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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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RESTRICTED BULLETIN

A STUDY OF THE EFFECT OF INCREASED SIZE AND SPEED OF PURSUIT AIRPLANES ON THE AILERON BALANCING PROBLEM

By H. A. Soulé and S. M. Harmon

INTRODUCTION

The present trend is toward faster and larger pursuit airplanes. Because both speed and size increase the aileron control forces, the design of ailerons for manual operation is becoming increasingly difficult. In order to obtain a clearer picture of the future problem of balancing ailerons, an inspection has been made of the effects of airplane size and speed on the control forces.

Computations were made of the aileron control forces required to meet specified rolling conditions for plain ailerons on wings with spans from 40 to 80 feet and for speeds up to 500 miles per hour. The rolling conditions were specified by two alternative criterions. One was the rolling criterion $pb/2V$ of reference 1. For reasons, which will be discussed later, a value of 0.09 rather than the recommended value of 0.07 was assigned to this criterion. For the criterion $pb/2V$, the required value of the rolling velocity p varies inversely with the airplane span b . There is some question as to whether the rolling velocity of a pursuit airplane can be permitted to decrease simply because its size is increased. For the second criterion, therefore, the rolling velocity is independent of span (p/V is a constant). The value assigned to this criterion was so chosen that for a wing of 40-foot span the value of $pb/2V$ would be 0.09.

The computations neglected compressibility effects. Available experimental data and the results of tests given in reference 2 indicate that the effect of compressibility is to increase the control force. Recent flight tests have indicated that, with certain types of aileron, serious compressibility effects may cause discontinuity at speeds of approximately 400 miles per hour in the aileron control force curves.

CONDITIONS

The dimensions of the wings inspected follow:

| | |
|--------------|------------------------|
| Taper ratio | 2 to 1 |
| Aspect ratio | 6 and 10 |
| Span, feet | 40, 50, 60, 70, and 80 |

The characteristics of the ailerons were:

| | |
|-----------------|--|
| Type | Plain, sealed ailerons extending to wing tip |
| Span | $0.40b/2$ |
| Deflection, deg | ± 15 |
| Chord | Adjusted to give the specified rolling condition |

The circumferential motion of the top of the control stick was taken as ± 10 inches. The computations were made for speeds of 100, 200, 300, 400, and 500 miles per hour (V equals 147, 294, 441, 588, 735 fps).

The method of computation was essentially that described in reference 3. A value of $\rho b/2V$ of 0.09 was employed in the computations because it was found that the use of this value of the rolling criterion gave aileron sizes more in line with current practice than the recommended value of 0.07. The allowance of 0.02 is apparently needed in the computations in order to compensate for the effects of wing twist, deflection or slack in the control system, and adverse aileron yaw. Section data for the plain ailerons considered in the computations were taken from reference 4.

RESULTS

The results of the computations are given in figures 1 to 3. Figure 1 shows the variation with wing span of the aileron chord required to meet the rolling criterions. Curves for aileron spans (b_a) of $0.3 b/2$ and $0.5 b/2$ have been added to the figure to show the effect of aileron span on the required chord. Figure 2 shows the variation

of the aileron control force with wing span and airspeed for the 0.4-span aileron. Figure 3 shows as a percentage, with plain ailerons used as a reference, the amount of aerodynamic balance that would be necessary in order to reduce the aileron forces to the value of 30 pounds recommended in reference 1.

The data presented in the figures apply to full aileron deflection for an airplane with a stick control under sea-level conditions. Both the control force and the control response with a given linkage vary directly with the control deflection so that the forces required for lower values of the rolling criterion at partial deflection can be readily determined from figure 2. It should be appreciated that it is the difference between unity and the value indicated in figure 3 rather than the value itself that varies directly with the response. For example, if conditions are chosen that show that a 95-percent reduction of the hinge moment is required for a $pb/2V$ of 0.07 in flight (0.09 in the computations), a 90-percent reduction would be required for a $pb/2V$ of 0.035. The effect of altitude is to decrease the stick forces for a given true airspeed in direct proportion to the density ratio. The effect of replacing the stick by a wheel control would be to divide the control force by 6 for a given set of conditions. None of these factors will greatly affect the conclusions drawn from the figures.

CONCLUDING REMARKS

The principal points illustrated by the computations may be summarized as follows:

1. As expected, increases in both speed and size of pursuit airplanes complicate the problem of obtaining satisfactorily light and powerful aileron control. For short spans the problem of balancing the ailerons sufficiently for manual operation is not too serious up to speeds of 500 miles per hour, provided that no critical compressibility effects with attendant discontinuities in the aileron hinge-moment-coefficient curves occur. Because the control forces vary as the square of the speed, ailerons that are suitably light at high speeds, however, may be extremely light at low speeds. A balancing device, the action of which increases at a rate greater than the square of the speed, is needed.

2. As the span is increased, the problem of balancing the ailerons becomes more serious because of the superposition of span and speed effects. It will be extremely difficult, if not impossible, to maintain constant rolling velocity when the wing span is increased much above 60 feet. Even for constant $pb/2V$ it will be necessary to balance out at least 97 percent of the hinge moment of a plain aileron in order to obtain a value for $pb/2V$ of 0.07 in flight for an 80-foot span wing at 500 miles per hour. In addition, these severe balance requirements are not noticeably relieved even though the aileron deflection is decreased markedly from the maximum.

3. The large amounts of aerodynamic balance required under extremes of span and speed will make conditions critical for manual operation, as deviations of dimensions with the normal manufacturers' tolerances will cause large changes in force characteristics. Some servo-device - aerodynamic, hydraulic, or mechanical - probably will be necessary. If a hydraulic or mechanical system is used, considerable aerodynamic balance will still be required to keep the mechanism to a reasonable size.

4. For a given wing area, in order to obtain the greatest rate of roll for a given stick force, the wing span should be as short as practicable.

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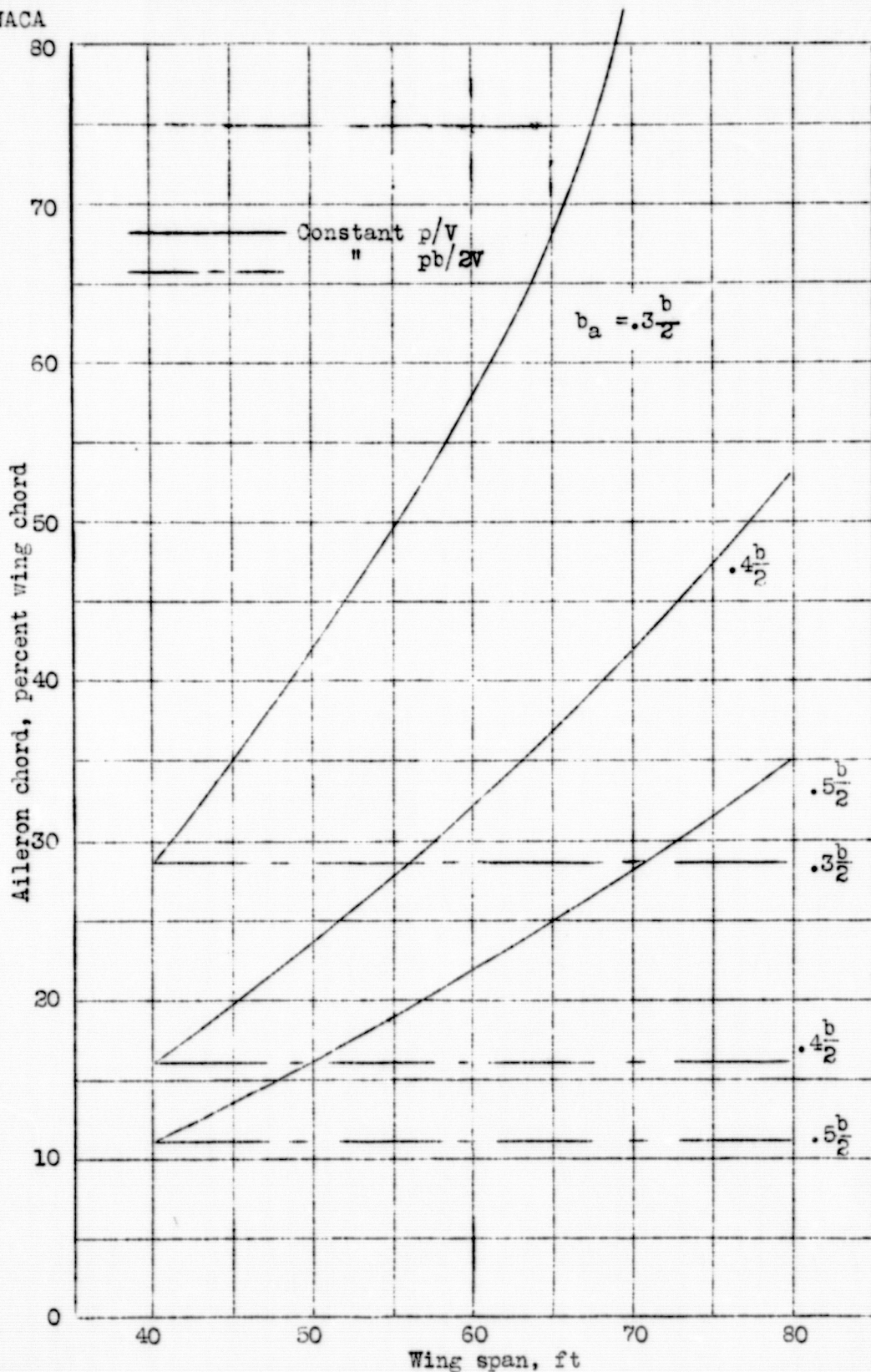


Figure 1.- Variation with wing span of the aileron chord required to obtain rates of roll corresponding to values of $pb/2V$ of 0.09 and of p/V of 0.0045.

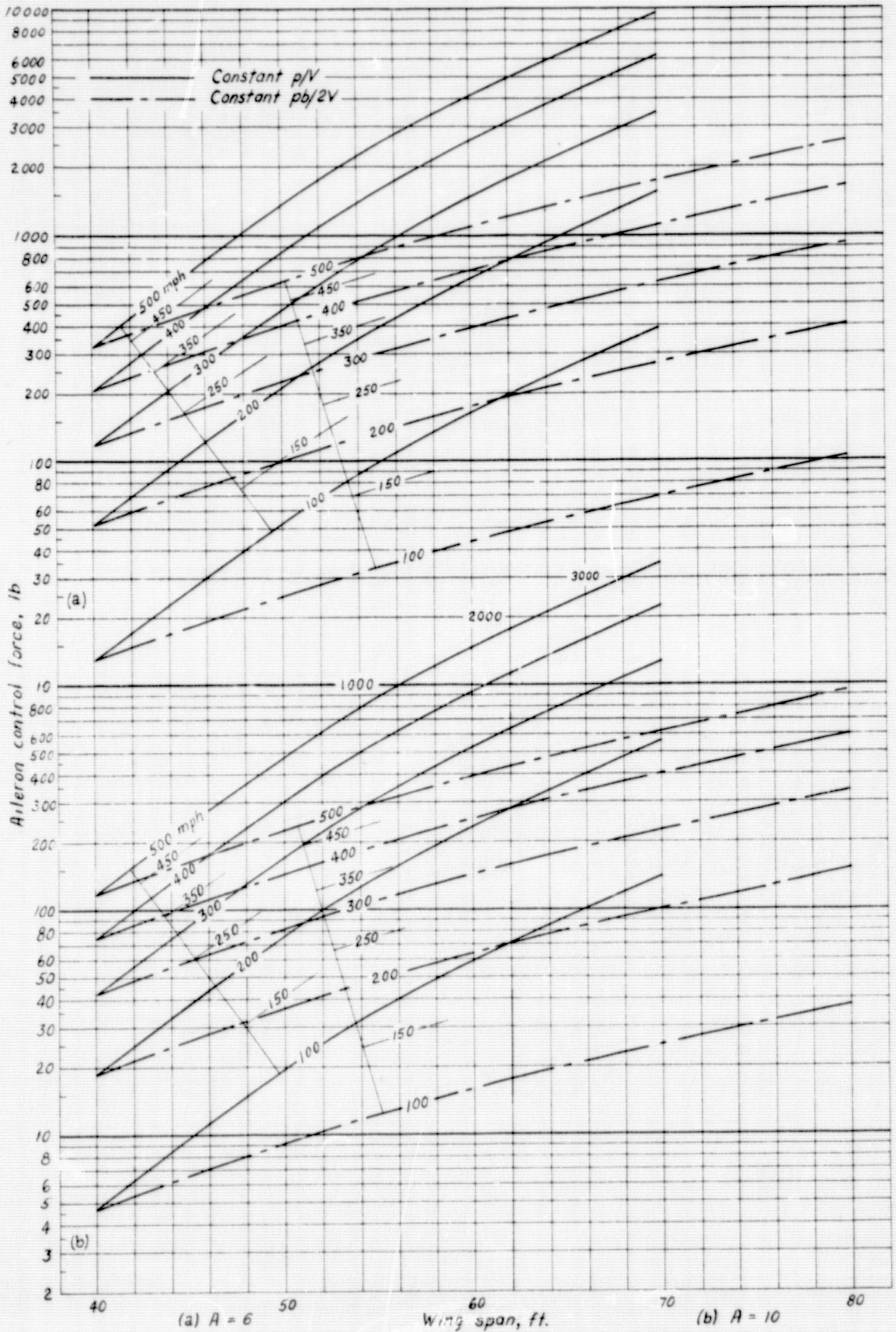


Figure 2 - Variation with wing span and airspeed of the aileron control force required with unbalanced ailerons to obtain rates of roll corresponding to values of $pb/2V$ of 0.09 and of p/V of 0.004s when $b_a = 0.40$.

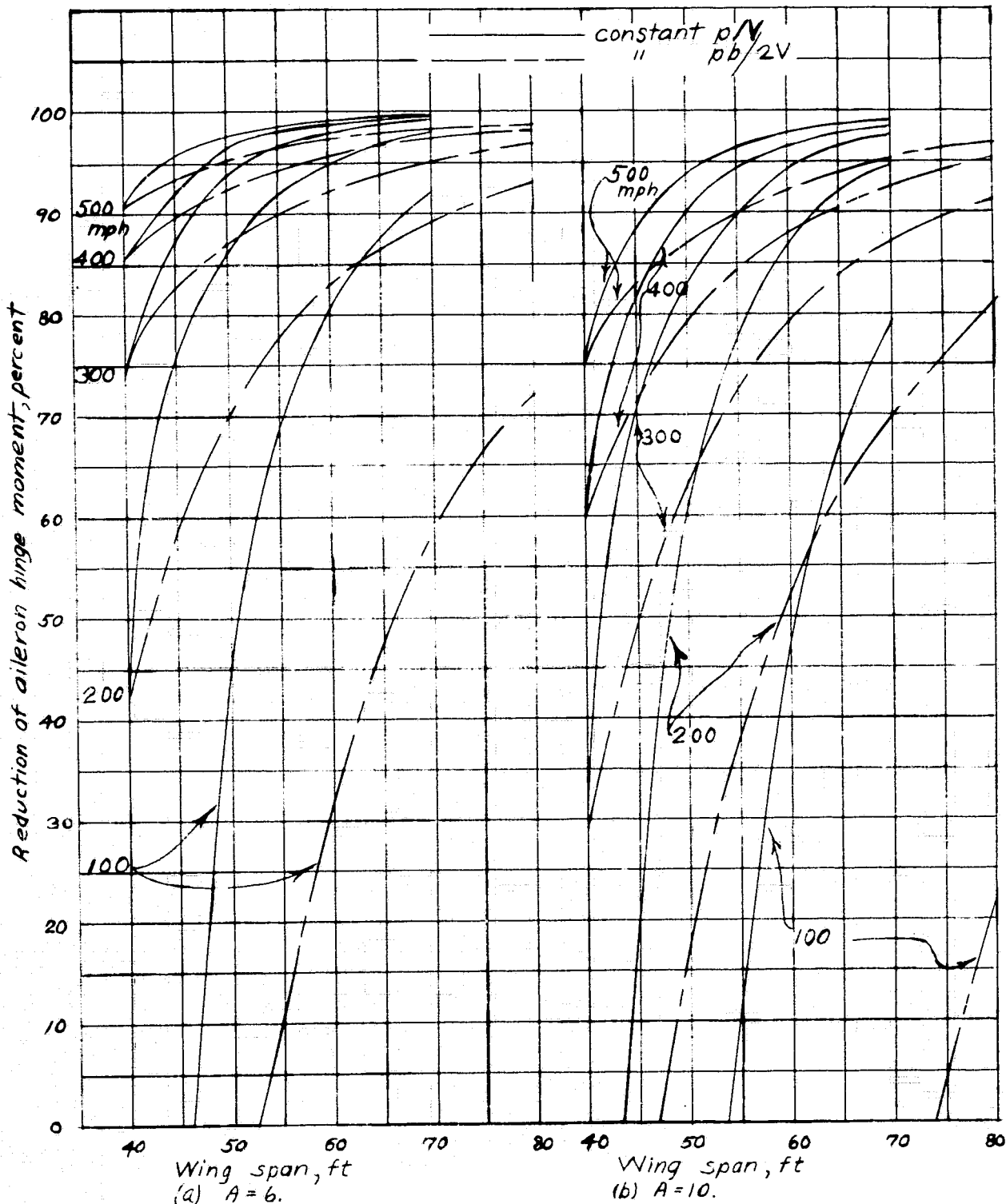


Figure 3.- Variation with wing span and airspeed of the percent that the aileron hinge moment must be reduced by aerodynamic balancing in order that the aileron control force shall not exceed 30 lbs at rates of roll corresponding to values of $pb/2V$ of 0.09 and of p/V of 0.0045 when b_a equals 0.4b.