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Wing lift coefficient increment at zero angle of attack due to deployment of plain trailing-edge flaps at low speeds

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THE PREPARATION OF THIS DATA ITEM

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WING LIFT COEFFICIENT INCREMENT AT ZERO ANGLE OF ATTACK DUE TO DEPLOYMENT OF PLAIN TRAILING-EDGE FLAPS AT LOW SPEEDS

CONTENTS

	Page
1. NOTATION AND UNITS	1
2. INTRODUCTION	4
3. REQUIRED DATA ITEMS	4
4. PREDICTION METHOD	4
4.1 Determination of ΔC_{L0t}	5
4.2 Determination of ΔC_{L0tw}	5
5. EFFECTS OF MACH NUMBER AND REYNOLDS NUMBER	6
5.1 Mach Number Effects	6
5.2 Reynolds Number Effects	6
6. APPLICABILITY AND ACCURACY	6
6.1 Applicability	6
6.2 Accuracy	8
7. DERIVATION AND REFERENCES	10
7.1 Derivation	10
7.1.1 ESDU Data Items	10
7.1.2 Wind-tunnel test reports	10
7.1.3 Thin-plate theory	11
7.2 References	11
8. EXAMPLE	13
FIGURES 1 to 2	17 to 18

WING LIFT COEFFICIENT INCREMENT AT ZERO ANGLE OF ATTACK DUE TO DEPLOYMENT OF PLAIN TRAILING-EDGE FLAPS AT LOW SPEEDS

1. NOTATION AND UNITS

		SI	British
A	aspect ratio, $2s/\bar{c}$		
a_t	theoretical rate of change of lift coefficient with plain trailing-edge flap deflection, Equation (4.3)	rad^{-1}	rad^{-1}
a_1	basic wing lift-curve slope, $dC_L/d\alpha$	rad^{-1}	rad^{-1}
C_L	lift coefficient; (lift)/ qS for wing, (lift)/ qc for aerofoil		
ΔC_{L0lw}	increment in wing lift coefficient at $\alpha = 0$ due to deployment of leading-edge device, based on S		
ΔC_{L0t}	increment in aerofoil lift coefficient at $\alpha = 0$ due to deployment of plain trailing-edge flap, based on c		
$\Delta C'_{L0t}$	increment in aerofoil lift coefficient at $\alpha = 0$ due to deployment of plain trailing-edge flap, based on c'		
ΔC_{L0tw}	increment in wing lift coefficient at $\alpha = 0$ due to deployment of plain trailing-edge flap, based on S		
c	chord of basic aerofoil chosen to be representative of wing, <i>i.e.</i> chord at mid-span of plain trailing-edge flap panel, see Sketch 1.1	m	ft
c'	extended aerofoil chord, <i>i.e.</i> chord with extended plain trailing-edge flap deployed, see Sketch 1.2b	m	ft
c_r	wing root (centre-line) chord, see Sketch 1.1	m	ft
c_t	chord of plain trailing-edge flap, see Sketch 1.2	m	ft
$\bar{c}$	wing geometric mean chord	m	ft
$\bar{\bar{c}}$	wing aerodynamic mean chord	m	ft
J_p	correlation factor (efficiency factor) for plain trailing-edge flap, Equation (4.5)		
J_{p0}	correlation factor (efficiency factor) for plain trailing-edge flap, on an unswept wing, Figure 1		

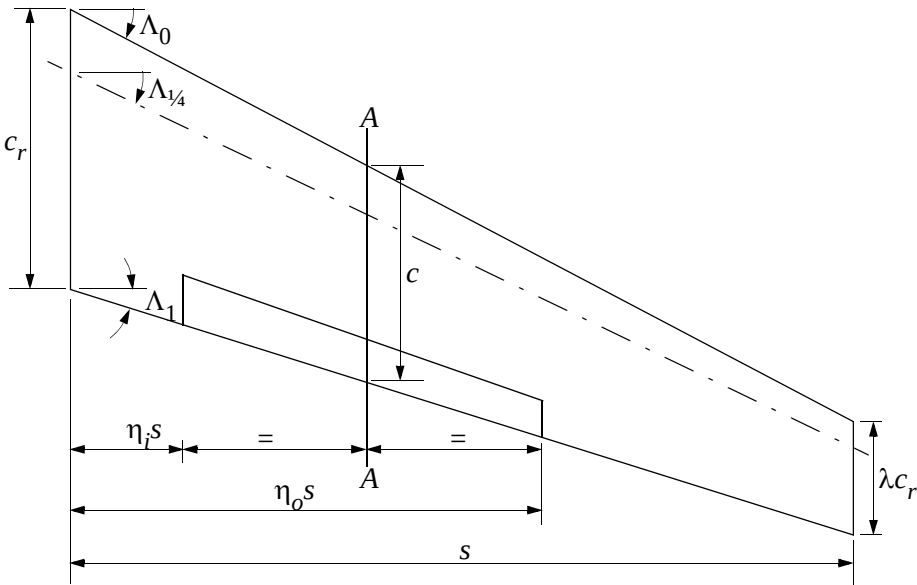
Issued March 1997 – 18 pages
With Amendment A, November 2003
This page Amendment A

K_{f0}	flap type correlation factor, Equation (4.4)		
K_{t0}	correlation parameter for aspect ratio and sweep, Equations (4.6) and (4.7)		
M	free-stream Mach number		
q	free-stream kinetic pressure	N/m ²	lbf/ft ²
R_l	Reynolds number based on free-stream conditions and l		
S	wing planform area, $2s\bar{c}$	m ²	ft ²
s	wing semispan, see Sketch 1.1	m	ft
α	angle of attack (wing incidence in Item No. 70011)	rad	rad
β	compressibility parameter, $(1 - M^2)^{1/2}$		
δ_t, δ_t°	deflection of plain trailing-edge flap, see Sketch 1.2	rad, deg	rad, deg
η	spanwise distance from wing centre-line as fraction of semispan		
η_i	value of η at inboard limit of flap, see Sketch 1.1		
η_o	value of η at outboard limit of flap, see Sketch 1.1		
Λ_0	wing leading-edge sweep angle, see Sketch 1.1	deg	deg
$\Lambda_{1/4}$	wing quarter-chord sweep angle, see Sketch 1.1	deg	deg
$\Lambda_{1/2}$	wing mid-chord sweep angle	deg	deg
Λ_1	wing trailing-edge sweep angle, see Sketch 1.1	deg	deg
λ	wing taper ratio (tip chord/root chord)		
Φ	part-span factor; lift coefficient increment due to part span plain trailing-edge flaps extending symmetrically from wing centre-line divided by lift coefficient increment due to full span plain trailing-edge flaps at the same deflection angle and wing angle of attack		
Φ_i	value of Φ corresponding to η_i , Figure 2		
Φ_o	value of Φ corresponding to η_o , Figure 2		
ϕ_t°	angle between aerofoil datum and tangent to upper surface at trailing edge, see Sketch 1.2a	deg	deg

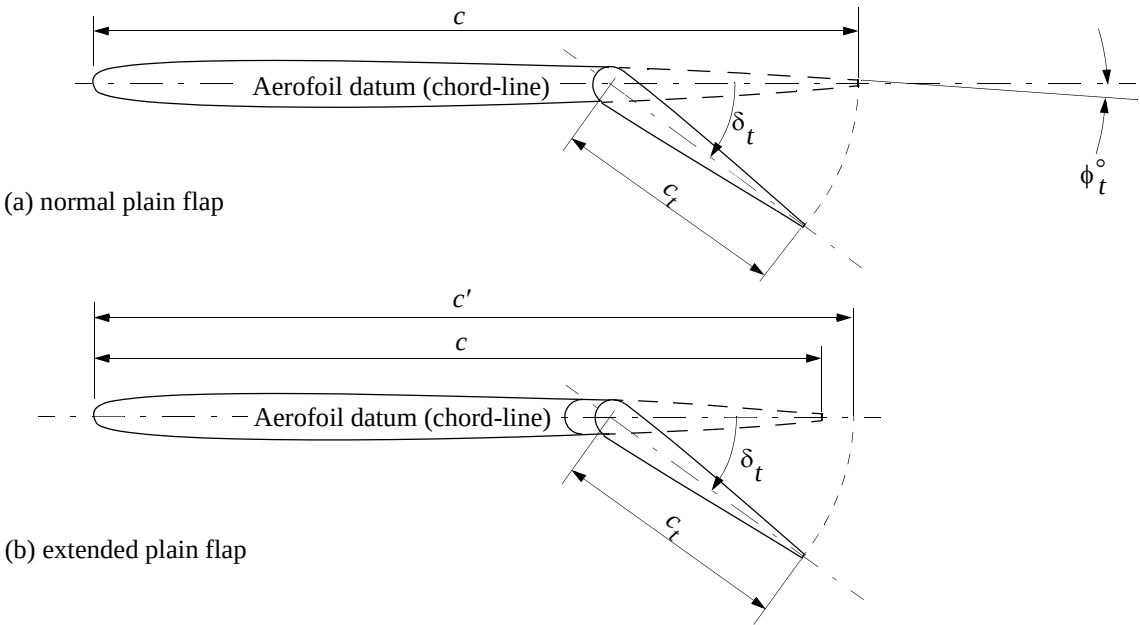
This page Amendment A

Subscripts

- $()_{expt}$ denotes experimental value
- $()_{pred}$ denotes predicted value



Sketch 1.1 Wing notation (flaps undeployed)



Sketch 1.2 Deployed plain flap notation (at section AA)

2. INTRODUCTION

In this Item, the increment in lift coefficient at zero angle of attack, due to the deployment of plain trailing-edge flaps on a wing, is derived from the increment due to the deployment of the plain flap on an aerofoil section that is representative of the wing. For wings with full-span plain trailing-edge flaps, factors are applied to allow for three-dimensional effects. For wings with part-span plain trailing-edge flaps, additional factors are introduced that are dependent on the wing geometry. Wings with single-slotted, double-slotted and split trailing-edge flaps are dealt with in Item Nos 93019, 95021 and 97009 (References 20, 22, 24).

At low speeds, the increment in lift coefficient at zero angle of attack, ΔC_{L0tw} , due to the deployment of a full-span plain trailing-edge flap on a high-aspect-ratio rectangular wing is strongly dependent on the corresponding value, ΔC_{L0t} , for an aerofoil/plain flap combination appropriate to the mid-semispan location. The main parameters that can influence ΔC_{L0t} are the flap angle, chord of the flap, the angle ϕ_t° between the aerofoil datum and the tangent to the upper surface at the trailing edge, the flow Reynolds number and Mach number. For plain trailing-edge flaps on wings the additional parameters that can influence ΔC_{L0tw} are the wing planform geometry (aspect ratio, taper ratio and sweep), and the spanwise extent of the flap. The effects of wing planform geometry for unswept wings are largely accounted for in terms of their effect on the wing lift-curve slope but for swept wings there is an additional dependency on a parameter combining sweep and aspect ratio. Provision is made for the case of an extended plain flap. The method applies only to plain flaps with a *sealed* leading-edge.

In the application of the method a number of other Data Items may be required, and these are listed in Section 3. Section 4 describes the method. The effects of Mach number and Reynolds number are discussed in Section 5. Section 6 addresses the applicability and accuracy of the method. Section 7 gives the Derivation and References. Section 8 presents a detailed example to illustrate the steps of the calculation.

3. REQUIRED DATA ITEMS

The ESDU Data Items that may be required in the use of this Item are:

Data Item No.	Derivation No.	To Determine
70011	1	Wing lift-curve slope
76003	2	Wing planform geometry

4. PREDICTION METHOD

The method of this Item is based on the theoretical characteristics of a plain flap on an aerofoil as detailed in Item No. 94028 (Derivation 3). The method for wings requires the use of the characteristics of the representative aerofoil/plain trailing-edge flap combination coupled with empirical corrections for the effects of wing planform geometry, and flap spanwise extent. However, peculiarly for plain flaps, the empirical correlation or efficiency factor for wings is different from that derived for aerofoil sections. Whilst the value of J_p is unity for both unswept wings and for aerofoil sections for $(\delta_t^\circ + \phi_t^\circ) \leq 5^\circ$, as the angle $(\delta_t^\circ + \phi_t^\circ)$ is increased above 5° the factor J_p decreases from unity earlier and more rapidly for aerofoils than for wings so that at $(\delta_t^\circ + \phi_t^\circ) = 27^\circ$ the efficiency factor for wings is 40% greater than for aerofoils. The difference between the efficiency factors then decreases steadily to 18% at $(\delta_t^\circ + \phi_t^\circ) = 80^\circ$. The reason for the greater efficiency for wings is not fully understood but appears to imply some delay in flow breakdown compared with aerofoils. All of the relevant information of Item No. 94028, required in the estimation of ΔC_{L0t} , is included in this Item. It is therefore unnecessary to refer to Item No. 94028

This page Amendment A