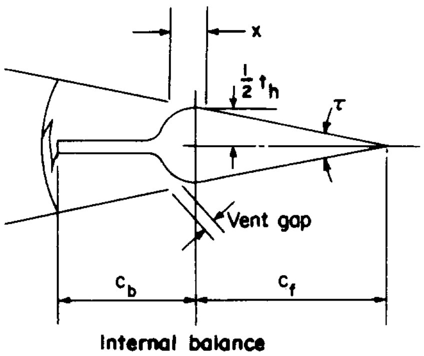
EFFECT OF IRVING INTERNAL BALANCE ON HINGE-MOMENT COEFFICIENT IN TWO-DIMENSIONAL FLOW

1. NOTATION AND UNITS

		SI	*British*
$(a_1)_0$	rate of change of lift coefficient with incidence in two-dimensional incompressible flow	rad^{-1}	rad^{-1}
$\Delta(b_1)_0$	increment, due to internal balance, to hinge-moment derivative $(b_1)_0$	rad^{-1}	rad^{-1}
$\Delta(b_2)_0$	increment, due to internal balance, to hinge-moment derivative $(b_2)_0$	rad^{-1}	rad^{-1}
c	aerofoil chord	m	ft
c_b	internal 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
F_1	factor on $\Delta(b_2)_0$ allowing for aerofoil section effect		
F_2	reduction factor on $\Delta(b_2)_0$ due to vent position		
K	reduction factor on $\Delta(b_2)_0$ due to leakage through nose seal		
t_h	control thickness at hinge line (see Sketch 1.1)	m	ft
x	distance from edge of shroud to position of pressure peak on control (see Sketch 1.1)	m	ft
τ	control trailing-edge angle as defined by angle between tangents to upper and lower surfaces at trailing edge	deg	deg



Sketch 1.1

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2. NOTES

The ratios $\Delta(b_1)_0/(a_1)_0$ and $(\Delta(b_2)_0)/(KF_1F_2)$ are plotted in Figures 1 and 2, respectively, against c_f/c for various values of internal balance ratio

$$[(c_b/c_f)^2 - (½t_h/c_f)^2]^{½}.$$

In Figures 3, 4 and 5, the factors K, F_1 and F_2 are plotted, respectively, against their relevant parameters.

The value of $(a_1)_0$ may be obtained from Item No. Aero W.01.01.05.

The curves are based on experimental data, most of which refer to conventional aerofoil sections.

The data are not, as yet, sufficient to determine the effects of all the parameters involved. It is very probable that $\Delta(b_1)_0$ is affected by variations in vent position and the ratio of leak area to vent area in a manner similar to that given by the factors F_2 and K for $\Delta(b_2)_0$. In the absence of further information, an average reduction factor of 0.55 has been applied to the theoretical value of $\Delta(b_1)_0$ so as to obtain agreement with experimental data.

The distance x should be measured from the pressure peak to the edge of the shroud. In the absence of pressure data, the pressure peak may be assumed to be at the position of maximum thickness of the control.

The vent area is defined as the product of the vent length and the shortest distance from the control surface to the edge of one of the shrouds. The leak area is generally made up of a number of components, such as nose seal leakage, gaps between the ends of the balance plate and the adjacent walls, gaps around the hinge brackets, leakage past rivets, etc. Tests indicate that the shape and position of such gaps or leaks have only a secondary effect and it is recommended that all leakages be converted to equivalent leak areas (*i.e*. areas which would allow the passage of the same volume of air under the same pressure difference) and that the areas so obtained be added to those of the gaps and the total assumed to be distributed uniformly over the vent length.

For low-drag aerofoils, within the range of incidence over which low-drag characteristics are maintained, the effect of leakage appears to be much more pronounced. The results for the only available information are plotted in Figure 3; these are for a 16 per cent thick section with the pressure peak at 0.6 of the chord. In general, the leakage effect for low-drag sections is much less severe than that shown in Figure 3, which refers to an extreme case; a typical value of K for such sections lies about midway between the two curves plotted.

The tension in the flexible nose seal strip due to the air loads on it may contribute significantly to the hinge balance moment; its contribution depends on the width of the sealing strip, the size of the nose gap, and the seal attachment position, and varies with control deflection. For nose gaps of the order of $0.05c_b$ to $0.10c_b$ the seal moment is small and positive (*i.e*. it increases the balance moments) at small angles of control deflection; it increases with control deflections up to about 15°, being then of the order of about 0.15 of the balance moment; at larger control deflection it falls rapidly and finally becomes negative. These values are based on seal strip widths of $0.4c_b$ to $0.6c_b$; experiments indicate that a sealing strip that just touches the shrouds when fully extended has the most favourable characteristics. For further information see References 3 and 4.

The tests were conducted at Reynolds numbers between 0.8×10^6 and 3.0×10^6; the effect, if any, of conversion to full-scale Reynolds numbers is unknown. Forward movement of the transition point causes a reduction in both $\Delta(b_1)_0$ and $\Delta(b_2)_0$.

The increments $\Delta(b_1)_0$ and $\Delta(b_2)_0$ should be added to the plain control hinge-moment coefficients $(b_1)_0$ and $(b_2)_0$ before correcting for finite aspect ratio, see Item No. 89009.

3. DERIVATION AND REFERENCES

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

Derivation

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

2. THOMAS, H.H.B.M. — An analysis of wind-tunnel data on the “Westland-Irving” type of balance. RAE Report Aero 2066, 1945.

References

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

3. MURRAY, H.E. AUSTIN, M.H. — Hinge moments of sealed-internal-balance arrangements for control surfaces. I –Theoretical investigation. NACA ARR L5F30, 1945.

4. FISCHEL, J. — Hinge moments of sealed-internal-balance arrangements for control surfaces. II – Experimental investigation of fabric seals in the presence of a thin-plate overhang. NACA ARR L5F30a, 1945.

4. EXAMPLE

Find the increments to $(b_1)_0$ and $(b_2)_0$ due to an Irving internal balance on a control with the following characteristics:-

$$c_b/c_f = 0.60;\ c_f/c = 0.25;\ ½t_h/c_f = 0.12;\ \tau = 14.5° \text{ and } x = 0.025c;$$

each vent gap is 0.012 m wide, and the sum of the leaks, per metre length, equals 0.003 m^2. It may be assumed that for the aerofoil section $(a_1)_0$ is 5.70 rad^{-1}. For the plain control, $(b_1)_0 = -0.38\ rad^{-1}$ and $(b_2)_0 = -0.72\ rad^{-1}$.

The balance ratio is $[(0.6)^2 - (0.12)^2]^{½} = 0.59$.

From Figure 1, with $c_f/c = 0.25$ and a balance ratio of 0.59,

$$\Delta(b_1)_0 = 0.0315 \times 5.70 = 0.18\ rad^{-1}.$$

The hinge-moment derivative $(b_1)_0$ for the balanced control is therefore $-0.38 + 0.18 = -0.20\ rad^{-1}$.

Leak area/vent area = 0.003/0.012 = 0.25. Hence from Figure 3, K = 0.65.

$\tau = 14.5°$; hence from Figure 4, F_1 = 1.30.
$x = 0.025c$; hence from Figure 5, F_2 = 0.68.

From Figure 2, with c_f/c = 0.25 and a balance ratio of 0.59,

$$\Delta(b_2)_0/(KF_1F_2) = 0.78\ \text{rad}^{-1}, \text{ so that } \Delta(b_2)_0 = 0.78 \times 0.65 \times 1.30 \times 0.68 = 0.45\ \text{rad}^{-1}.$$

The hinge-moment derivative $(b_2)_0$ for the balanced control is therefore – 0.72 + 0.45 = – 0.27 rad^{-1} .

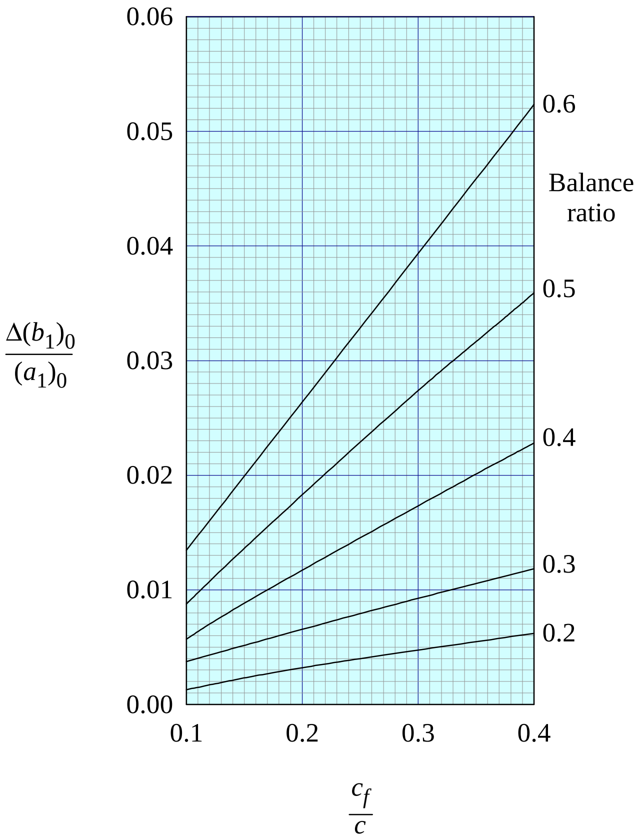

FIGURE 1

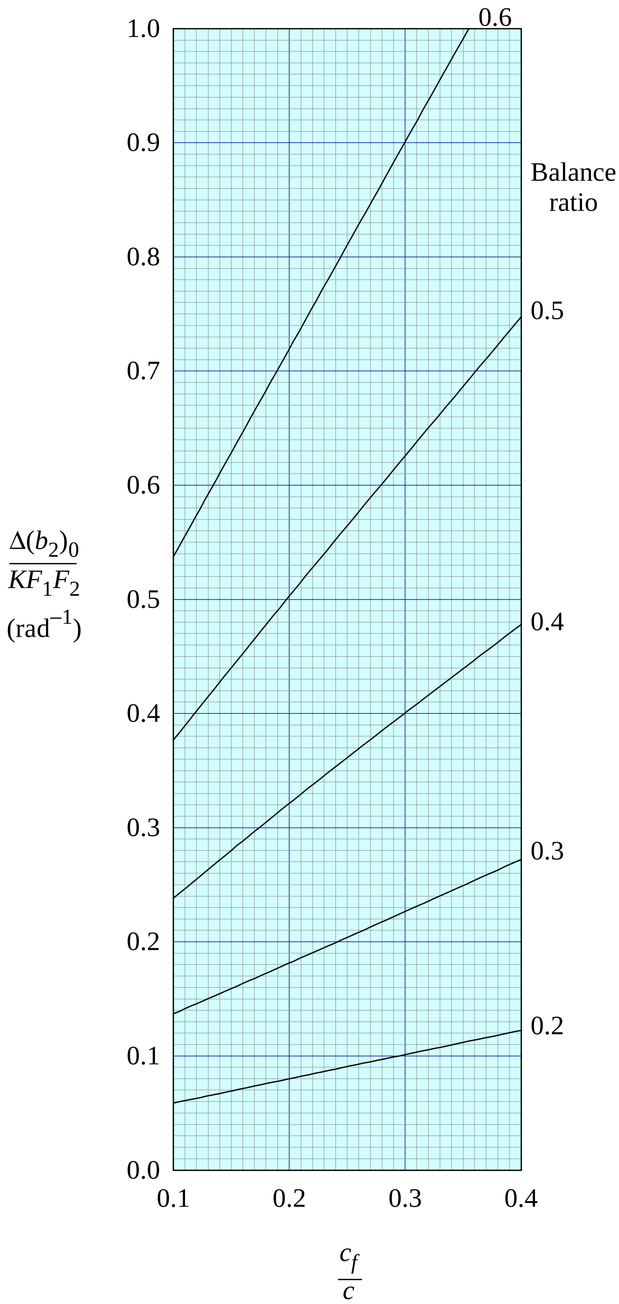

FIGURE 2

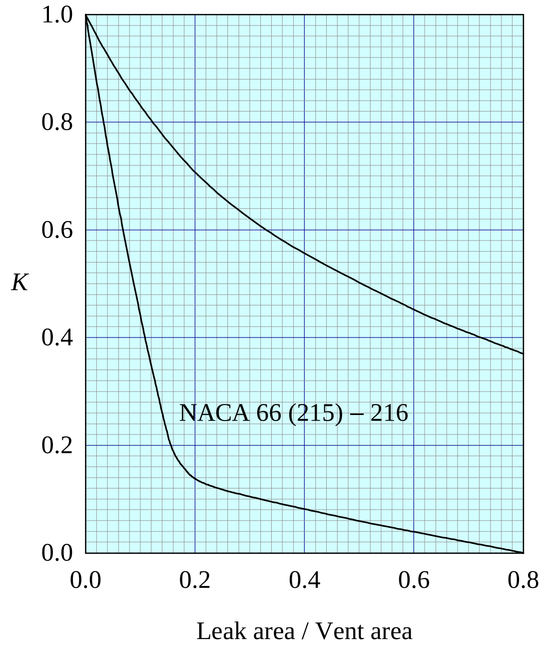

FIGURE 3

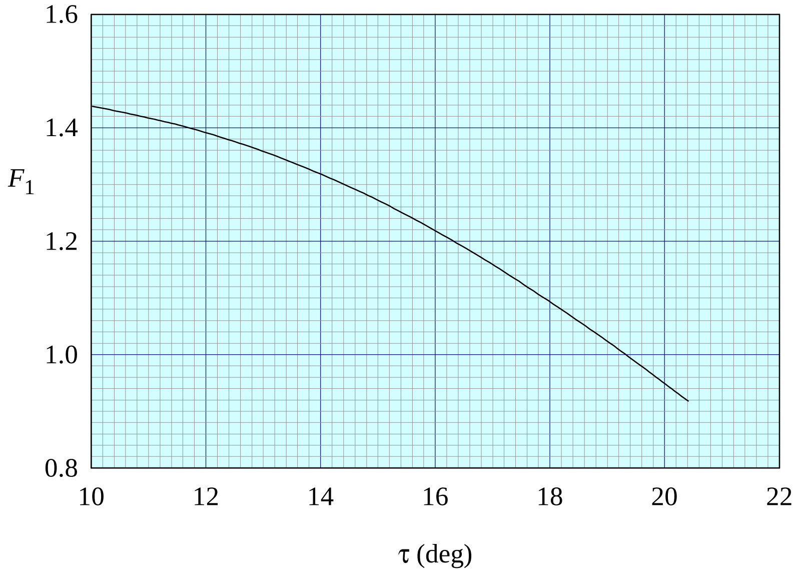

FIGURE 4

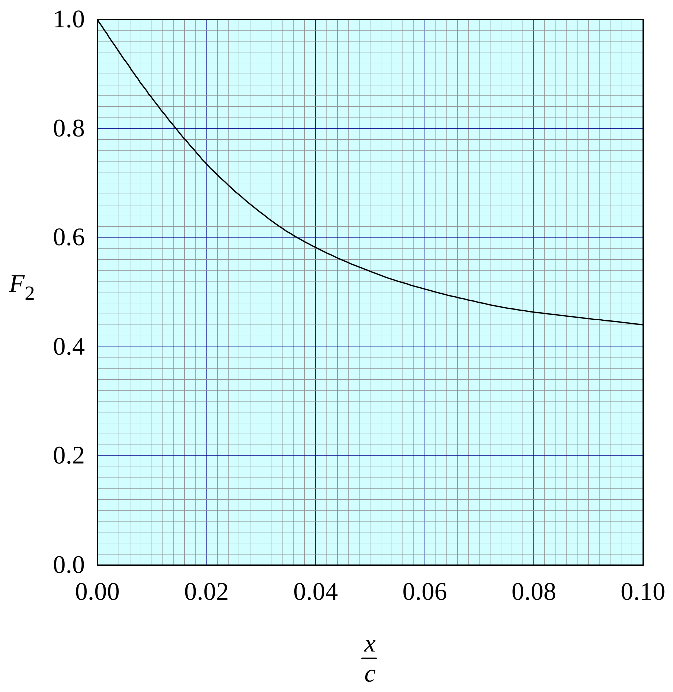

FIGURE 5