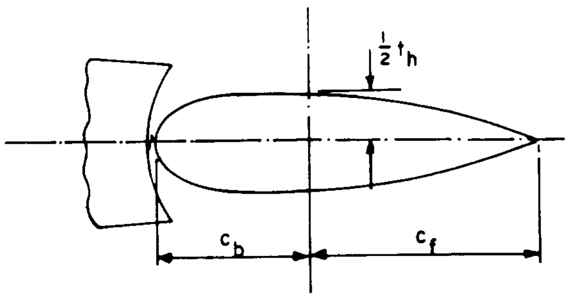
EFFECT OF NOSE BALANCE ON TWO-DIMENSIONAL CONTROL HINGE-MOMENT COEFFICIENTS

1. NOTATION AND UNITS

		SI	*British*
$(b_1)_{0Bal}$	rate of change of control hinge-moment coefficient with incidence in two-dimensional flow for sealed control surface with nose balance in incompressible flow	rad^{-1}	rad^{-1}
$(b_1)_{0Plain}$	rate of change of control hinge-moment coefficient with incidence in two-dimensional flow for plain sealed control of chord c_f (see Item No. Aero C.04.01.01) in incompressible flow	rad^{-1}	rad^{-1}
$(b_2)_{0Bal}$	rate of change of control hinge-moment coefficient with control surface deflection in two-dimensional flow for sealed control surface with nose balance in incompressible flow	rad^{-1}	rad^{-1}
$(b_2)_{0Plain}$	rate of change of control hinge-moment coefficient with control surface deflection in two-dimensional flow for plain sealed control of chord c_f in incompressible flow (see Item No. Aero C.04.01.02)	rad^{-1}	rad^{-1}
c	aerofoil chord	m	ft
c_b	balance chord forward of hinge line (see Sketch 1.1)	m	ft
c_f	control chord aft of hinge line (see Sketch 1.1)	m	ft
t_h	control thickness at hinge line (see Sketch 1.1)	m	ft



Nose balance

Sketch 1.1

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2. NOTES

This Item presents the ratios $(b_1)_{0Bal}/(b_1)_{0Plain}$, Figure 1, and $(b_2)_{0Bal}/(b_2)_{0Plain}$, Figure 2, plotted against balance ratio

$$[(c_b/c_f)^2 - (½t_h/c_f)^2]^{½} \tag{2.1}$$

for three types of control nose shape, sharp, elliptic and round. The values of $(b_1)_0$ and $(b_2)_0$ for plain controls can be obtained from Item Nos Aero C.04.01.01 and 02 respectively.

The curves are based on experimental data on sealed controls. The tests are as yet neither sufficiently numerous nor accurate enough to allow for the effects of all parameters which are known to influence the hinge-moment coefficients. Most of the data were obtained from tests on aerofoils having a control chord/aerofoil chord ratio of about 0.3; variation of this ratio between 0.15 and 0.40 is likely to have only a small effect. With increasing thickness/chord ratio of the aerofoil the reduction in $(b_2)_0$ at the same balance ratio seems to be smaller, but systematic information is lacking. The effect of the aerofoil section shape, other than that taken into account in estimating the plain control hinge moments, is also uncertain, the only low drag aerofoil section tested showing close agreement with conventional sections as regards the reduction in $(b_1)_0$. The effect of aerofoil section shape on $(b_2)_0$ is shown in Figure 2.

It should be emphasised that small changes in nose shape, trailing edge shape and conditions of air flow may have a considerable effect on the hinge moments of balanced control surfaces, and no close prediction can be expected. It should be noted that conversion to three-dimensional flow conditions, as given in Item No. 89009 adds a positive increment to $(b_1)_0$ and $(b_2)_0$.

Unsealing the gap between the nose of the control surface and the main aerofoil affects the control hinge-moment coefficients of both the plain and nose-balanced controls. The changes are generally in the same sense, the hinge-moment coefficients becoming more positive. For low-drag sections, however, a change in the opposite sense has been observed. Tests indicate that the effect is larger for the balanced than for the plain controls, but the evidence is not sufficient to give systematic information.

If the nose balance is cut out over part of the span to allow for the installation of hinge brackets, control actuating mechanism, etc., the control hinge-moment coefficients, particularly b_2, may be seriously affected. This change depends in some measure on the size of the cut-outs, though more important is the size of the gaps through which air may flow from the pressure to the suction side of the control surface. When the gaps are wide, wind-tunnel data indicate that the control surface should be assumed unbalanced over a spanwise length at least three to four times that covered by the cut-out. When the gaps are small $(<0.003c)$, only that part of the control surface behind the cut-out need be taken as unbalanced when calculating b_2.

3. DERIVATION

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

1.	SEARS, R.I. HOGGARD, H.P., Jr	Effect of gap on the aerodynamic characteristics of a NACA 0009 airfoil with a 30-per cent-chord plain flap. ARC Rep. 5319, 1941.
2.	SEARS, R.I. HOGGARD, H.P., Jr	A large aerodynamic balance of various nose shapes, with a 30-per cent-chord flap on a NACA 0009 airfoil. ARC Rep. 5375, 1941.

3. AMES, M.B., Jr — A small aerodynamic balance of various nose shapes used with a 30-per cent-chord flap on a NACA 0009 airfoil. ARC Rep. 5396, 1941.

4. AMES, M.B., Jr; EASTMAN, D.R., Jr — A medium aerodynamic balance of various nose shapes used with a 30-per cent-chord flap on a NACA 0009 airfoil. ARC Rep. 5415, 1941.

5. SEARS, R.I.; LIDDELL, R.B. — A 30-per cent-chord plain flap on the NACA 0015 airfoil. ARC Rep. 6063, 1942

6. SEARS, R.I.; HOGGARD, H.P., Jr — A medium aerodynamic balance of two nose shapes used with a 30-per cent-chord flap on a NACA 0015 airfoil. ARC Rep. 6237, 1942.

7. SEARS, R.I.; GILLIS, C.I. — A large aerodynamic balance of two nose shapes used with a 30-per cent-chord flap on a NACA 0015 airfoil. ARC Rep. 6322, 1942.

8. SEARS, R.I. — Wind-tunnel data on the aerodynamic characteristics of airplane control surfaces. NACA ACR 3L08 (ARC Rep. 7986), 1943.

9. THOMAS, H.H.B.M.; LOFTS, M. — Application of thin aerofoil theory to controls having set back hinge balance, with analysis of wind-tunnel data on aerofoils of finite thickness. ARC R&M 2256, 1948.

4. EXAMPLE

Find the rate of change of hinge moment coefficient with control deflection due to a nose-balanced control with elliptic nose shape in two-dimensional incompressible flow, when $c_f/c = 0.35$, $c_b/c_f = 0.40$, $\frac{1}{2}t_h/c_f = 0.11$, the aerofoil is of NACA 0012 section, and $(b_2)_{0Plain} = -0.83$ rad^{-1} .

The balance ratio is $[(0.4)^2 - (0.11)^2]^{1/2} = [0.1600 - 0.0121]^{1/2} = 0.385$.

From Figure 2, with a balance ratio of 0.385, for a NACA 0012 aerofoil associated with an elliptic-nosed control,

$$(b_2)_{0Bal}/(b_2)_{0Plain} = 0.52.$$

Therefore,

$$(b_2)_{0Bal} = 0.52 \times (-0.83)$$

$$= -0.43 \text{ rad}^{-1}.$$

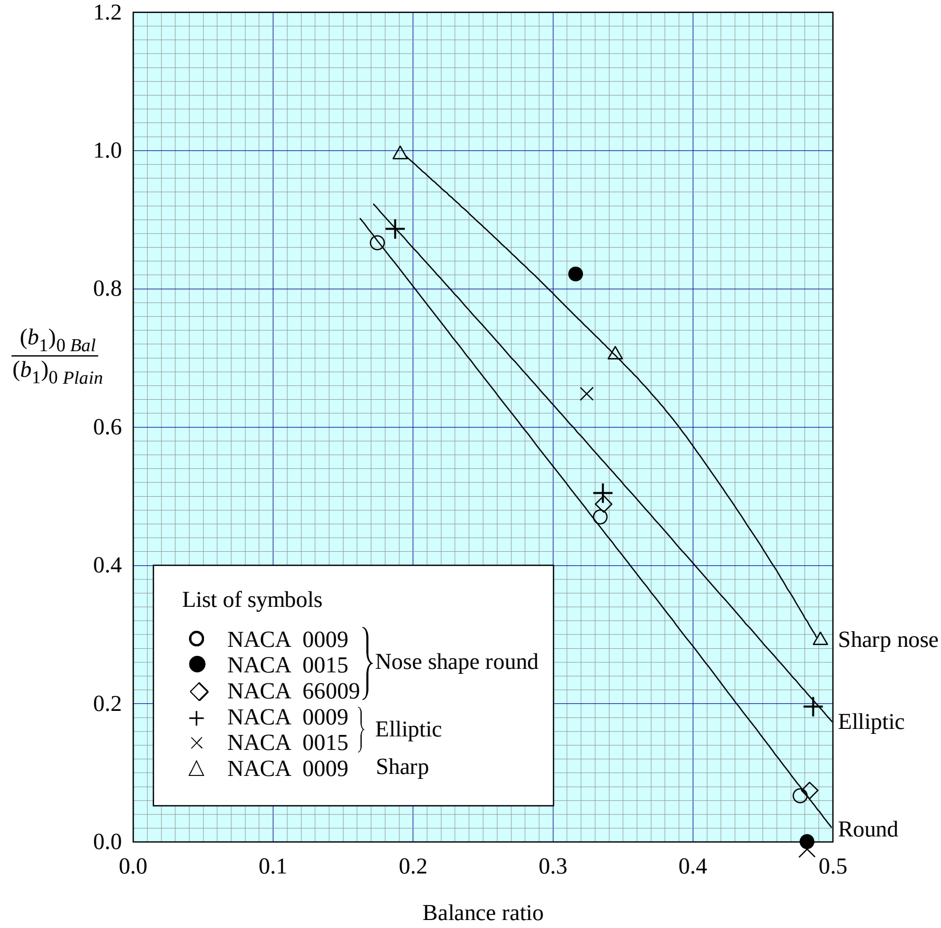

FIGURE 1

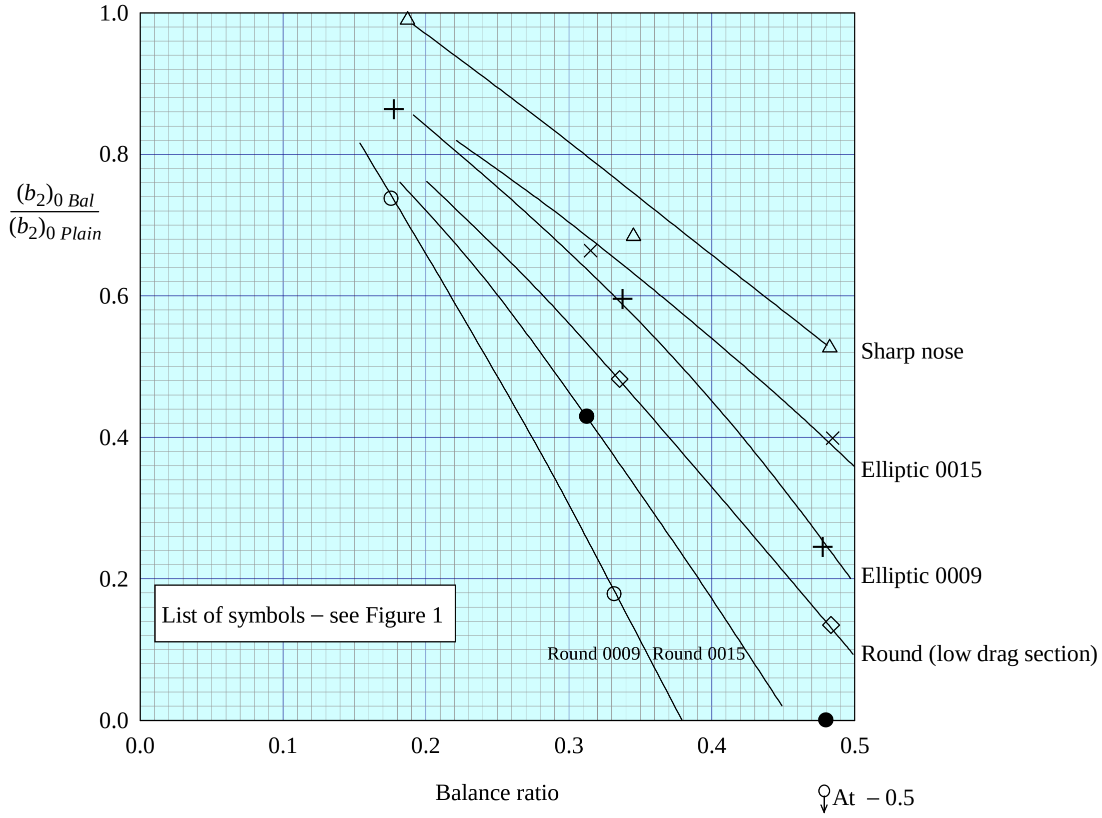

FIGURE 2