



ESDU 88003

Issued April 1988

With Amendments A to D

March 1997

Supersedes ESDU 87032 and

ESDU Aero C.04.01.07

Effect of unshielded and shielded horn balances on hinge moment coefficients for controls at low speeds

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THE PREPARATION OF THIS DATA ITEM

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EFFECT OF UNSHIELDED AND SHIELDED HORN BALANCES ON HINGE MOMENT COEFFICIENTS FOR CONTROLS AT LOW SPEEDS

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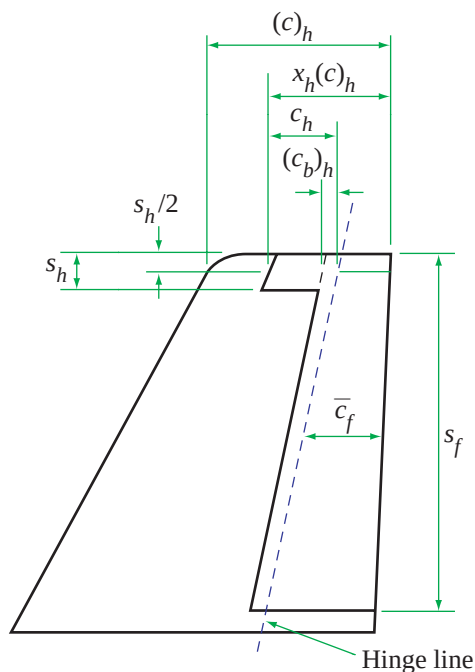
EFFECT OF UNSHIELDED AND SHIELDED HORN BALANCES ON HINGE MOMENT COEFFICIENTS FOR CONTROLS AT LOW SPEEDS

1. NOTATION AND UNITS (see Sketch 1.1)

		SI	British
A_h	aspect ratio of horn, $s_h/\bar{c}_h$		
B	increase in balance due to horn (see Sketch 1.1)		
b_1	rate of change of hinge-moment coefficient with angle of attack	rad^{-1}	rad^{-1}
b_2	rate of change of hinge-moment coefficient with control deflection	rad^{-1}	rad^{-1}
Δb_{1h}	increment in b_1 due to horn balance	rad^{-1}	rad^{-1}
Δb_{2h}	increment in b_2 due to horn balance	rad^{-1}	rad^{-1}
$(b_1)_0^*/(b_1)_{0T}^*$	ratio of viscid to inviscid flow values of b_1 in two dimensions for aerofoil with $(t/c)_h = \tan^{1/2}\tau_h$ (from Item No. Aero C.04.01.01)		
$(b_2)_0^*/(b_2)_{0T}^*$	ratio of viscid to inviscid flow values of b_2 in two dimensions for aerofoil with $(t/c)_h = \tan^{1/2}\tau_h$ (from Item No. Aero C.04.01.02)		
C_H	hinge-moment coefficient, $H/1/2\rho V^2 S_f \bar{c}_f$		
$(c)_h$	wing chord at mid-span of horn	m	ft
$(c_b)_h$	chord of basic control (without horn) forward of hinge line at mid-span of horn (see Sketch 1.1)	m	ft
$\bar{c}_f$	mean chord of control aft of hinge line	m	ft
c_h	chord of horn forward of hinge line at mid-span of horn	m	ft
F_1, F_2	section thickness factors		
H	hinge moment, positive nose up	N m	lbf ft
N	nose shape correction factor		
K	correlating function depending on $(t/c)_h - \tan^{1/2}\tau_h$		
R	Reynolds number based on wing mean chord		

Issued April 1988
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S_f	area of control aft of hinge line	m ²	ft ²
s_f	span of control	m	ft
s_h	span of horn	m	ft
t	maximum section thickness	m	ft
$(t/c)_h$	thickness to chord ratio of wing at mid-span of horn		
V	free-stream velocity	m/s	ft/s
x_h	distance of horn leading edge ahead of trailing edge at mid-span of horn, as fraction of local wing chord		
ρ	density of air	kg/m ³	slug/ft ³
τ_h	trailing-edge angle at mid-span of horn	deg	deg



$$B = \left(\frac{s_h}{s_f} \right) \left(\frac{c_h}{\bar{c}_f} \right)^2 \left[1 - \left\{ \frac{(c_b)_h}{c_h} \right\}^2 \right]$$

Sketch 1.1

2. METHOD

This Item gives a semi-empirical method for predicting the increments in the rates of change of hinge-moment coefficient with angle of attack and control deflection, Δb_{1h} and Δb_{2h} , for horn balances fitted to the tips of unswept or moderately swept controls at low speeds. The increments are given in terms of the parameters $\Delta b_{1h}/A_h B F_1$ and $\Delta b_{2h}/A_h B F_2 N K$ which are presented in Figures 1 and 2, respectively, as functions of the horn leading-edge position x_h and span ratio s_h/s_f . The section thickness factors F_1 and F_2 are given in Figure 3 as functions of $(t/c)_h$. The function N is given in Figure 4 as a function of x_h and provides a correction for the different effects on Δb_{2h} of round-nosed and elliptically-nosed horns.

The function K is given in Figure 5 and allows for the effect of section shape on Δb_{2h} through the parameter $[(t/c)_h - \tan^{1/2}\tau_h]$. The function K was determined primarily for application to unshielded horns, and for shielded horns the range of $[(t/c)_h - \tan^{1/2}\tau_h]$ for which $K = 1$ should be taken to define a limit on applicability.

The method provides compatible predictions for the two types of horn, with the estimated values for the unshielded horns forming acceptable limiting values for shielded horns as x_h approaches unity. Because of the larger number of experimental data available, and its greater simplicity, a method restricted to unshielded horns was developed initially. A number of deductions from that analysis were then used in the construction of the method for shielded horns. This process is described in Section 2.1.

2.1 Development of Method

2.1.1 Unshielded horns

The method for unshielded horns has been developed by following Derivation 1 where the analysis of the hinge-moment data available when that report was published allowed $\Delta b_{1h}/A_h B$ and $\Delta b_{2h}/A_h B$ to be correlated linearly against $(t/c)_h$, the mean thickness to chord ratio of the wing over the span of the horn. Examination of information from Derivations 3, 5 and 6 that has become available since publication of Derivation 1 has now enabled different linear trends with $(t/c)_h$ to be established for Δb_{1h} and Δb_{2h} , but in the latter case with correction for trailing-edge angle. Thus Figures 1a and 2a give $\Delta b_{1h}/A_h B F_1$ and $\Delta b_{2h}/A_h B F_2 N K$ where the functions F_1 and F_2 are taken from Figure 3. These provide a better prediction for current control geometries. Almost all of the data studied were in the range $0.09 \leq (t/c)_h \leq 0.15$, but a linear extrapolation has been made to $(t/c)_h = 0.05$, where a single data point from Derivation 2 suggests that this is adequate.

In addition, empirical variations with the span ratio s_h/s_f , as shown in Figures 1a and 2a, have been determined to allow for the relatively larger effectiveness of horns with span ratio smaller than those considered in Derivation 2. These were established by looking at systematic tests in which a number of horns of different spans were tested with $(t/c)_h$ a constant.

The factor N is given in Figure 4 as a function of nose shape and is unity for unshielded horns, but is included in the ordinate of Figure 2a to give a consistent presentation with the data for shielded horns.

Most of the data examined were for section shapes for which $-0.01 \leq [(t/c)_h - \tan^{1/2}\tau_h] \leq 0.04$. However, a set of tests reported in Derivation 5 on three pairs of models that were identical apart from large changes in control trailing-edge angle suggested that outside this range there was a pronounced variation in Δb_{2h} , but not in Δb_{1h} . The factor K in Figure 5 has been derived from those data, the part of the curve demonstrating the observed behaviour in Δb_{2h} . Because the shape of the curve has been deduced from a small number of data over a limited range of Reynolds number it must be taken as being indicative of trends rather than a precise correlation.

2.1.2 Shielded horns

The method for shielded horns has been developed similarly from the technique of Derivation 1. Again the parameters $\Delta b_{1h}/A_h B F_1$ and $\Delta b_{2h}/A_h B F_2 N$ are associated with F_1 and F_2 , the same empirically determined functions of $(t/c)_h$, that were established for unshielded horns. The experimental data in Derivations 2 and 4 to 8 allow the parameters to be correlated in Figures 1b and 2b in terms of s_h/s_f and x_h . They show an increase in magnitude with decreasing s_h/s_f that is similar in form but somewhat faster than that for unshielded horns; their variation with x_h allows a smooth transition into the values for unshielded horns corresponding to $x_h = 1$. Regions of the carpets that have been interpolated by using the predictions for unshielded horns are shown dashed.