

JAN 16 1947

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED
April 1942 as
Restricted Bulletin

CALCULATION OF TAB CHARACTERISTICS FOR FLIGHT

CONDITIONS FROM WIND-TUNNEL DATA

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RESTRICTED BULLETIN

CALCULATION OF TAB CHARACTERISTICS FOR FLIGHT

CONDITIONS FROM WIND-TUNNEL DATA

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Certain tail-surface characteristics calculated from wind-tunnel data have been reported not to check with flight-test measurements. This discrepancy might have been caused by failure to account for the changes in equilibrium conditions that occurred in flight when the wind-tunnel data measured in static-force tests were applied.

The problem under consideration is the calculation of the effect of tab deflection upon the free-floating angle of the elevator, as in a servocontrol. Flight-test measurements are reported to have shown nearly twice as great a change in elevator deflection per degree tab deflection as wind-tunnel tests have indicated. The following illustration may be given in order to show that such a discrepancy may be expected if the tab characteristics are computed without consideration of the response of the airplane to a deflection of the elevator.

It can be shown that, for zero pitching velocity, the hinge-moment coefficient of the elevator may be expressed by the following relation:

$$C_{h_e} = C_{h_{e\alpha'}} \alpha' + C_{h_{e\delta_e}} \delta_e + C_{h_{e\delta_t}} \delta_t$$

or

$$C_{h_e} = C_{h_{e\alpha'}} (\alpha_0 + i_t) + C_{h_{e\delta_t}} \delta_t \\ + \left[C_{h_{e\delta_e}} + C_{h_{e\alpha'}} \frac{\partial \alpha}{\partial \delta_e} (1 - \epsilon_\alpha) \right] \delta_e$$

where

 α' angle of attack of tail α angle of attack of airplane

α_0 angle of attack of airplane at zero lift

i_t angle of incidence of tail

δ_e elevator deflection

δ_t tab deflection

ϵ angle of downwash

C_{h_e} elevator hinge-moment coefficient

and

$$C_{h_{e\alpha}} = \frac{\partial C_{h_e}}{\partial \alpha}$$

$$C_{h_{e\delta_e}} = \frac{\partial C_{h_e}}{\partial \delta_e}$$

$$C_{h_{e\delta_t}} = \frac{\partial C_{h_e}}{\partial \delta_t}$$

$$\epsilon_\alpha = \frac{\partial \epsilon}{\partial \alpha}$$

Thus, when $C_{h_e} = 0$, the free-floating angle of the elevator is

$$\delta_{e\text{free}} = - \frac{C_{h_{e\alpha}} (\alpha_0 + i_t) + C_{h_{e\delta_t}} \delta_t}{C_{h_{e\delta_e}} + C_{h_{e\alpha}} (1 - \epsilon_\alpha) \frac{\partial \alpha}{\partial \delta_e}}$$

The rate of change of free-floating angle of the elevator with tab deflection is

$$\left(\frac{\partial \delta_e}{\partial \delta_t} \right)_{\text{free}} = - \frac{C_{h_{e\delta_t}}}{C_{h_{e\delta_e}} + C_{h_{e\alpha}} (1 - \epsilon_\alpha) \frac{\partial \alpha}{\partial \delta_e}}$$

From reference 1, it can be seen that, for typical airplanes, $\frac{\partial \alpha}{\partial \delta_e}$ lies between 0 and -1.0 and has a recommended value of -0.5. It should be noted that the sign of δ_e is taken opposite to that used in reference 1. For airplane 3 of reference 1, with various center-of-gravity positions

$$\frac{\partial \alpha}{\partial \delta_e} = \frac{1}{\frac{\partial \delta_e}{\partial \alpha}} = -1.08, -2.22, -2.85$$

From reference 2, the section parameters for an NACA 0009 airfoil with a 0.30c flap are:

$$C_{h_{e_{\alpha i}}} = -0.0075$$

$$C_{h_{e_{\delta_e}}} = -0.0130$$

$$C_{h_{e_{\delta_t}}} = -0.0094 \quad \text{for a } 0.10 \text{ } c_e \text{ tab}$$

$$= -0.0130 \quad \text{for a } 0.20 \text{ } c_e \text{ tab}$$

$$= -0.0160 \quad \text{for a } 0.30 \text{ } c_e \text{ tab}$$

$$\text{Assume } \frac{\partial \xi}{\partial \alpha} = 0.6$$

$$\text{Thus, for a } 0.20 \text{ } c_e \text{ tab, when } \frac{\partial \alpha}{\partial \delta_e} = -2.22$$

$$\frac{\partial \delta_e}{\partial \delta_t} = - \frac{-0.0130}{(-0.0130) + (-0.0075)(1 - 0.6)(-2.22)} = -2.06$$

The curves of figure 1 have been computed in this manner. They give the parameter $\frac{\partial \delta_e}{\partial \delta_t}$ for various amounts of the airplane response factor $\frac{\partial \alpha}{\partial \delta_e}$. Thus, it can be seen

that the reported discrepancy between computed results and the flight-test measurements might well be explained if the computation neglected the response of the airplane to elevator movement. Such computations would be represented by the points at $\frac{\partial \alpha}{\partial \delta_e} = 0$.

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REFERENCES

1. Gilruth, R. R., and White, M. D.: Analysis and Prediction of Longitudinal Stability of Airplanes. Rep. No. 711, NACA, 1941.
2. Ames, Milton B., Jr., and Sears, Richard I.: Determination of Control-Surface Characteristics from NACA Plain-Flap and Tab Data. Rep. No. 721, NACA, 1941.

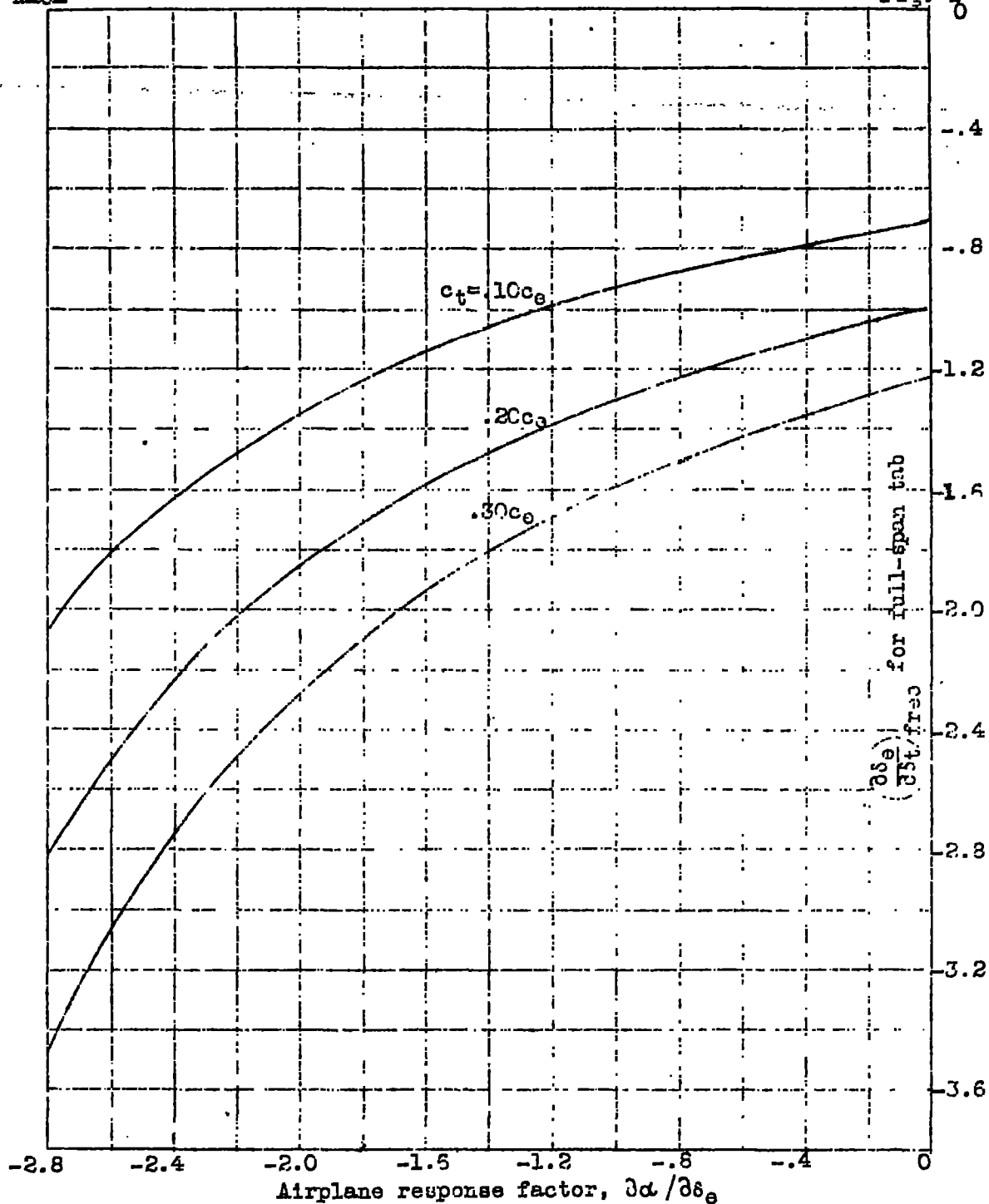


Figure 1.- Variation of tab effectiveness with airplane response to elevator deflection. NACA 0009 airfoil 0.30c elevator.

TITLE: Calculation of Tab Characteristics for Flight Conditions from Wind-Tunnel Data

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ORIGINATING AGENCY: National Advisory Committee for Aeronautics, Washington, D. C.

PUBLISHED BY: (Same)

ATI- 6599

REVISION
(None)

ORIG. AGENCY NO.

RB-L-218

PUBLISHING AGENCY NO.

DATE	DOC. CLASS.	COUNTRY	LANGUAGE	PAGES	ILLUSTRATIONS
April '42	Unclass.	U. S.	Eng.	5	graph

ABSTRACT:

Calculations were made concerning tail surface characteristics in flight which do not check with wind-tunnel data. Calculation of effect of tab deflection upon free floating angle of elevator is considered. Discrepancy is pointed out as caused by failure to account for changes in equilibrium conditions that occurred in flight, when wind-tunnel static force tests were applied. Graph of airplane response factor is included showing variation of tab effectiveness with airplane response to elevator deflection.

DISTRIBUTION: Request copies of this report only from Originating Agency

DIVISION: Aerodynamics (2)

SECTION: Control Surfaces (3)

SUBJECT HEADINGS:

Tabs, Elevator - Effectiveness (91614.6); Tabs, Trim (91616.6)

ATI SHEET NO.: R-2-3-17