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FLIGHT TESTS OF A RUDDER WITH A SPRING TAB ON AN F6F-3 AIRPLANE (BUAER NO. 04776)

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NACA

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MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

FLIGHT TESTS OF A RUDDER WITH A SPRING TAB ON AN F6F-3 AIRPLANE (BUAER NO. 04776)

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SUMMARY

Flight tests were made of an F6F-3 airplane having a spring-tab rudder which was designed and constructed by National Advisory Committee for Aeronautics personnel at Langley Field, Va. Measurements were made of the directional stability and control characteristics of the F6F-3 airplane when equipped with this installation. Tests were made with the preload in the springs equivalent to a pedal force of ±50 pounds and with the preload corresponding to ±4 pounds which was equal to the friction in the tab control linkage. The use of the spring-tab rudder with either of the preloads resulted in a lower trim-force change with speed and lower pedal forces in sideslips than that obtained with original F6F-3 rudder. Any oscillations of the rudder or spring tab following an abrupt control deflection were well damped and no tendency to flutter was evident up to an indicated airspeed of 400 miles per hour. Although the tab arrangement with the smaller preload gave rudder forces somewhat lighter than desirable in maneuvers, the pilots preferred this arrangement to the tab with the larger preload because of the ease with which small trim changes could be offset with the more lightly preloaded arrangement.

INTRODUCTION

At the request of the Bureau of Aeronautics, Navy Department, flight tests were made on an F6F-3 airplane (BuAer No. 04776) with a spring-tab rudder in an effort to reduce the large change in rudder-trim force with speed of this airplane in the original configuration, and to obtain general information concerning the use of spring tabs on high-speed airplanes. Considerable interest has been shown in the use of spring tabs as a means of balancing control surfaces on high-speed airplanes because this device makes it possible to obtain light control force at high speeds without making the balancing action critical to small changes in control-surface contour. These advantages are obtained because the balancing action provided by a spring tab is proportional to the applied control force, regardless of surface deflection or speed, and very close aerodynamic balance of the control surface is not required.

The design and construction of the spring-tab installation, as well as the flight test program was handled by NACA personnel at the Langley Field laboratory.

AIRPLANE AND SPRING-TAB ARRANGEMENT

The F6F-3 airplane is a low-wing, single-place, single-engine, fighter-type monoplane. A three-view drawing of the F6F-3 airplane with the spring-tab rudder is shown in figure 1. Complete dimensions and details of the F6F-3 airplane are given in reference 1.

A sketch of the rudder with the spring tab is given in figure 2. Figures 3 and 4 are photographs giving general views of the arrangement. A schematic sketch of the spring unit is shown in figure 5. An assembly drawing of the spring-tab installation is shown in figure 6. Figure 7(a) gives a view of the spring unit installed. Spring units were used in both rudder push-pull tubes. The tab linkage, however, was connected only to the left push-pull tube. Figure 7(b) shows the tab actuating arms. The spring tab and the trim tab were constructed of plywood and were sealed at their hinge lines. The spring tab was statically mass overbalanced to give dynamic balance for rotation of the rudder in accordance with the analysis presented in reference 2. The mass overbalance of the rudder was the same as the original rudder.

The variation of rudder position with pedal position with the spring tab neutral is given in figure 8. The variation of spring-tab position with rudder-pedal force is shown in figure 9 for the two values of preload used, ±50 pounds and ±4 pounds, measured at the rudder pedals.

The latter value is equal to the friction in the spring-tab linkage and in the spring units. There was approximately 0.11 inch pedal travel per degree spring-tab travel with the rudder fixed and with the springs removed.

INSTRUMENTATION

Standard NACA photographically recording instruments, synchronized by means of an electrical timer, were used to measure airspeed, angular velocities, sideslip angles, rudder-pedal force, rudder and spring-tab angle. Service indicated airspeed as used herein is defined below.

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

where

f_o compressibility correction at sea level

q_c measured difference between static and total head pressure corrected for position error, inches of water

TESTS, RESULTS, AND DISCUSSION

Measurements were made in flight of the directional stability and control of the F6F-3 airplane with the spring-tab rudder having two values of spring preload. Most of the measurements were made with the airplane in the climbing condition; that is, flaps and gear up, with normal rated power (43 inches of mercury manifold pressure and 2550 rpm). The first value of spring preload used was equivalent to ±50 pounds pedal force with the rudder at neutral. This value varied somewhat with rudder deflection as the mechanical advantage between the pedals and the spring unit changed with rudder deflection. Tests were made with the 50 pounds preload first because it was felt that any tendencies for the tab to flutter or oscillate would be less serious with this value of preload. Tests were also conducted with the spring units preloaded equivalent to ±4 pounds pedal force. This value corresponded to the friction in the spring-tab system, and was considered the minimum preload since with less preload the tab would not be self-centering. During preliminary flights, difficulty was experienced in trimming the rudder-pedal forces to zero at speeds below approximately 275 miles per hour in the climbing condition. This was attributed to the trim tab being less effective than the one on the original rudder. The two trim tabs were approximately the same size but the trim tab on the spring-tab rudder was lower on the rudder and more in the fuselage wake. To overcome this trim difficulty a 1/8-inch cord was placed on the left side of the rudder trailing edge above the spring tab. (See fig. 4.) With this cord, trim was satisfactory.

Tests were made to determine whether the spring-tab rudder tended to oscillate. These tests consisted of maneuvers in which the pilot abruptly deflected and released rudder control at various speeds in the climbing condition. Typical time histories of these maneuvers are shown in figures 10 and 11 for the ±50-pound and ±4-pound preloads, respectively. As can be seen by inspection of these figures, any oscillations of the spring tab or the rudder were heavily damped. There was no evidence of flutter in the speed range up to 400 miles per hour.

The directional trim characteristics in the climbing condition were determined by measuring the rudder force and angle required to trim with the wings level throughout the speed range with the rudder force trimmed to zero at a given speed. The data obtained are shown in figure 12 for ±50 pounds preload and in figure 13 for the ±4 pounds preload. These figures give rudder force and rudder position, as well as sideslip angle and spring-tab angle as functions of service indicated airspeed. Data for the original rudder, which were presented in reference 3, are shown in these figures by a dashed line. The data given in figures 12 and 13 show that the spring-tab rudder with either preload gives lower values of rudder-trim-force change with speed than the original rudder. It should be noted, however, that the spring-tab rudder with 50 pounds preload gives lower values of rudder-trim force even before the spring tab deflects. (See fig. 12.) It is felt that these differences in trim force can be attributed to the fact that the effect of the modified trim tab and trailing-edge cord on the rudder hinge-moment coefficients changes with speed in a different manner from that of the original trim tab. In addition, there are some differences in rudder angle, sideslip angle, and trim speed which would tend to make the results dissimilar. Comparison of figures 12 and 13 shows that when the airplane was trimmed at approximately the same speed, the rudder with the higher spring preload gave lower rudder-trim forces in the lower speed range. It should be noted, however, that with the higher preloaded arrangement less rudder deflection was used than with the lightly preloaded arrangement. This difference in rudder deflection is probably due to the method used in making the tests. In these tests continuous records were taken as the speed was changed. In the case of the ±50 pounds preloaded rudder, the run was begun at the high-speed end and the speed decreased down to the stall, whereas in the more lightly preloaded arrangement, the run began at the stall and the speed increased to 400 miles per hour. It is felt that the failure to obtain sufficiently steady conditions during the runs would account for the small differences in rudder deflection required to trim. The data for the original rudder were obtained in spot records taken for steady conditions at each speed. In addition, the spring tab with the lighter preload reaches full deflection within the flight speed range and the pedal forces, therefore, in accordance with spring-tab theory, assume a slope similar to that obtained with a rudder without the spring tab.

Measurements were also made of the characteristics of the F6F-3 airplane with the spring-tab rudder in steady sideslips made in the climbing condition. These tests consisted of sideslips made by slowly deflecting the rudder while using the ailerons and elevator to maintain straight flight at a given speed. The data obtained are shown in figures 14 to 18. These figures give rudder deflection, rudder force, and spring-tab deflection as functions of sideslip angle. Figures 14, 15, and 16 give data obtained in sideslips made at approximately 150, 200, and 300 miles per hour, respectively, with the ±50 pounds preload in the spring tab. Figures 17 and 18 present data obtained with the ±4 pounds preload in the spring tab at 200 and 300 miles per hour, respectively. Figures 14 and 15 show that the spring-tab rudder with the 50 pounds preload gave the expected results; that is, the curves of pedal force against sideslip angle are parallel to the curves for the original rudder until the preload of the spring is exceeded at which point the tab deflects and the slope of the pedal-force curve is decreased. With the lighter preload, figures 17 and 18, the pedal-force curves were similar in shape to those obtained with the original rudder; the slopes of the curves, however, were reduced, resulting in lower values of pedal force per degree rudder deflection. Somewhat higher values of rudder deflection per degree sideslip were obtained because of the decrease in rudder effectiveness when the spring tab was deflected.

Although there was some reduction in available rudder deflection when the spring tab was deflected, the pilots reported there was sufficient rudder control available in all conditions of flight. Typical time histories of take-offs made with the original rudder and the ±4-pound pre-loaded spring-tab rudder are shown in figures 19 and 20, respectively. It can be seen by comparing these figures that the rudder forces are considerably lighter with the spring-tab rudder.

In general, the pilots were favorably impressed with the characteristics of the spring-tab rudder and felt that the spring-tab rudder improved the airplane. They considered the ±50-pound preload was too high because the rudder forces were too heavy, as with the original rudder, for the small rudder deflections necessary to overcome changes in trim. In addition, the change in slope of the pedal-force curves when the high preload was exceeded and the spring tab came into action was objectionable to the pilots and gave the control, as they described it, a "spongy" feeling. (See figs. 14 to 16.) With the lighter preloaded arrangement (±4 pounds), this change in slope of the force curves was not apparent to the pilots. They also preferred this arrangement because of the ease with which they could offset yaw and roll changes due to changes in power or speed or due to rough air. The rudder pedal forces in maneuvers, however, were considered somewhat lighter than desirable. This lightness of control resulted in some difficulty in coordinating maneuvers at high speed. The rudder pedal forces could, of course, be made heavier by using stiffer springs. No tests, however, were made as they were not considered necessary.

CONCLUSIONS

1. The spring-tab rudder on the F6F-3 airplane with either the 50 pounds or 4 pounds preload showed no tendency to flutter in the speed range up to 400 miles per hour and any oscillations following abrupt control deflections were heavily damped.

2. The spring-tab rudder gave desirably light trim-force changes with speed. The rudder-pedal force in sideslips was decreased by the spring-tab rudder.

3. The pilots preferred the characteristics of the spring-tab rudder to those of the original F6F-3 rudder. Although the spring-tab arrangement with the lighter preload gave rudder forces somewhat lighter than desirable in maneuvers, the pilots preferred this arrangement to the more highly preloaded tab because of the ease with which small trim changes could be offset with the more lightly preloaded arrangement.

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1. Williams, Walter C., and Reeder, John P.: Flight Measurements of the Flying Qualities of an F6F-3 Airplane (BuAer No. 04776). I - Longitudinal Stability and Control. NACA MR No. L5B13, 1945.

2. Collar, A. R.: The Prevention of Flutter of Spring Tabs. Rep. No. 3249, British R.A.E., May 1943.

3. Williams, Walter C., and Reeder, John P.: Flight Measurements of the Flying Qualities of an F6F-3 Airplane (BuAer No. 04776). II - Lateral and Directional Stability and Control. NACA MR No. L5B13a, 1945.

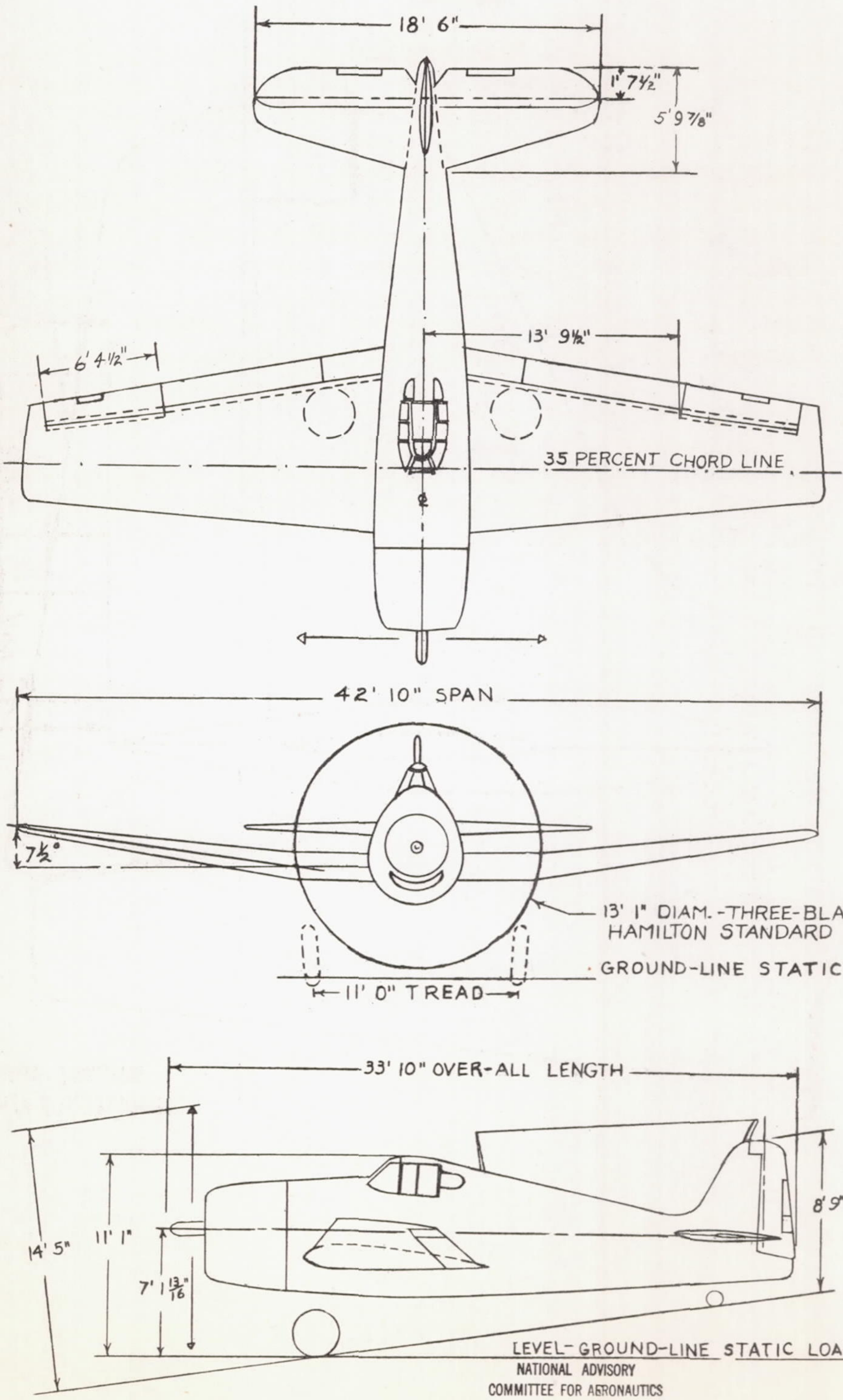

Figure 1.- Three-view drawing of F6F-3 airplane.

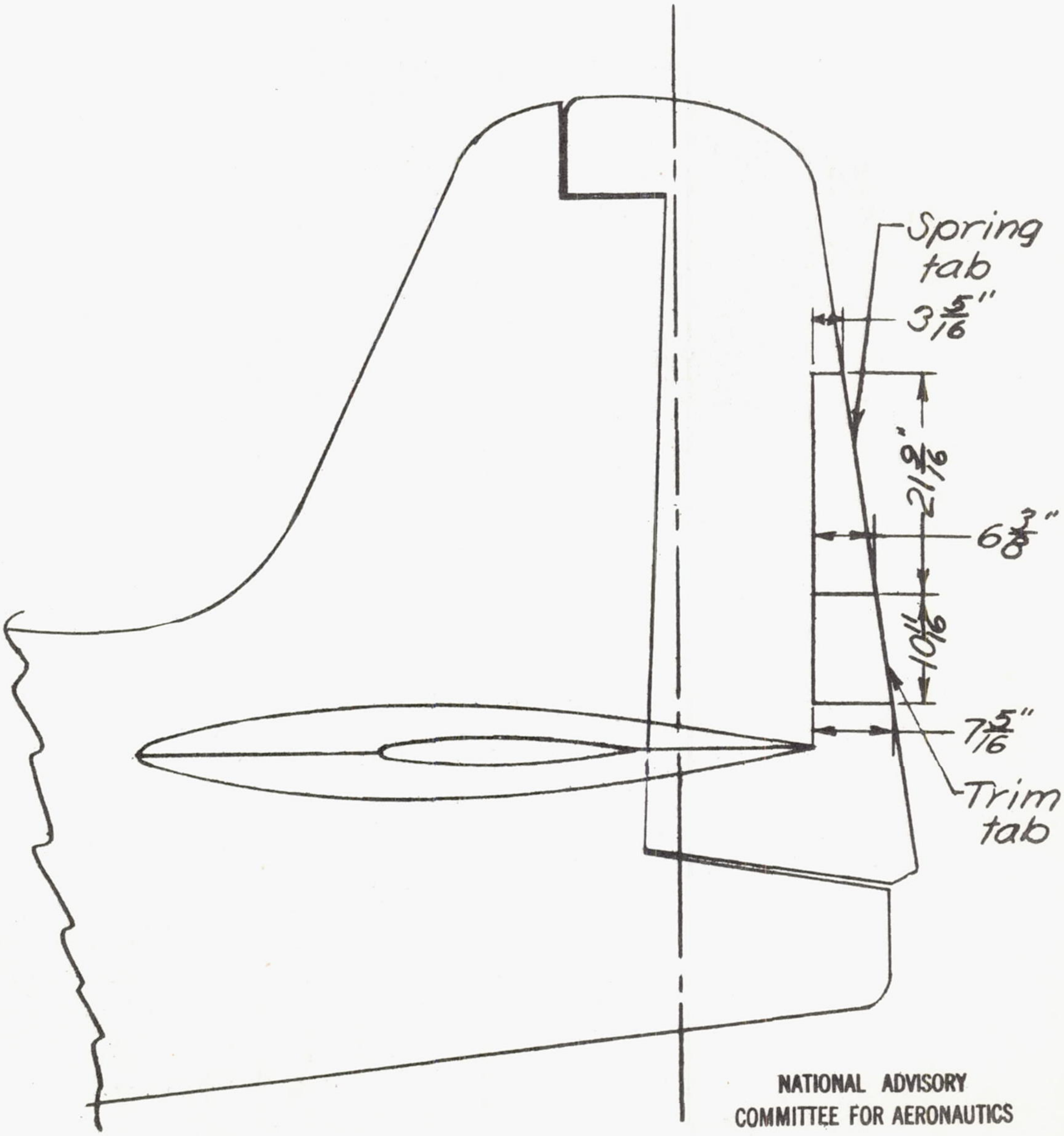

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Figure 2. - Detail sketch of spring tab rudder, F6F-3 airplane.

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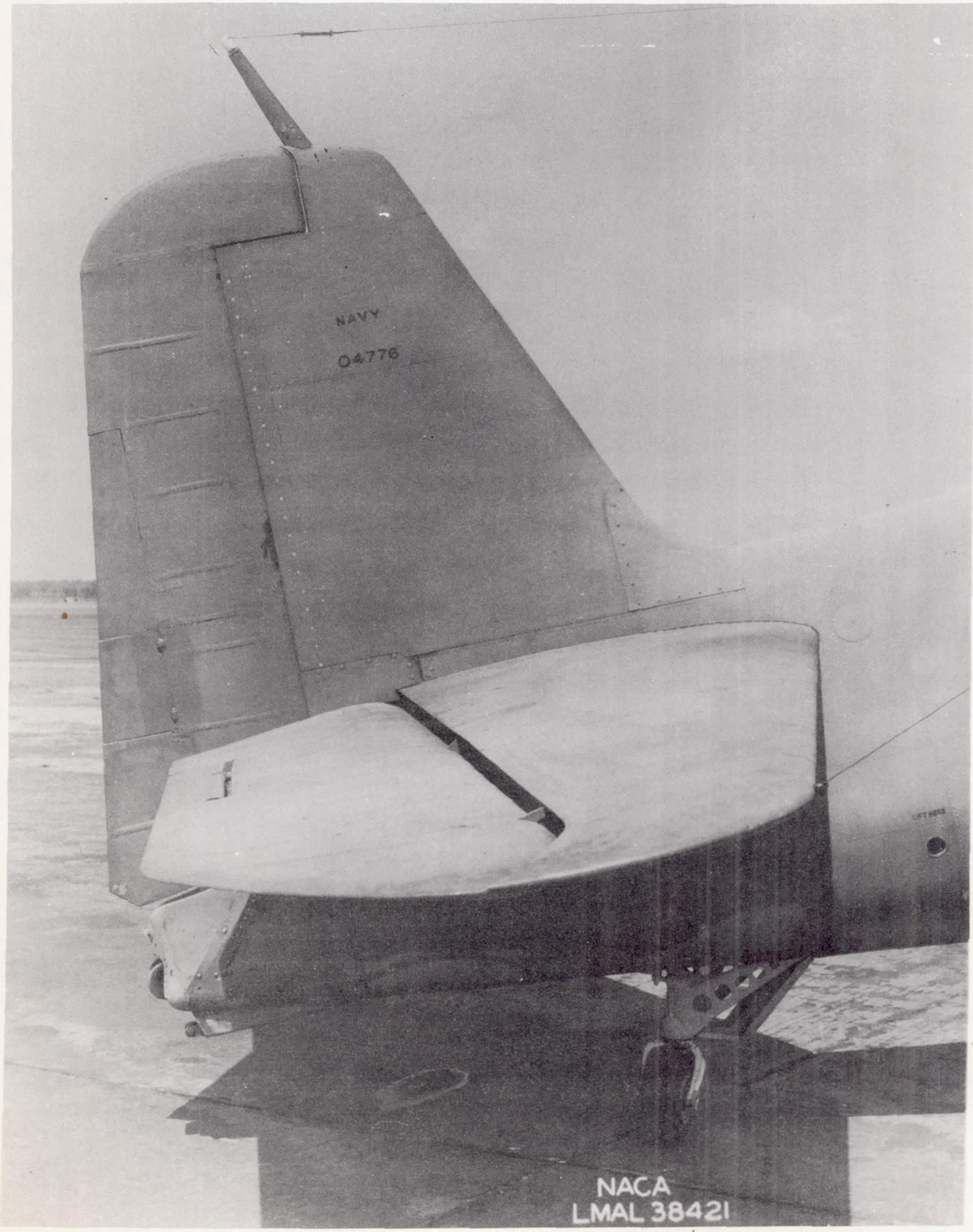

Figure 3.- General view of right side of spring tab rudder, F6F-3 airplane.

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Figure 4.- General view of left side of spring tab rudder, F6F-3 airplane. (Note trailing-edge cord)

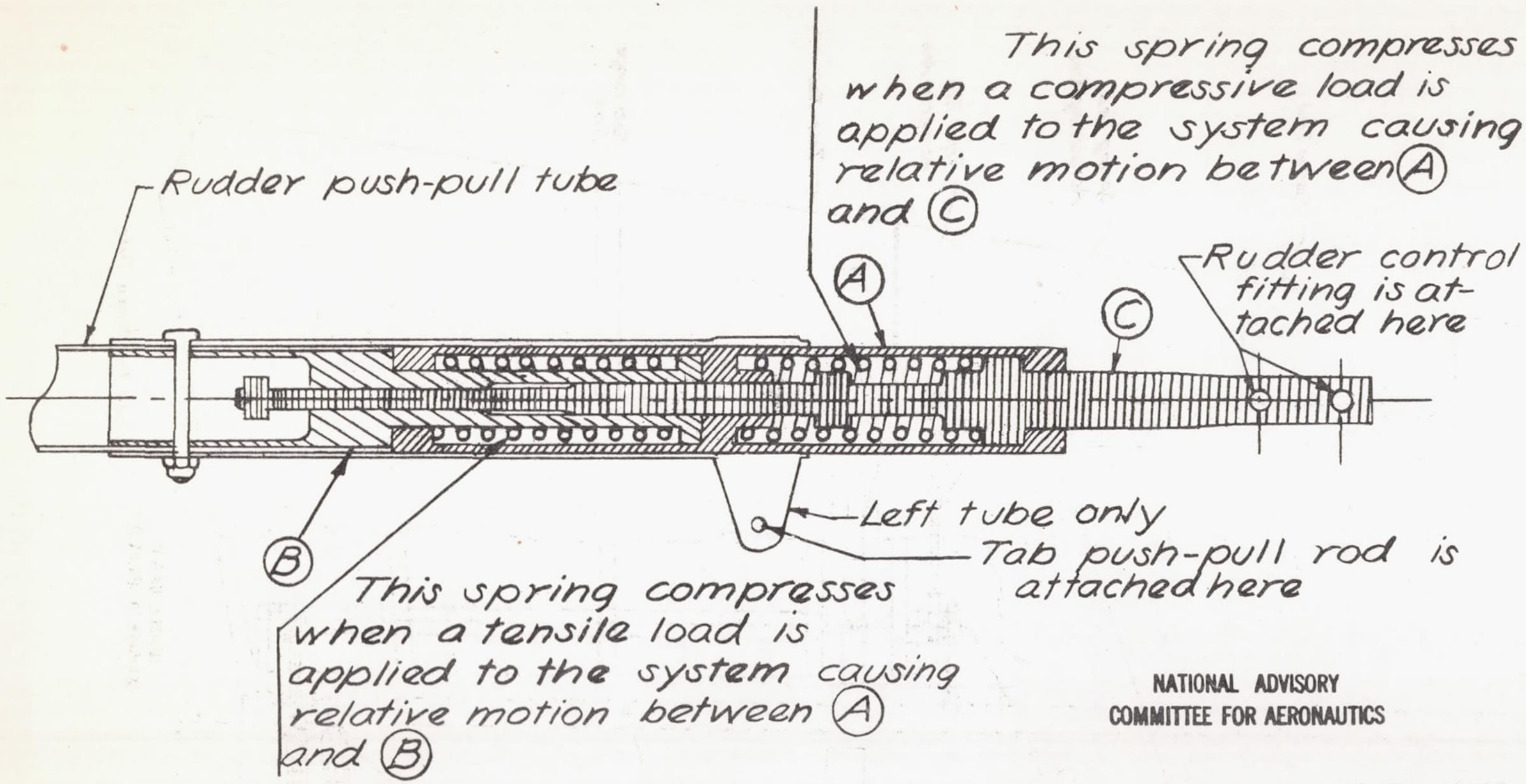

Figure 5. - Schematic sketch of spring unit, F6F-3 spring tab rudder.

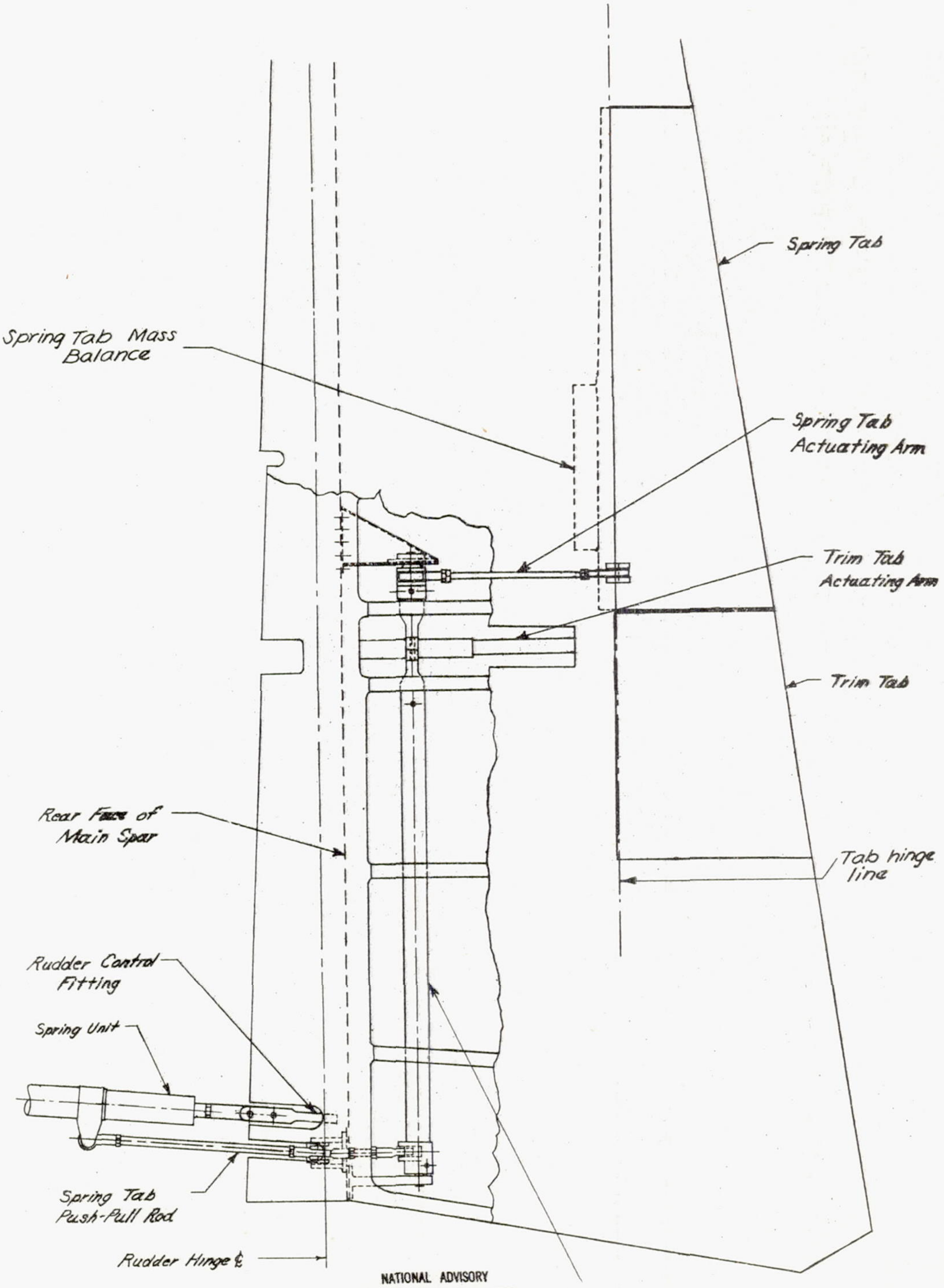

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Figure 6. - Assembly drawing of spring tab, F6F-3 airplane.

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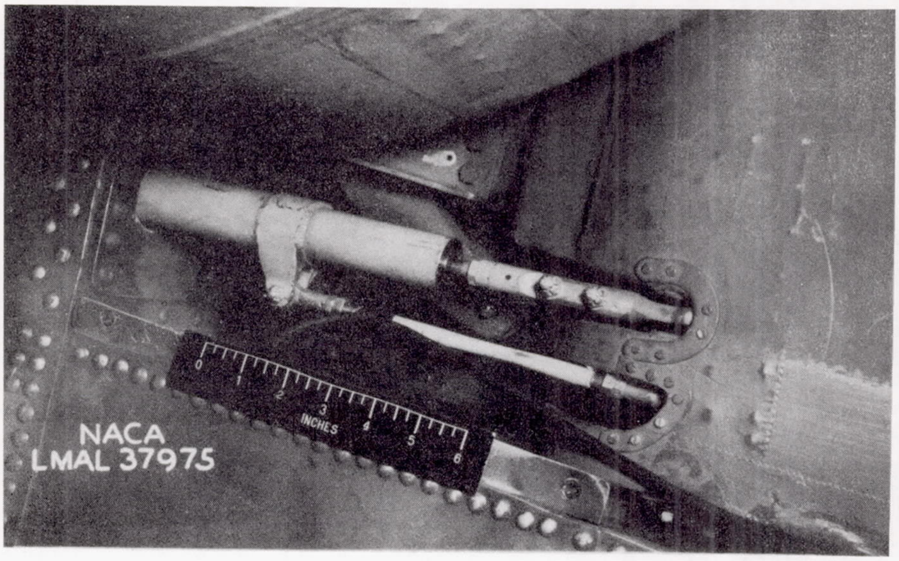

Figure 7a.- Detail view of spring unit installation F6F-3 spring tab rudder.

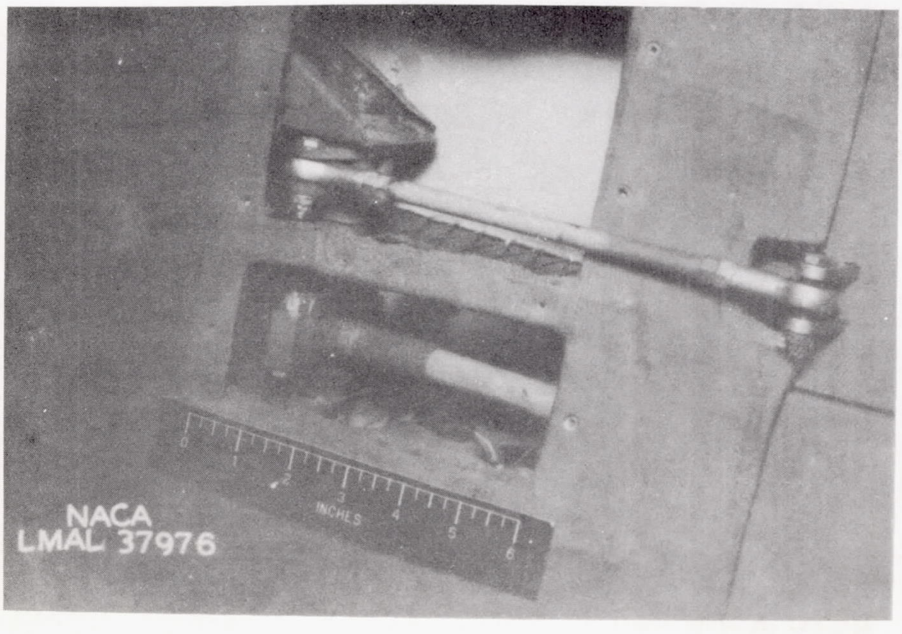

Figure 7b.- Detail view of tab actuating linkage, F6F-3 spring tab rudder.

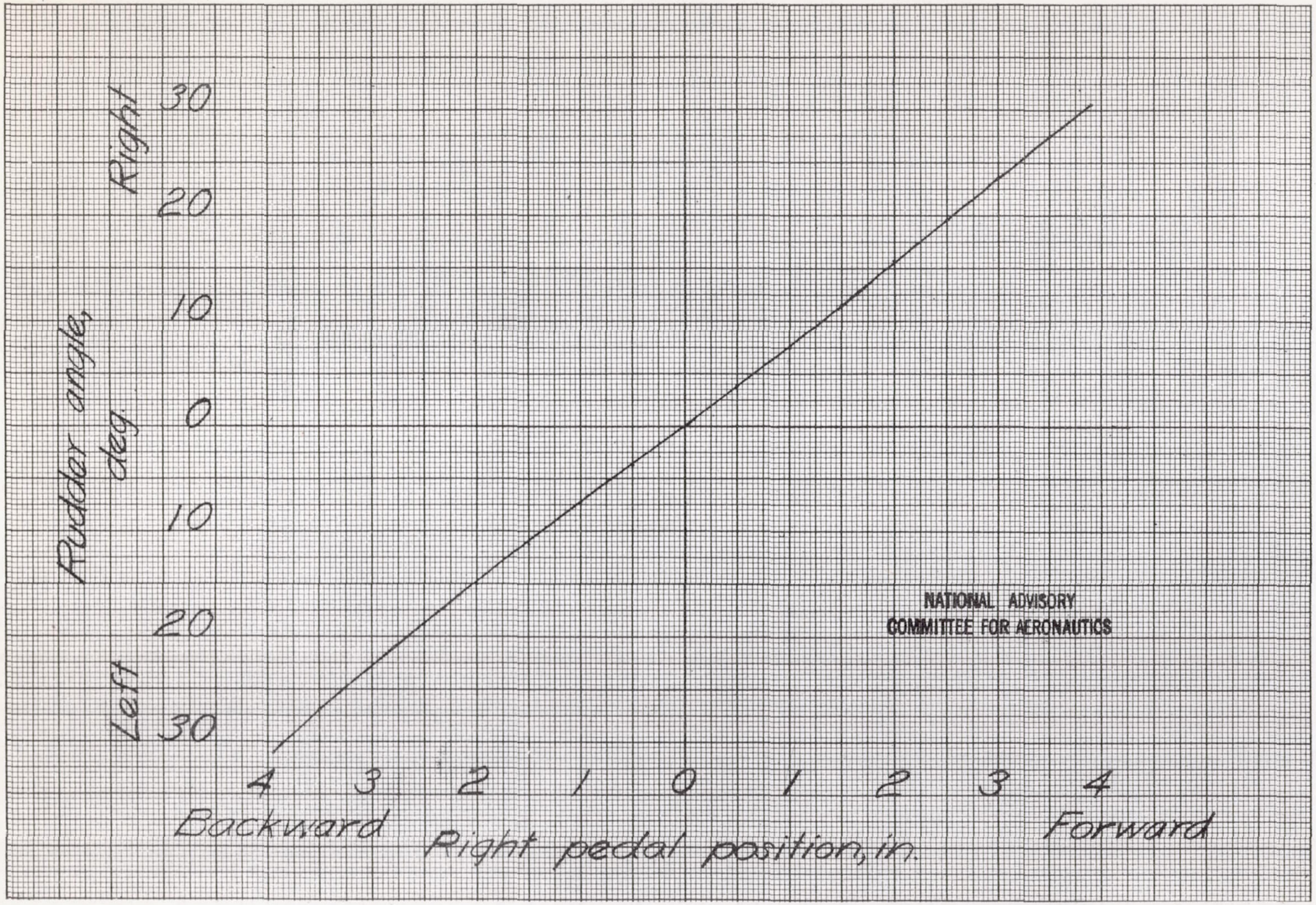

Figure 8. - Variation of rudder position with rudder pedal position with spring tab held neutral, F6F-3 airplane.

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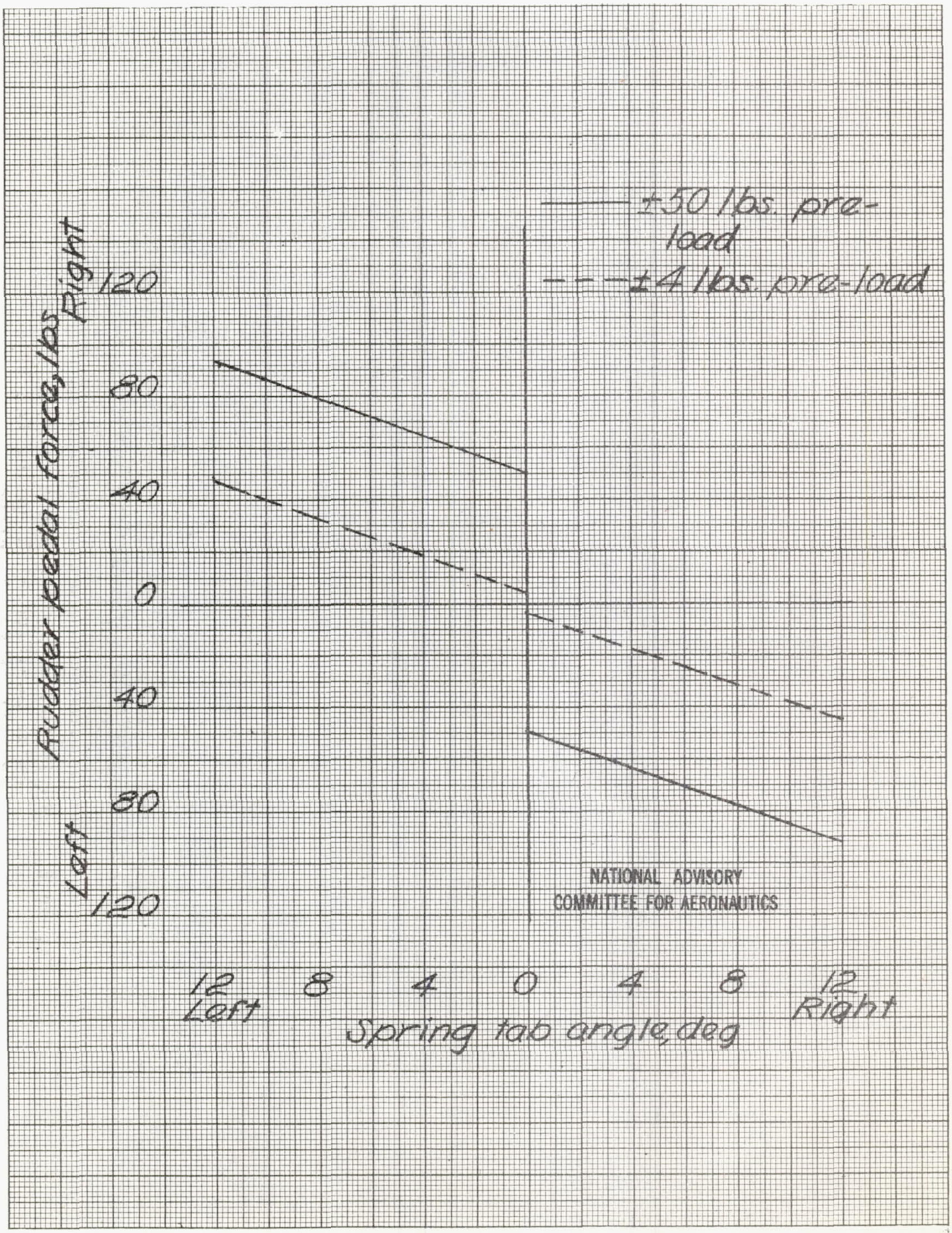

Figure 9. - Variation of spring tab position with rudder pedal force, ±50 pounds preload and ±4 pounds preload, rudder at neutral, F6F-3 airplane.

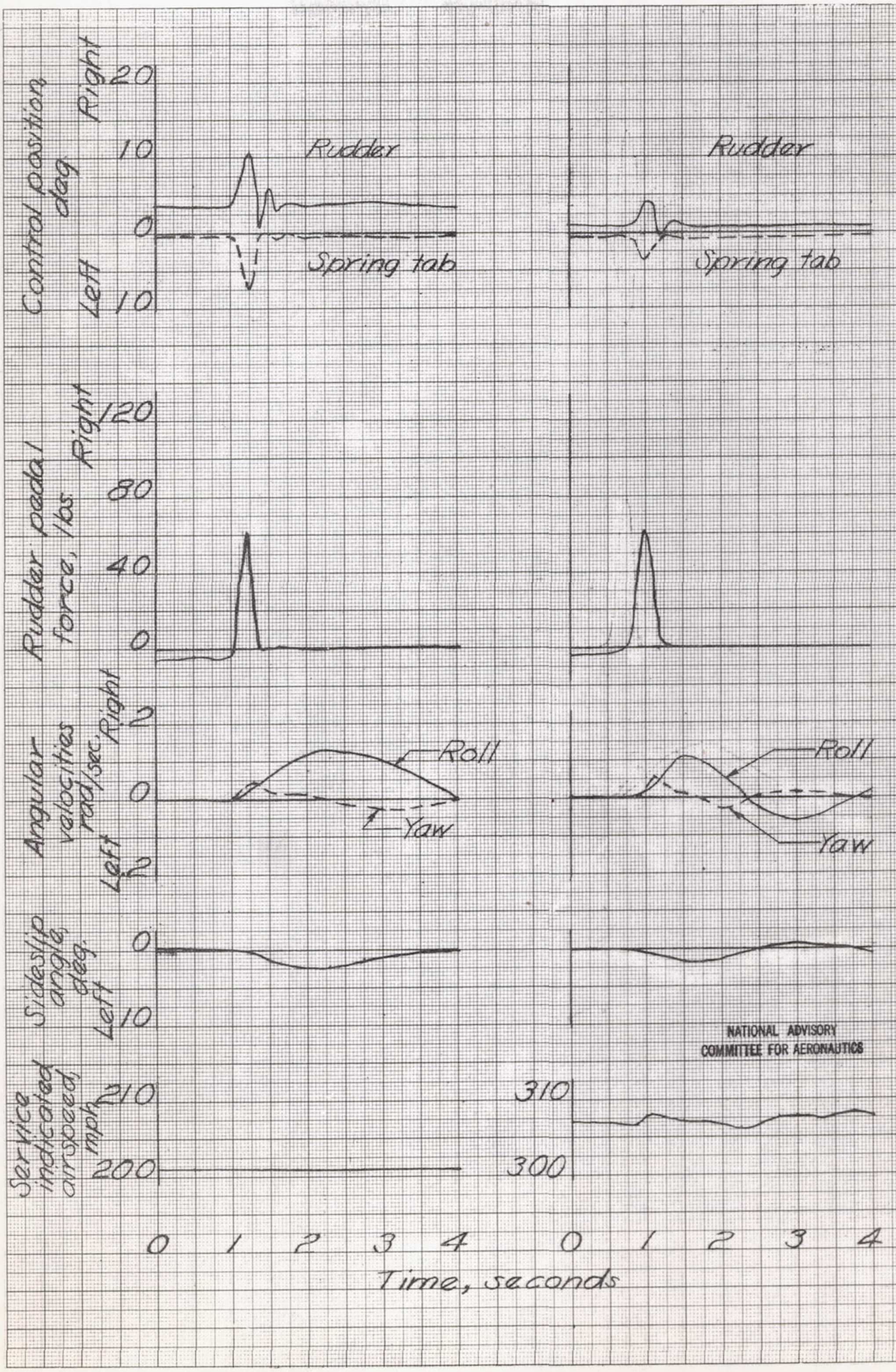

Figure 10. - Time histories of typical lateral oscillations following abrupt rudder deflection spring tab rudder with ±50 pounds preload, F6F-3 airplane.

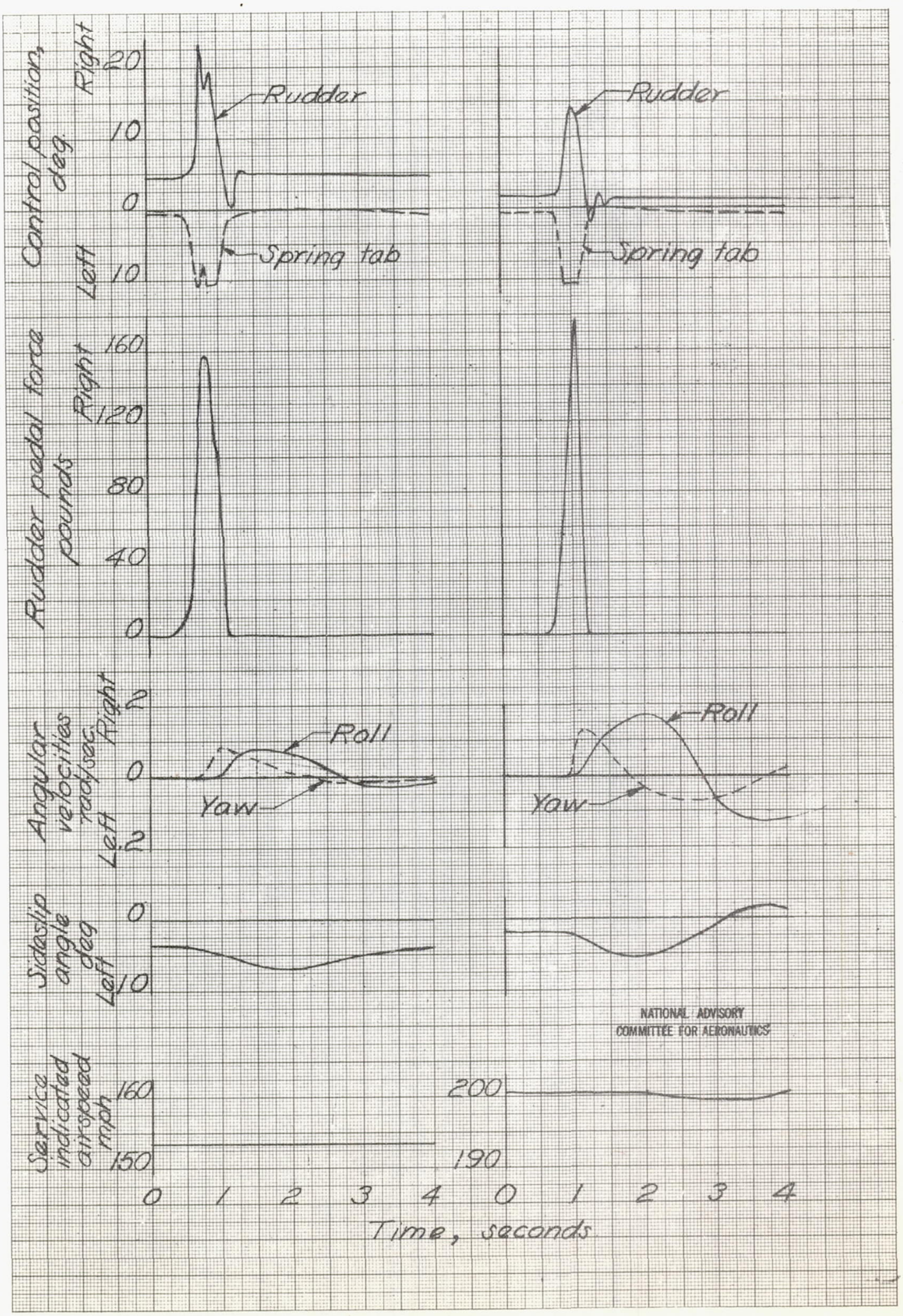

Figure 11. - Time histories of typical lateral oscillations following abrupt rudder deflections, spring tab rudder with ±4 pounds preload, climbing condition, F6F-3 airplane.

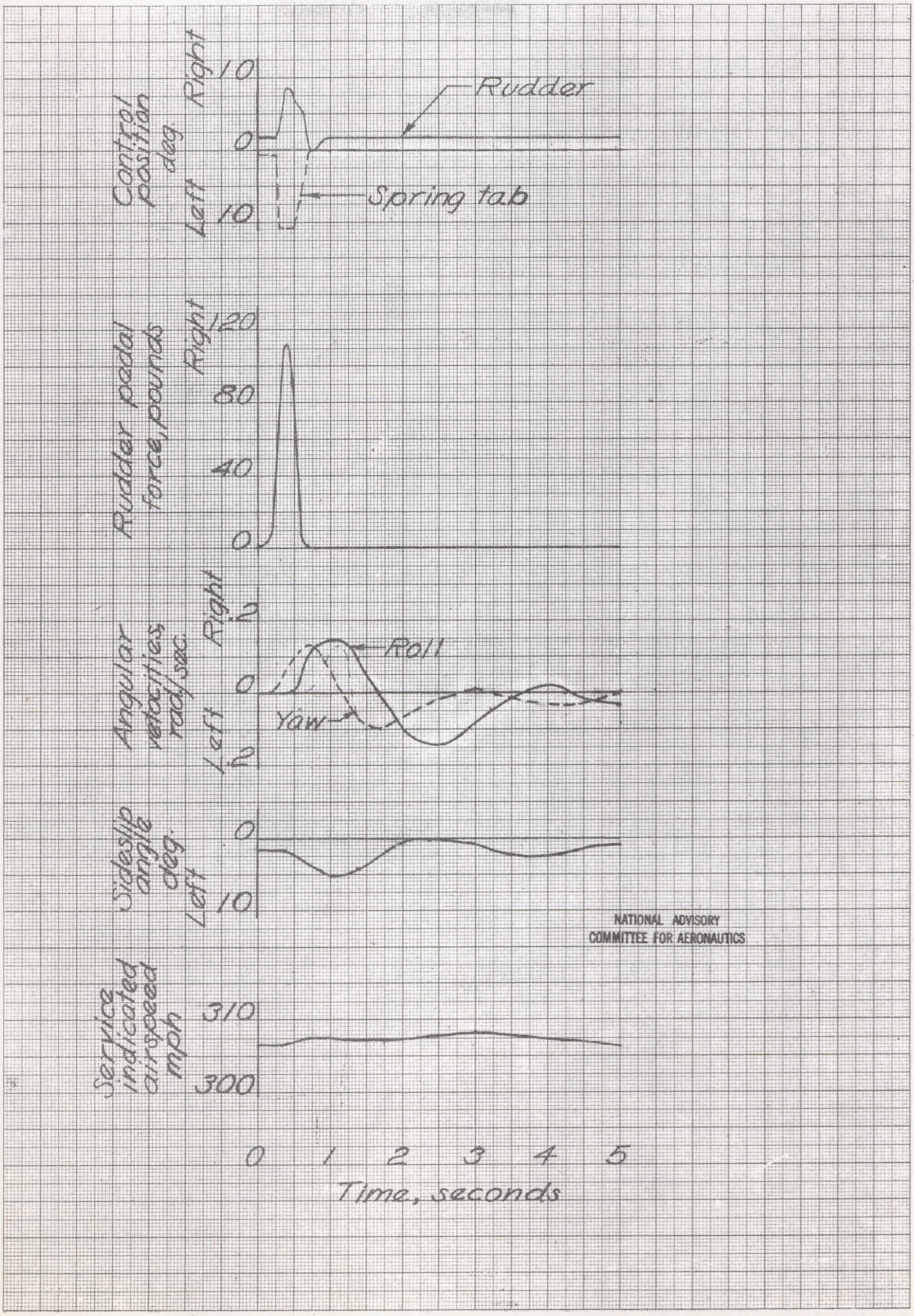

Figure 11. - Concluded.

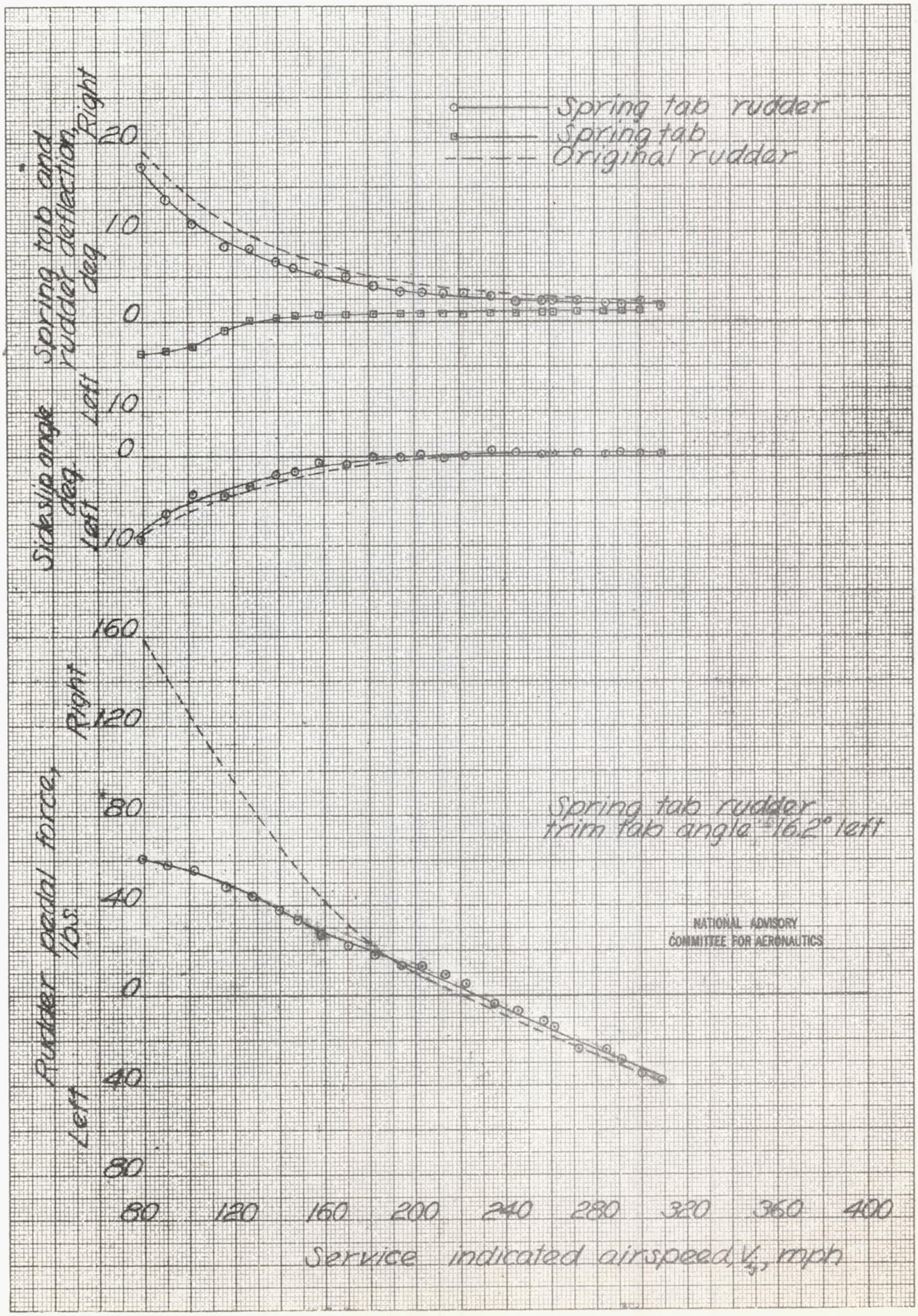

Figure 12. - Directional trim characteristics, spring tab rudder with ±50 pounds preload, climbing condition, F6F-3 airplane.

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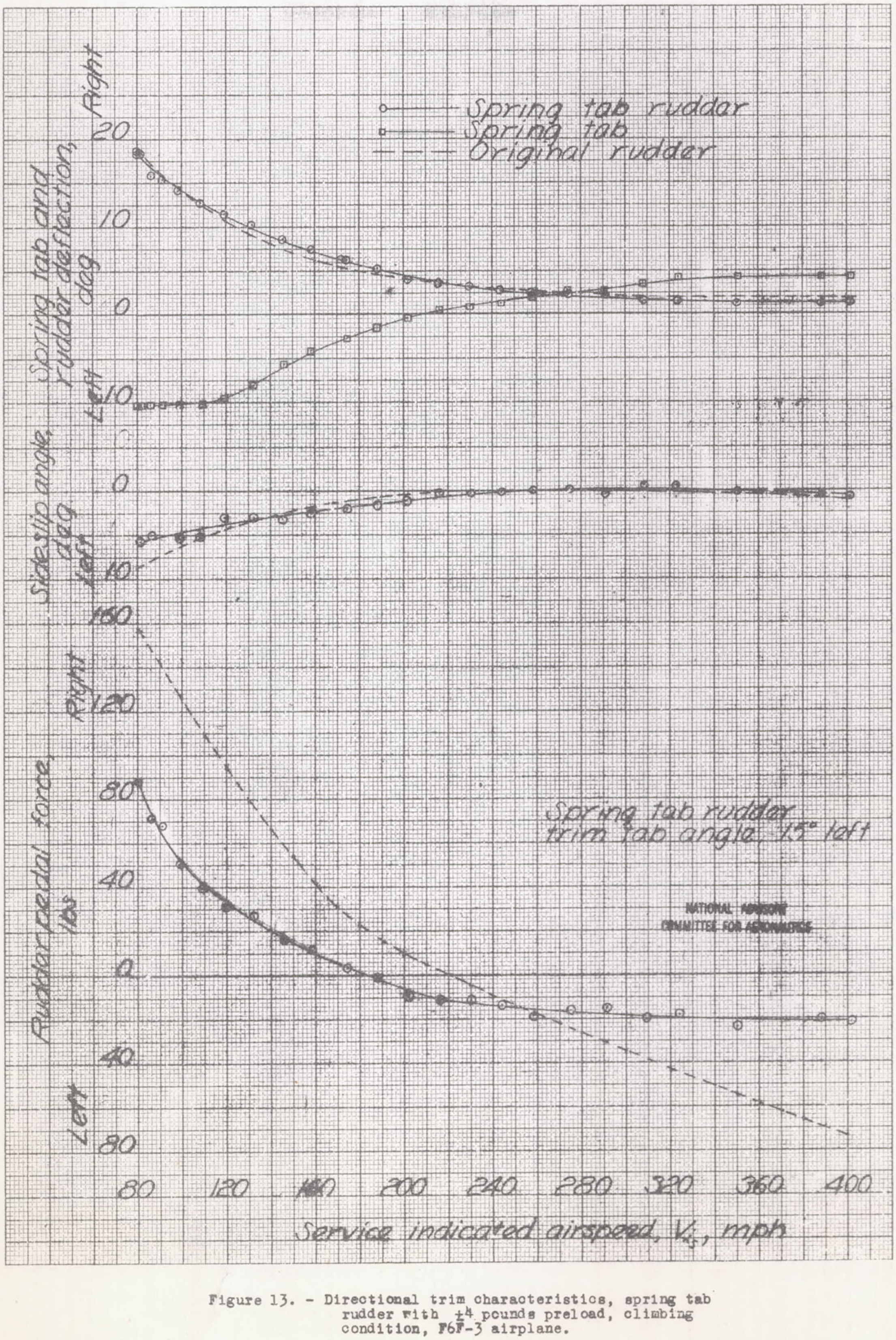

Figure 13. - Directional trim characteristics, spring tab rudder with ±4 pounds preload, climbing condition, F6F-3 airplane.

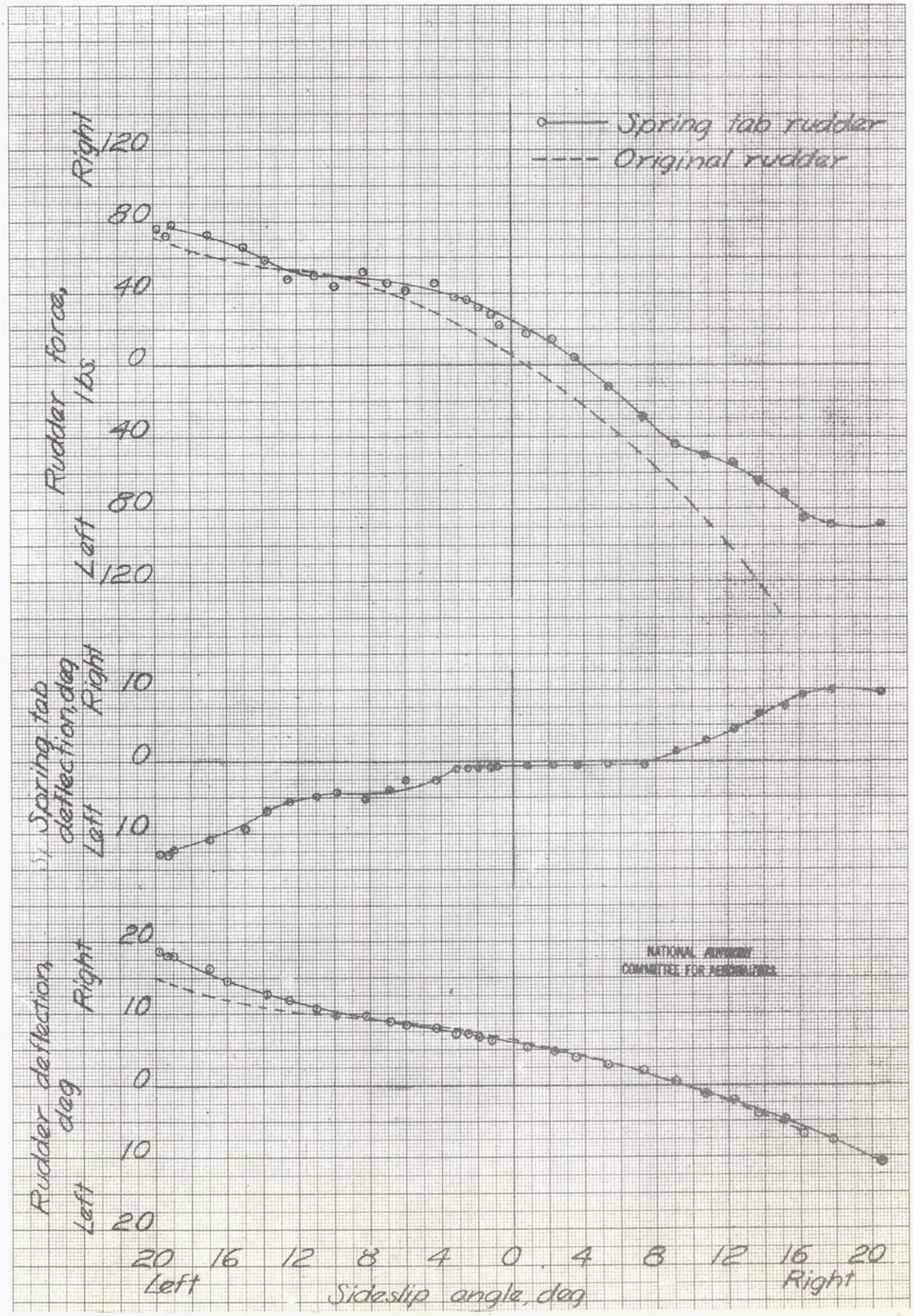

Figure 14. - Steady sideslip characteristics, at 150 miles per hour in the climbing condition, spring tab rudder with ±50 pounds preload, F6F-3 airplane.

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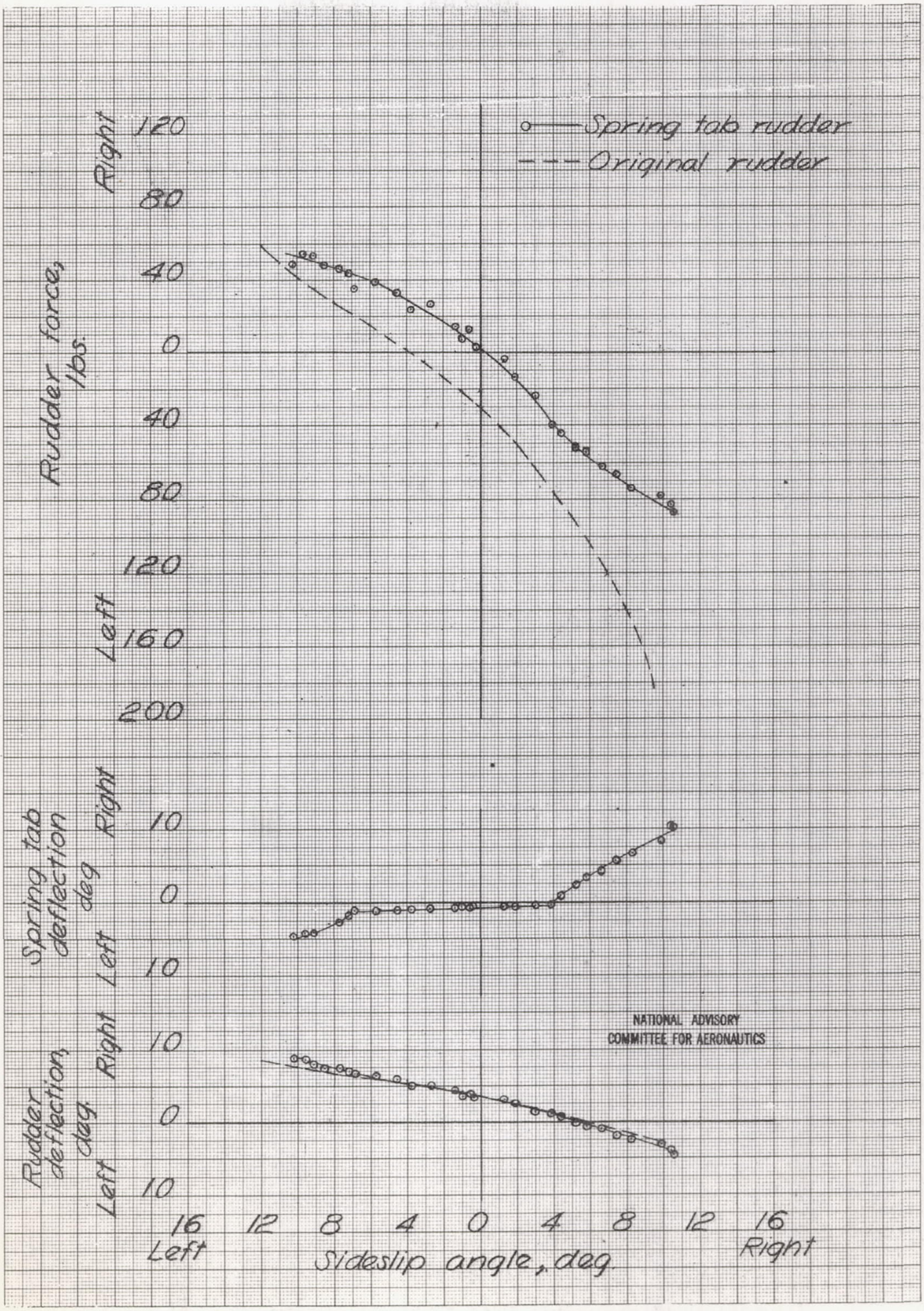

Figure 15. - Steady sideslip characteristics at 200 miles per hour in the climbing condition, spring tab rudder with ±50 pounds preload, F6F-3 airplane.

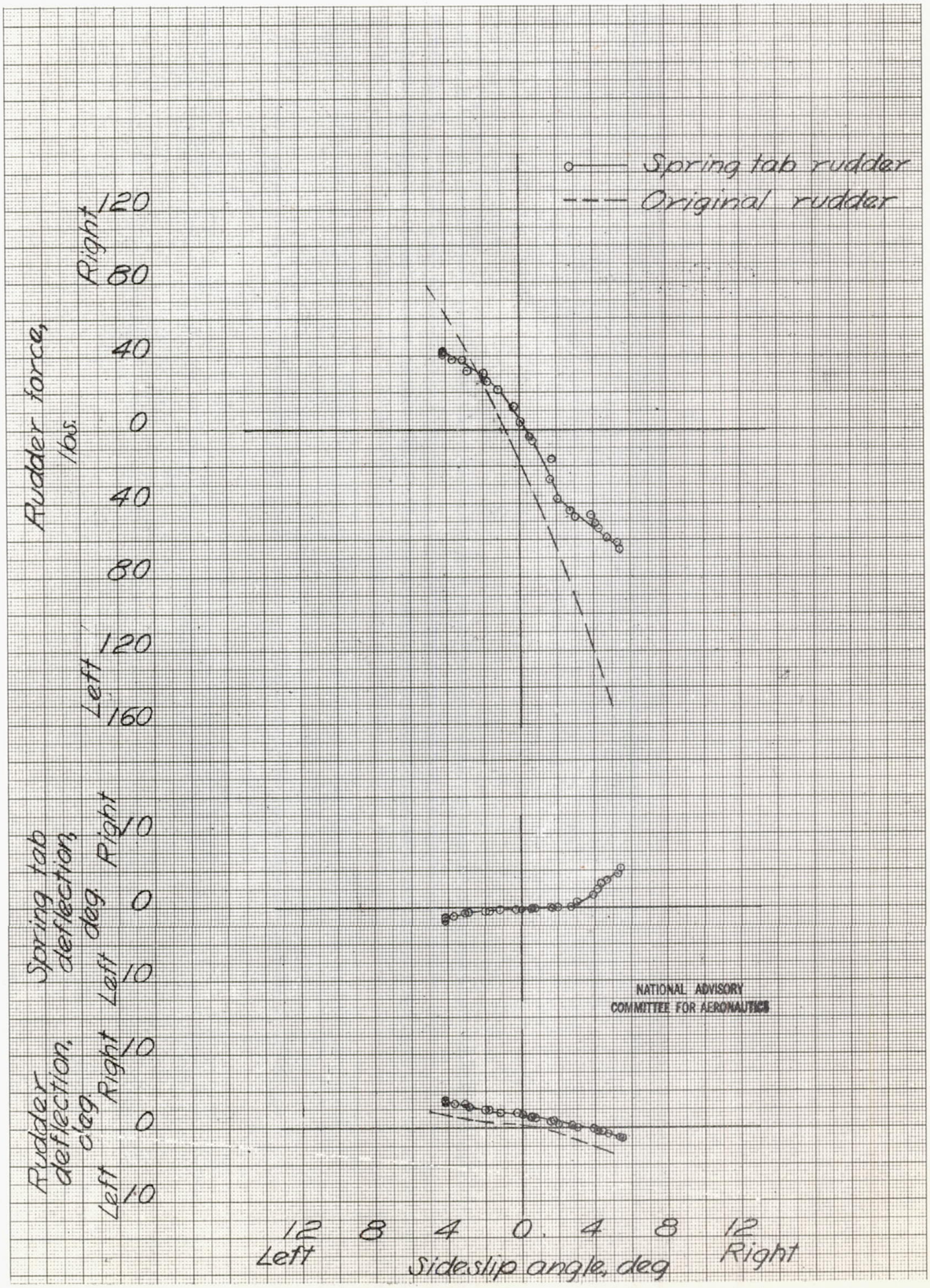

Figure 16. - Steady sideslip characteristics at 300 miles per hour in the climbing condition, spring tab rudder with ±50 pounds preload, F6F-3 airplane.

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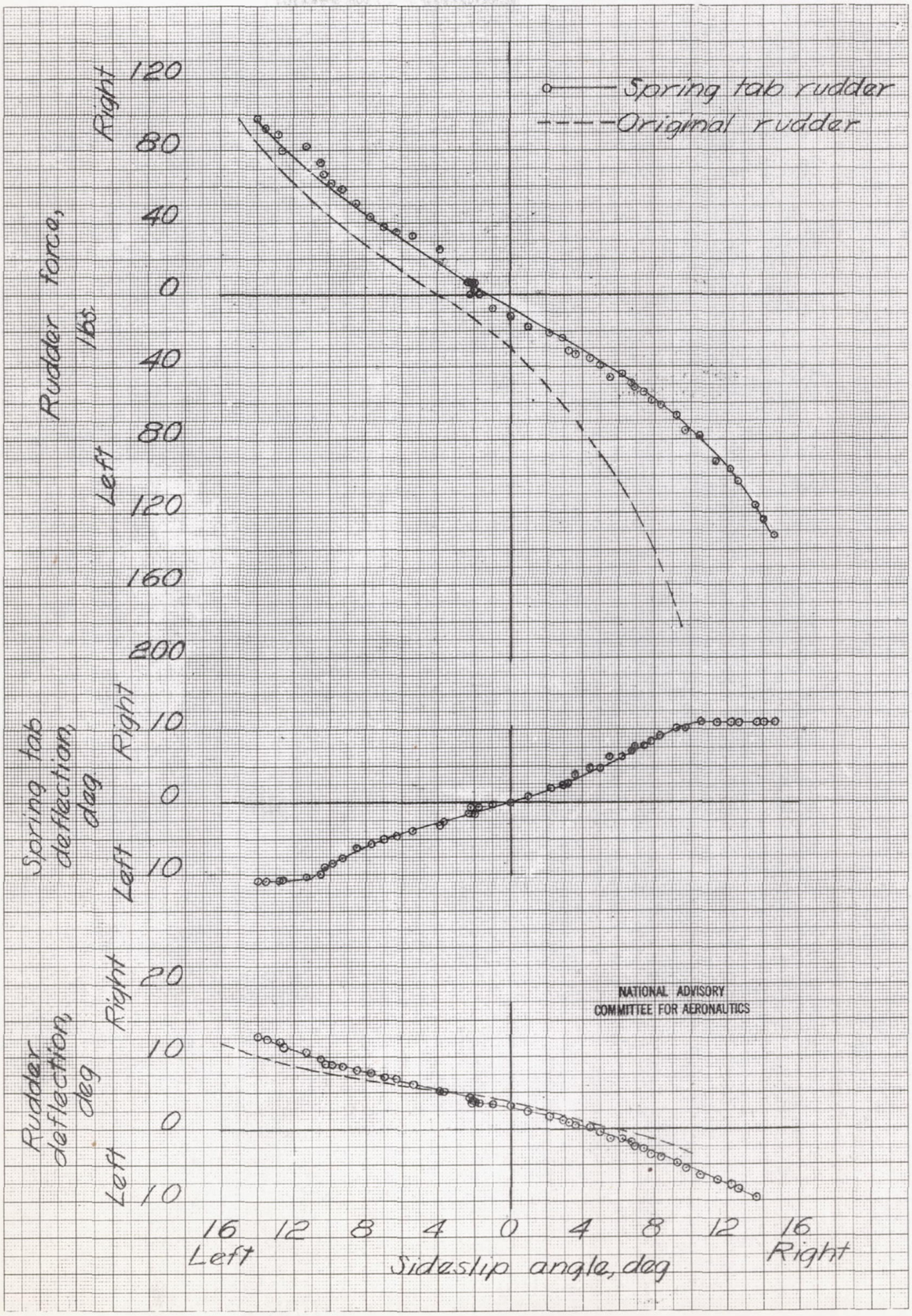

Figure 17. - Steady sideslip characteristics at 200 miles per hour in the climbing condition, spring tab rudder with ±4 pounds preload, F6F-3 airplane.

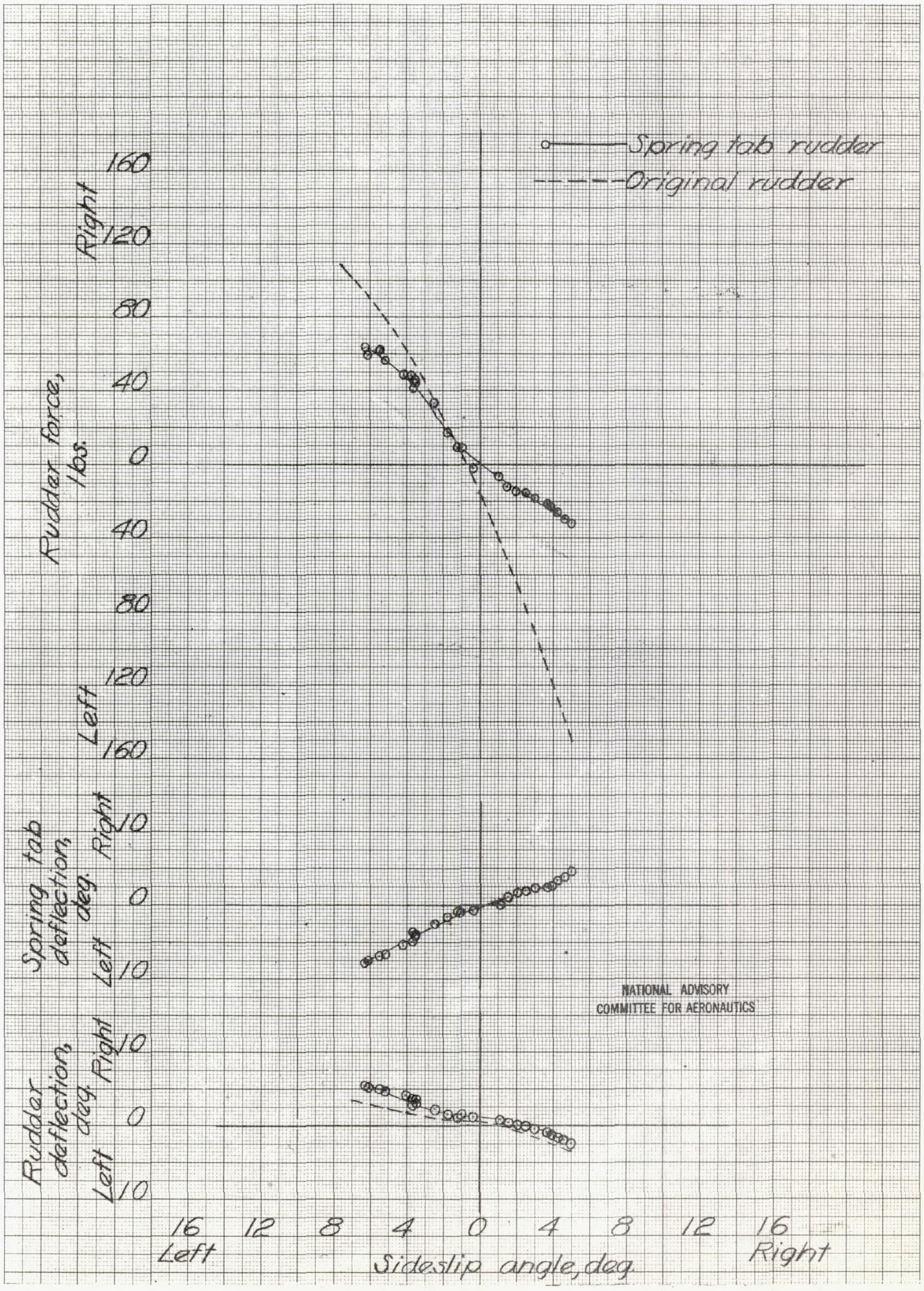

Figure 18. - Steady sideslip characteristics at 300 miles per hour in the climbing condition, spring tab rudder with ± 4 pounds preload, F6F-3 airplane.

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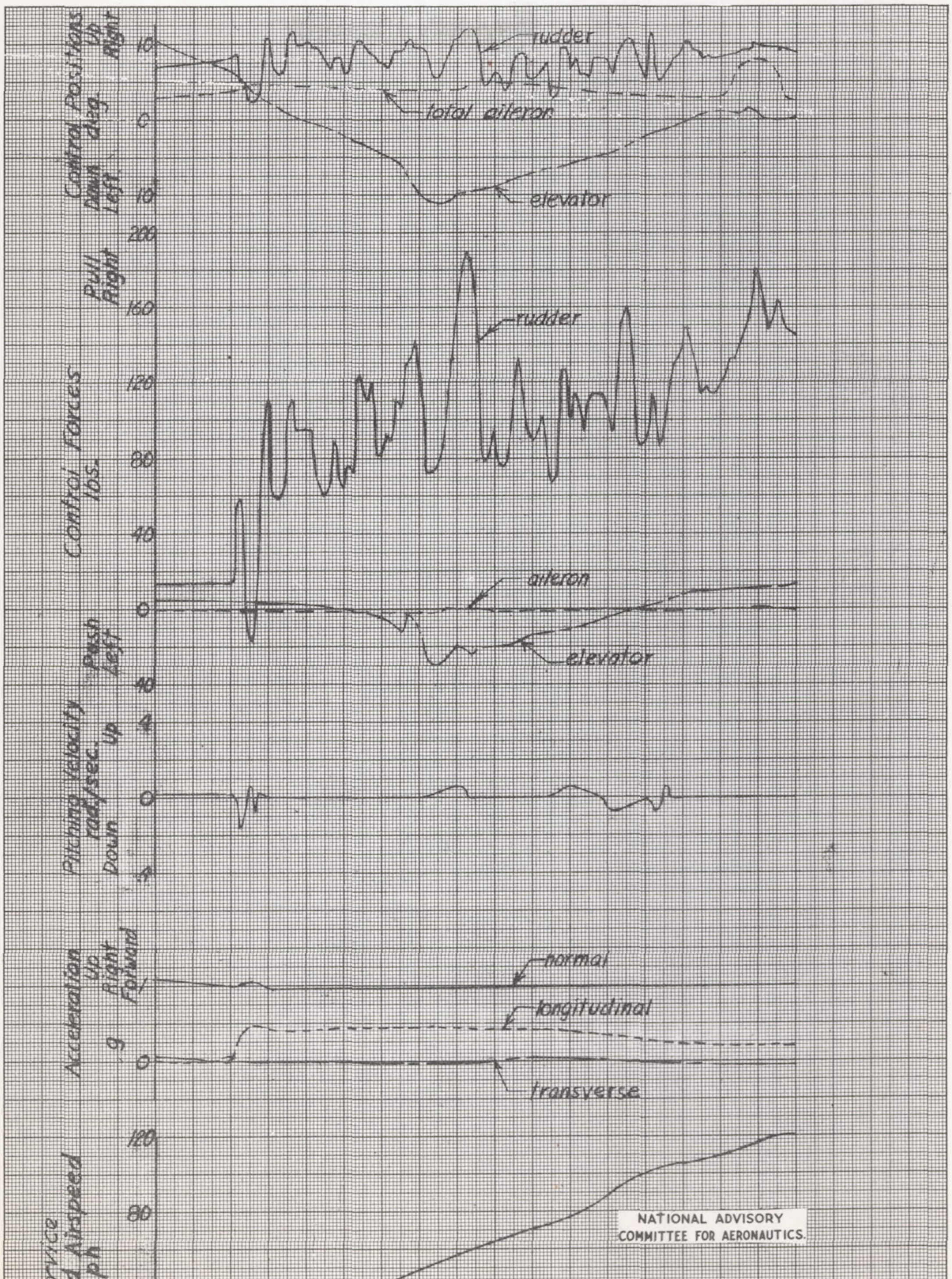

Figure 19. - Time history of a typical take-off.
FoF-3 airplane with original rudder.

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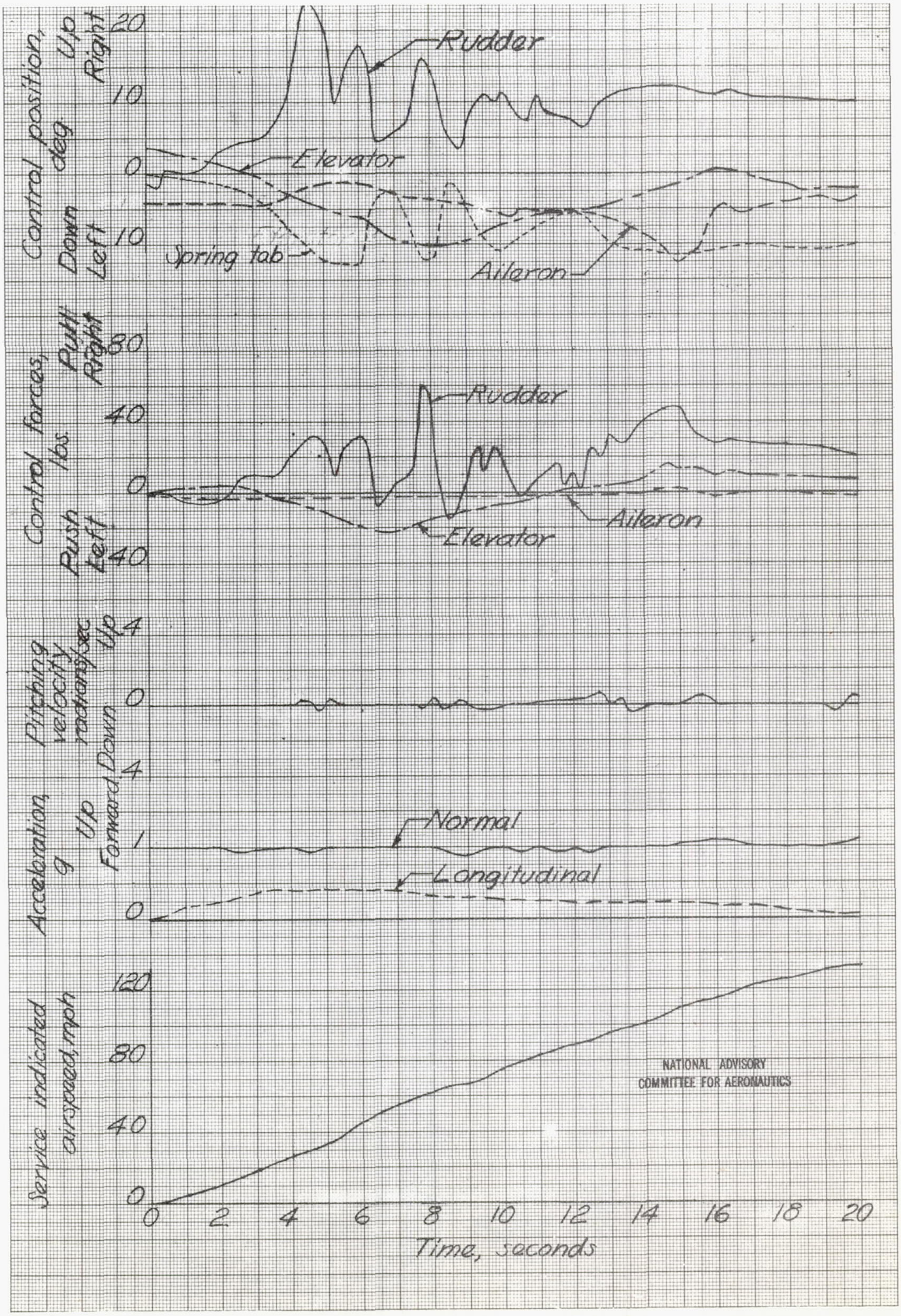

Figure 20. - Time history of a take-off, spring tab rudder with ±4 pounds preload, F6F-3 airplane.