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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

$$C_{h_e} = C_{h_{e_{\alpha'}}}\left(\alpha_o + i_t\right) + C_{h_{e_{\delta_t}}}\delta_t$$

$$+ \left[C_{h_{e_{\delta_e}}} + C_{h_{e_{\alpha'}}}\frac{\partial\alpha}{\partial\delta_e}\left(1 - \epsilon_\alpha\right)\right]\delta_e$$

where

α' angle of attack of tail

α angle of attack of airplane

α_o	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

$$\delta_{e_{free}} = - \frac{C_{h_{e_{\alpha'}}}\left(\alpha_o + i_t\right) + C_{h_{e_{\delta_t}}}\,\delta_t}{C_{h_{e_{\delta_e}}} + C_{h_{e_{\alpha'}}}\left(1 - \epsilon_\alpha\right)\frac{\partial \alpha}{\partial \delta_e}}$$

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

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

From reference 1, it can be seen that, for typical airplanes, $\frac{\partial \delta_e}{\partial \alpha}$ 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:

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

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

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

$= -0.0130$ for a 0.20 c_e tab

$= -0.0160$ for a 0.30 c_e tab

Assume $\frac{\partial \epsilon}{\partial \alpha} = 0.6$

Thus, for a 0.20 c_e 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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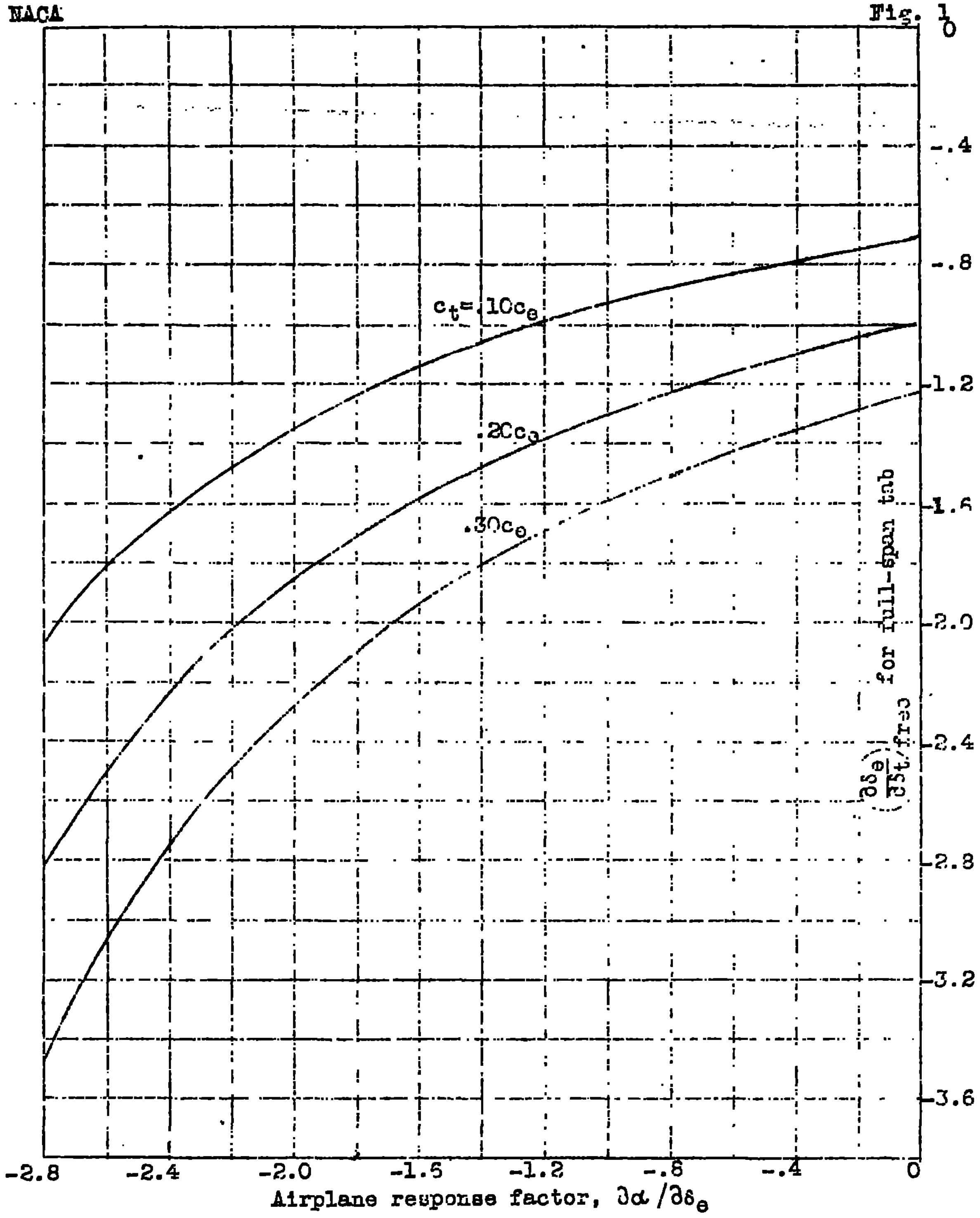

Figure 1.- Variation of tab effectiveness with airplane response to elevator deflection. NACA 0009 airfoil 0.30c elevator.