CONTROL HINGE-MOMENT COEFFICIENT DERIVATIVE DUE TO TAB

1. NOTATION AND UNITS (see Sketch 1.1)

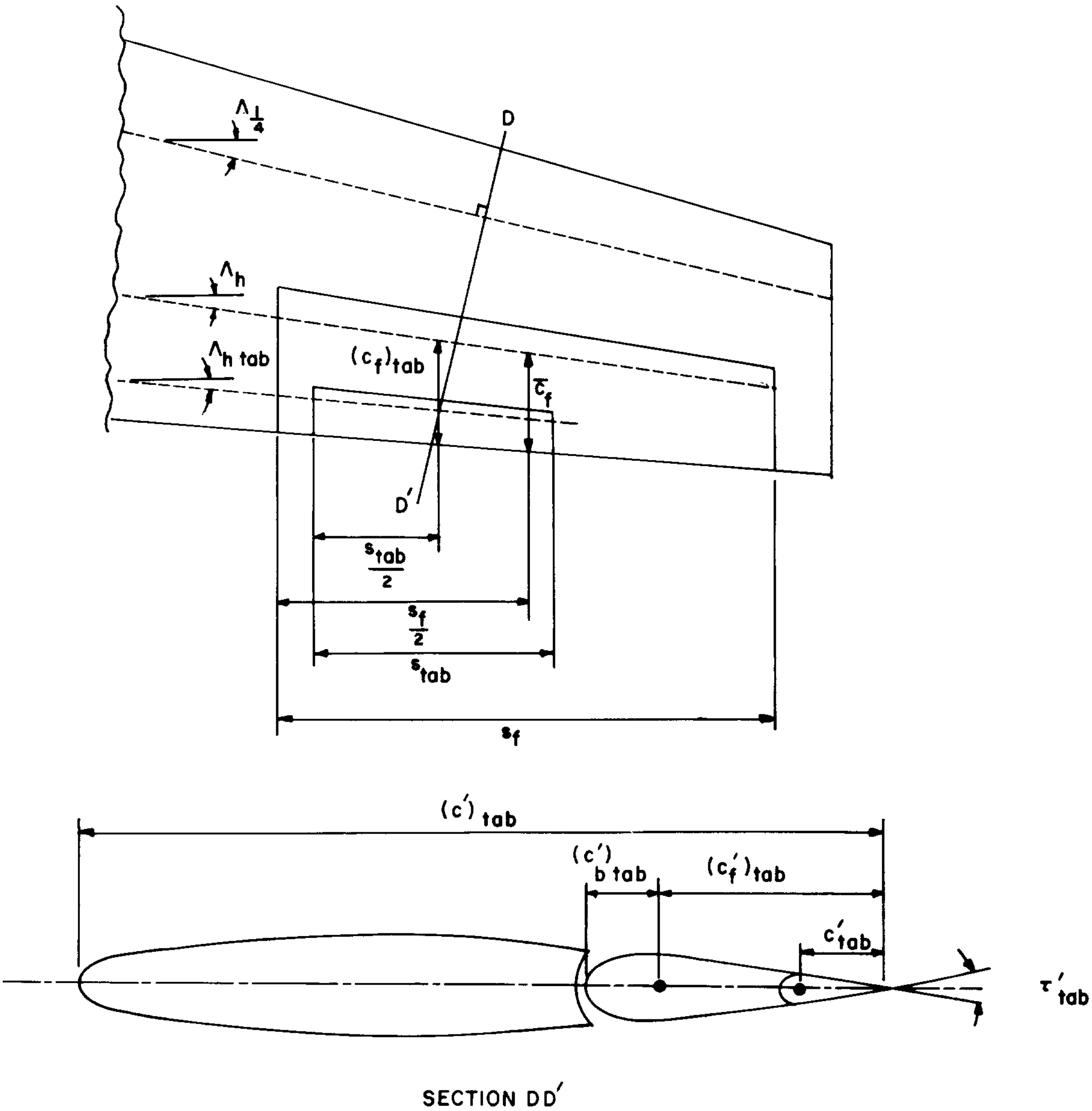
		SI	British
b'_3	rate of change of control hinge-moment coefficient with tab deflection angle, $\partial C_H/\partial\delta'_{tab}$	rad^{-1}	rad^{-1}
C_H	control hinge-moment coefficient, $H/(\tfrac{1}{2}\rho V^2 S_f \bar{c}_f)$		
$(c)_{tab}$	wing chord at mid-span of tab hinge line	m	ft
$(c_b)_{tab}$	control chord forward of hinge line at mid-span of tab	m	ft
$\bar{c}_f$	mean chord of control surface aft of hinge line	m	ft
$(c_f)_{tab}$	chord of control surface aft of hinge line at mid-span of tab hinge line	m	ft
c_{tab}	chord of tab aft of its hinge line at mid-span of tab hinge line	m	ft
F	factor for trailing-edge angle		
G	factor defined by Equation (2.1)		
H	control hinge-moment	N m	lbf ft
M	free-stream Mach number		
S_f	area of control surface aft of hinge line	m^2	ft^2
s_f	span of control surface	m	ft
s_{tab}	span of tab	m	ft
V	free-stream velocity	m/s	ft/s
β	Prandtl-Glauert compressibility factor, $(1 - M^2)^{1/2}$		
δ'_{tab}	tab deflection angle relative to control surface measured about tab hinge line	rad	rad
Λ_h	sweepback of control hinge line	deg	deg
$\Lambda_{h\,tab}$	sweepback of tab hinge line	deg	deg
$\Lambda_{1/4}$	sweepback of wing quarter-chord line	deg	deg

Issued July 1948
With Amendments A and B, August 1989

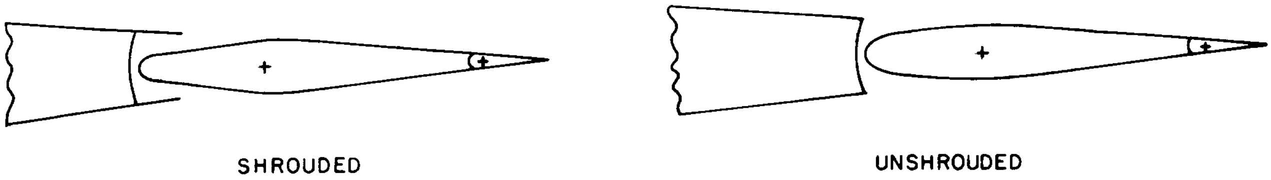
ρ	density of air	kg/m^3	slug/ft^3
τ_{tab}	trailing-edge angle of tab at mid-span of tab hinge line	deg	deg

Superscript

$'$	as in c' or τ' denotes quantities measured in plane normal to wing quarter-chord line and in δ'_{tab} an angle measured about tab hinge line



Sketch 1.1



Sketch 1.2

2. NOTES

This Item provides the control hinge-moment coefficient resulting from the deflection of a sealed tab in a subsonic stream.

Figure 1 shows $-b'_3/G$ plotted against tab chord to local wing chord ratio $c'_{tab}/(c')_{tab}$ from 0 to 0.12 for values of local forward balance $(c'_b)_{tab}/(c'_f)_{tab}$ from 0 to 0.8. Both of those chord ratios are taken for a section DD' defined by a plane normal to the wing quarter-chord line and passing through the mid-span of the tab hinge line, see Sketch 1.1. The factor G is defined as

$$G = \left[\frac{s_{tab}(c_f)^2{}_{tab}}{s_f \bar{c}_f^2}\right]\frac{F}{\beta}\cos\Lambda_{1/4}\cos\Lambda_h\cos\Lambda_{h\,tab}\,, \qquad (2.1)$$

where $(c_f)_{tab}$ and $\bar{c}_f$ are measured streamwise. The bracketed expression allows for the tab covering only a fraction of the control span, and F is a function of trailing-edge angle τ'_{tab} presented in Figure 2. The factor β allows for first-order compressibility effects and the cosine factors correct estimates based on the section DD' for the effects of sweep.

The correlation of the tab hinge-moment derivative was originally developed in Derivation 1 from a study limited to low-speed experimental data for unswept wings. The corrections for compressibility and sweep have been added on theoretical grounds. The available data for verifying this approach are sparse, but tests for three configurations, Derivations 2 to 4, show satisfactory agreement between predicted and experimental values.

The data apply to wings, tailplanes and fins at incidences up to 5 degrees and control deflections and tab angles within the range ± 10 degrees. Tab gaps of under $0.001\,(c')_{tab}$ may be regarded as effectively sealed; for gaps larger than this value a reduction in b'_3 up to 20% may occur. In any case, a scatter of $\pm 10\%$ may be expected.

Existing data on b'_3 are not consistent enough to give generalised information on the effects of control gap and Reynolds number. These effects are probably within the scatter mentioned above.

The present curves are based on experiments on aerofoil sections with the maximum thickness at about 30% behind the leading edge and a far forward position of transition to turbulent flow. Due to lack of information no attempt has been made to include the effect of varying the type of aerofoil section or of extending the region of laminar flow.

The method can be applied to shrouded and unshrouded cases (see Sketch 1.2). From Figure 1 it will be seen that the effect of the tab decreases with increase of local forward balance of the control. The method should not be applied in the extreme case when a portion of the tab lies behind a horn balance.

3. DERIVATION AND REFERENCES

3.1 Derivation

The Derivation lists selected sources that have assisted in the preparation of this Item.

1.	WARNER, J.M. URRY, S.A.	An analysis of experimental data on the hinge moments of control surfaces due to tabs. ARC Rep. 9632, 1946.
2.	ANDERSON, J.L. ANDREW, M.	High-speed aerodynamic characteristics of a model tail plane with modified NACA 65-010 section and 0° and 45° sweepback. NACA RM A7J22 (TIL 1567), 1947.
3.	JOHNSON, H.I. BROWN, B.P.	Measurement of aerodynamic characteristics of a 35° sweptback NACA 65-009 airfoil model with ¼-chord bevelled-trailing-edge flap and trim tab by the NACA wing-flow method. NACA RM L9K11 (TIL 2409), 1950.
4.	LOCKWOOD, V.E. FIKES, J.E.	Preliminary investigation at transonic speeds of the effect of balancing tabs on the hinge-moment and other aerodynamic characteristics of a full-span flap on a tapered 45° sweptback wing of aspect ratio 3. NACA RM L52A23 (TIL 3078), 1952.

3.2 References

The References are sources of information supplementary to that in this Item.

5.	ESDU	Example of procedure in calculation of control hinge moments. Item No. 89010, ESDU International, 1989.

4. EXAMPLE

Find the low-speed control hinge-moment coefficient due to tab on a control surface of an unswept wing $(\Lambda_{1/4} \approx \Lambda_h \approx \Lambda_{h\,tab} \approx 0)$ with conventional aerofoil sections. In a section normal to the wing quarter chord line and passing through the mid-span of the tab hinge line, the local tab chord to wing chord ratio is 0.0592 and the local forward balance is 0.39. The trailing-edge angle is 14° . The span of the tab is 1.55 m and the span of the control is 4.84 m. The ratio of the mean control chord at the mid-span of the tab to the mean control chord is 1.037.

From Figure 1 with $c'_{tab}/(c')_{tab} = 0.0592$ and $(c_b{}')_{tab}/(c_f{}')_{tab} = 0.39$,

$$\frac{-b'_3}{G} = 0.50 \text{ rad}^{-1},$$

and from Figure 2 with $\tau'_{tab} = 14°$,

$$F = 1.13.$$

At low speeds β can be taken as unity; therefore from Equation (2.1)

$$G = \left[\frac{s_{tab}(c_f)^2{}_{tab}}{s_f \bar{c}_f^2}\right]\frac{F}{\beta}\cos\Lambda_{1/4}\cos\Lambda_h\cos\Lambda_{h\,tab}$$

$$= \left[\frac{1.55}{4.84}\times 1.037^2\right]\frac{1.13}{1.0}\times 1.0\times 1.0\times 1.0 = 0.389\,.$$

Hence $$b_3' = -0.50 \times 0.389 = -0.195 \text{ rad}^{-1}\,,$$

and so the control hinge-moment coefficient due to the tab is

$$C_H = b_3'\,\delta'_{tab} = -0.195\times\left(\frac{8}{57.3}\right) = -0.027\,.$$

A more general example of a tab fitted to a control on a swept wing is included in Item No. 89010 (Reference 5).

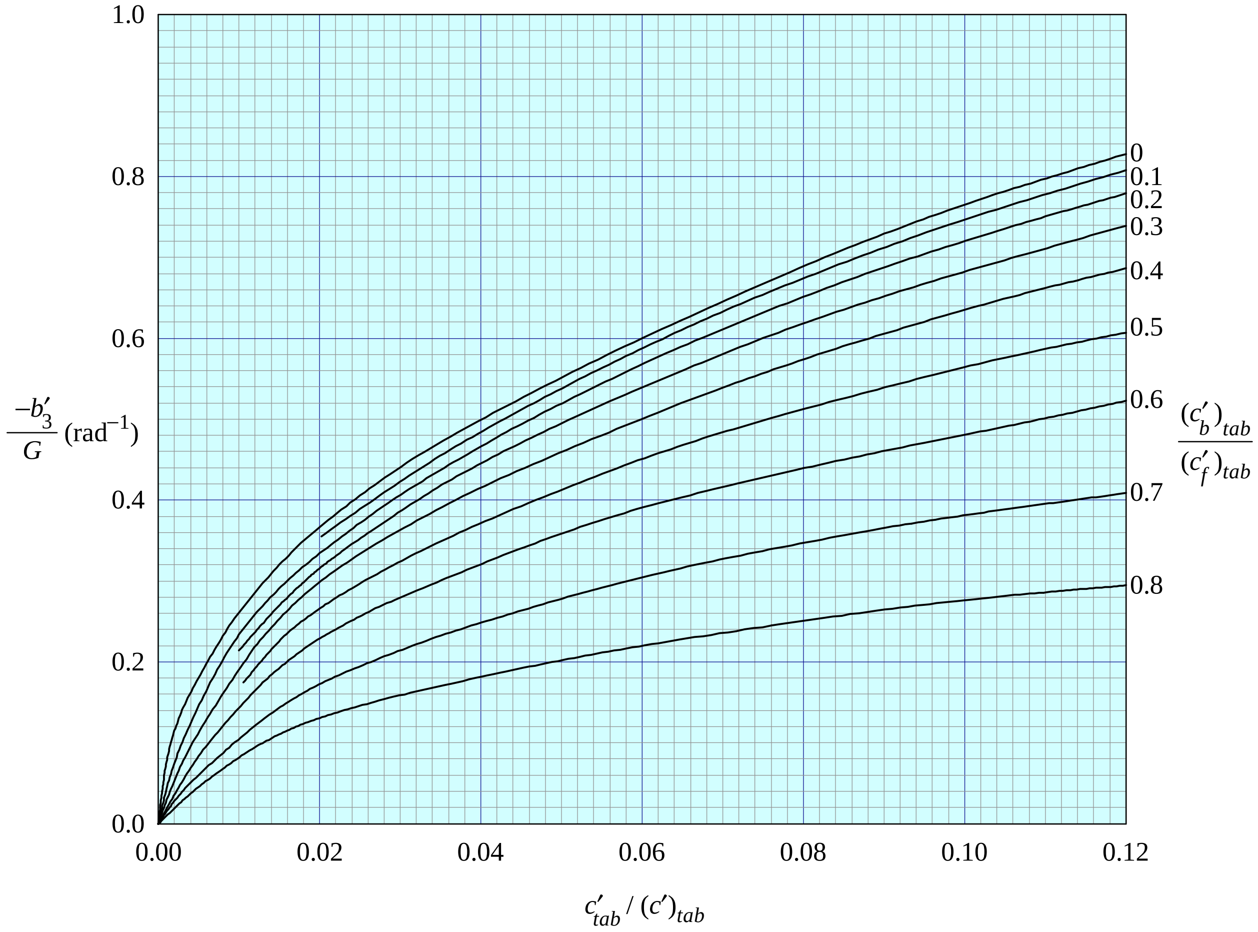


FIGURE 1 TAB HINGE-MOMENT COEFFICIENT DERIVATIVE

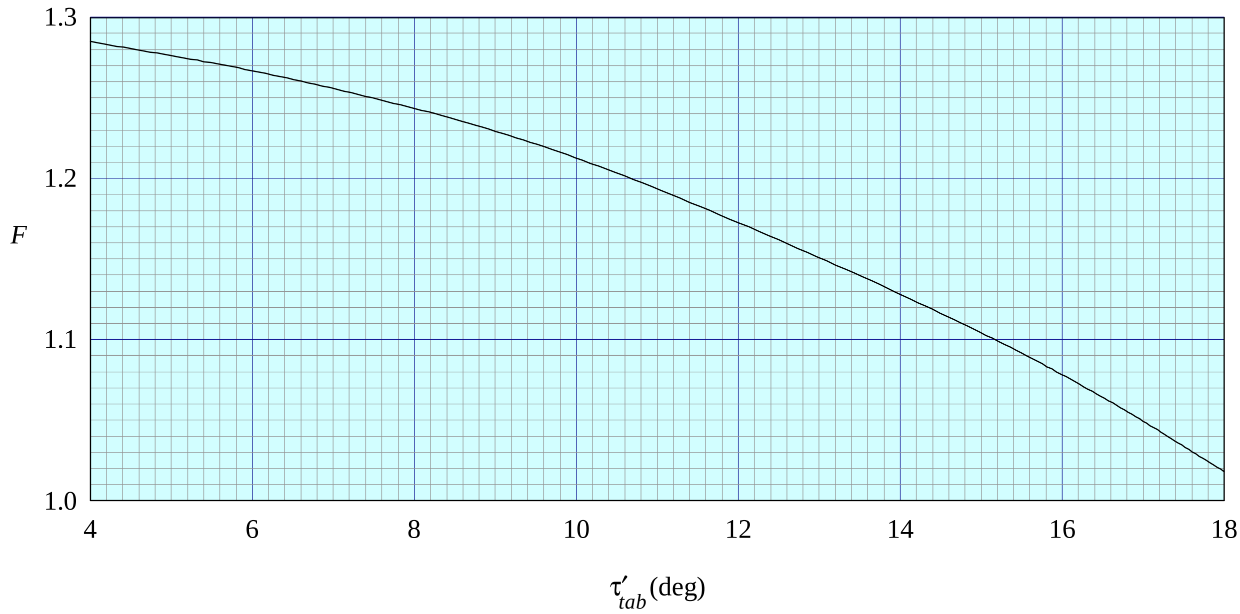


FIGURE 2 FACTOR FOR TRAILING-EDGE ANGLE