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A FLIGHT INVESTIGATION OF INTERNALLY BALANCED  
SEALED AILERONS

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SEALED AILERONS

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SUMMARY

Flight tests were made of a type of internally balanced sealed ailerons installed on a Ryan ST airplane. Aileron effectiveness and stick forces were measured at various airspeeds using NACA recording instruments. For comparison, the aileron characteristics were also determined without the internal balances and seals. The section characteristics of the ailerons tested are presented in nondimensional form.

The seals and the balances increased aileron effectiveness 6 percent and reduced hinge-moment coefficients by an average of 45 percent.

INTRODUCTION

Wind-tunnel tests of control surfaces employing internal balance and a positive seal showed that aerodynamic balance completely enclosed in the wing materially reduced hinge moments while the control effectiveness of sealed-type controls was retained.

The present report describes flight tests of a similar balance arrangement in which the control effectiveness and hinge moments were determined under actual operating conditions.

These flight tests were conducted at the Langley Field Laboratory of the National Advisory Committee for Aeronautics.

APPARATUS

Internally balanced sealed ailerons were designed for installation on a Ryan ST airplane. In the design the plan form of the original ailerons was retained, but the control linkage that gave differential deflections of  $30^\circ$  up and  $20^\circ$  down was replaced with one that gave equal deflections up and down of  $16^\circ$ . (The deflection range was limited by the movement of the balance.) On the basis of data from reference 1, the ailerons could be

expected to give a maximum  $pb/2V$  value of 0.07 which, at the low airspeeds of the Ryan airplane, would be inadequate control for acrobatics.. Since the investigation was being made to determine the characteristics of the ailerons and not the airplane, the installation was considered satisfactory for the tests.

Figure 1 shows a three-view layout of the airplane and the plan form of the ailerons. Details of the sealed and balanced aileron arrangement are given in figure 2. The seal was sheet rubber 1/32-inch thick, continuous along the length of the aileron. It was securely fastened at both edges to assure a positive seal between the wing and the leading edge of the balance. Because of structural difficulties, the balance extended only to a point 12 inches from the outboard tip of the ailerons, leaving 6.5 percent of the total aileron area unbalanced. The aileron hinge brackets and the push-pull tubes of the control system were designed to lie close to the lower surface of the wing, thereby providing an unobstructed space for the movement of the seal and the balance.

Standard NACA recording Instruments, synchronized by an electric timer, were used to measure airspeed, aileron position, aileron stick force, and rolling velocity. The aileron positions were determined by recording the position of the control stick. A correction of  $0.3^\circ$  per pound of stick force was applied to the recorded aileron deflections to take care of control-cable stretch. This correction was obtained by measuring the deflections between the stick and the ailerons for various static loads.

The relation between stick and aileron positions for the no-load condition is shown in figure 3.

#### SYMBOLS

The symbols used in this report are as follows:

- $p$  rolling velocity, radians per second
- $V$  true airspeed, feet per second
- $b$  wing span, feet
- $\bar{c}_a$  average chord of aileron back of hinge line
- $c_w$  wing chord, feet

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- $S_a$  aileron **area**, square feet
- $t_a$  aileron thickness at the hinge line
- $q$  dynamic pressure  $\left(\frac{1}{2}\rho V^2\right)$
- $H$  hinge moment, foot-pounds
- $C_h$  hinge-moment coefficient  $\left(\frac{H}{q S_a t_a}\right)$
- $F$  control force, pounds
- $\alpha$  angle of attack, degrees
- $\delta$  aileron deflection, degrees
- $k$  aileron effectiveness factor  $(\Delta\alpha/\Delta\delta)$  (See reference 1.)

#### TESTS AND RESULTS

Two series of tests were conducted: one with the seals and balances installed, the other with them removed. The flight-test procedure for measuring aileron characteristics consisted in trimming the airplane at a given airspeed and then abruptly deflecting the ailerons with the rudder held steady. Records were taken of rolling velocity, control position, stick force, and airspeed. Runs were made at speeds of 60, 105, and 130 miles per hour indicated airspeed with the ailerons one-quarter, one-half, three-quarters, and fully deflected. Full deflection was determined by stops on the control system; other deflections were determined by means of a strap in the cockpit. The effectiveness of the aileron arrangements tested is shown in figures 4 and 5 where the wing tip helix angle,  $\rho b/2V$  is plotted as a function of aileron deflection.

Control forces are usually obtained from abrupt control deflections. The stick forces on the Ryan airplane, however, were extremely small; special precautions were therefore necessary to eliminate the effect of friction forces. Instead of abrupt deflections being employed, the ailerons were slowly deflected (eliminating inertia forces) and continuous records were taken of the variations of stick force with aileron deflection. Friction was known to be opposing the pilot while the stick was moving; the slow rolls therefore gave data from which it was possible to subtract

the effect of friction. Typical curves showing the variations of control force with deflection of the ailerons are given in figures 6 and 7. It is apparent that the friction can be corrected for by displacing the curves parallel to themselves to give zero force at the trim position. The force curves given in figures 8, 9, and 10 were obtained in this manner and were also corrected for control-cable stretch.

The variation of hinge-moment coefficient  $C_h$  with aileron deflection is presented in figure 11. The values given are one-half the sum of the hinge-moment coefficients for the two ailerons because the left and the right aileron forces were not separated.

#### DISCUSSION

The sealed and balanced aileron installation was expected to give a value of  $pb/2V$  of 0.07 at a total aileron deflection of  $32^\circ$ . Figure 4 indicates that the ailerons were slightly more effective than expected, the value of  $pb/2V$  of 0.07 being reached at  $30^\circ$  total aileron deflection. With the seals and balances removed (fig. 5) aileron effectiveness decreased approximately 6 percent as shown by the increased angle required to obtain a  $pb/2V$  value of 0.07. The relatively small difference in effectiveness between the sealed and unsealed arrangements is attributed to the very narrow vent between the aileron and the wing. There was a difference in total aileron angle change for right and left displacements of the stick because approximately  $2^\circ$  of right aileron were required to trim the airplane.

Calculated values of  $k$  (aileron effectiveness factor) were 0.331 and 0.312 for the sealed balanced and the unsealed unbalanced ailerons, respectively. These values are somewhat higher than those previously obtained in flight for sealed and unsealed plain ailerons. (See fig. 3 of reference 1.) The values given in reference 1, however, are not corrected for control-cable stretch.

From figures 8, 9, and 10 it can be seen that the seals and the balances caused a definite reduction in stick force that varied from approximately 50 percent at the high angle-of-attack condition to 43 percent at the low angle-of-attack condition. Figure 11 shows a similar reduction due to balances in the hinge-moment coefficients. No wind-tunnel data are available for direct comparison; but there is general agreement with the hinge-moment coefficients in unpublished data when proper allowance is made for the floating tendencies of the ailerons during the roll.

## CONCLUDING REMARKS

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The flight tests indicate that internal aerodynamic balance in conjunction with a positive seal may be used to reduce hinge moments.

In the present instance an internal balance projecting forward of the hinge line 32.5 percent of the aileron chord reduced the hinge moments by an average of 45 percent. The aileron effectiveness was comparable with that of other sealed ailerons that have been tested in flight.

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## REFERENCE

1. Gilruth, R. R., and Turner, W. N.: Lateral Control Required for Satisfactory Flying Qualities Based on Flight Tests of Numerous Airplanes. Rep. No. 715, NACA, 1941.

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Figure 1. A three view drawing of a Ryan ST airplane with sealed and balanced ailerons.

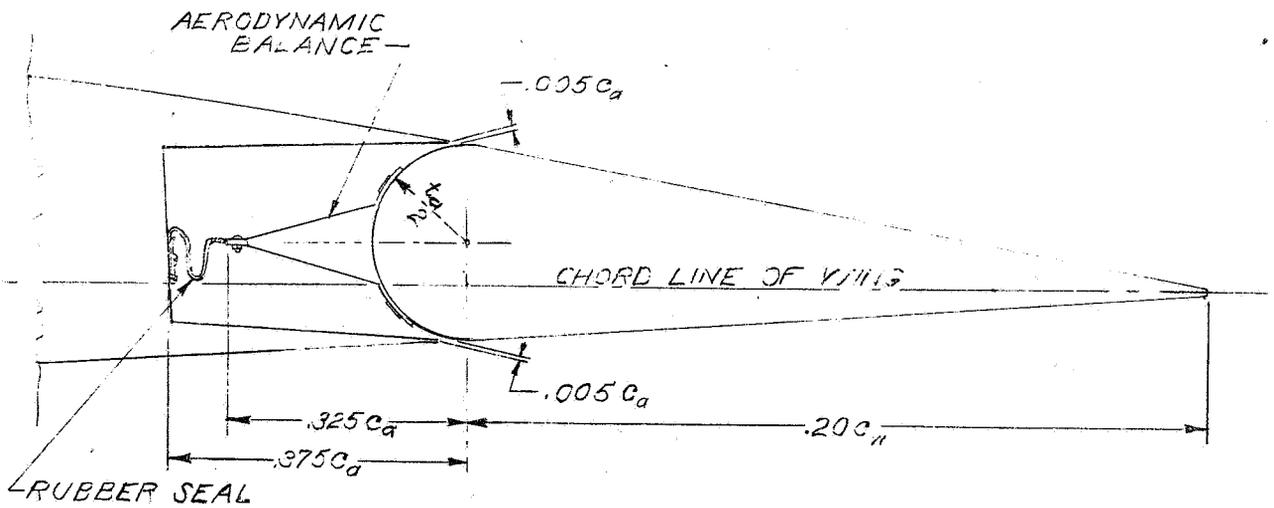
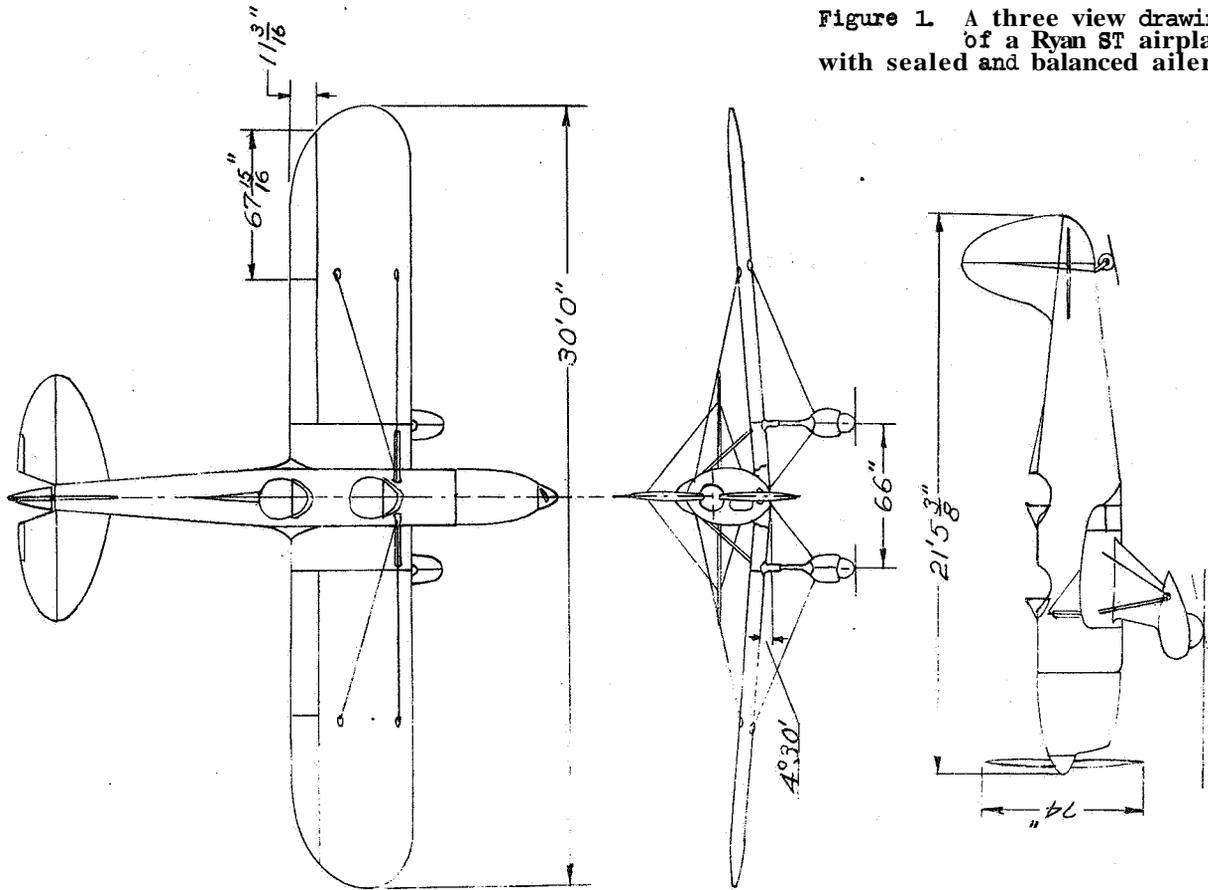


Figure 2. Sketch of sealed and balanced aileron arrangement as used on Ryan ST airplane.

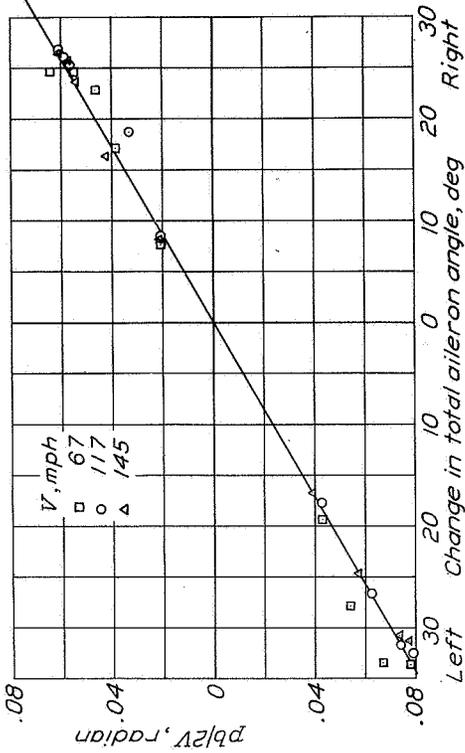


Figure 4.- Variation of helix angle  $pb/2V$  with change in aileron deflection. Ryan ST airplane with internally balanced ailerons.

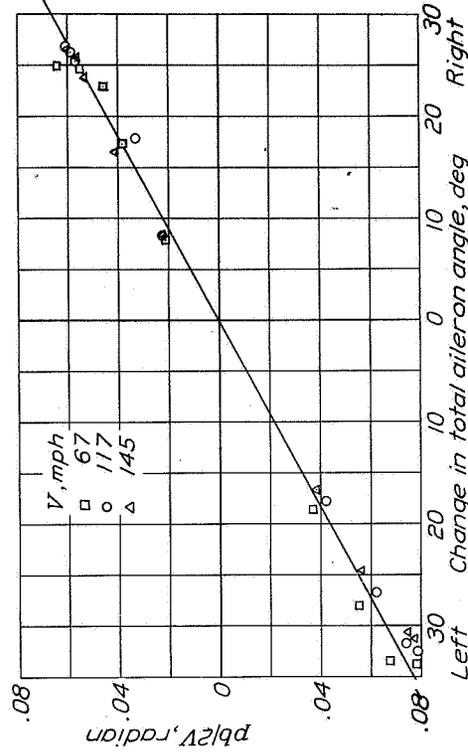


Figure 5.- Variation of helix angle  $pb/2V$  with change in aileron deflection. Ryan ST airplane with seals and balances removed.

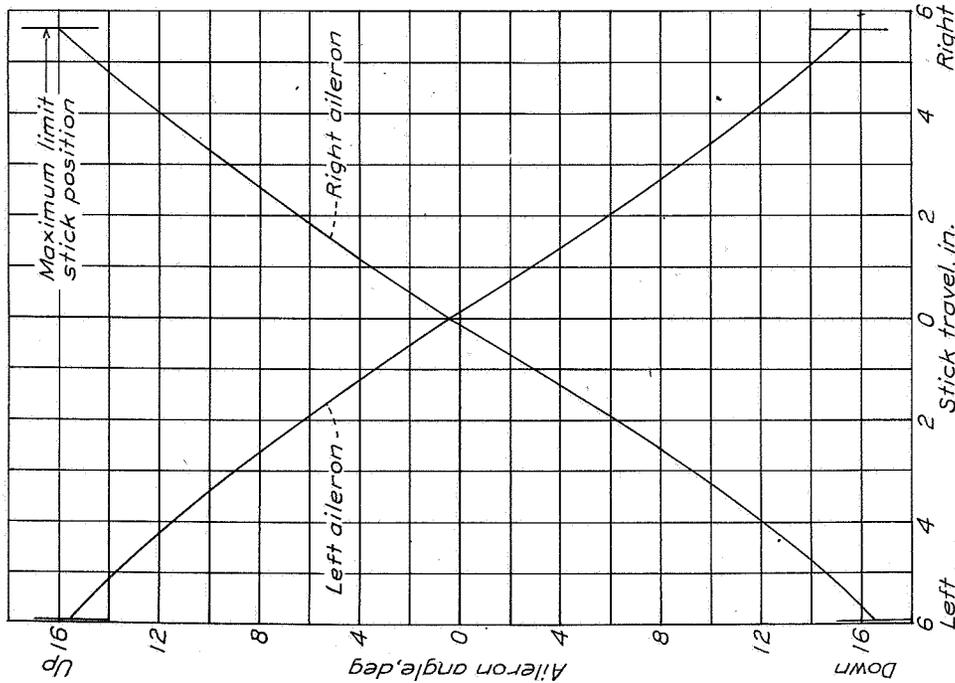
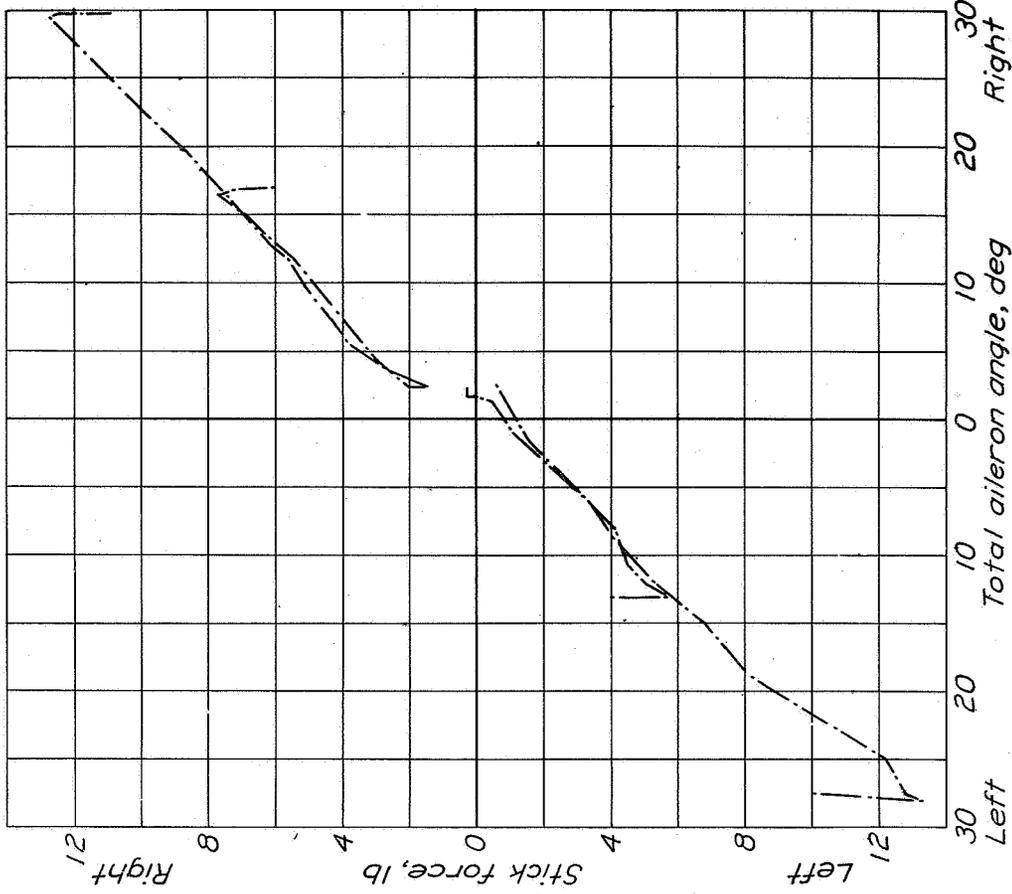


Figure 3.- Relation between aileron and stick position. Ryan ST airplane with internally balanced aileron installation. (No load condition.)

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Fig# 6,7

Figure 7.- Variation of stick force with aileron deflection as recorded in slow control movements. Ryan ST airplane with seals and balances removed. Indicated airspeed, 130 miles per hour;  $C_L$ , 0.26.

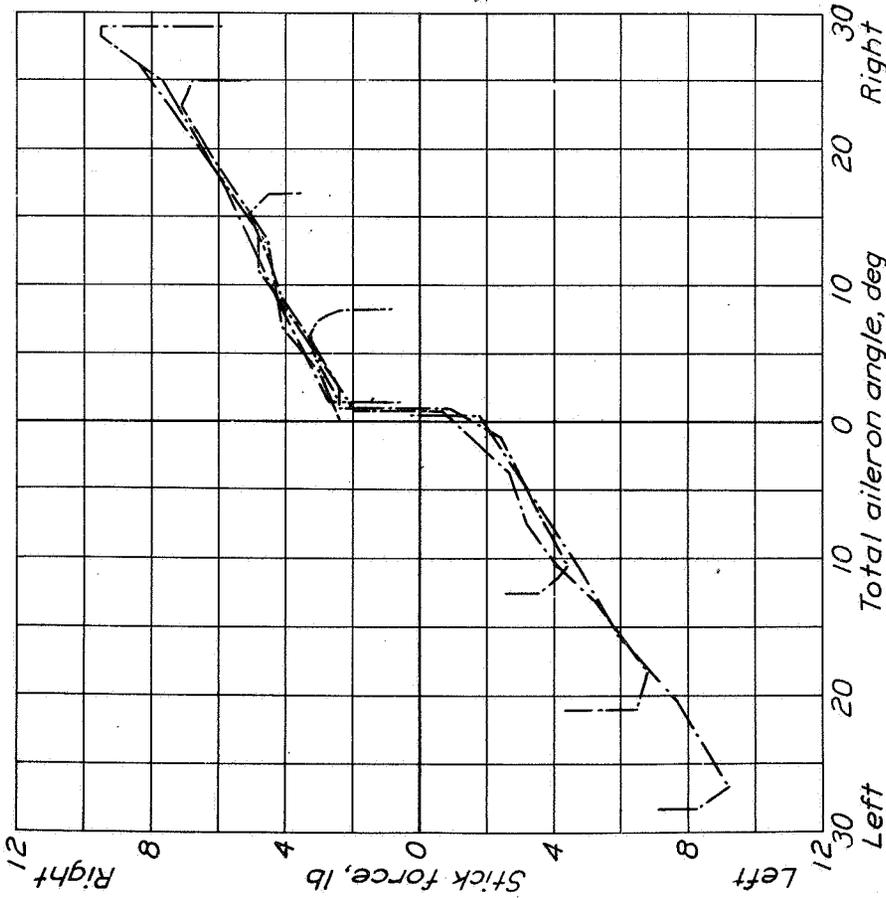


Figure 6.- Variation of stick force with aileron deflection as recorded in slow control movements. Ryan ST airplane with internally balanced ailerons. Indicated airspeed 130 miles per hour;  $C_L$ , 0.26.

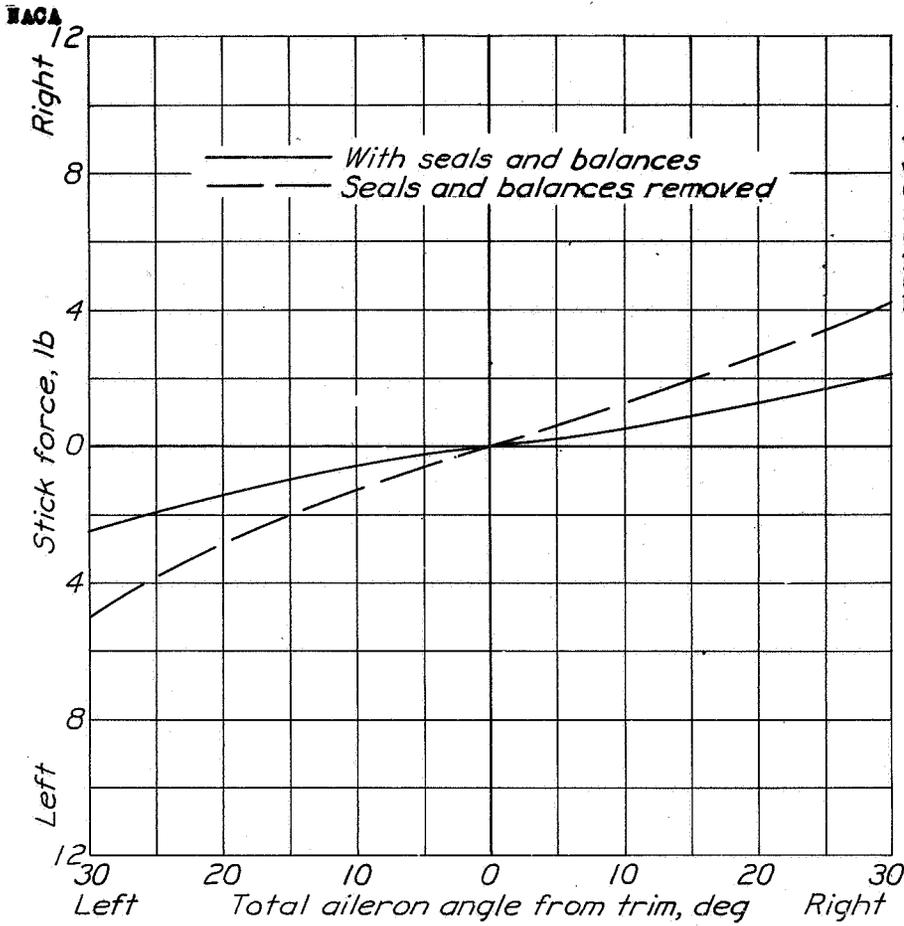


Figure 8.-  
Variation of stick force with aileron deflection. Curves corrected for friction and cable stretch. Ryan ST airplane. Indicated airspeed, 60 miles per hour;  $C_L, 1.24$ .

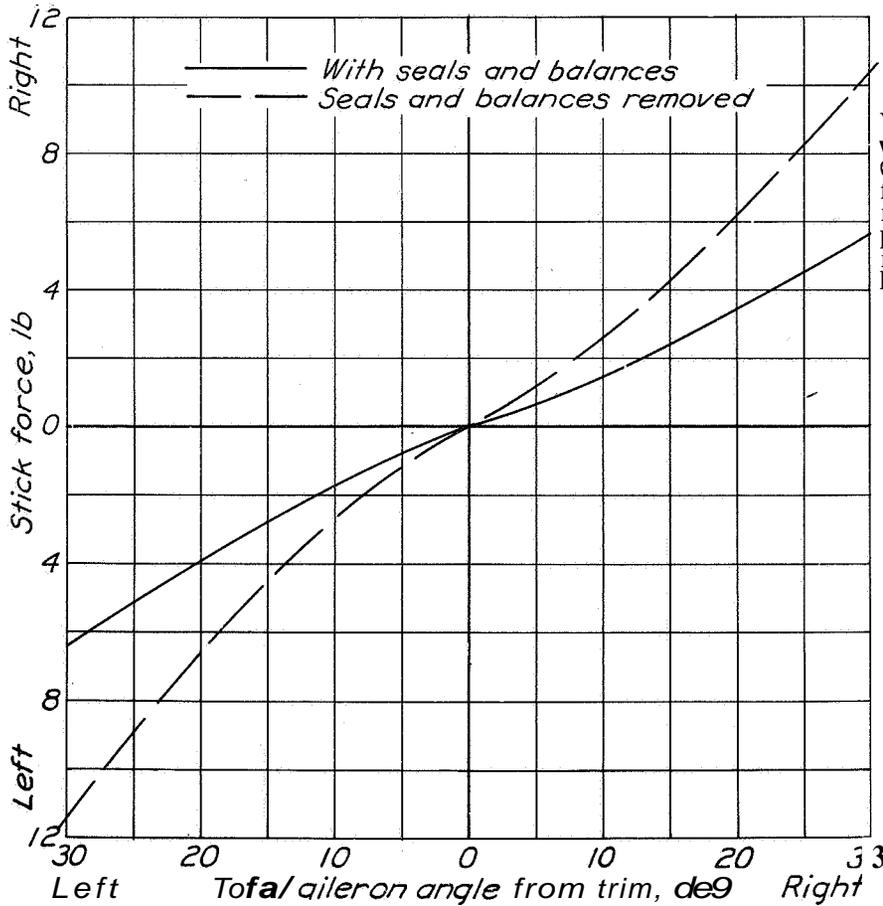


Figure 9.-  
Variation of stick force with aileron deflection. Curves corrected for friction and cable stretch. Ryan ST airplane. Indicated airspeed, 105 miles per hour;  $C_L, 0.41$ .

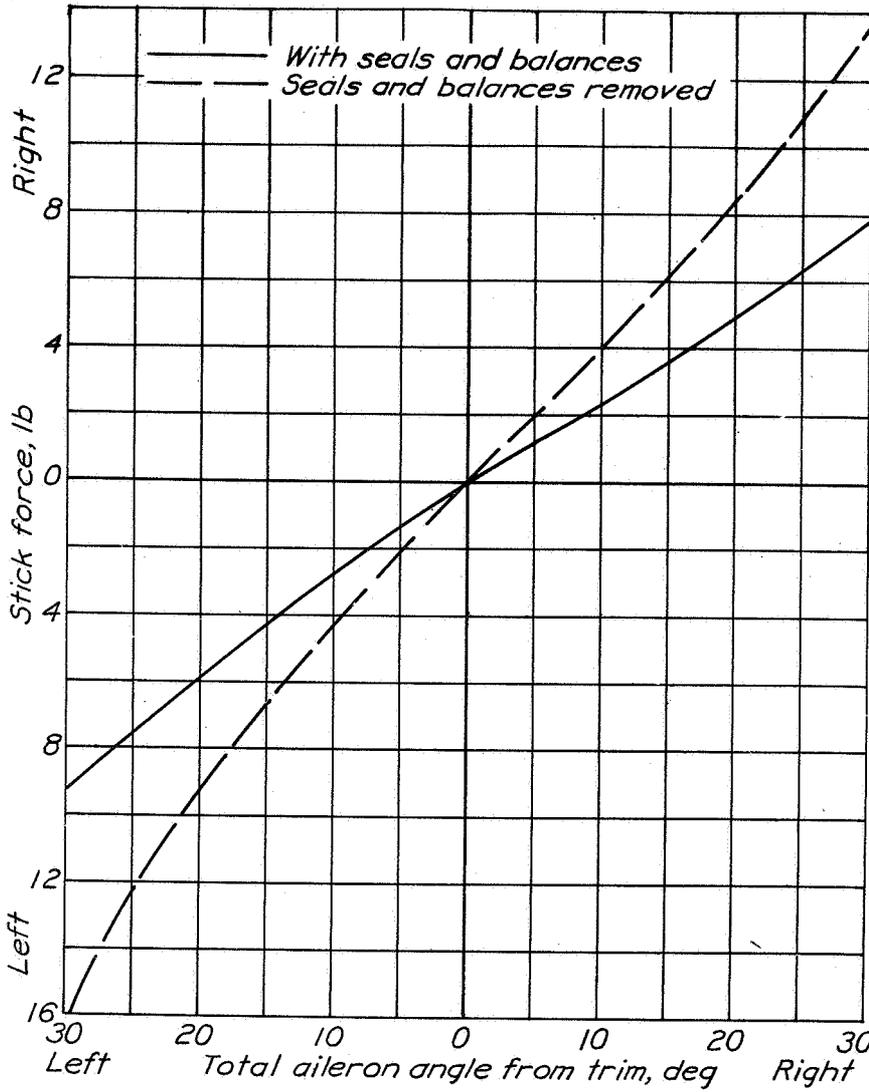


Figure 10.- Variation of stick force with aileron deflection. Curves corrected for friction and cable stretch. Ryan ST airplane. Indicated airspeed, 130 miles per hour;  $C_L$ , 0.26.

Figure 11.- Variation of hinge-moment coefficient with aileron deflection for internally balanced and plain ailerons. Ryan ST airplane.

