RATE OF CHANGE OF LIFT COEFFICIENT WITH CONTROL DEFLECTION IN INCOMPRESSIBLE TWO-DIMENSIONAL FLOW, $(a_2)_0$

1. NOTATION AND UNITS

		SI	*British*
$(a_1)_0$	slope of lift-coefficient curve with incidence for two-dimensional aerofoil in incompressible flow, $\partial C_L/\partial\alpha$	radian^{-1}	radian^{-1}
$(a_1)_{0T}$	theoretical slope of lift-coefficient curve with incidence for two-dimensional aerofoil in inviscid, incompressible flow	radian^{-1}	radian^{-1}
$(a_2)_0$	slope of lift-coefficient curve with control deflection for two-dimensional aerofoil in incompressible flow, $\partial C_L/\partial\delta$	radian^{-1}	radian^{-1}
$(a_2)_{0T}$	theoretical slope of lift-coefficient curve with control deflection for a two-dimensional aerofoil in inviscid, incompressible flow	radian^{-1}	radian^{-1}
C_L	lift coefficient		
c	chord of aerofoil	m	ft
c_f	control chord, aft of hinge line	m	ft
t	maximum thickness of aerofoil	m	ft
α	angle of incidence measured from no-lift angle with control undeflected	radian	radian
δ	control deflection angle, positive downwards	radian	radian
τ	trailing-edge angle	degree	degree

2. NOTES

The theoretical rate of change of lift coefficient with control deflection $(a_2)_{0T}$ is plotted against c_f/c for various values of t/c in Figure 1. In Figure 2 $(a_2)_0/(a_2)_{0T}$ is plotted against c_f/c for various values of $(a_1)_0/(a_1)_{0T}$. Values of $(a_1)_0/(a_1)_{0T}$ for a given aerofoil section may be obtained from Item No. Aero W.01.01.05.

Within the linear range of the lift-incidence curve and over the range of control deflection for which the increment of lift is linear with control deflection, the lift coefficient C_L of a two-dimensional aerofoil at an angle of incidence α and a control surface deflection δ is given by

$$C_L = (a_1)_0\alpha + (a_2)_0\delta. \tag{2.1}$$

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For small angles of incidence this should apply within a range of δ of about $\pm 15°$. The accuracy of this Item is assessed to be within ± 5 per cent.

It may be noted that Equation (2.1) may be written as

$$C_L = (a_1)_0[\alpha + \delta(a_2)_0/(a_1)_0] \tag{2.2}$$

and the expression $[\alpha + \delta(a_2)_0/(a_1)_0]$ may therefore be regarded as the equivalent angle of incidence for the two-dimensional aerofoil with the control deflected. For calculations in which this concept is used, $(a_2)_0$ may be obtained from this Item and $(a_1)_0$ from Item No. Aero W.01.01.05.

The data apply to controls with the gap sealed; for plain and balanced controls the effect of unsealing the gap is given in Item No. Aero C.01.01.04.

For controls of finite aspect ratio $(a_2)_0$ must be corrected for induced effects and use may be made of the method given in Item No. 74011.

3. DERIVATION

1.	WOODS, L.C.	The theory of aerofoils with hinged flaps in two-dimensional compressible flow. ARC CP 138, 1952.
2.	GARNER, H.C.	Charts for low-speed characteristics of two-dimensional trailing-edge flaps. ARC R & M 3174, 1957.

4. EXAMPLE

Find the lift coefficient increment due to a control deflection of 10° for a two-dimensional aerofoil in incompressible flow for which $c_f/c = 0.35$ and $t/c = 0.10$. The profile of the aerofoil from 80 per cent of the chord to the trailing edge is generated by two straight lines such that $\tan\frac{1}{2}\tau = 0.12$. The Reynolds number based on the chord c is 1×10^7 and transition may be assumed to occur at mid-chord.

From Item No. Aero W.01.01.05, for $\tan\frac{1}{2}\tau = 0.12$ and $R = 1 \times 10^7$ and with transition at mid-chord

$$(a_1)_0/(a_1)_{0T} = 0.880\,.$$

From Figure 1, with $t/c = 0.10$ and $c_f/c = 0.35$,

$$(a_2)_{0T} = 4.80 \text{ rad}^{-1}\,.$$

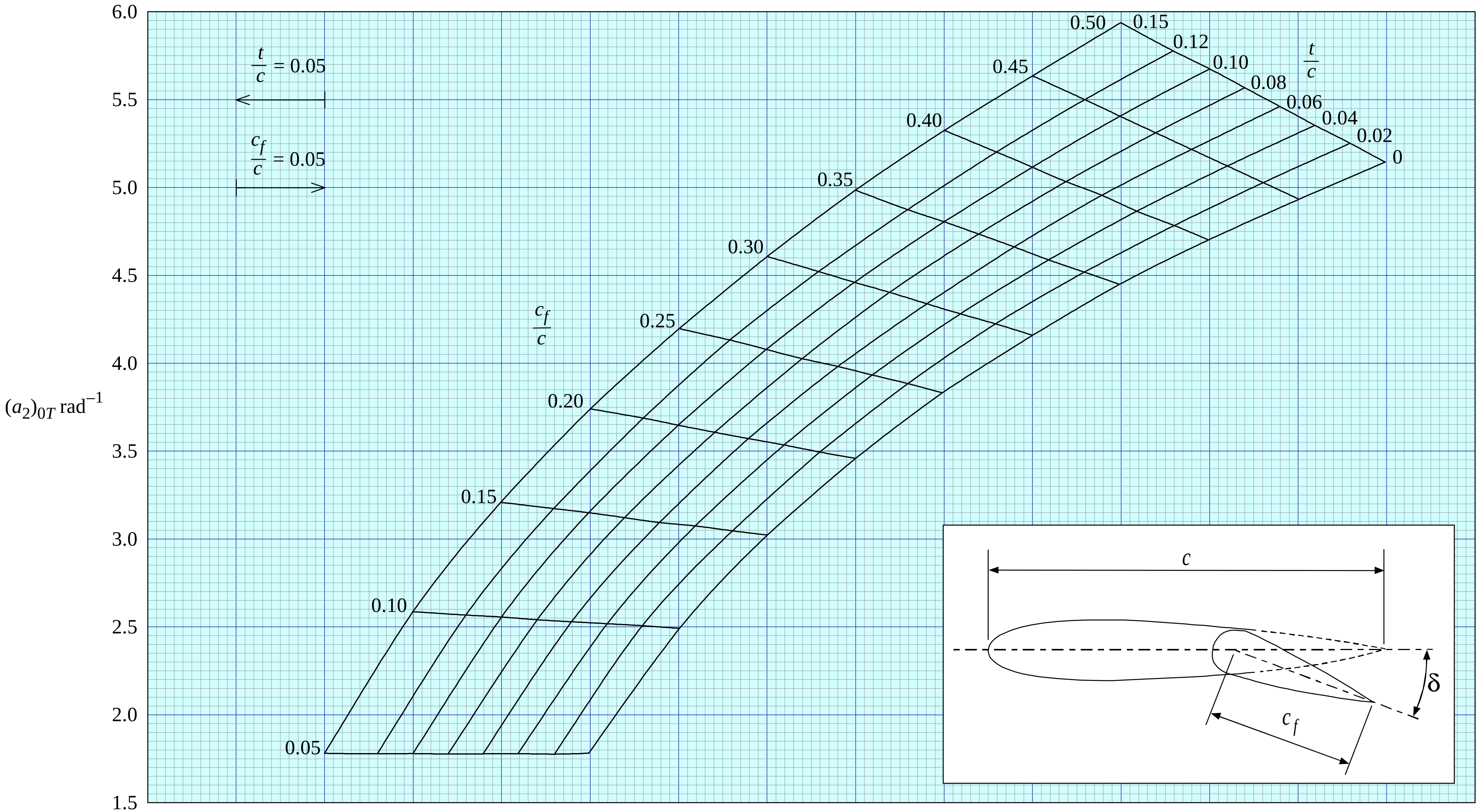
From Figure 2, with $(a_1)_0/(a_1)_{0T} = 0.880$ and $c_f/c = 0.35$,

$$(a_2)_0/(a_2)_{0T} = 0.83\,.$$

Hence $$(a_2)_0 = 0.83 \times 4.80 = 3.98 \text{ rad}^{-1}\,.$$

Thus the lift-coefficient increment due to a control deflection of 10° is

$$(a_2)_0\delta = 3.98 \times 10 \times \pi/180 = 0.69\,.$$



6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
$(a_2)_{0T}$ rad^{-1}
$\frac{t}{c}$ = 0.05
$\frac{c_f}{c}$ = 0.05
$\frac{c_f}{c}$
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
$\frac{t}{c}$
0.15
0.12
0.10
0.08
0.06
0.04
0.02
0
c
δ
c_f

FIGURE 1

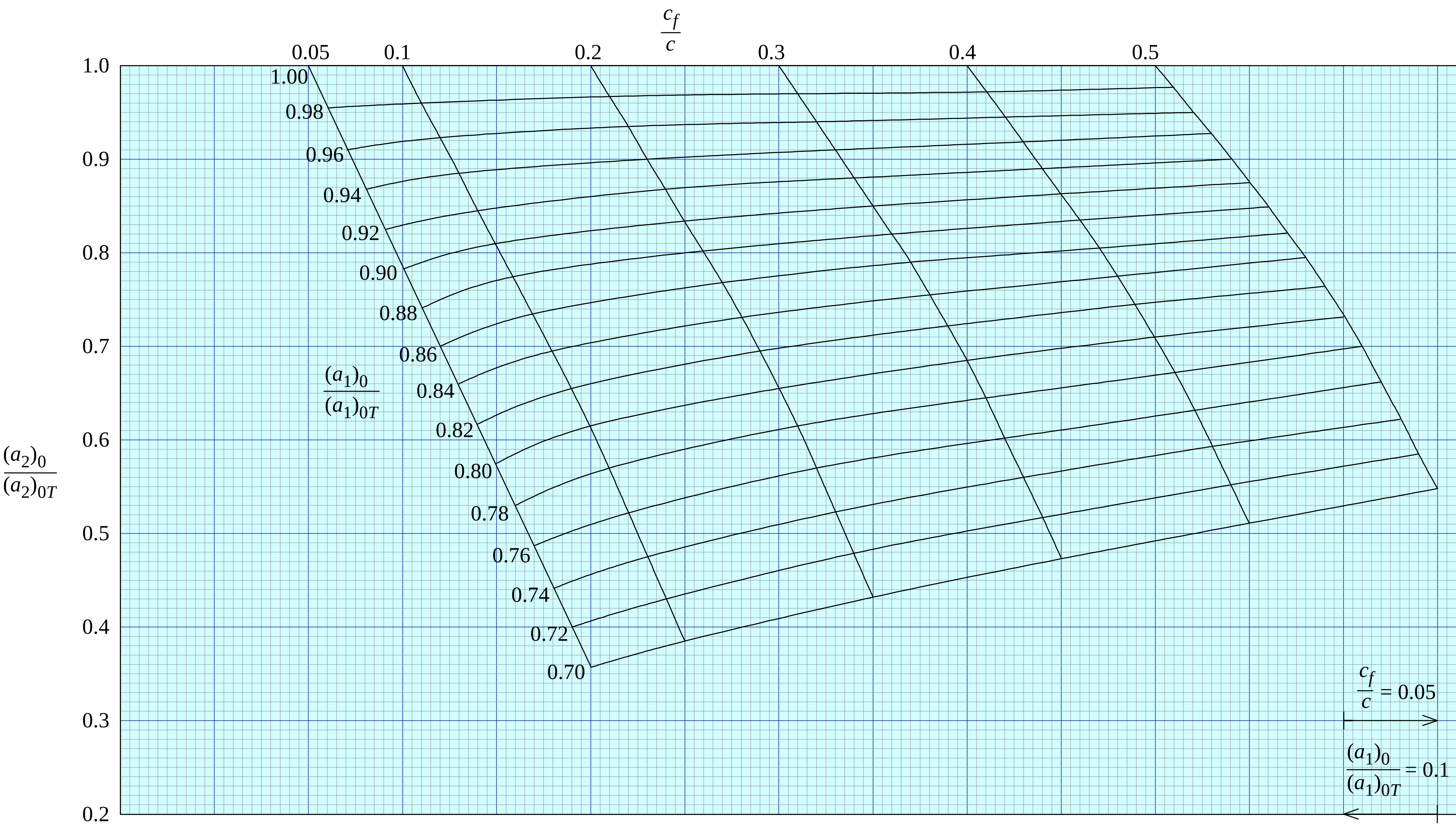

$\frac{c_f}{c}$
0.05
0.1
0.2
0.3
0.4
0.5
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
$\frac{(a_2)_0}{(a_2)_{0T}}$
$\frac{(a_1)_0}{(a_1)_{0T}}$
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.78
0.76
0.74
0.72
0.70
$\frac{c_f}{c} = 0.05$
$\frac{(a_1)_0}{(a_1)_{0T}} = 0.1$

FIGURE 2