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RESUMÉ OF HINGE-MOMENT DATA FOR UNSHIELDED

HORN-BALANCED CONTROL SURFACES

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RESTRICTED BULLETIN

RÉSUMÉ OF HINGE-MOMENT DATA FOR UNSHIELDED HORN-BALANCED CONTROL SURFACES

By John G. Lowry

SUMMARY

The available hinge-moment data for unshielded horn-balanced control surfaces have been summarized herein. An attempt has been made to present the data in a form that may be of some assistance in the preliminary design of horn-balanced controls.

The data indicate that an increase in stick-free stability can be obtained with a horn balance, but care must be taken to eliminate the undesirable heaviness of control forces that accompanies this increase in stick-free stability.

INTRODUCTION

In conjunction with the control-surface investigation by the National Advisory Committee for Aeronautics, the available data on unshielded horn balances have been summarized herein. The purpose of this paper is to correlate the available data and to present them in a form that may be of some assistance in the estimation of the balance characteristics for use in the design and alteration of control surfaces with horn balances.

The data used in preparing this résumé include the results of wind-tunnel investigations by the NACA and by British experimenters and of flight tests by the NACA. The data were obtained from references 1 to 6 and from previously circulated restricted data obtained for the Bureau of Aeronautics, Navy Department.

A bibliography that gives discussions of horn balances outside the scope of this résumé is also presented.

PARAMETERS AND SYMBOLS

C_h hinge-moment coefficient $(H/q\bar{c}^2b$; British use H/qSc', which should reduce value of C_h by less than 10 percent for surfaces presented)

H hinge moment of control surface about hinge axis; positive when moment tends to give positive deflection

c chord of control surface, measured from hinge axis to trailing edge

c' mean chord of control surface

$\bar{c}$ root-mean-square chord of control surface

b span of control surface

S area of control surface behind hinge axis

B balance coefficient

$$\left(\sqrt{\frac{\text{horn area} \times \text{horn mean chord}}{\text{control-surface area} \times \text{control-surface mean chord}}}\right)$$

$C_{h_\delta} = (\partial C_h/\partial\delta)_\alpha$

ΔCh_δ C_{h_δ} of control surface with horn balance $-$ C_{h_δ} of control surface without horn balance

$C_{h_\alpha} = (\partial C_h/\partial\alpha)_\delta$

ΔCh_α C_{h_α} of control surface with horn balance $-$ C_{h_α} of control surface without horn balance

α angle of attack of control surface

δ deflection of control surface

q free-stream dynamic pressure $\left(\frac{1}{2}\rho V^2\right)$

ρ mass density of air

V velocity of air stream

The subscript outside the parentheses in the definitions of C_{h_δ} and C_{h_α} indicates the variable held constant during the measurement of the parameter.

DISCUSSION

Because most of the data used in this résumé came from British reports and the complete data were not available in many cases, it was necessary to make the correlation by using available parameters. Priestley in reference 3 presented the horn-balance data in terms of the parameter

$$\sqrt{\frac{\text{horn area} \times \text{horn mean chord}}{\text{control-surface area} \times \text{control-surface mean chord}}}$$

which is called herein the balance coefficient B. The data of reference 3, which were presented in the form of C_{h_δ} and C_{h_α}, have been replotted in the form of ΔC_{h_δ} and ΔC_{h_α} along with data from references 1, 2, 4 to 6, and unpublished data. It was observed from these graphs that the balance coefficient B gave a correlation, with a few exceptions, if the horns were divided according to type into two groups. Inasmuch as the horns were similar within each group, they were designated type A (fig. 1) and type B (fig. 2). The values of ΔC_{h_δ} and ΔC_{h_α} were plotted for control surfaces with horns of type A in figures 3 and 4 and with horns of type B in figures 5 and 6. The data for horns of type A appear to correlate very well, but the values for horns of type B show considerable scatter. Because the loads on the horn depend to some extent on the tip shape, it would be expected that some factor accounting for the tip shape would be needed for a correlation of horn balances, particularly for horns of type B. No attempt was made to determine a tip-shape factor that would improve the correlation, as no systematic variation of tip shape has been made.

The results of this correlation indicate that sufficient data are available for the preliminary design of horn-balanced control surfaces. The effectiveness of the horn balance depends on the flow over the tip of the control surface; it would therefore be advisable to make relatively large-scale wind-tunnel tests of horn-balanced controls before the final design is completed. Appropriate efficiency factors should be applied to the wind-tunnel data to account for the nonuniform flow along the span of the control if the control surface is in the wake of undercarriages, propellers, nacelles, and so forth.

The graph of C_{h_α} against C_{h_δ} for horns of type A and type B (fig. 7) shows a considerable range in which an airplane equipped with a horn-balanced control will be more stable with the stick free than with the stick fixed; that is, C_{h_α} is positive while C_{h_δ} remains negative (reference 7). This increase in stick-free stability results from the floating of the control in such a manner as to give a returning moment if the airplane is displaced. Because the magnitude of control motion with controls free is a function of both C_{h_α} and C_{h_δ} it is possible, if C_{h_δ} is small and negative and C_{h_α} is positive, to have the returning moment large enough to displace the airplane in the opposite direction and set up a condition of continuous steady oscillations (reference 8).

The increase in stick-free stability is accompanied by an increased heaviness of the control forces. This increase in heaviness, which is a result of the positive value of C_{h_α} without a comparable change in the value of C_{h_δ}, may be eliminated if the value of C_{h_α} is kept near zero and the negative values of C_{h_δ} are reduced by a balancing tab or by some other means. Unpublished NACA flight-test data as well as theoretical consideration confirm the foregoing statement. The region in which both C_{h_α} and C_{h_δ} are positive (fig. 7) is of little interest as the control is overbalanced in this region.

Horn balances, in general, have proved unsatisfactory for use on ailerons because they are adversely affected by yaw. The effect of yaw on the tail surfaces should depend on the shielding effect of the fuselage, the flow over the tail surface during yaw, and other characteristics peculiar to each installation. Recent unpublished flight-test data showed that a control surface with unshielded horns of type A required a large push force to prevent upward deflection of the elevator when the airplane was yawed. No investigation of these effects or of any possible modifications to help eliminate the adverse affect has been made.

CONCLUSIONS

From the data presented in this résumé, it would appear that preliminary designs of horn balances can be made on the basis of the curves given herein.

The stick-free stability of any airplane can be improved to some extent by the use of horn balances, but care must be taken to eliminate any undesirable heaviness of control forces.

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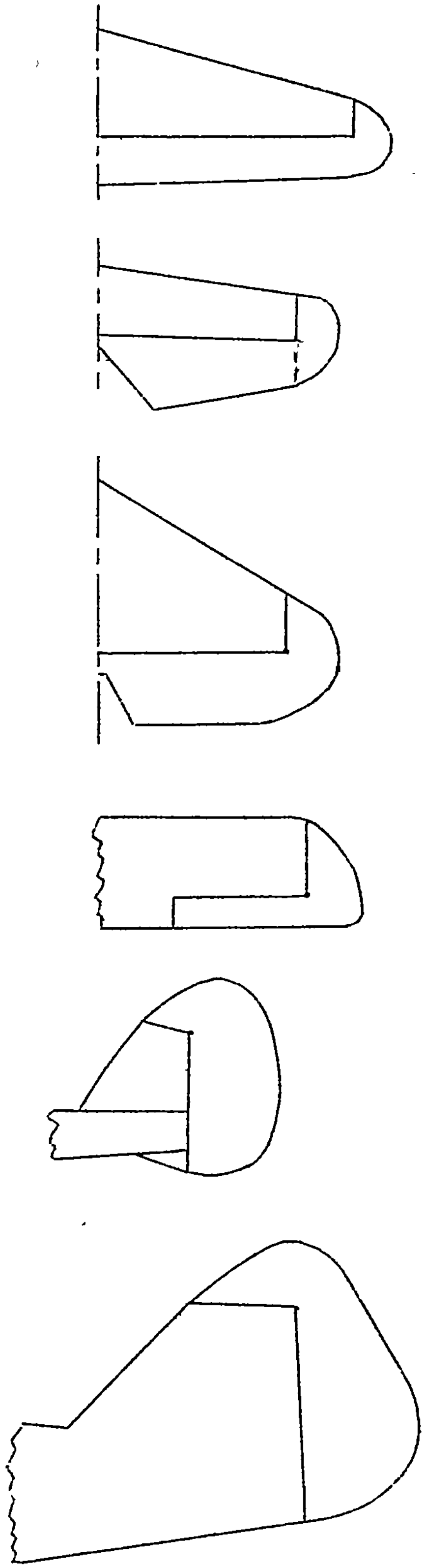

Control surface	Symbol used on figs. 3 to 7	Reference
1	○	3
2	▽	Unpublished
3	□	2
4	×	6
5	◇	3
6	△	3

Figure 1.- Plan forms of horn-balanced control surfaces. Type A.

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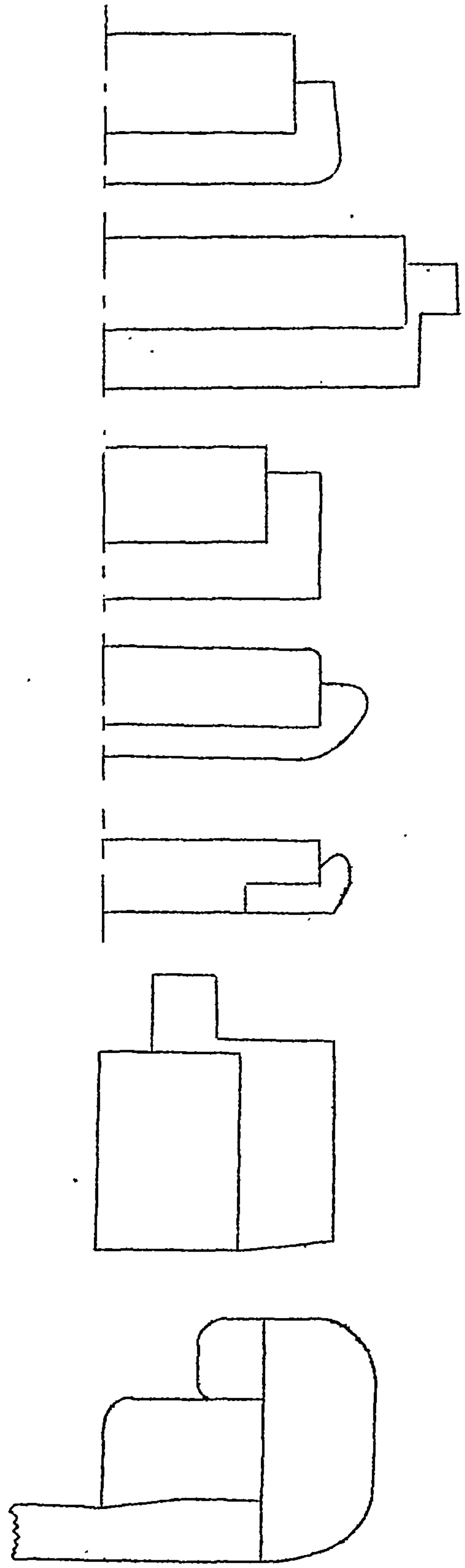
Fig. 2



Control surface	Symbol used on figs. 3 to 7	Reference
7		3
8		3
9		3
10		4
11	+	5
12		1
13		3

Figure 2.- Plan forms of horn-balanced control surfaces. Type B.

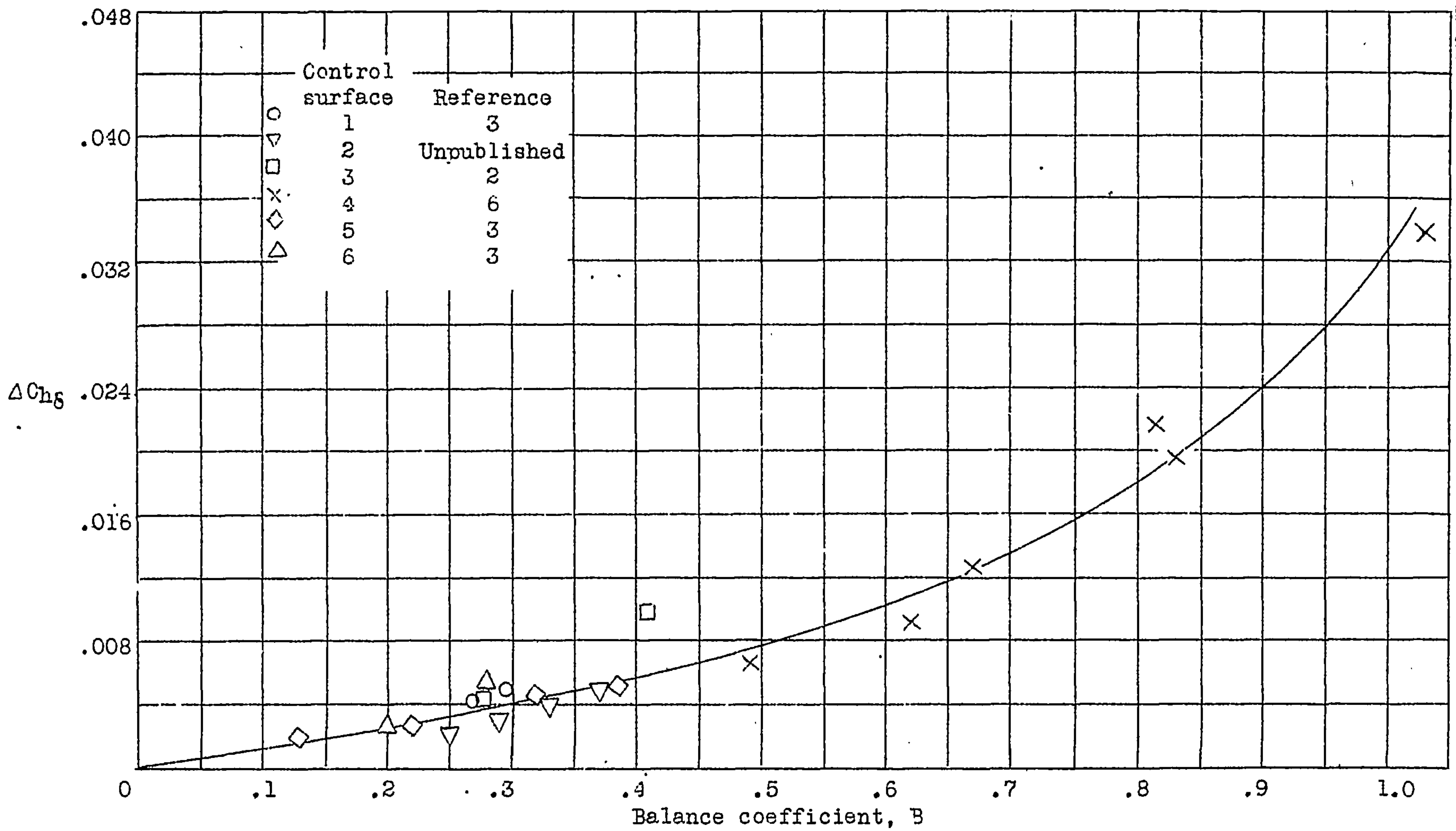


Figure 3.- Variation of incremental hinge-moment-coefficient slope ΔC_{h_δ} with balance coefficient B. Horns, type A.

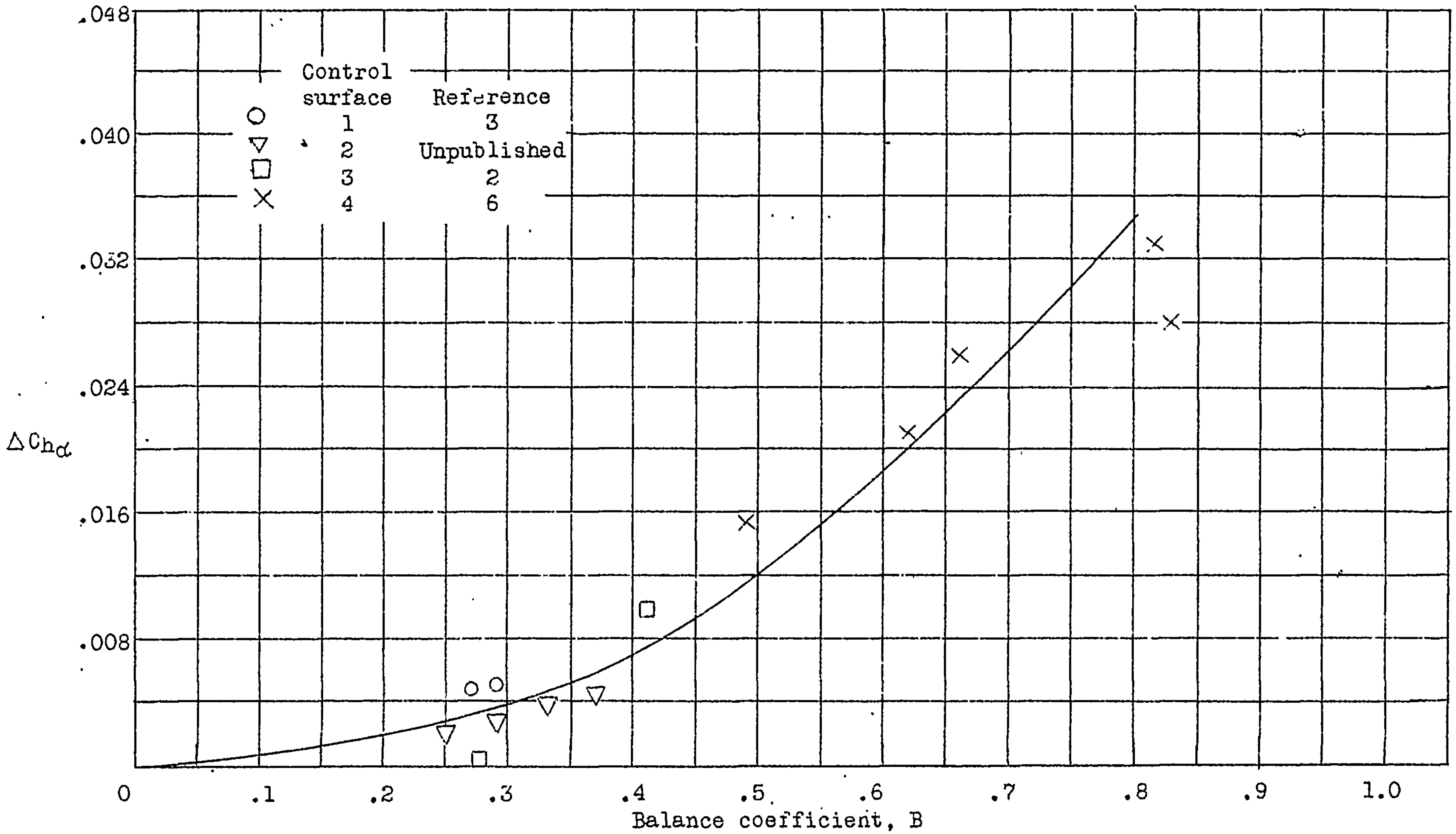


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Figure 4.- Variation of incremental hinge-moment-coefficient slope ΔC_{h_α} with balance coefficient B. Horns, type A.

Fig. 4

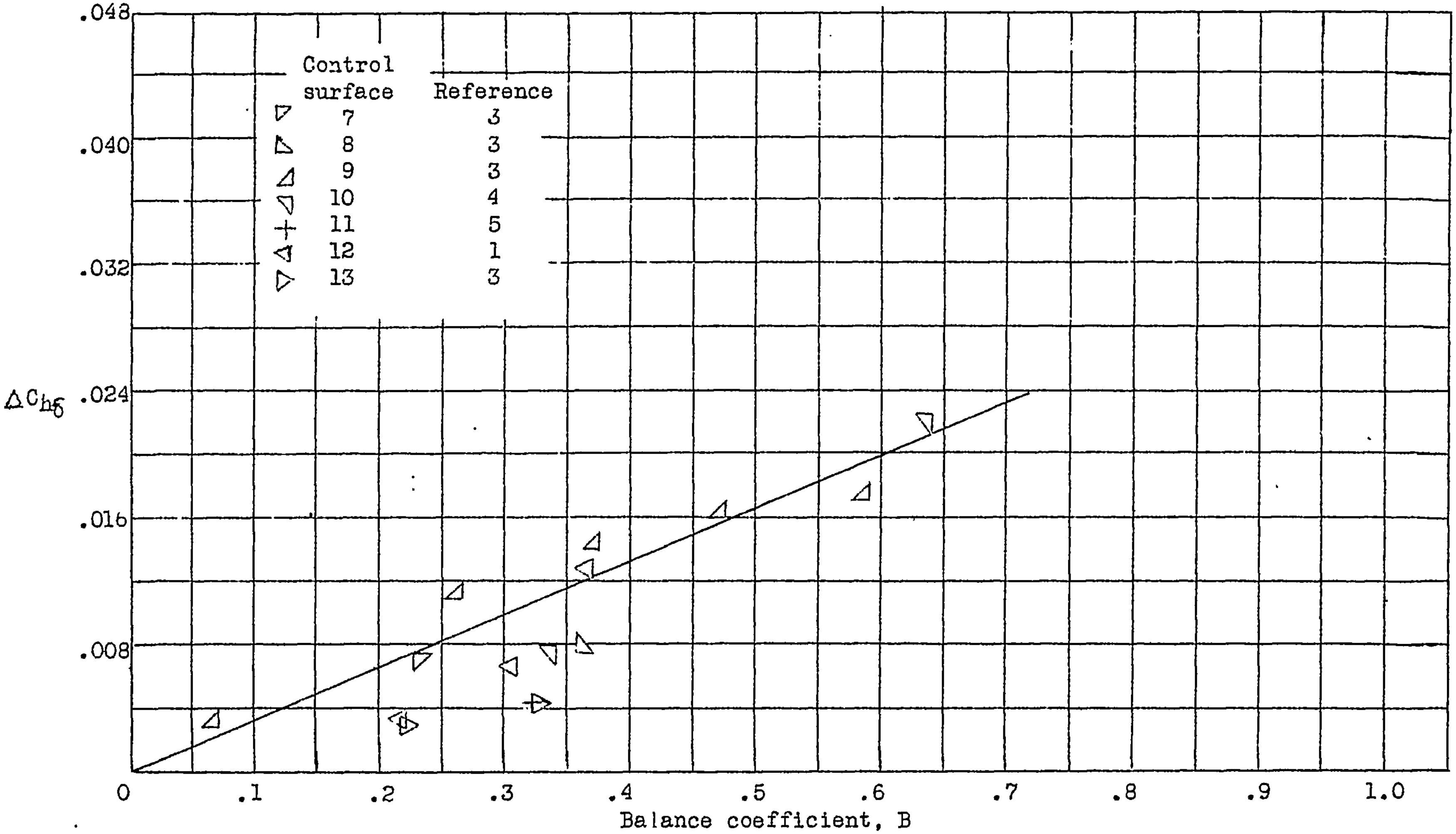

Figure 5.- Variation of incremental hinge-moment-coefficient slope ΔC_{h_δ} with balance coefficient B. Horns, type B.

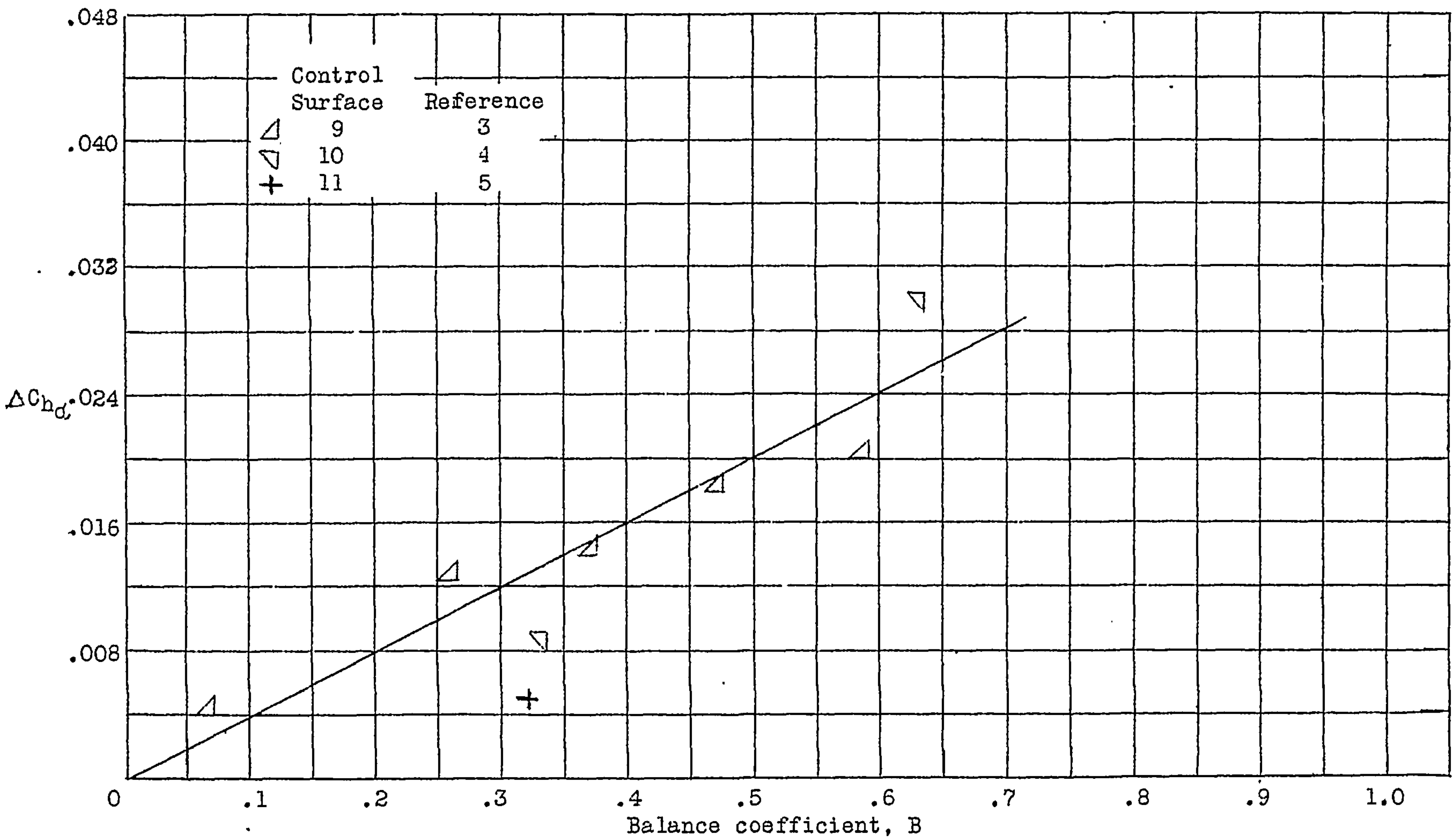

Figure 6.- Variation of incremental hinge-moment-coefficient slope ΔC_{h_α} with balance coefficient B. Horns, type B.

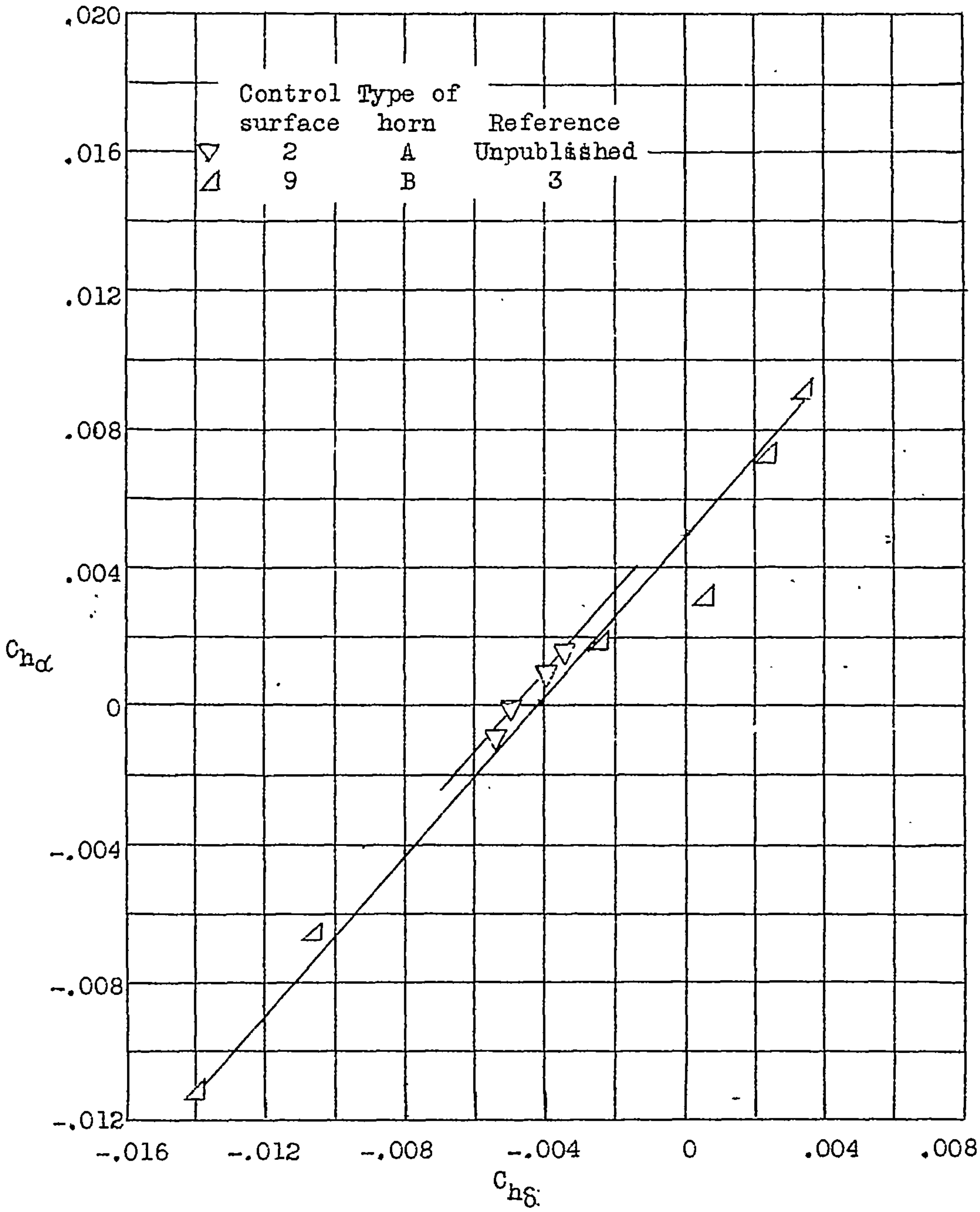

Figure 7.- Variation of C_{h_α} with C_{h_δ} for unshielded horn-balanced control surfaces.

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ABSTRACT:

Data from various sources, which may be of assistance in the estimation of the balance characteristics for use in alteratioo and design of horn-balanced cootrol surfaces, were collected and presented in curve form. Results indicate that stick-free stability of any airplane can be improved to some extent by the use of control horn balances, but care must be taken to eliminate any undesirable heaviness of control forces.

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