EXAMPLE OF PROCEDURE IN CALCULATION OF CONTROL HINGE MOMENTS

1. NOTATION AND UNITS (see Sketch 1.1)

		SI	*British*
A	aspect ratio of wing		
A_h	aspect ratio of horn		
a_1, a_2	rates of change of lift coefficient with angle of attack and control deflection respectively	rad^{-1}	rad^{-1}
B	increase in balance due to horn, see Table 2.3		
b_1, b_2, b_3	rates of change of hinge-moment coefficient with angle of attack, control deflection and tab deflection respectively, $b_1 = \partial C_H/\partial a$, $b_2 = \partial C_H/\partial \delta$, $b_3 = \partial C_H/\partial \delta_{tab}$	rad^{-1}	rad^{-1}
$\Delta b_{1h}, \Delta b_{2h}$	increments in b_1, b_2 due to horn	rad^{-1}	rad^{-1}
C_H	hinge-moment coefficient, $C_H = H/(½\rho V^2 c_f^2)$ for two-dimensional sections; $= H/(½\rho V^2 \bar{\bar{c}}_f^2 s_f)$ for wings; $= H/(½\rho V^2 S_f \bar{c}_f)$ for increments due to horns and tabs		
C_L	wing lift coefficient		
c	wing chord	m	ft
$(c)_h$	wing chord at mid-span of horn	m	ft
$(c)_{tab}$	wing chord at mid-span of tab hinge line	m	ft
$\bar{c}$	geometric mean chord of wing	m	ft
c_b	control chord forward of hinge line,	m	ft
$(c_b)_h$	value of c_b (without horn) at mid-span of horn	m	ft
$(c_b)_{tab}$	value of c_b at mid-span of tab hinge line	m	ft
c_f	control chord aft of hinge line	m	ft
$(c_f)_{tab}$	value of c_f at mid-span of tab hinge line	m	ft

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$\bar{c}_f$	geometric mean chord of control aft of hinge line $\bar{c}_f = \int c_f \, d\eta$	m	ft
$\bar{\bar{c}}_f$	aerodynamic mean chord of control aft of hinge line, $\bar{\bar{c}}_f = \int c_f^2 \, d\eta / \bar{c}_f$	m	ft
c_h	horn chord forward of hinge line at mid-span of horn	m	ft
c_{tab}	tab chord aft of tab hinge line at mid-span of tab hinge line	m	ft
F	factor used in calculating effect of tab (Item No. Aero C.04.01.08[1])		
F_1, F_2	factors used in calculating effect of horn (Item No. 88003[9])		
F_B	factor used in calculating b_1 and b_2 for control on wing (Item No. 89009[10])		
G	factor used in calculating effect of tab (Item No. Aero C.04.01.08[1])		
G_1, G_2, G_3	factors used in calculating b_1 and b_2 for control on wing (Item No. 89009[10])	rad^{-1}	rad^{-1}
H	hinge moment measured about hinge line	N m	lbf ft
K	factor used in calculating effect of horn (Item No. 88003[9])		
M	Mach number		
N	factor used in calculating effect of horn (Item No. 88003[9])		
R	Reynolds number based on c		
S_f	control area aft of hinge line	m^2	ft^2
s	wing semispan	m	ft
s_f	control span, $(\eta_o - \eta_i)s$	m	ft
s_h	horn span	m	ft
s_{tab}	tab span	m	ft
t	maximum section thickness	m	ft
$(t/c)_h$	thickness to chord ratio of wing at mid-span of horn		
t_h	section thickness at control hinge line	m	ft

V	free-stream velocity	m/s	ft/s
x_h	distance of horn leading-edge from control trailing-edge at mid-span of horn, as fraction of local wing chord		
x_{tr}	position of boundary layer transition aft of leading edge as fraction of local wing chord		
α	angle of attack	rad	rad
β	compressibility parameter, $(1 - M^2)^{½}$		
δ	control deflection angle, measured in streamwise plane	rad	rad
δ_{tab}	tab deflection angle relative to control surface	rad	rad
η	spanwise distance from wing centre-line as fraction of semispan		
η_i, η_o	value of η at inboard, outboard ends of control at hinge line		
Λ_h	sweepback of tab hinge line	deg	deg
$\Lambda_{h\ tab}$	sweepback of tab hinge line	deg	deg
Λ_m	sweepback of m'th chord line	deg	deg
λ	ratio of wing tip chord to wing centre-line chord		
ρ	density of air	kg/m^3	slug/ft^3
τ	section trailing-edge angle	deg	deg
τ_h	trailing-edge angle at mid-span of horn	deg	deg
τ_{tab}	trailing-edge angle at mid-span of tab hinge line	deg	deg

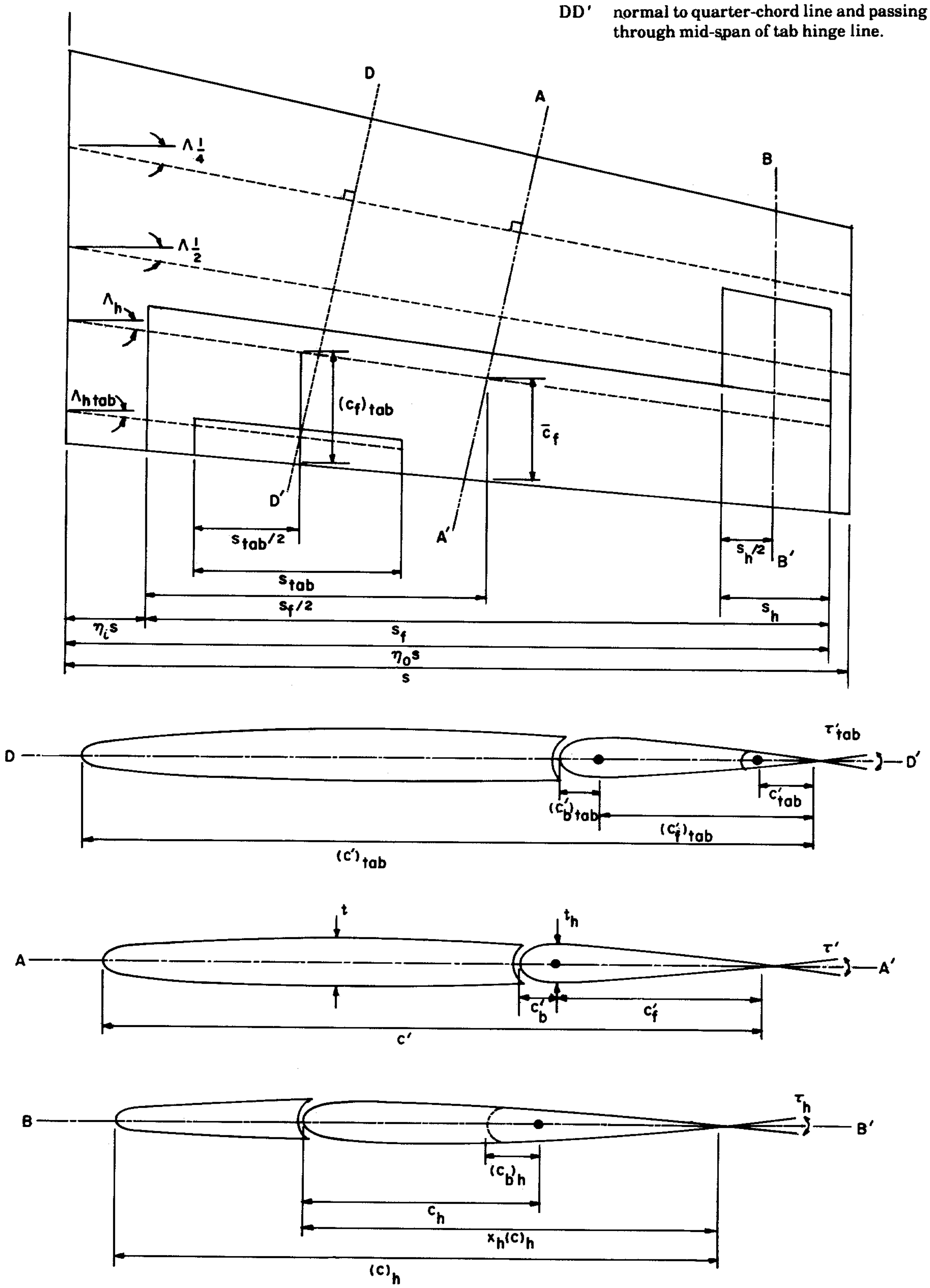
Subscripts

0	as in $(a_1)_0$ or H_0 denotes value in two-dimensional incompressible flow
h	denotes horn or, in Λ_h and $\Lambda_{h\ tab}$, hinge line
tab	denotes tab
T	as in $(a_1)_{0T}$ denotes theoretical value
Bal	denotes value for a balanced control section
Plain	denotes value for a plain control section

Superscripts

*	asterisks as in $(a_1)_0^*$ denote values for a ‘standard’ section with $\tan \frac{1}{2}\tau = t/c$
′	primes as in c' denote quantities measured in planes normal to the wing quarter-chord line, or as in δ' and δ'_{tab} angles of deflection measured about their hinge lines. In both cases the primes provide a distinction from measurements in a streamwise plane. The hinge moment coefficient derivatives b'_2 and b'_3 denote $\partial C_H/\partial\delta'$ and $\partial C_H/\partial\delta'_{tab}$, respectively.

AA′	normal to quarter-chord line and passing through mid-span of control hinge line.
BB′	streamwise through mid-span of horn
DD′	normal to quarter-chord line and passing through mid-span of tab hinge line.



Sketch 1.1

2. INTRODUCTION

This Item provides calculation charts for use when estimating the control hinge-moment coefficient derivatives for trailing-edge controls fitted to a wing, tailplane or fin, possibly with horn balance or tab. It uses the methods of Derivations 1 to 10, and the limitations on applicability quoted in those Items apply.

Table 2.1 provides the routine to determine the two-dimensional characteristics needed in subsequent calculations.

Table 2.2 provides the routine to determine b_1 and b_2 for the control without horn or tab balance.

Table 2.3 provides the routine to determine the additional contribution of a horn balance.

Table 2.4 provides the routine to determine the effect of a tab.

Table 2.5 summarises the results.

Blank tables are provided in this Section and may be duplicated for the user’s own calculations.

A worked example is given in Section 4 for a nose-balanced control fitted with a shielded horn and a tab, and demonstrates how the Tables would be filled in during a calculation.

TABLE 2.1

Calculation of two-dimensional properties for section AA′ that is normal to the wing quarter-chord line and passes through the mid-span of the control hinge line. The method of Item Nos Aero W.01.01.05[4] and C.01.01.03[5] are used for calculating aerofoil characteristics, C.04.01.01[6] and 02[7] for calculating the hinge moment coefficient derivatives of plain controls, and C.04.01.03[2] or 04[3] for determining the effects of a nose or Irving internal balance, respectively.

Parameter	*Source*	*Value*	*Comments*
R	Flow conditions		Based on wing mean chord $\bar{c}$
x_{tr}	Flow conditions, section geometry		Boundary layer transition point for section AA′
c_f'/c' c_b'/c_f' τ' t/c' $2\tan^{-1} t/c'$ t_h/c_f'	Geometry of section AA′ that is normal to wing quarter-chord line and passes through mid-span of control hinge line		
$(a_1)_0/(a_1)_{0T}$ $(a_1)_{0T}$ $(a_1)_0$ $(a_2)_{0T}$ $(a_2)_0/(a_2)_{0T}$ $(a_2)_0$	Item No. Aero W.01.01.05 (Fig. 1) Item No. Aero W.01.01.05 (Fig. 2) Item No. Aero C.01.01.03 (Fig. 1) Item No. Aero C.01.01.03 (Fig. 2)		Calculations for plain (unbalanced) control with τ' equal to geometric value as defined in Item No. Aero W.01.01.05
$(a_1)_0^*/(a_1)_{0T}^*$ $(a_1)_{0T}^*$ $(a_1)_0^*$ $(a_2)_{0T}^*$ $(a_2)_0^*/(a_2)_{0T}^*$ $(a_2)_0^*$	Item No. Aero W.01.01.05 (Fig. 1) Item No. Aero W.01.01.05 (Fig. 2) Item No. Aero C.01.01.03 (Fig. 1) Item No. Aero C.01.01.03 (Fig. 2)		Calculations as above, but for ‘standard’ section with $\tau' = 2\tan^{-1} t/c'$

TABLE 2.1 (continued)

Parameter	*Source*	*Value*	*Comments*
$(b_1)_{0T}^*$ $(b_1)_0^*/(b_1)_{0T}^*$ $(b_1)_0^*$ $(b_2)_{0T}^*$ $(b_2)_0^*/(b_2)_{0T}^*$ $(b_2)_0^*$	Item No. Aero C.04.01.01 (Fig. 1) Item No. Aero C.04.01.01 (Fig. 2) Item No. Aero C.04.01.02 (Fig. 1) Item No. Aero C.04.01.02 (Fig. 2)		Values for 'standard' section, plain control
$(b_1)_0$ $(b_2)_0$	$(b_1)_0^* + 2[(a_1)_{0T}^* - (a_1)_0^*](\tan ½\tau - t/c)$ (Item No. Aero C.04.01.01) $(b_2)_0^* + 2[(a_2)_{0T}^* - (a_2)_0^*](\tan ½\tau - t/c)$ (Item No. Aero C.04.01.02)		Values for plain control. Strictly $(b_1)_{0Plain}$ and $(b_2)_{0Plain}$
$\left[(c'_b/c'_f)^2 - (½t_h/c'_f)^2\right]^{½}$	Section geometry		Balance as defined in Item Nos Aero C.04.01.03 and 04
$(b_1)_{0Bal}/(b_1)_{0Plain}$ $(b_2)_{0Bal}/(b_2)_{0Plain}$ or $(b_1)_{0Bal}/(b_1)_{0Plain}$ $(b_2)_{0Bal}/(b_2)_{0Plain}$	Item No. Aero C.04.01.03 (Figs 1 and 2) for nose balance, or Item No. Aero C.04.01.04 (Figs 1 to 5) for Irving internal balance		Ratios of balanced to plain control values
$(b_1)_0$ $(b_2)_0$	$(b_1)_{0Plain}[(b_1)_{0Bal}/(b_1)_{0Plain}]$ $(b_2)_{0Plain}[(b_2)_{0Bal}/(b_2)_{0Plain}]$		Values for balanced control. Strictly $(b_1)_{0Bal}$ and $(b_2)_{0Bal}$

TABLE 2.2

Calculation of hinge-moment coefficient derivatives for controls without horn or tab. The calculation follows the main method described in Sections 3.2 and 3.3 of Item No. 89009[10]. For a rectangular wing with part-span controls, see the extended method in Section 3.4 of that Item.

Parameter	*Source*	*Value*	*Comments*
M	Flow conditions		
β	$(1 - M^2)^{1/2}$		
A $\Lambda_{1/4}$ $\Lambda_{1/2}$ Λ_h λ η_i η_0	Planform geometry of wing and control		
βA $A \tan \Lambda_{1/2}$ $(1/\beta) \tan \Lambda_{1/4}$			
$\mathrm{d}C_L/\mathrm{d}\alpha$	Item No. 70011[8]		$(1/A)\mathrm{d}C_L/\mathrm{d}\alpha$ obtained as function of βA, $A \tan \Lambda_{1/2}$ and λ
c_b'/c_f' c_f'/c'	Geometry of section AA' that is normal to wing quarter-chord line and passes through mid-span of control hinge line		
$\dfrac{2\pi\beta G_1}{F_B (a_1)_0 \cos \Lambda_h}$ F_B $\dfrac{2\pi\beta G_2}{F_B (a_1)_0 \cos \Lambda_h}$ $\dfrac{2\pi\beta G_3}{F_B (a_1)_0 \cos \Lambda_h}$	Item No. 89009 (Fig. 1) Item No. 89009 (Fig. 2a or 2b) Item No. 89009 (Fig. 3) Item No. 89009 (Fig. 4)		Function of $(1/\beta)\tan\Lambda_{1/4}$, βA and c_f'/c' Function of c_b'/c_f' and c_f'/c' Function of $A \tan \Lambda_{1/2}$ and η_i Function of η_i
$\dfrac{F_B (a_1)_0 \cos \Lambda_h}{2\pi\beta}$			With $(a_1)_0$ from Table 2.1
G_1 G_2 G_3			
b_1 b_2	Item No. 89009*, Equations (3.4) and (3.5) Item No. 89009*, Equation (3.6)		With substitution of sectional values from Table 2.1, based on $\frac{1}{2}\rho V^2 \bar{\bar{c}}_f^{\,2} s_f$, control deflection δ measured in streamwise plane.

* see continuation of table

TABLE 2.2 (continued)

$$b_1 = \frac{(b_1)_0}{(a_1)_0}\left(\frac{dC_L}{d\alpha}\right)\cos\Lambda_h + G_1 + G_2$$ $$b_2 = \left((b_2)_0 - \frac{(a_2)_0}{(a_1)_0}(b_1)_0\right)\frac{\cos\Lambda_h}{\left(\beta^2 + \tan^2\Lambda_{1/4}\right)^{1/2}} + \frac{(a_2)_0}{(a_1)_0}(b_1 + G_3)$$
b_1 = b_2 =

TABLE 2.3

Calculation of incremental changes in hinge-moment coefficient derivatives due to horn balance. The method of Item No. 88003[9] is used.

Parameter	*Source*	*Value*	*Comments*
s_h/s_f $(c_b)_h/c_h$ x_h $c_h/\bar{c}_f$ $A_h(=s_h/c_h)$	Geometry of planform and streamwise section BB′ that passes through mid-span of horn		
B	$(s_h/s_f)(c_h/\bar{c}_f)^2[1-\{(c_b)_h/c_h\}^2]$		Increase in balance due to horn
$(t/c)_h$ τ_h	Section geometry		
$\Delta b_{1h}/A_hBF_1$ $\Delta b_{2h}/A_hBF_2NK$	Item No. 88003 (Fig. 1) Item No. 88003 (Fig. 2)		Functions of s_h/s_f for unshielded horns and of s_h/s_f and x_h for shielded horns
F_1 F_2 N K	Item No. 88003 (Fig. 3) Item No. 88003 (Fig. 3) Item No. 88003 (Fig. 4) Item No. 88003 (Fig. 5)		Function of $(t/c)_h$ Function of $(t/c)_h$ Nose shape correction factor, function of x_h Section shape correction factor, function of $[(t/c)_h - \tan \frac{1}{2}\tau_h]$
Δb_{1h} Δb_{2h}			Increments due to horn balance, based on $\frac{1}{2}\rho V^2 S_f \bar{c}_f$, control deflection δ measured in streamwise plane

TABLE 2.4

Calculation of effect of tab. The method of Item No. Aero C.04.01.08[1] is used

Parameter	*Source*	*Value*	*Comments*
M	Flow conditions		
β	$(1 - M^2)^{½}$		
s_{tab}/s_f $\Lambda_{¼}$ Λ_h Λ_{htab} $c'_{tab}/(c')_{tab}$ $(c'_b)_{tab}/(c'_f)_{tab}$ $(c_f)_{tab}/\bar{c}_f$ τ'_{tab}	Geometry of planform and section DD′ that is normal to wing quarter-chord line and passes through mid-span of tab hinge line		
$-b'_3/G$ F	Item No. Aero C.04.01.08 (Fig. 1) Item No. Aero C.04.01.08 (Fig. 2)		Function of $(c'_b)_{tab}/(c'_f)_{tab}$ and $c'_{tab}/(c')_{tab}$ Function of τ'_{tab}
G	Item No. Aero C.04.01.08* (Equation 2.1)		
b'_3			Based on $½\rho V^2 S_f \bar{c}_f$, for tab deflection angle measured about tab hinge line

* $$G = \left[\frac{s_{tab}}{s_f}\frac{(c_f)^2_{tab}}{\bar{c}_f^2}\right]\frac{F}{\beta}\cos\Lambda_{¼}\cos\Lambda_h\cos\Lambda_{htab}$$

TABLE 2.5

Calculation of final values

Parameter	*Source*	*Value*	*Comments*
$\bar{c}_f / \bar{\bar{c}}_f$ Λ_h	Planform geometry		
b_1 b_2	Table 2.2 Table 2.2		Values for control without horn or tab
Δb_{1h} Δb_{2h}	Table 2.3 Table 2.3		Increments due to horn
b_1 b_2	$b_1\text{(Table 2.2)} + \Delta b_{1h}(\bar{c}_f / \bar{\bar{c}}_f)^2$ $b_2\text{(Table 2.2)} + \Delta b_{2h}(\bar{c}_f / \bar{\bar{c}}_f)^2$		Values for control with horn*
b'_2 b'_3	$b_2 \cos \Lambda_h$ b'_3 (Table 2.4) $(\bar{c}_f / \bar{\bar{c}}_f)^2$		For control and tab deflection angles measured about their hinge lines

* All final values of coefficient derivatives are based on $\frac{1}{2}\rho V^2 \bar{\bar{c}}_f^2 s_f$.

3. DERIVATION

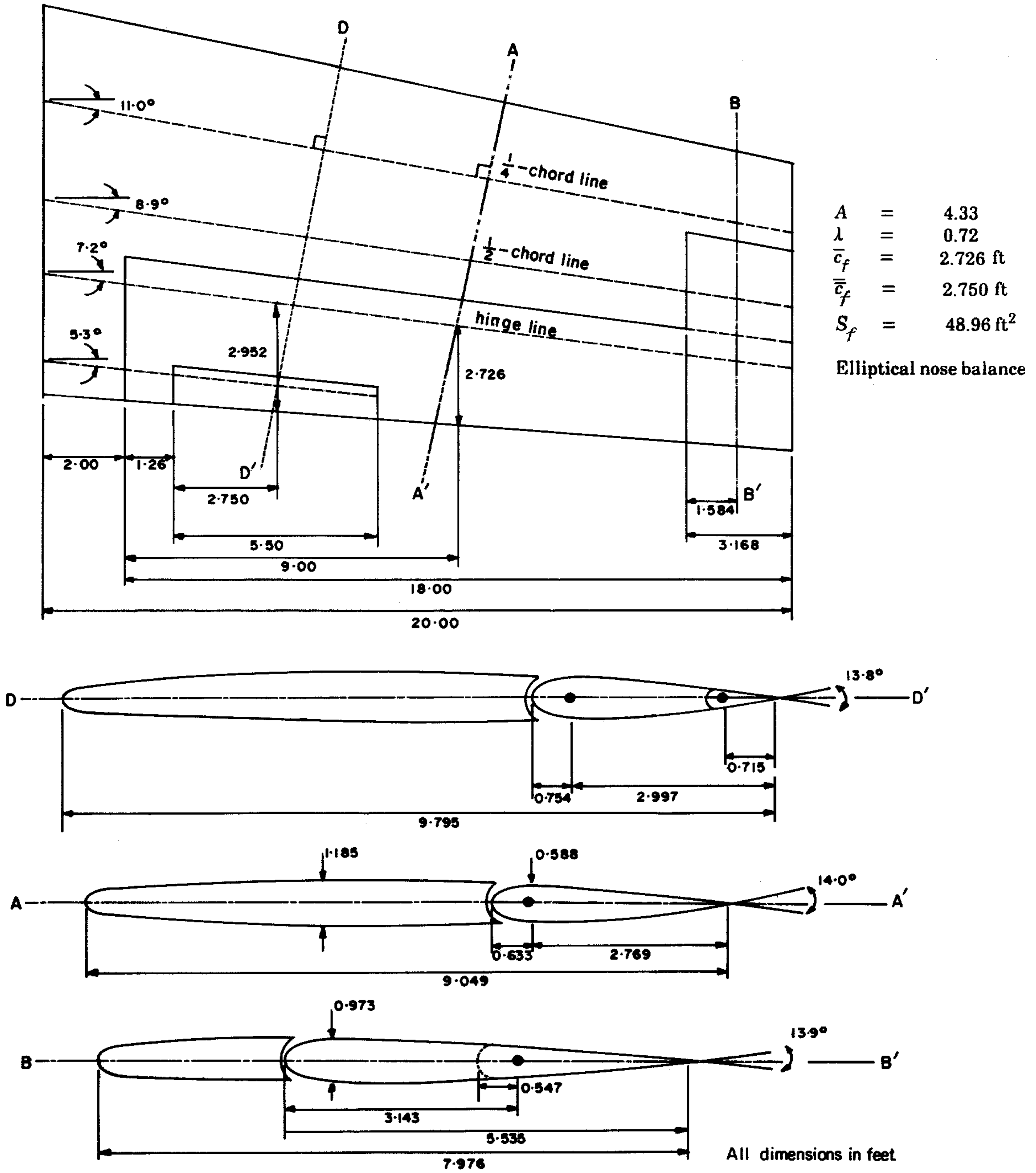
The Derivation lists selected sources that have assisted in the preparation of this Item.

1.	ESDU	Control hinge-moment coefficient derivative due to tab. Item No. Aero C.04.01.08. ESDU International, 1948.
2.	ESDU	Effect of nose balance on two-dimensional control hinge-moment coefficients. Item No. Aero C.04.01.03. ESDU International, 1949.
3.	ESDU	Effect of Irving internal balance on hinge-moment coefficient in two-dimensional flow. Item No. Aero C.04.01.04. ESDU International, 1949.
4.	ESDU	Slope of lift curve for two-dimensional flow. Item No. Aero W.01.01.05. ESDU International, 1955.
5.	ESDU	Rate of change of lift coefficient with control deflection in incompressible two-dimensional flow. Item No. Aero C.01.01.03. ESDU International, 1956.
6.	ESDU	Rate of change of hinge-moment coefficient with incidence for a plain control in incompressible two-dimensional flow, $(b_1)_0$. Item No. Aero C.04.01.01. ESDU International, 1956.
7.	ESDU	Rate of change of hinge-moment coefficient with control deflection for a plain control in incompressible two-dimensional flow, $(b_2)_0$. Item No. Aero C.04.01.02. ESDU International, 1956.
8.	ESDU	Lift-curve slope and aerodynamic centre position of wings in inviscid subsonic flow. Item No. 70011. ESDU International, 1970.
9.	ESDU	Effect of unshielded and shielded horn balances on hinge-moment coefficients for controls at low speeds. Item No. 88003. ESDU International, 1988.
10.	ESDU	Hinge moment coefficient derivatives for trailing-edge controls on wings at subsonic speeds. Item No. 89009. ESDU International, 1989.

4. EXAMPLE

Calculate the hinge moment characteristics for the control shown in Sketch 4.1 for $R = 3.5 \times 10^7$ and $M = 0.4$. The tab is geared so that $\delta'_{tab}/\delta' = -0.9$.

The values calculated are set out in Tables 4.1 to 4.5.



Sketch 4.1

TABLE 4.1

Calculation of two-dimensional properties for section AA′ that is normal to the wing quarter-chord line and passes through the mid-span of the control hinge line. The method of Item Nos Aero W.01.01.05[4] and C.01.01.03[5] are used for calculating aerofoil characteristics, C.04.01.01[6] and 02[7] for calculating the hinge moment coefficient derivatives of plain controls, and C.04.01.03[2] or 04[3] for determining the effects of a nose or Irving internal balance, respectively.

Parameter	*Source*	*Value*	*Comments*
R	Flow conditions	3.5×10^7	Based on wing mean chord $\bar{c}$
x_{tr}	Flow conditions, section geometry	0.30	Boundary layer transition point for section AA′
c_f'/c'	Geometry of section AA′ that is normal to wing quarter-chord line and passes through mid-span of control hinge line	0.306	2.769/9.049
c_b'/c_f'		0.229	0.633/2.769
τ'		14.0 deg	
t/c'		0.131	1.185/9.049
$2\tan^{-1} t/c'$		14.9 deg	
t_h/c_f'		0.212	0.588/2.769
$(a_1)_0/(a_1)_{0T}$	Item No. Aero W.01.01.05 (Fig. 1)	0.890	Calculations for plain (unbalanced) control with τ' equal to geometric value as defined in Item No. Aero W.01.01.05
$(a_1)_{0T}$	Item No. Aero W.01./01.05 (Fig. 2)	$6.94\ \text{rad}^{-1}$	
$(a_1)_0$		$6.18\ \text{rad}^{-1}$	
$(a_2)_{0T}$	Item No. Aero C.01.01.03 (Fig. 1)	$4.58\ \text{rad}^{-1}$	
$(a_2)_0/(a_2)_{0T}$	Item No. Aero C.01.01.03 (Fig. 2)	0.835	
$(a_2)_0$		$3.82\ \text{rad}^{-1}$	
$(a_1)_0^* / (a_1)_{0T}^*$	Item No. Aero W.01.01.05 (Fig. 1)	0.884	Calculations as above, but for ‘standard’ section with $\tau' = 2\tan^{-1} t/c'$
$(a_1)_{0T}^*$	Item No. Aero W.01.01.05 (Fig. 2)	$6.94\ \text{rad}^{-1}$	
$(a_1)_0^*$		$6.13\ \text{rad}^{-1}$	
$(a_2)_{0T}^*$	Item No. Aero C.01.01.03 (Fig. 1)	$4.58\ \text{rad}^{-1}$	
$(a_2)_0^* / (a_2)_{0T}^*$	Item No. Aero C.01.01.03 (Fig. 2)	0.830	
$(a_2)_0^*$		3.80	

TABLE 4.1 (continued)

Parameter	*Source*	*Value*	*Comments*
$(b_1)_{0T}{}^*$ $(b_1)_0{}^*/(b_1)_{0T}{}^*$ $(b_1)_0{}^*$ $(b_2)_{0T}{}^*$ $(b_2)_0{}^*/(b_2)_{0T}{}^*$ $(b_2)_0{}^*$	Item No. Aero C.04.01.01 (Fig. 1) Item No. Aero C.04.01.01 (Fig. 2) Item No. Aero C.04.01.02 (Fig. 1) Item No. Aero C.04.01.02 (Fig. 2)	–0.535 rad^{-1} 0.730 –0.391 rad^{-1} –0.855 rad^{-1} 0.850 –0.727 rad^{-1}	Values for ‘standard’ section, plain control
$(b_1)_0$ $(b_2)_0$	$(b_1)_0{}^* + 2[(a_1)_{0T}{}^* - (a_1)_0{}^*](\tan½\tau - t/c)$ (Item No. Aero C.04.01.01) $(b_2)_0{}^* + 2[(a_2)_{0T}{}^* - (a_2)_0{}^*](\tan½\tau - t/c)$ (Item No. Aero C.04.01.02)	–0.404 rad^{-1} –0.739 rad^{-1}	Values for plain control. Strictly $(b_1)_{0Plain}$ and $(b_2)_{0Plain}$
$\left[(c'_b/c'_f)^2 - (½t_h/c'_f)^2\right]^{½}$	Section geometry	0.203	Balance as defined in Item Nos Aero C.04.01.03 and 04
$(b_1)_{0Bal}/(b_1)_{0Plain}$ $(b_2)_{0Bal}/(b_2)_{0Plain}$ or $(b_1)_{0Bal}/(b_1)_{0Plain}$ $(b_2)_{0Bal}/(b_2)_{0Plain}$	Item No. Aero C.04.01.03 (Figs 1 and 2) for nose balance, or Item No. Aero C.04.01.04 (Figs 1 to 5) for Irving internal balance	0.850 0.840 – –	Ratios of balanced to plain control values
$(b_1)_0$ $(b_2)_0$	$(b_1)_{0Plain}[(b_1)_{0Bal}/(b_1)_{0Plain}]$ $(b_2)_{0Plain}[(b_2)_{0Bal}/(b_2)_{0Plain}]$	–0.343 rad^{-1} –0.621 rad^{-1}	Values for balanced control. Strictly $(b_1)_{0Bal}$ and $(b_2)_{0Bal}$

TABLE 4.2

Calculation of hinge-moment coefficient derivatives for controls without horn or tab. The calculation follows the main method described in Sections 3.2 and 3.3 of Item No. 89009[10]. For a rectangular wing with part-span controls, see the extended method in Section 3.4 of that Item.

Parameter	*Source*	*Value*	*Comments*
M	Flow conditions	0.40	
β	$(1 - M^2)^{1/2}$	0.917	
A $\Lambda_{1/4}$ $\Lambda_{1/2}$ Λ_h λ η_i η_0	Planform geometry of wing and control	4.33 11.0 deg 8.9 deg 7.2 deg 0.72 0.10 1.00	 2.0/20.00 20.00/20.00
βA $A \tan \Lambda_{1/2}$ $(1/\beta) \tan \Lambda_{1/4}$		3.97 0.678 0.212	
$\mathrm{d}C_L/\mathrm{d}\alpha$	Item No. 70011[8]	3.90 rad^{-1}	$(1/A)\mathrm{d}C_L/\mathrm{d}\alpha$ obtained as function of βA, $A \tan \Lambda_{1/2}$ and λ
c'_b/c'_f c'_f/c'	Geometry of section AA' that is normal to wing quarter-chord line and passes through mid-span of control hinge line	0.229 0.306	0.633/2.769 2.769/9.049
$\dfrac{2\pi\beta G_1}{F_B(a_1)_0 \cos \Lambda_h}$	Item No. 89009 (Fig. 1)	0.058 rad^{-1}	Function of $(1/\beta) \tan \Lambda_{1/4}$, βA and c'_f/c'
F_B	Item No. 89009 (Fig. 2a or 2b)	0.90	Function of c'_b/c'_f and c'_f/c'
$\dfrac{2\pi\beta G_2}{F_B(a_1)_0 \cos \Lambda_h}$	Item No. 89009 (Fig. 3)	0.004 rad^{-1}	Function of $A \tan \Lambda_{1/2}$ and η_i
$\dfrac{2\pi\beta G_3}{F_B(a_1)_0 \cos \Lambda_h}$	Item No. 89009 (Fig. 4)	0.010 rad^{-1}	Function of η_i
$\dfrac{F_B(a_1)_0 \cos \Lambda_h}{2\pi\beta}$		0.958	With $(a_1)_0$ from Table 2.1
G_1 G_2 G_3		0.056 rad^{-1} 0.004 rad^{-1} 0.010 rad^{-1}	
b_1 b_2	Item No. 89009*, Equations (3.4) and (3.5) Item No. 89009*, Equation (3.6)	–0.155 rad^{-1} –0.522 rad^{-1}	With substitution of sectional values from Table 2.1, based on $\frac{1}{2}\rho V^2 \bar{\bar{c}}_f^2 s_f$, control deflection δ measured in streamwise plane.

* see continuation of table

TABLE 4.2 (continued)

$$b_1 = \frac{(b_1)_0}{(a_1)_0}\left(\frac{\mathrm{d}C_L}{\mathrm{d}\alpha}\right)\cos\Lambda_h + G_1 + G_2$$

$$b_2 = \left((b_2)_0 - \frac{(a_2)_0}{(a_1)_0}(b_1)_0\right)\frac{\cos\Lambda_h}{\left(\beta^2 + \tan^2\Lambda_{1/4}\right)^{1/2}} + \frac{(a_2)_0}{(a_1)_0}(b_1 + G_3)$$

$$b_1 = \frac{-0.343}{6.18}(3.90)\cos 7.2° + 0.056 + 0.004 = -0.155\,\mathrm{rad}^{-1}$$

$$b_2 = \left(-0.621 - \frac{3.82}{6.18}(-0.343)\right)\frac{\cos 7.2°}{(0.917^2 + \tan^2 11.0°)^{1/2}} + \frac{3.82}{6.18}(-0.155 + 0.010) = 0.522\,\mathrm{rad}^{-1}$$

TABLE 4.3

Calculation of incremental changes in hinge-moment coefficient derivatives due to horn balance. The method of Item No. 88003[9] is used.

Parameter	*Source*	*Value*	*Comments*
s_h/s_f	Geometry of planform and streamwise section BB′ that passes through mid-span of horn	0.176	3.168/18.00
$(c_b)_h/c_h$		0.174	0.547/3.143
x_h		0.694	5.535/7.976
$c_h/\bar{c}_f$		1.153	3.143/2.726
$A_h(=s_h/c_h)$		1.008	3.168/3.143
B	$(s_h/s_f)(c_h/\bar{c}_f)^2[1-\{(c_b)_h/c_h\}^2]$	0.227	Increase in balance due to horn
$(t/c)_h$	Section geometry	0.122	0.973/7.976
τ_h		13.0 deg	
$\Delta b_{1h}/A_h BF_1$	Item No. 88003 (Fig. 1)	0.255 rad^{-1}	Functions of s_h/s_f for unshielded horns and of s_h/s_f and x_h for shielded horns
$\Delta b_{2h}/A_h BF_2 NK$	Item No. 88003 (Fig. 2)	0.398 rad^{-1}	
F_1	Item No. 88003 (Fig. 3)	3.33	Function of $(t/c)_h$
F_2	Item No. 88003 (Fig. 3)	2.58	Function of $(t/c)_h$
N	Item No. 88003 (Fig. 4)	1.0	Nose shape correction factor, function of x_h
K	Item No. 88003 (Fig. 5)	1.0	Section shape correction factor, function of $[(t/c)_h - \tan ½\tau_h]$
Δb_{1h}		0.194 rad^{-1}	Increments due to horn balance, based on $½\rho V^2 S_f \bar{c}_f$, control deflection δ measured in streamwise plane
Δb_{2h}		0.235 rad^{-1}	

TABLE 4.4

Calculation of effect of tab. The method of Item No. Aero C.04.01.08[1] is used

Parameter	*Source*	*Value*	*Comments*
M	Flow conditions	0.40	
β	$(1 - M^2)^{½}$	0.917	
s_{tab}/s_f	Geometry of planform and section DD′ that is normal to wing quarter-chord line and passes through mid-span of tab hinge line	0.306	5.50/18.00
$\Lambda_{¼}$		11.0 deg	
Λ_h		7.2 deg	
Λ_{htab}		5.3 deg	
$c'_{tab}/(c')_{tab}$		0.073	0.715/9.795
$(c'_b)_{tab}/(c'_f)_{tab}$		0.252	0.754/2.997
$(c_f)_{tab}/\bar{c}_f$		1.083	2.952/2.726
τ'_{tab}		13.8 deg	
$-b'_3/G$	Item No. Aero C.04.01.08 (Fig. 1)	0.61 rad^{-1}	Function of $(c'_b)_{tab}/(c'_f)_{tab}$ and $c'_{tab}/(c')_{tab}$
F	Item No. Aero C.04.01.08 (Fig. 2)	1.135	Function of τ'_{tab}
G	Item No. Aero C.04.01.08* (Equation 2.1)	0.431	
b'_3		–0.263 rad^{-1}	Based on $½\rho V^2 S_f \bar{c}_f$, for tab deflection angle measured about tab hinge line

* $G = \left[\dfrac{s_{tab}}{s_f}\dfrac{(c_f)^2_{tab}}{\bar{c}^2_f}\right]\dfrac{F}{\beta}\cos\Lambda_{¼}\cos\Lambda_h\cos\Lambda_{htab} = [0.306 - 1.083^2]\dfrac{1.135}{0.917}\cos 11.0°\cos 7.2°\cos 5.3° = 0.431$

TABLE 4.5

Calculation of final values

Parameter	*Source*	*Value*	*Comments*
$\bar{c}_f/\bar{\bar{c}}_f$ Λ_h	Planform geometry	0.991 7.2°	2.726/2.750
b_1 b_2	Table 4.2 Table 4.2	–0.155 rad^{-1} –0.522 rad^{-1}	Values for control without horn or tab
Δb_{1h} Δb_{2h}	Table 4.3 Table 4.3	0.194 rad^{-1} 0.235 rad^{-1}	Increments due to horn
b_1 b_2	$b_1(\text{Table 4.2}) + \Delta b_{1h}(\bar{c}_f/\bar{\bar{c}}_f)^2$ $b_2(\text{Table 4.2}) + \Delta b_{2h}(\bar{c}_f/\bar{\bar{c}}_f)^2$	0.036 rad^{-1} –0.291 rad^{-1}	Values for control with horn*
b'_2 b'_3	$b_2 \cos \Lambda_h$ b'_3 (Table 2.4) $(\bar{c}_f/\bar{\bar{c}}_f)^2$	–0.289 rad^{-1} –0.258 rad^{-1}	For control and tab deflection angles measured about their hinge lines†

* All final values of coefficient derivatives are based on $\frac{1}{2}\rho V^2 \bar{\bar{c}}_f^2 s_f$.

† For a geared tab such that $\delta'_{tab}/\delta' = -0.9$, $\partial C_H/\partial\delta' = -0.289 + (-0.9) \times (-0.258) = -0.057 \text{ rad}^{-1}$

THE PREPARATION OF THIS DATA ITEM

The work on this particular Item, which supersedes Item No. Aero C.04.01.09, was monitored and guided by the Aerodynamics Committee, which first met in 1942 and now has the following membership:

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