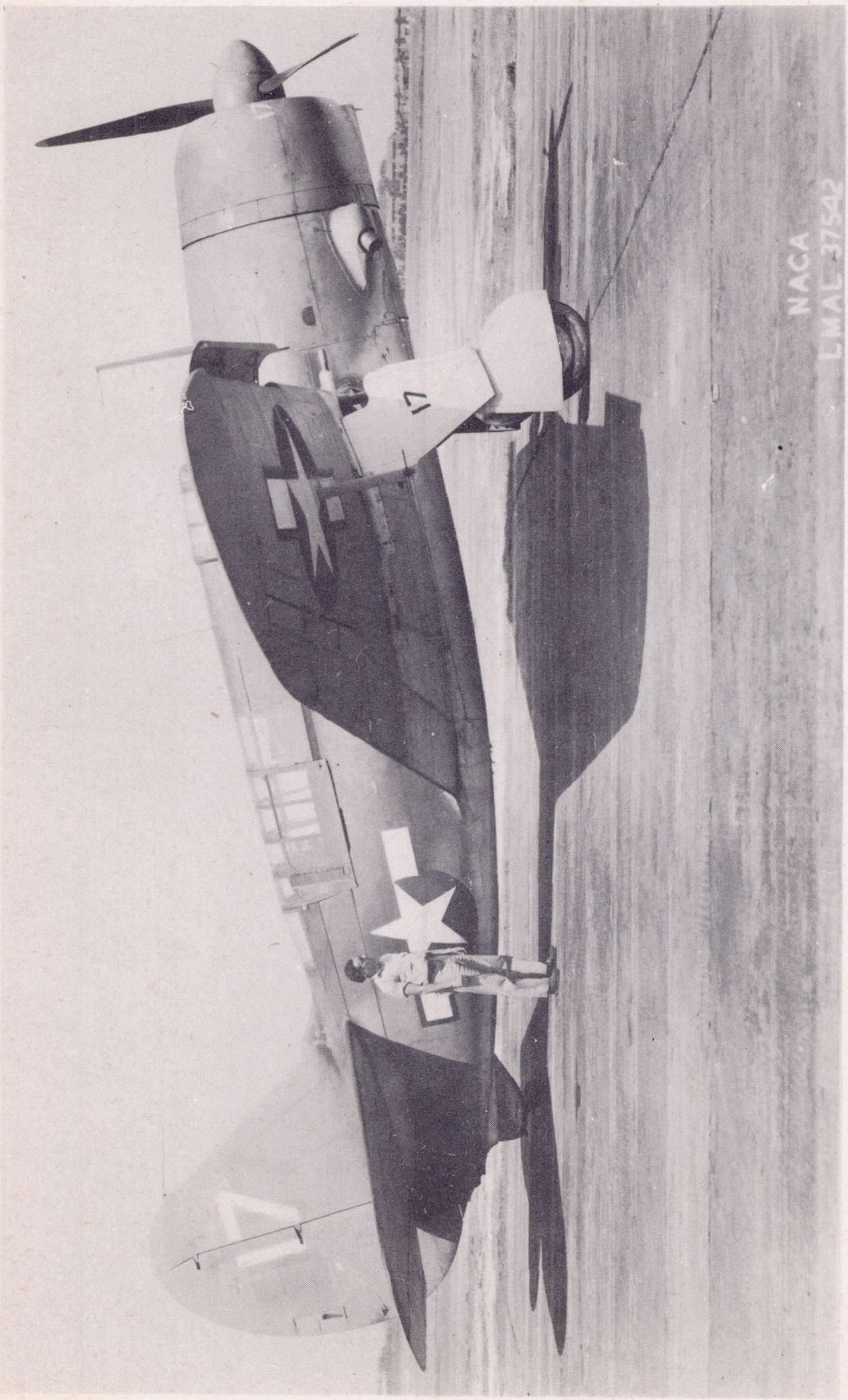

Figure 1.- Side view of the low-wing scout bomber used in the investigation.

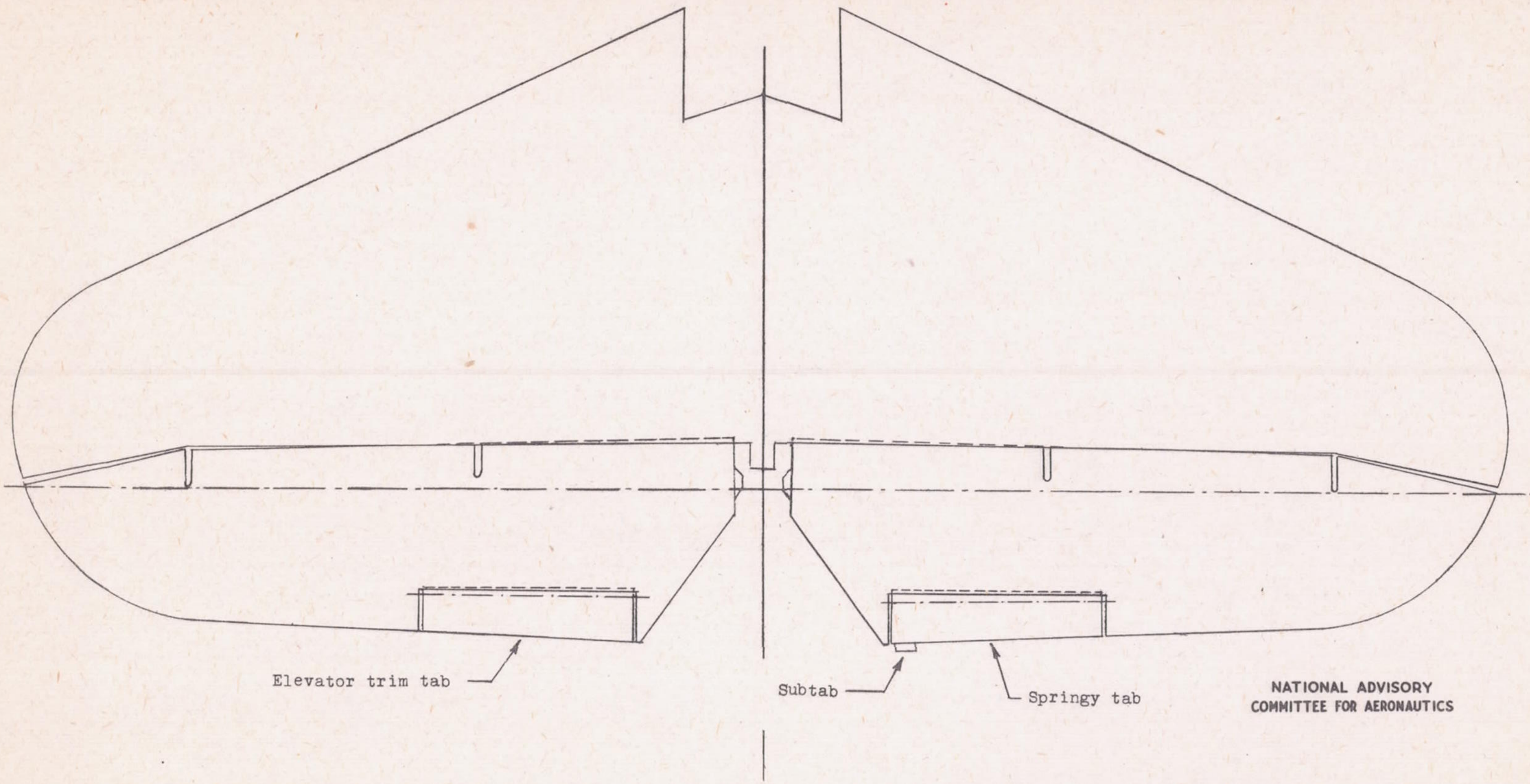

Figure 2.- Plan view of the stabilizer, elevator, and tab used in the tests.

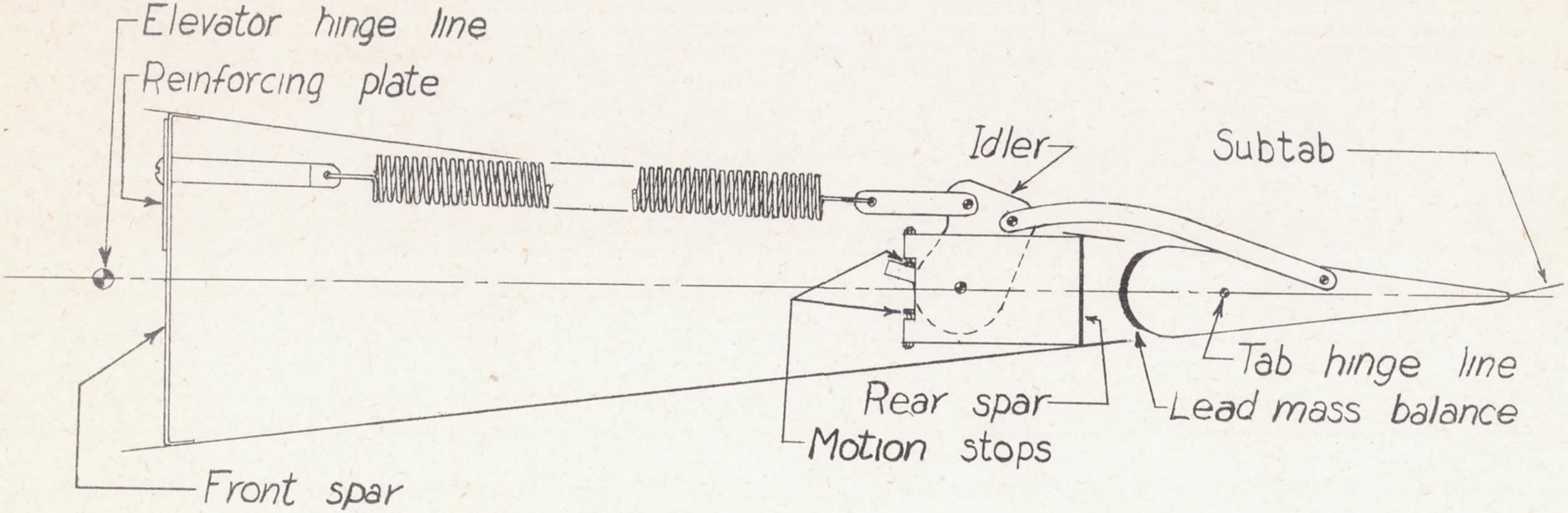

Figure 3.- Diagram of the springy-tab test installation.

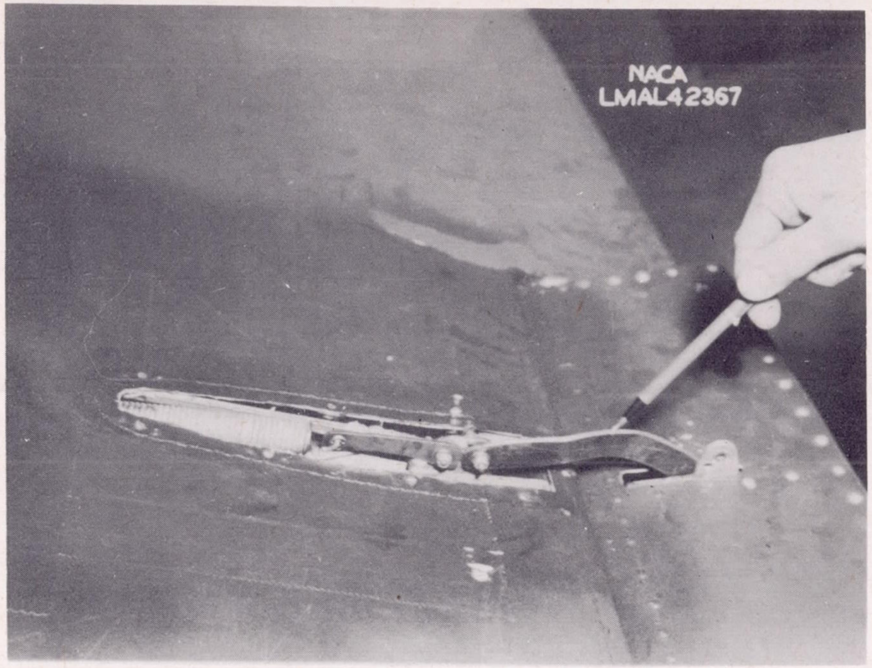

Figure 4.- Uncovered springy-tab mechanism installed on the elevator.

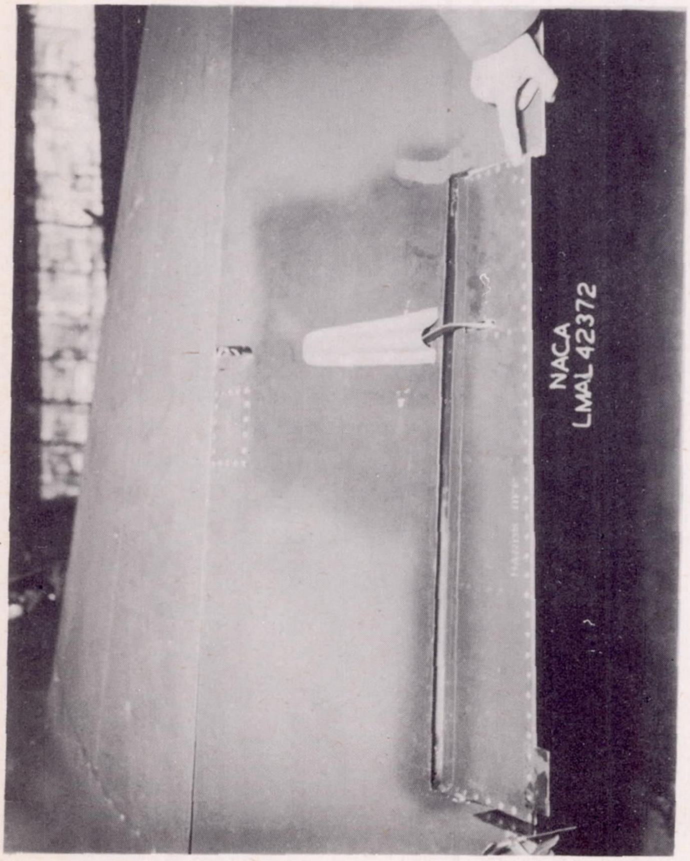

Figure 5.- Springy-tab mechanism as covered for flight.

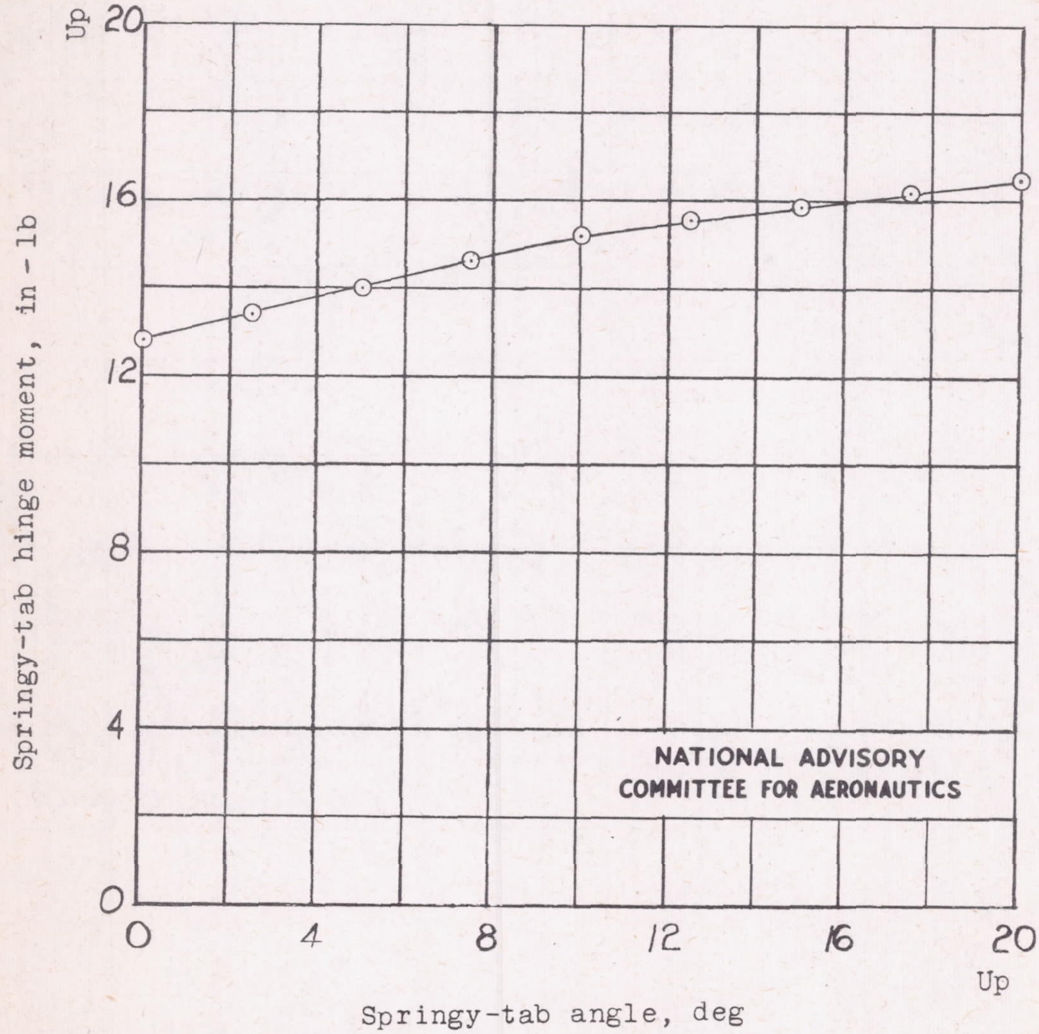

Figure 6.- Variation of springy-tab hinge moment with springy-tab angle (as measured on the ground).

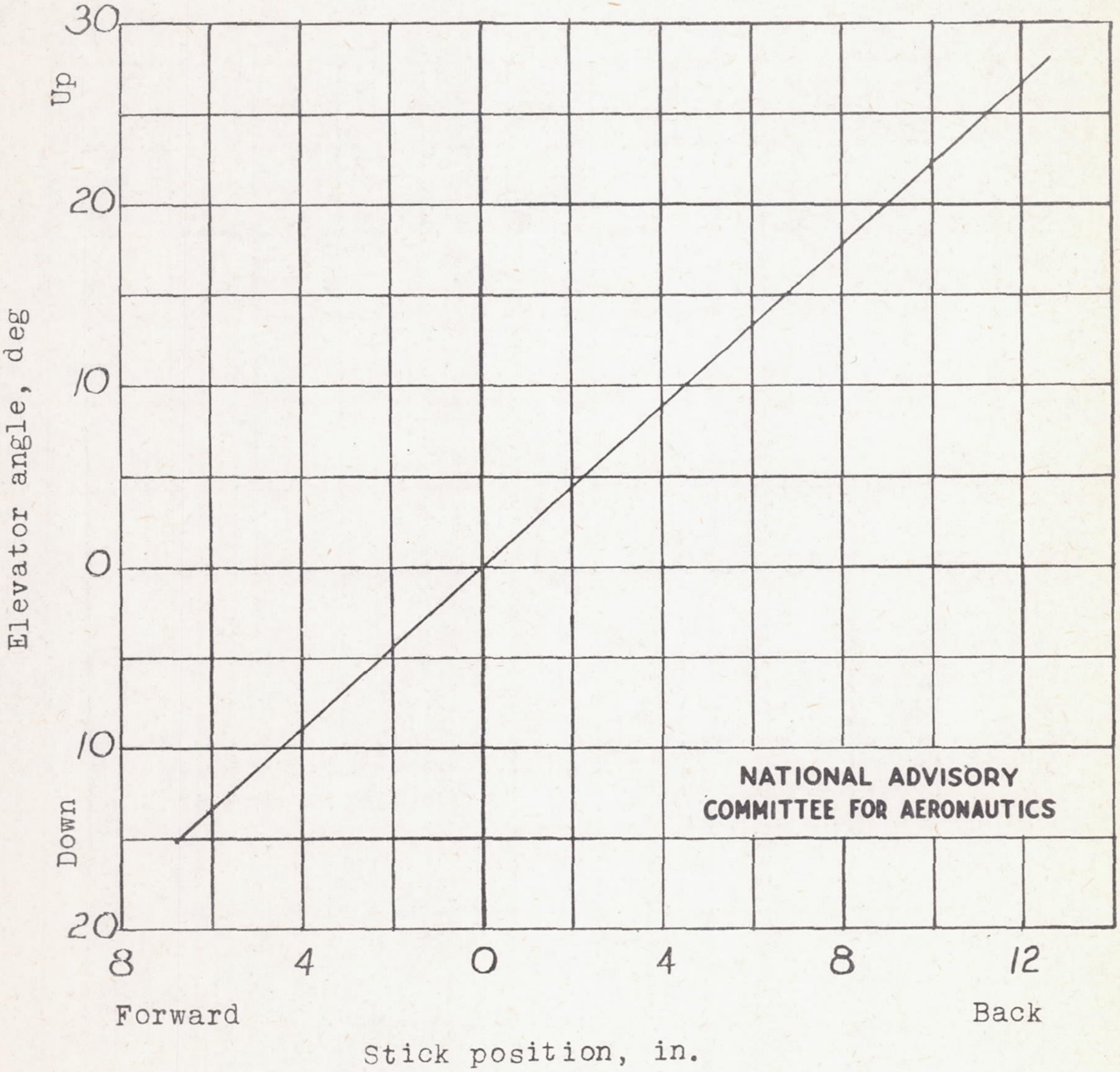

Figure 7.- Variation of elevator angle, measured from the stabilizer, with stick position for the test airplane.

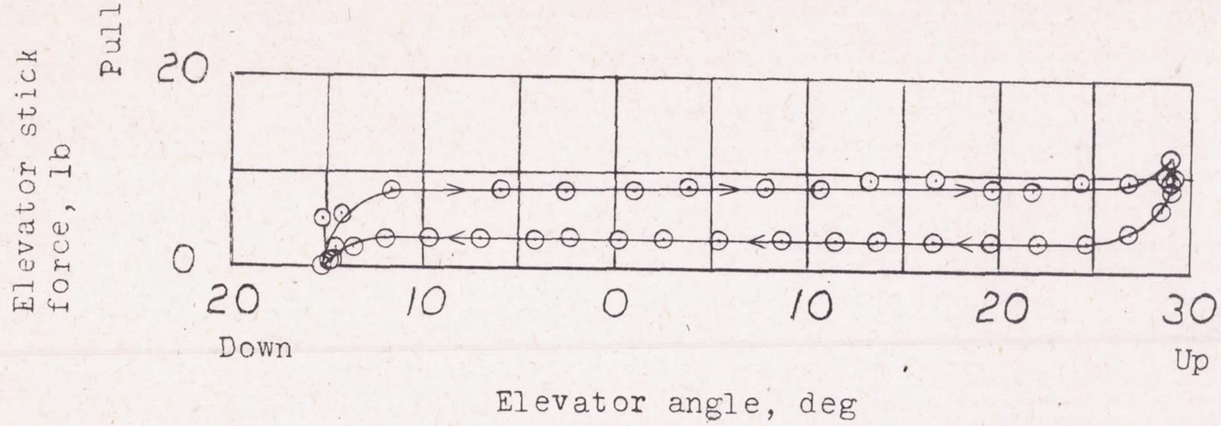

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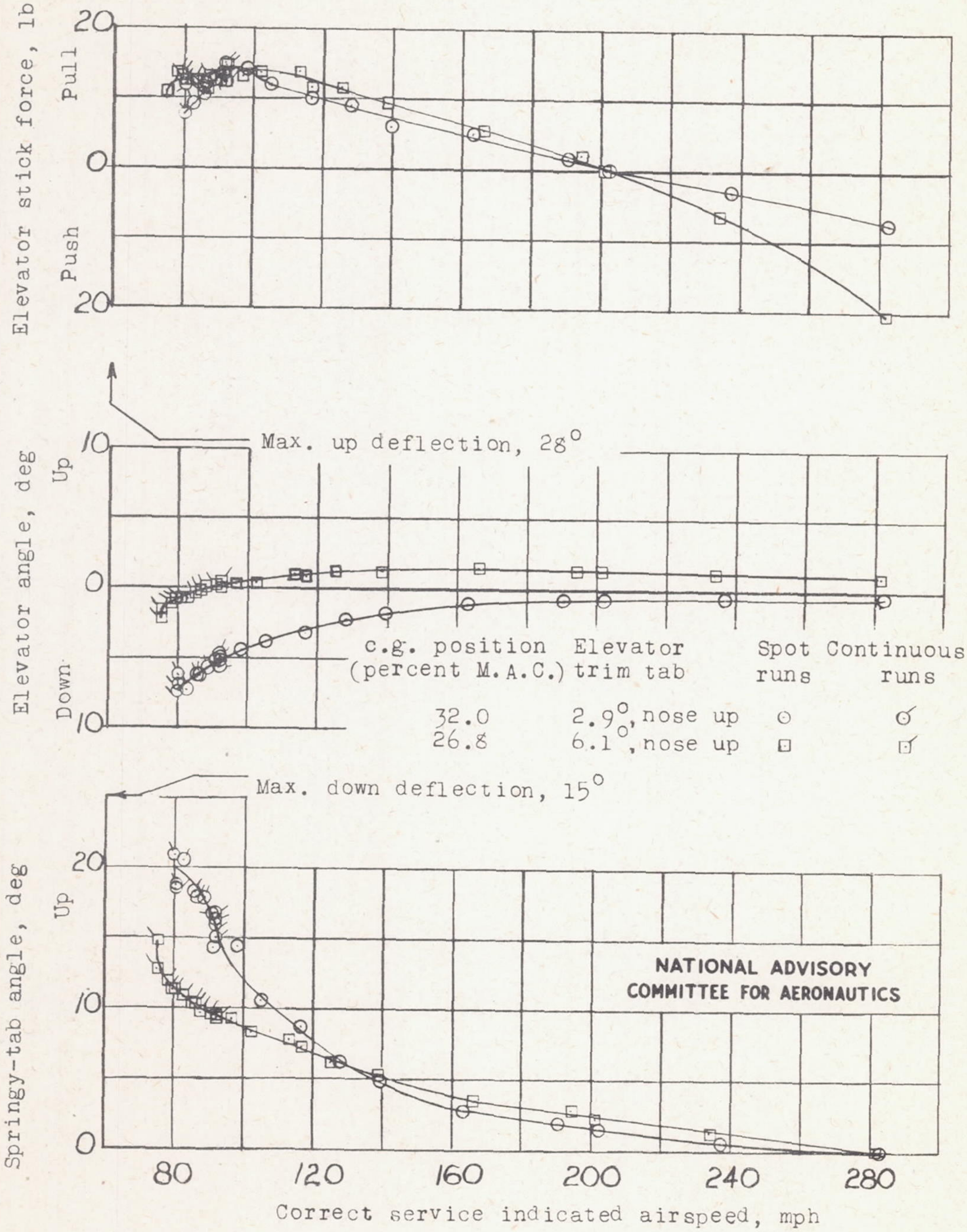
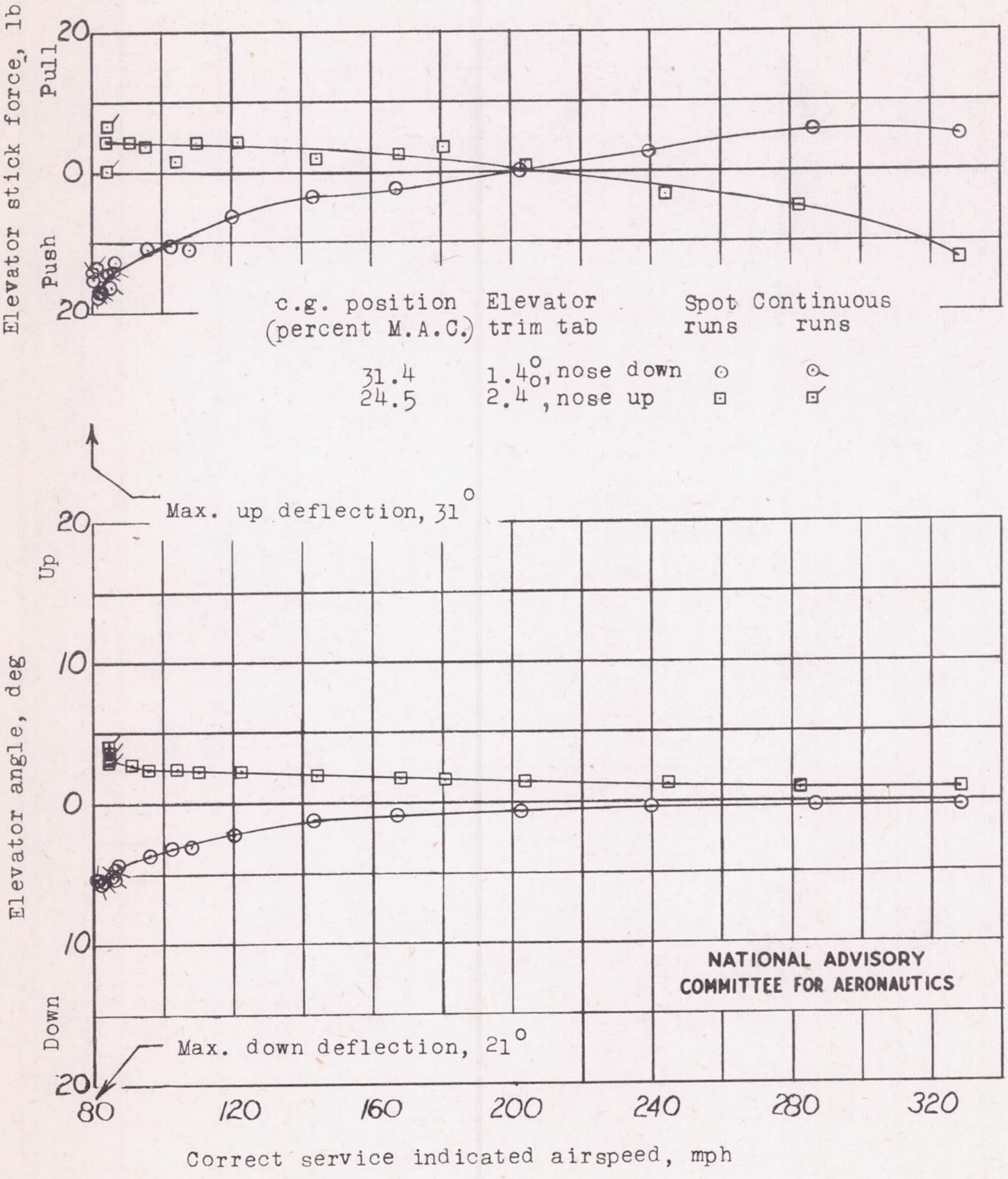
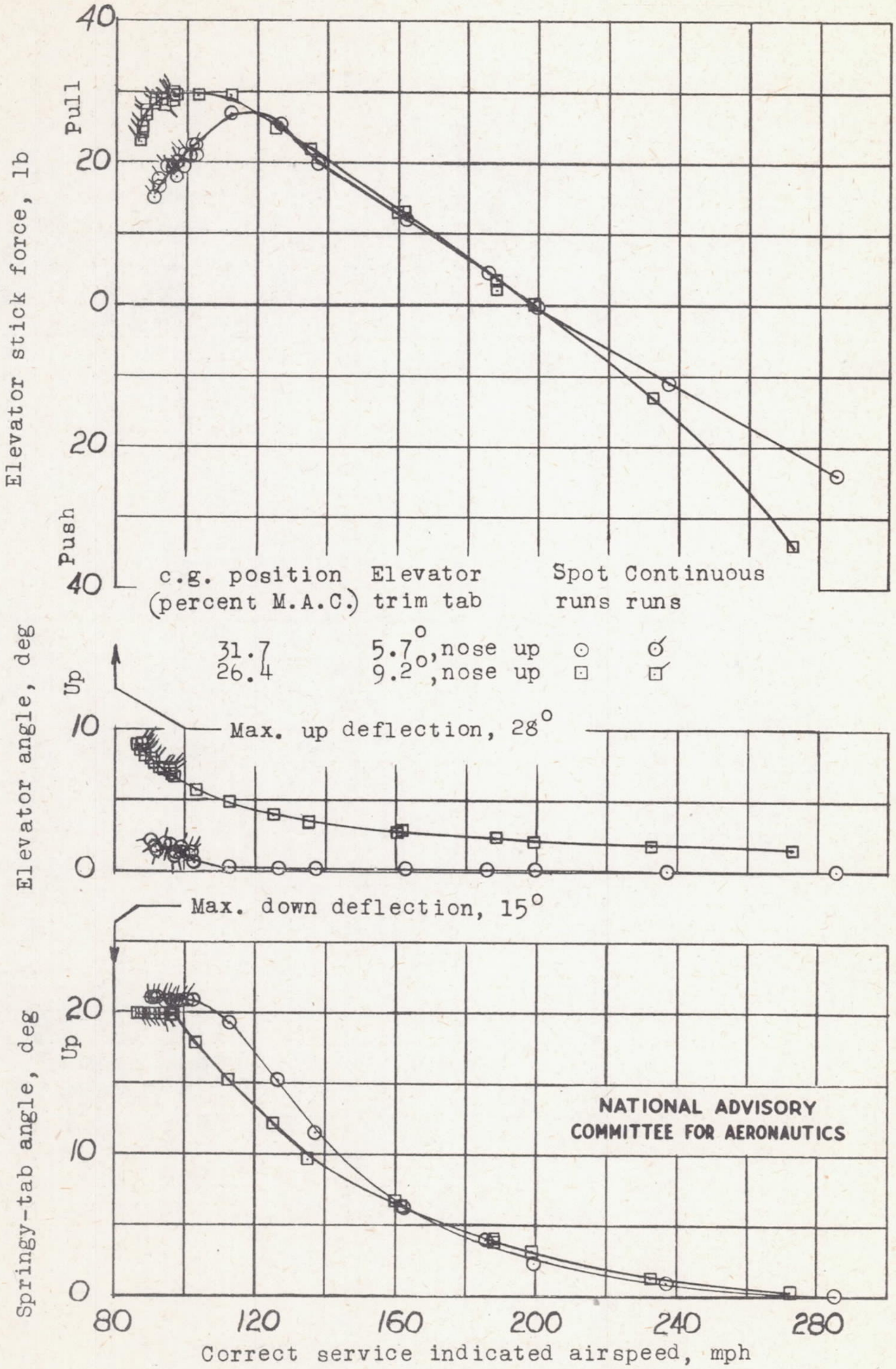
Figure 8.- Elevator stick force required to move the elevator slowly (as measured on the ground).



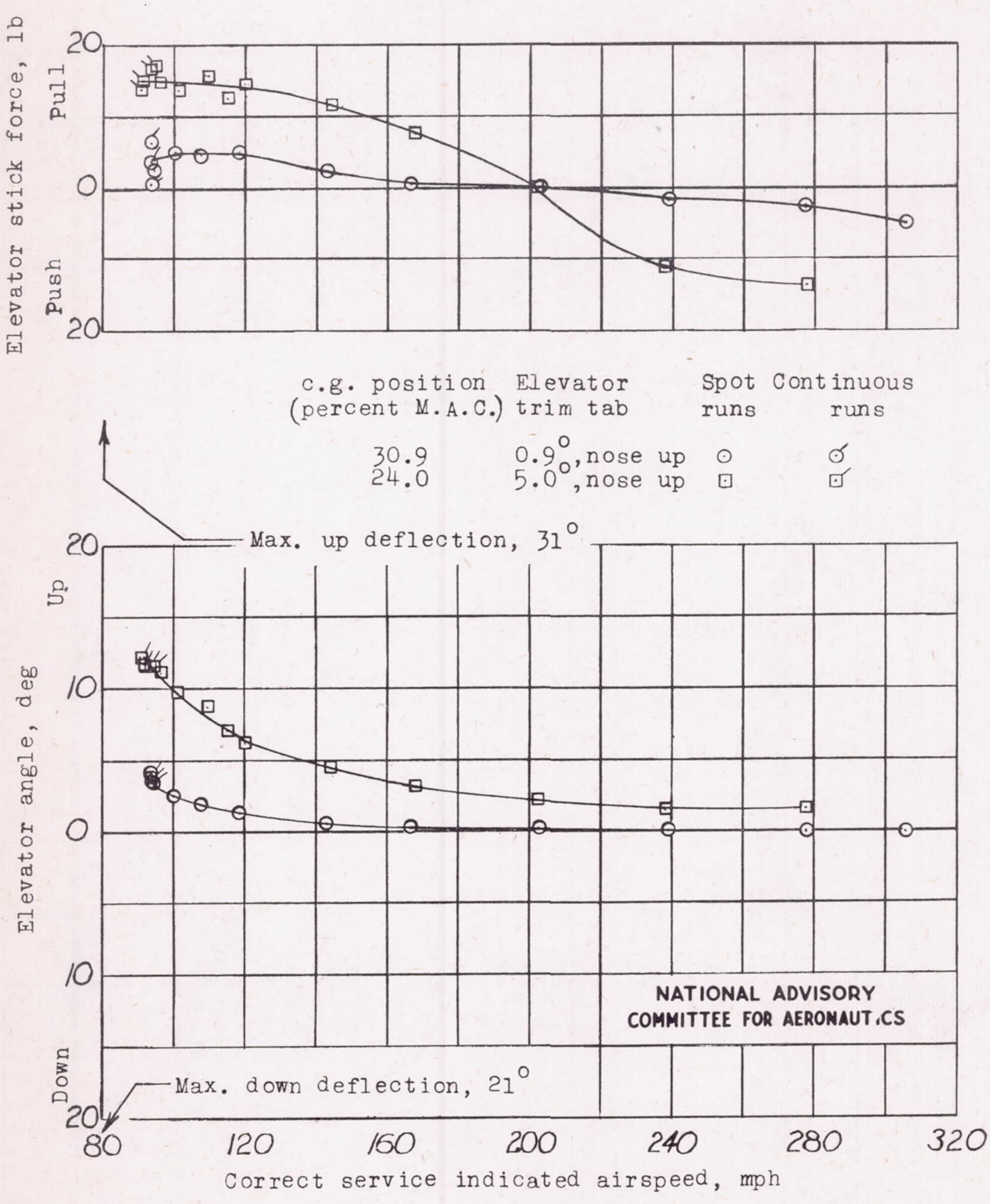
(a) Airplane with springy tab installed on elevator.
Figure 9.- Static longitudinal stability characteristics in the climbing condition.



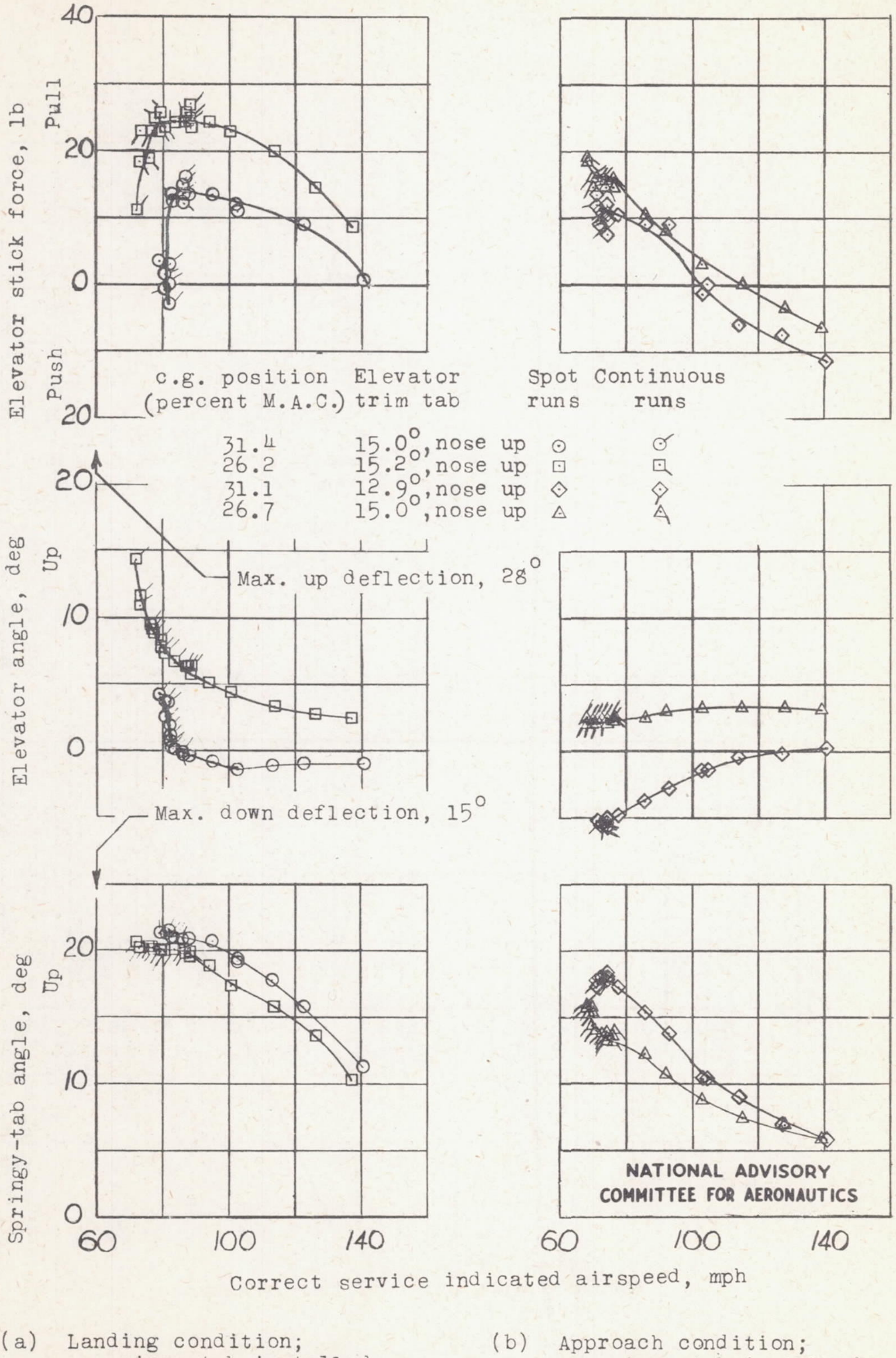
(b) Airplane with original tab on elevator locked.
Figure 9.- Concluded.



(a) Airplane with springy tab installed on elevator.
Figure 10.- Static longitudinal stability characteristics in the gliding condition.



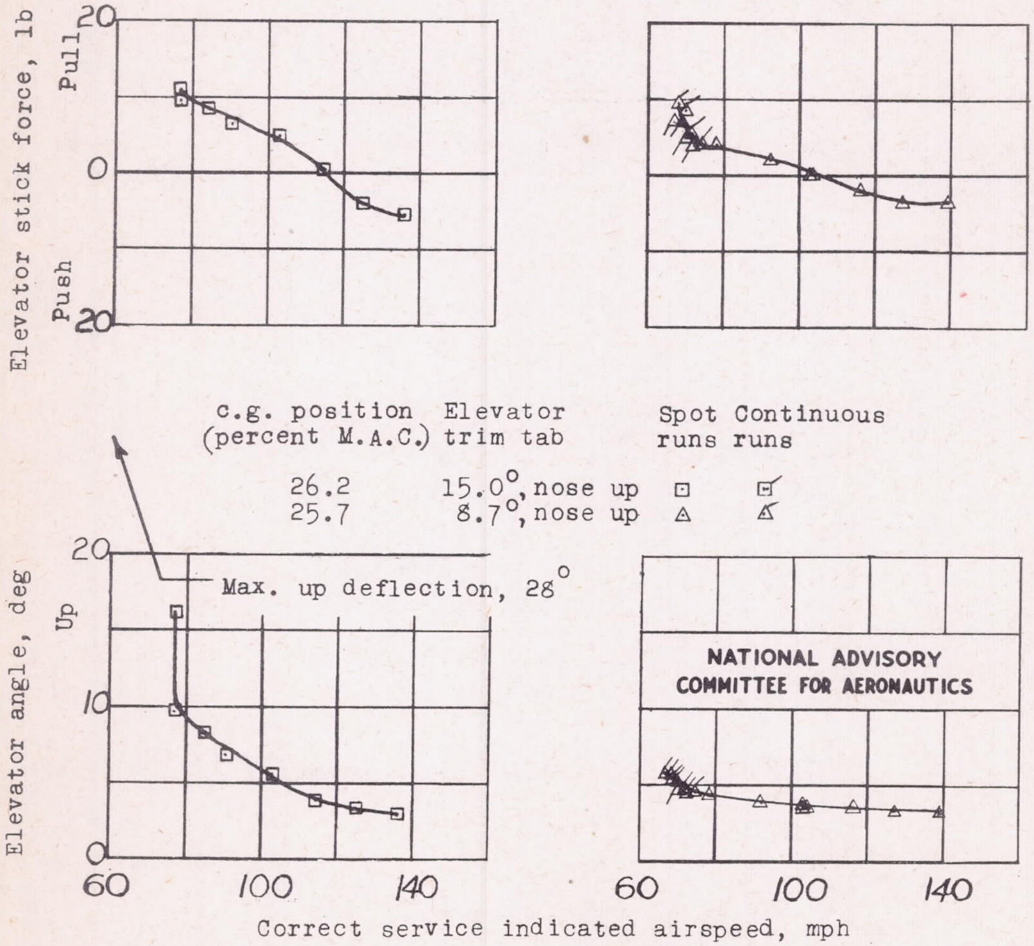
(b) Airplane with original tab on elevator locked.
Figure 10.- Concluded.



(a) Landing condition; springy tab installed on elevator.

(b) Approach condition; springy tab installed on elevator.

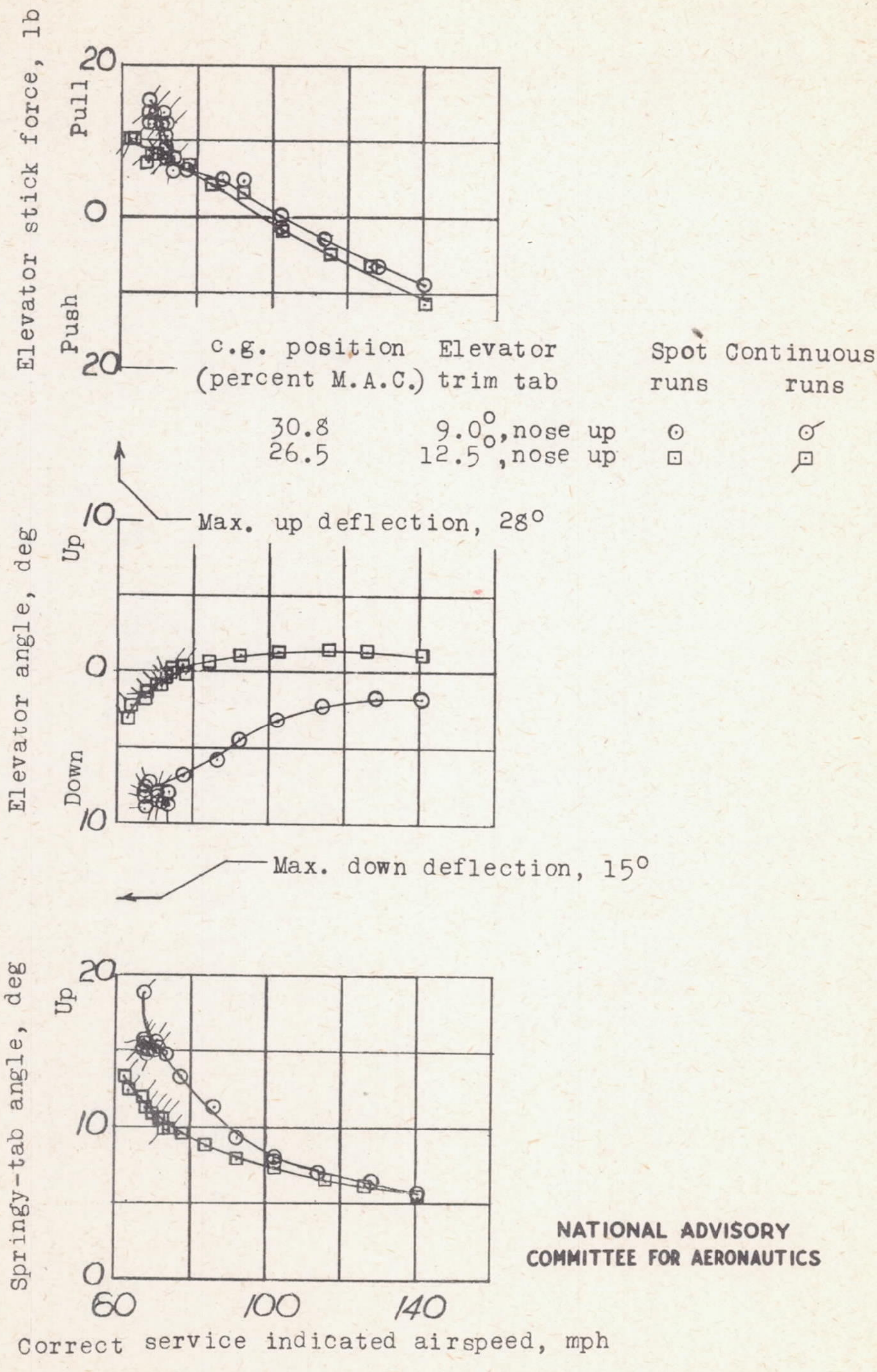
Figure 11.- Static longitudinal characteristics.



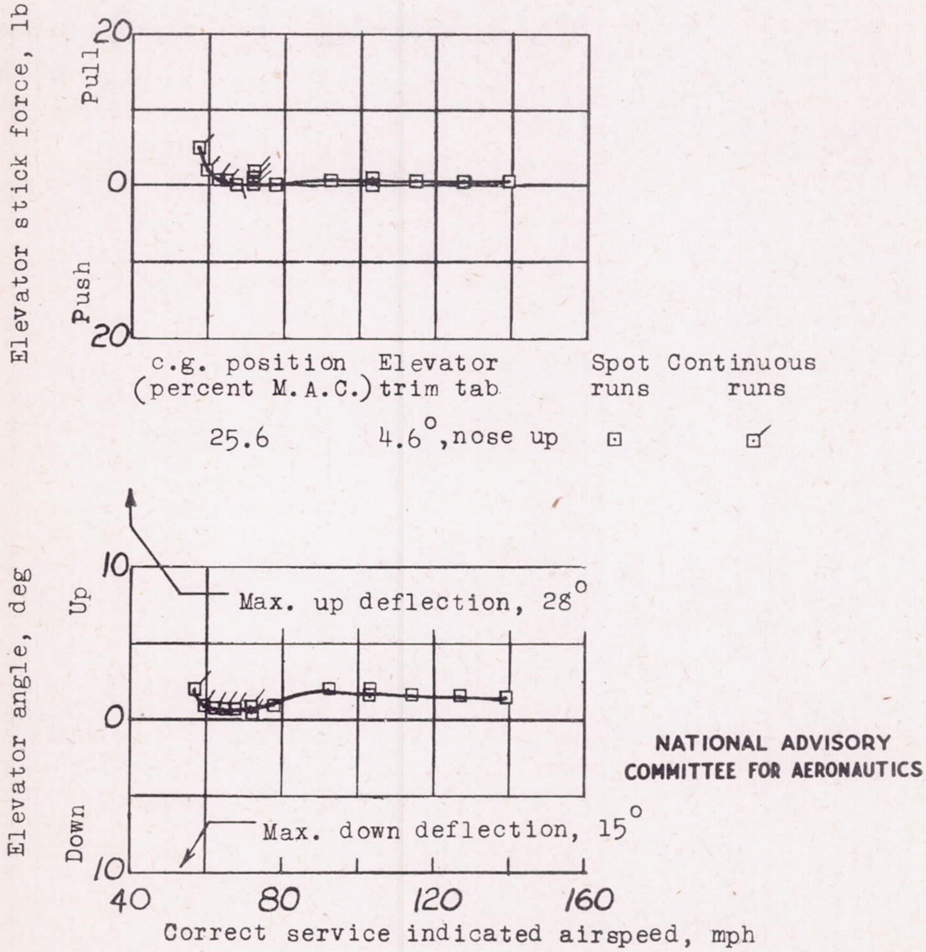
(c) Landing condition; original tab on elevator locked.

(d) Approach condition; original tab on elevator locked.

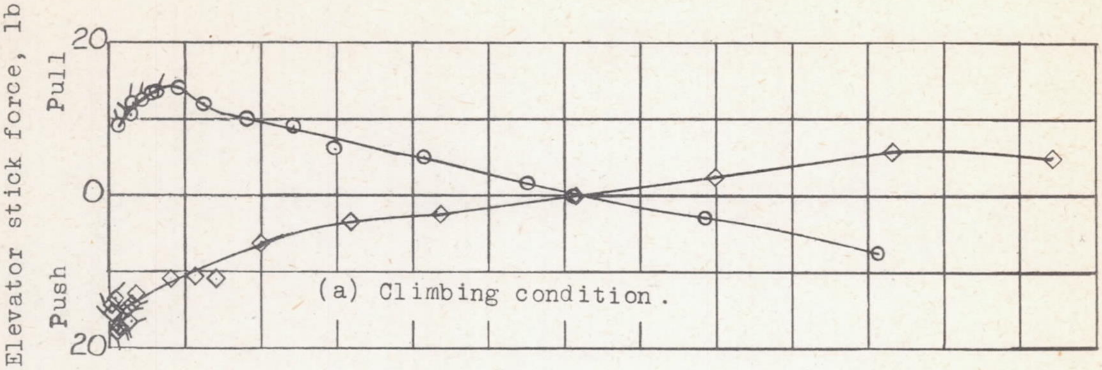
Figure 11.- Concluded.



(a) Airplane with springy tab installed on elevator.
Figure 12.- Static longitudinal stability characteristics in the wave-off condition.



(b) Airplane with original tab on elevator locked.
Figure 12.- Concluded.



c.g. position (percent M.A.C.)	Elevator trim tab	Spot runs	Continuous runs	
32.0	2.9°, nose up	⊙		Elevator with springy tab installed
31.7	5.7°, nose up	⊡		
31.4	1.4°, nose down	◇		Elevator with original tab locked
30.9	0.9°, nose up	△		

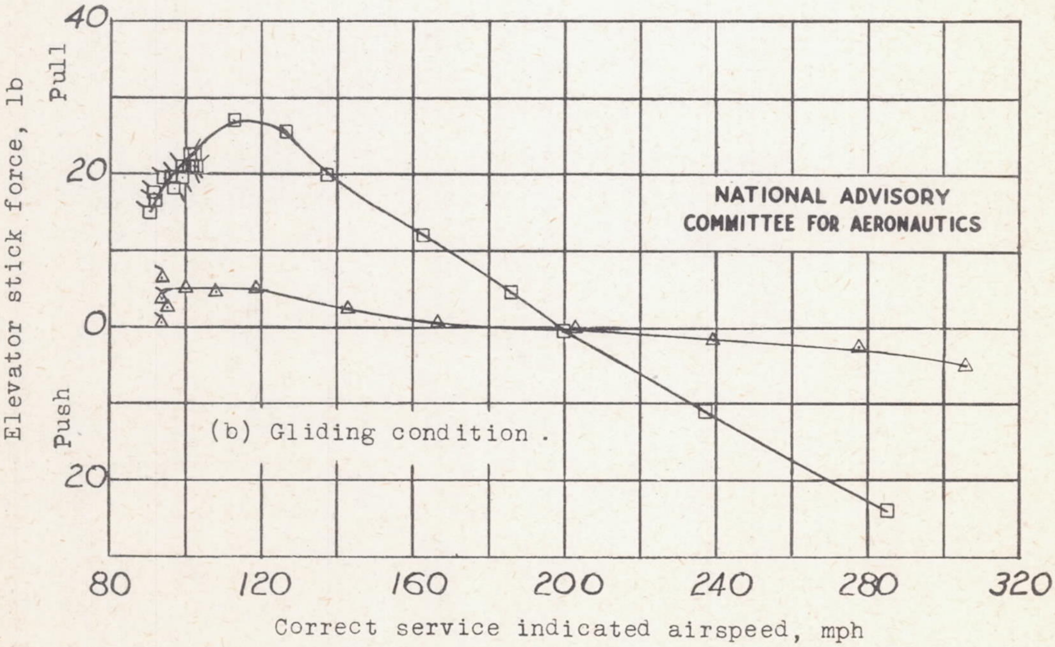
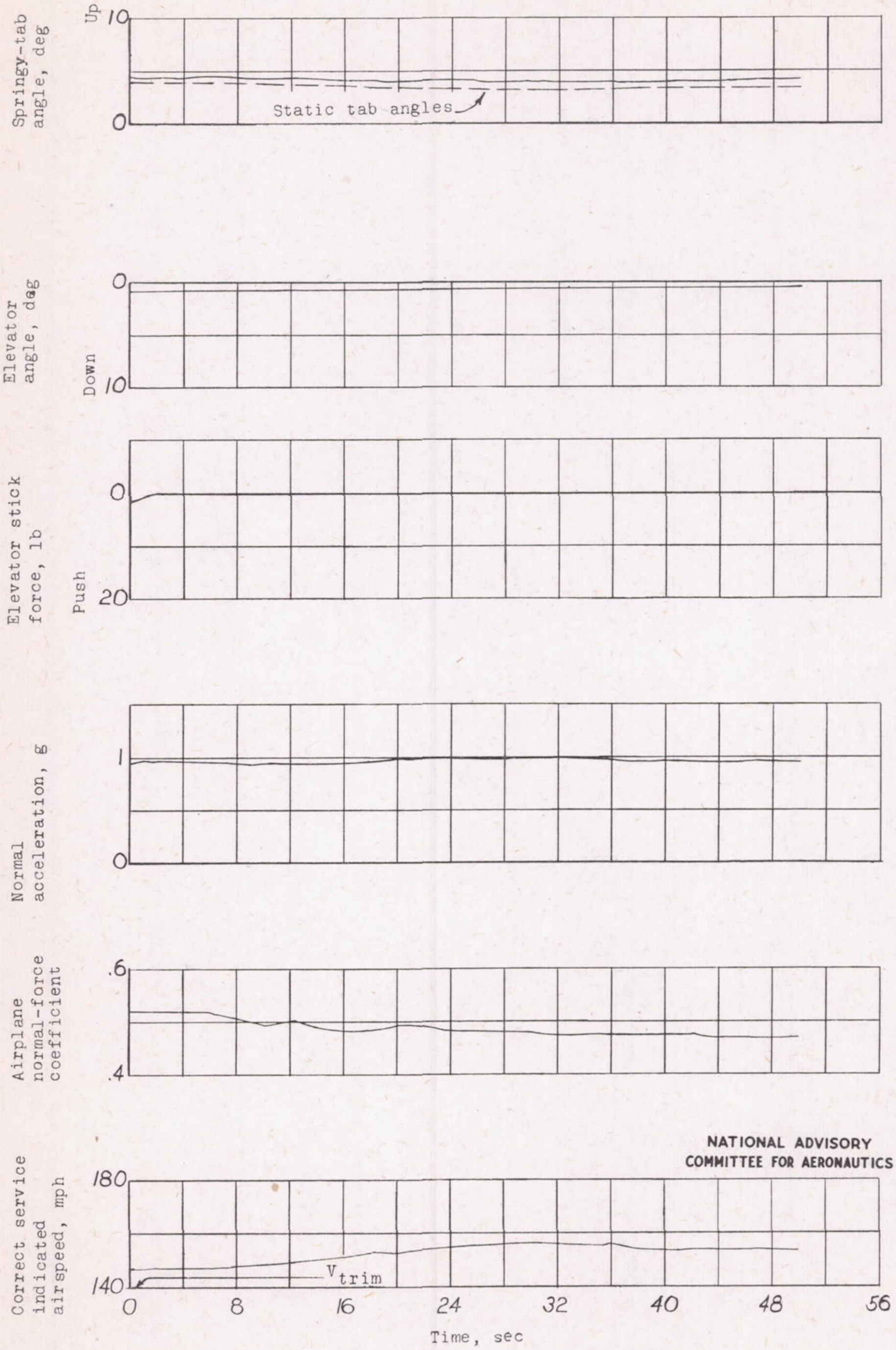
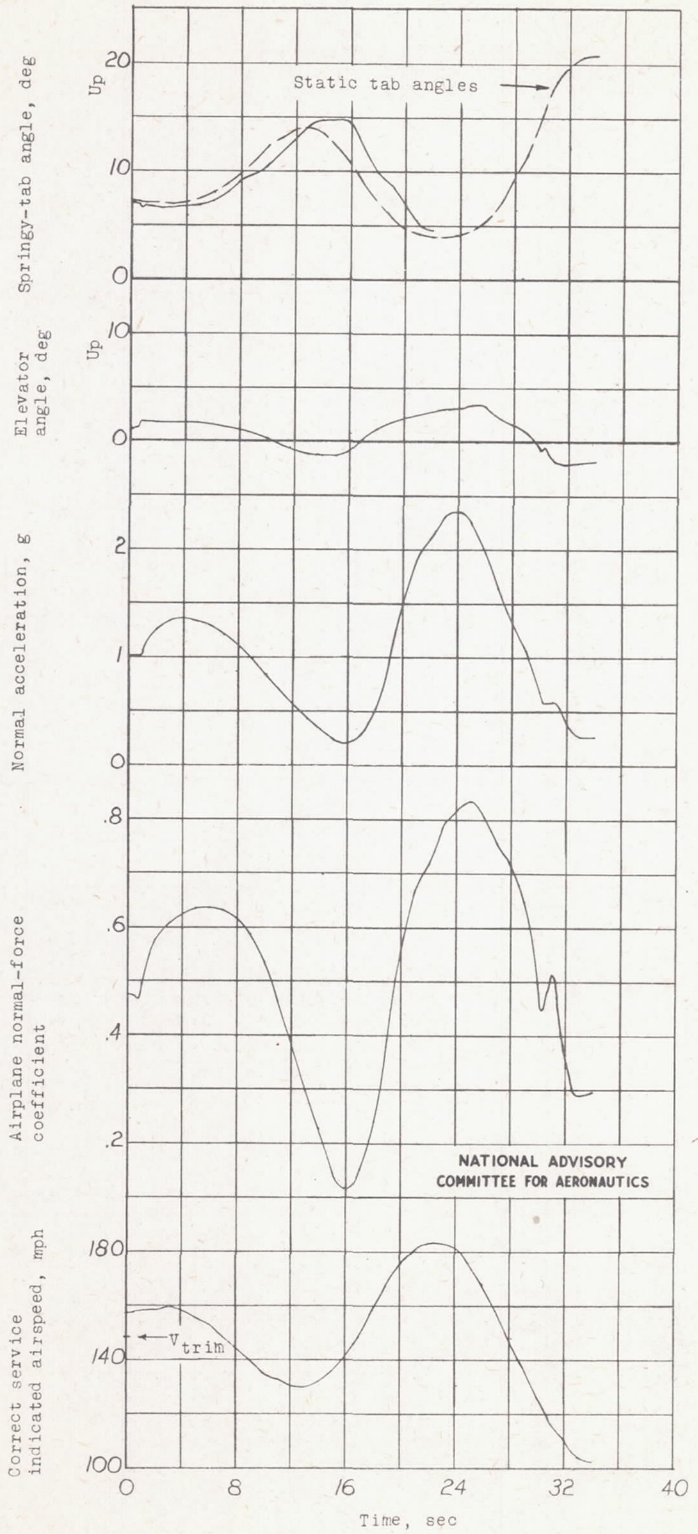


Figure 13.- Comparison of stick-free static longitudinal stability characteristics of airplane with springy tab installed and of airplane with original tab locked.



(a) Climbing condition; center of gravity at 30.3 percent mean aerodynamic chord; springy tab installed on elevator.

Figure 14.- Time history of motion following stick release at speed slightly above trim.



(b) Gliding condition; center of gravity at 30.2 percent mean aerodynamic chord; springy tab installed on elevator.

Figure 14.- Concluded.

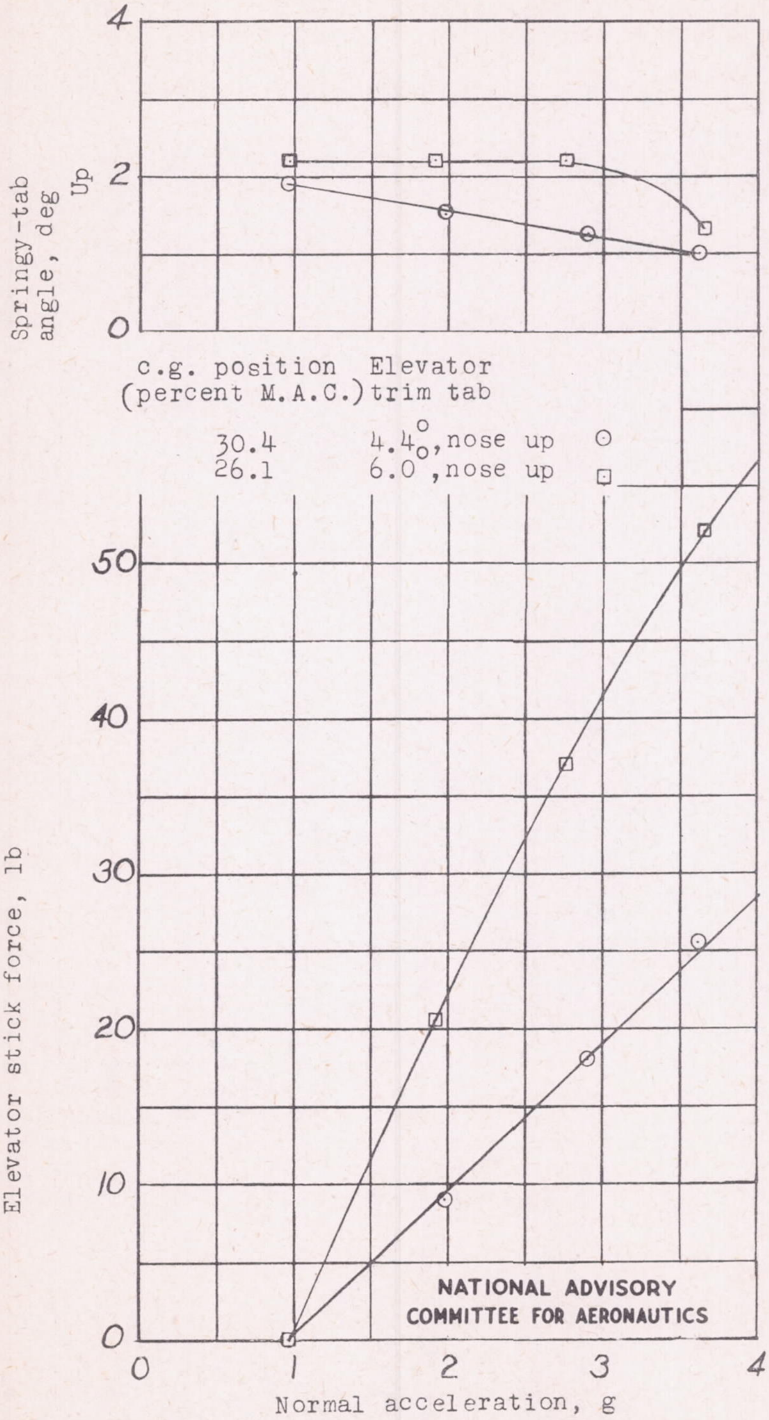


Figure 15.- Variation of elevator stick force and springy-tab angle with normal acceleration in turns at 196 miles per hour. Airplane with springy tab installed on elevator.

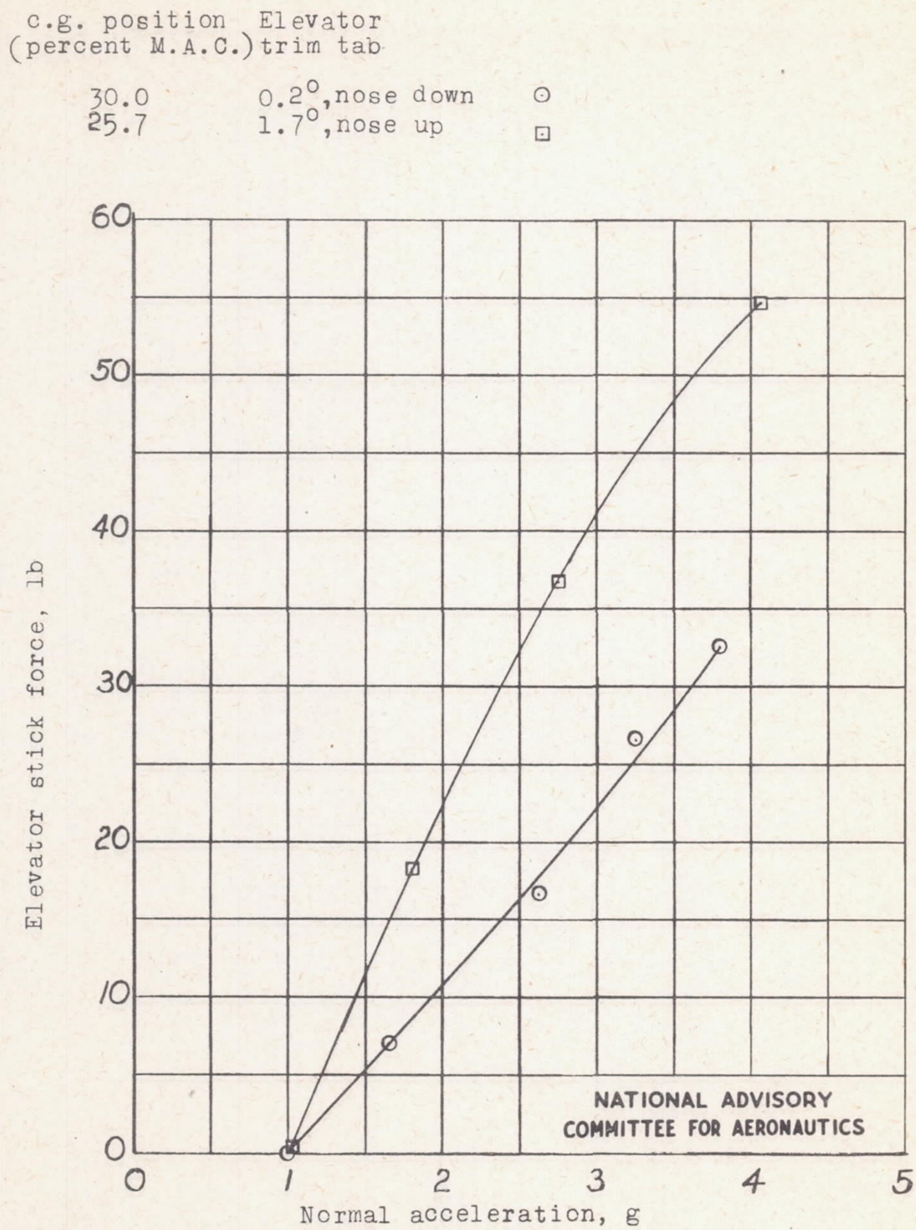
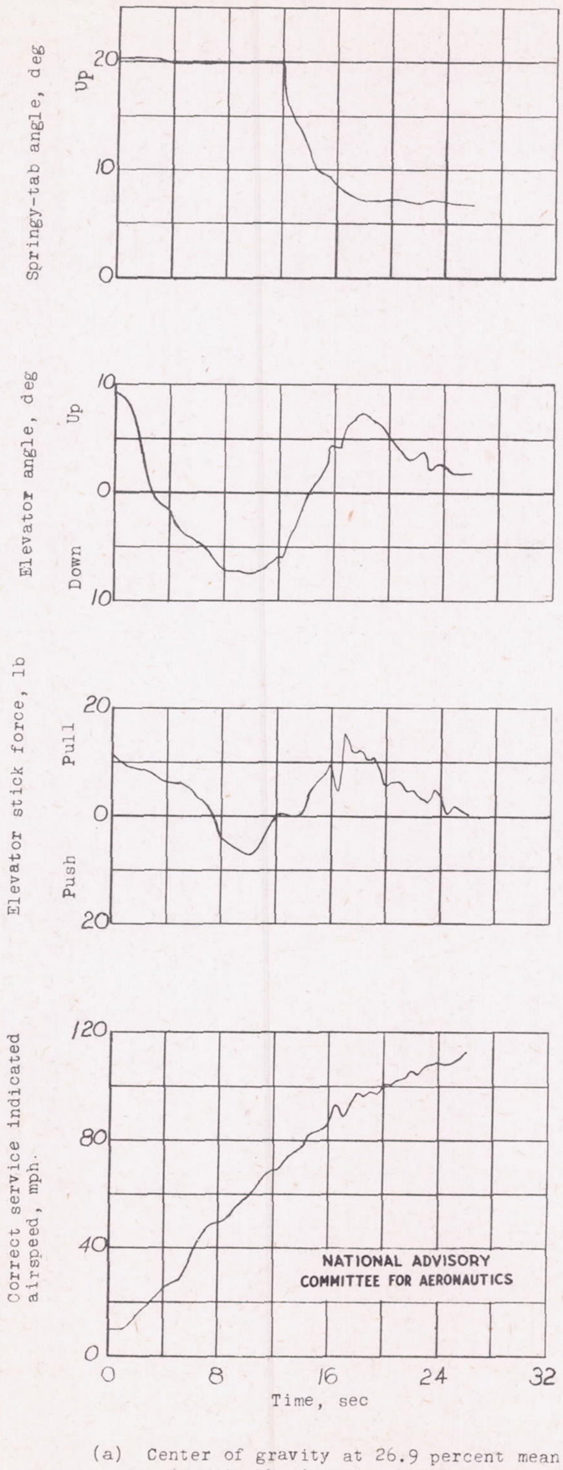
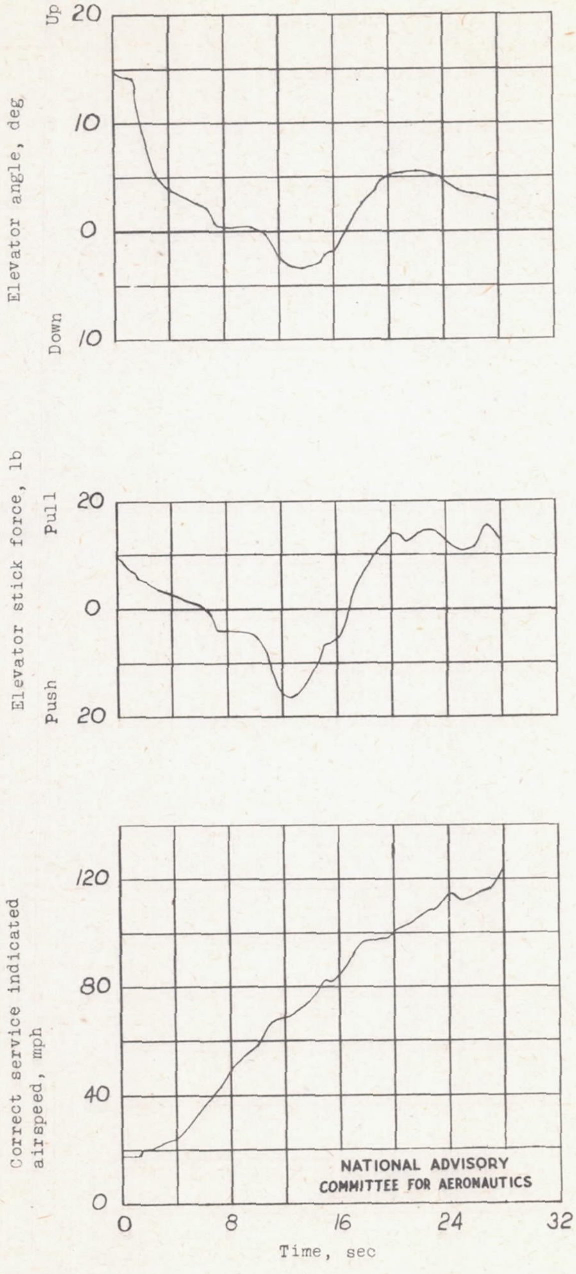


Figure 16.- Variation of elevator stick force with normal acceleration in turns at 196 miles per hour. Airplane with original tab on elevator locked.



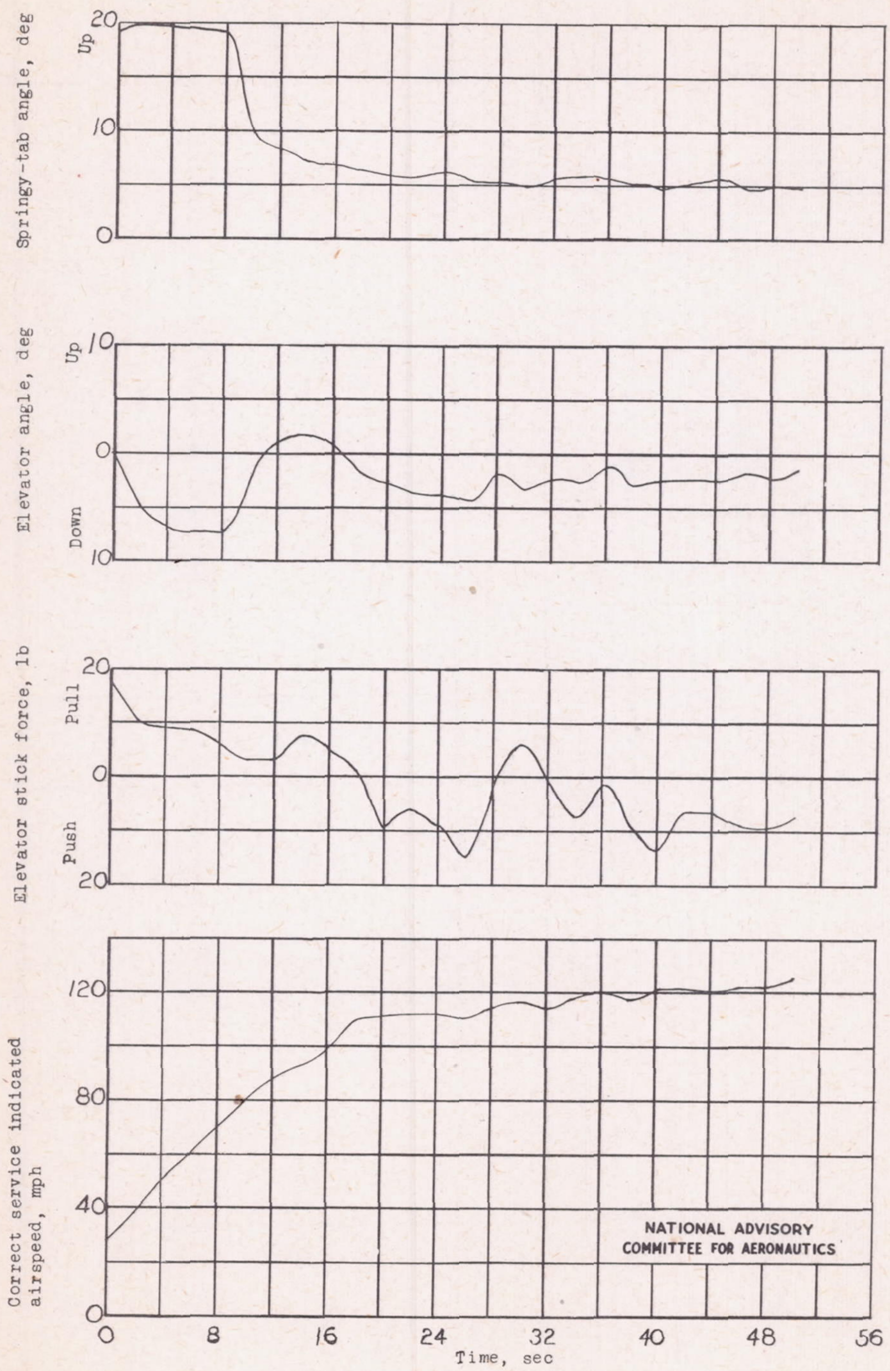
(a) Center of gravity at 26.9 percent mean aerodynamic chord ; elevator-trim-tab setting, 11.6° (nose up) ; airplane with springy tab installed on elevator.

Figure 17.- Time history of a take-off.



(b) Center of gravity at 27.2 percent mean aerodynamic chord ; elevator-trim-tab setting, 0° ; airplane with original tab on elevator locked.

Figure 17.- Continued.



(c) Center of gravity at 32.1 percent mean aerodynamic chord ; elevator-trim-tab setting, 8.1° (nose up) ; airplane with springy tab installed on elevator.

Figure 17.- Concluded.

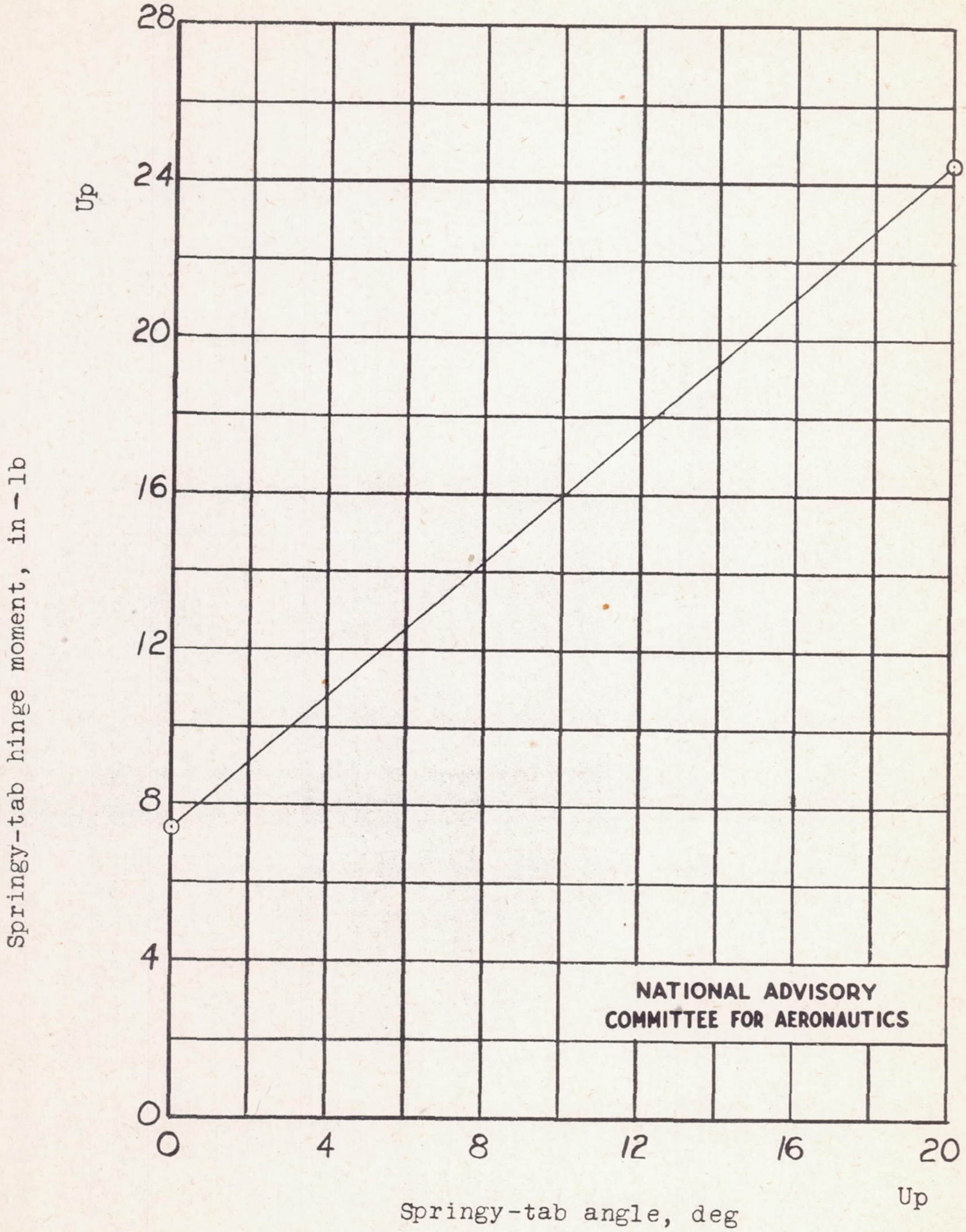


Figure 18.- Variation of springy-tab hinge moment with springy-tab angle as measured on the ground for the initial springy-tab configuration.

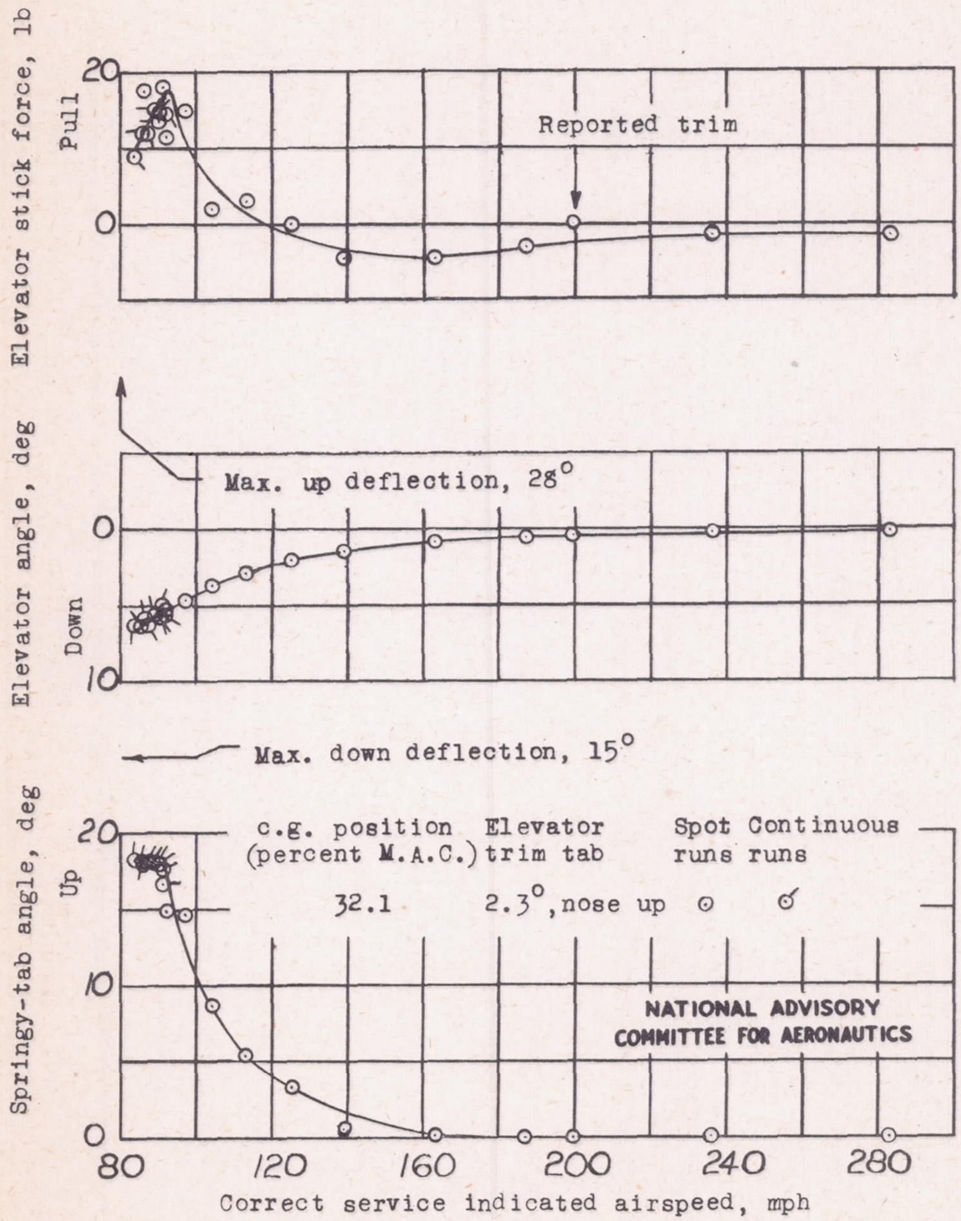


Figure 19.- Static longitudinal stability characteristics in the climbing condition with the initial springy-tab configuration.