



ESDU 95021

Issued August 1995

Supersedes ESDU

Aero F.01.01.09

Wing lift coefficient increment at zero angle of attack due to deployment of double-slotted or triple-slotted flaps at low speeds

ESDU Copyright material. For current status contact ESDU.

Endorsed by
The Royal Aeronautical Society

AVA Documents
Document Sharing Hub

ESDU DATA ITEMS

Data Items provide validated information in engineering design and analysis for use by, or under the supervision of, professionally qualified engineers. The data are founded on an evaluation of all the relevant information, both published and unpublished, and are invariably supported by original work of ESDU staff engineers or consultants. The whole process is subject to independent review for which crucial support is provided by industrial companies, government research laboratories, universities and others from around the world through the participation of some of their leading experts on ESDU Technical Committees. This process ensures that the results of much valuable work (theoretical, experimental and operational), which may not be widely available or in a readily usable form, can be communicated concisely and accurately to the engineering community.

We are constantly striving to develop new work and review data already issued. Any comments arising out of your use of our data, or any suggestions for new topics or information that might lead to improvements, will help us to provide a better service.

THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item which supersedes Item No. Aero F.01.01.09, was monitored and guided by the Aerodynamics Committee. This Committee first met in 1942 and now has the following membership:

Chairman	
Mr H.C. Garner	— Independent
Members	
Mr G.E. Bean*	— Boeing Commercial Airplane Co., Seattle, Wash., USA
Dr N.T. Birch	— Rolls-Royce plc, Derby
Dr P.C. Dexter	— British Aerospace plc, Sowerby Research Centre, Bristol
Mr J.R.J. Dovey	— Independent
Dr K.P. Garry	— Cranfield University
Mr D. Graham*	— Northrop Grumman Corp., Pico Rivera, Calif., USA
Mr M.J.Green	— Avro International Aerospace Ltd, Woodford
Dr H.P. Horton	— Queen Mary and Westfield College, University of London
Dr D.W. Hurst	— University of Southampton
Mr P. K. Jones	— Independent
Mr K. Karling*	— Saab-Scania AB, Linköping, Sweden
Mr M. Maurel	— Aérospatiale, Toulouse, France
Mr C.M. Newbold	— Aircraft Research Association, Bedford
Mr J.B. Newton	— British Aerospace Defence Ltd, Warton
Mr R. Sanderson	— Daimler-Benz Aerospace Airbus GmbH, Bremen, Germany
Mr A.E. Sewell*	— McDonnell Douglas Aerospace, Long Beach, Calif., USA
Mr M.R. Smith	— British Aerospace Airbus Ltd, Bristol
Mr J. Tweedie	— Short Brothers plc, Belfast.

* Corresponding Member

The construction and subsequent development of the Data Item was undertaken under contract ESDU by

Mr J.R.J Dovey

The person with overall responsibility for the work in this subject area is Mr P.D. Chappell, Head of Aircraft Aerodynamics Group.

WING LIFT COEFFICIENT INCREMENT AT ZERO ANGLE OF ATTACK DUE TO DEPLOYMENT OF DOUBLE-SLOTTED OR TRIPLE-SLOTTED FLAPS AT LOW SPEEDS

CONTENTS

	Page
1. NOTATION AND UNITS	1
2. INTRODUCTION	5
3. REQUIRED DATA ITEMS	6
4. LIFT COEFFICIENT INCREMENT FOR DOUBLE-SLOTTED AND TRIPLE-SLOTTED FLAPS	6
4.1 General	6
4.2 Prediction Method for	6
4.3 Required Aerofoil/Flap Geometry	8
5. APPLICABILITY AND ACCURACY	8
5.1 Applicability	8
5.2 Accuracy	10
6. DERIVATION AND REFERENCES	12
6.1 Derivation	12
6.1.1 ESDU Data Items	12
6.1.2 Wind-tunnel test reports	12
6.2 References	13
7. EXAMPLE	13

WING LIFT COEFFICIENT INCREMENT AT ZERO ANGLE OF ATTACK DUE TO DEPLOYMENT OF DOUBLE-SLOTTED OR TRIPLE-SLOTTED FLAPS AT LOW SPEEDS

1. NOTATION AND UNITS

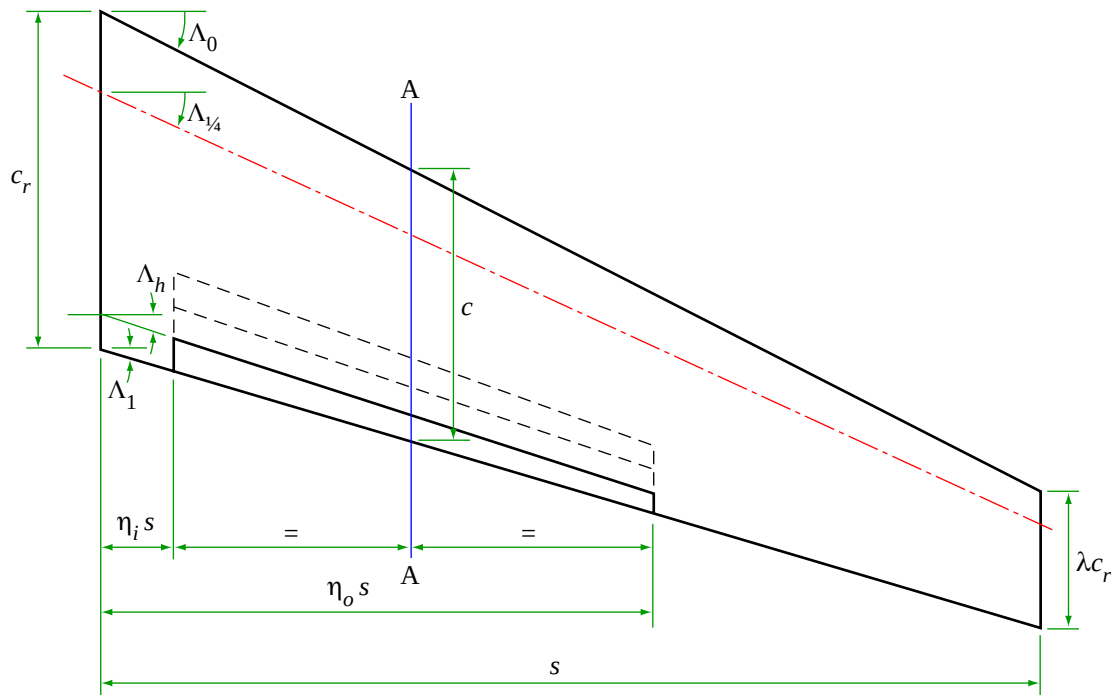
		SI	British
A	aspect ratio, $2s/\bar{c}$		
a_1	basic wing lift-curve slope, $dC_L/d\alpha$ (see Item No. 70011)	rad^{-1}	rad^{-1}
$(a_1)_0$	basic aerofoil lift-curve slope in incompressible flow	rad^{-1}	rad^{-1}
C_L	lift coefficient; (lift per unit span)/ qc for aerofoil, (lift)/ qS for wing		
ΔC_{L0t}	increment in aerofoil lift coefficient at $\alpha = 0$ due to deployment of trailing-edge flap, based on c (see Item No. 94031 for double-slotted and triple-slotted flaps)		
$\Delta C'_{L0t}$	increment in aerofoil lift coefficient at $\alpha = 0$ due to deployment of trailing-edge flap, based on c' (see Item No. 94031 for double-slotted and triple-slotted flaps)		
ΔC_{L0tw}	increment in wing lift coefficient at $\alpha = 0$ due to deployment of trailing-edge flap, based on S		
$\Delta C'_{L1}, \Delta C'_{L2}, \Delta C'_{L3}$	increment in lift coefficient associated with deployment of equivalent first, second, third element of slotted trailing-edge flap on aerofoil with lift-curve slope of 2π , based on c' , Figures 4, 5, 6 (from Item No. 94031)		
c	chord at mid-span of flap panel, see Sketch 1.1; basic (plain) aerofoil chord (<i>i.e.</i> chord with trailing-edge flap undeployed), see Sketch 1.2 or 1.3	m	ft
c'	extended aerofoil chord (<i>i.e.</i> chord with trailing-edge flap deployed), see Sketch 1.2 and Equation (4.7) for double-slotted flap and Sketch 1.3 and Equation (4.10) for triple-slotted flap	m	ft
$c_{et1}, c_{et2}, c_{et3}$	equivalent flap chord of first, second, third element of slotted trailing-edge flap, see Sketch 1.2 and Equations (4.8), (4.9) for double-slotted flap, Sketch 1.3 and Equations (4.11), (4.12), (4.13) for triple-slotted flap	m	ft
c_r	wing root (centre-line) chord, see Sketch 1.1	m	ft

c_{t1}, c_{t2}, c_{t3}	chord of first, second, third element of slotted trailing-edge flap, see Sketch 1.2 for double flap, Sketch 1.3 for triple-slotted flap	m	ft
$\Delta c_{t1}, \Delta c_{t2}, \Delta c_{t3}$	increment in c_{t1}, c_{t2}, c_{t3} , see Sketch 1.2 for double-slotted flap, Sketch 1.3 for triple-slotted flap	m	ft
$c'_{t1}, c'_{t2}, c'_{t3}$	extended chord of first, second, third element of slotted trailing-edge flap, see Sketch 1.2 for double-slotted flap, Sketch 1.3 for triple-slotted flap	m	ft
$\bar{c}$	wing geometric mean chord	m	ft
$\bar{\bar{c}}$	wing aerodynamic mean chord	m	ft
J_{t1}, J_{t2}, J_{t3}	correlation factor (efficiency factor) for first, second, third element of slotted trailing-edge flap, Figure 1, Figure 2, Figure 3 (from Item No. 94031)		
M	free-stream Mach number		
q	free-stream kinetic pressure	N/m ²	lbf/ft ²
$R_{\bar{c}}$	Reynolds number based on free-stream conditions and $\bar{\bar{c}}$		
S	wing planform area, $2s\bar{c}$	m ²	ft ²
s	wing semi-span, see Sketch 1.1	m	ft
x	chordwise distance aft from aerofoil leading edge	m	ft
x_{ts}	chordwise location of flap-shroud trailing edge, see Sketch 1.2 or 1.3	m	ft
α	angle of attack	rad	rad
β	compressibility parameter, $(1 - M^2)^{1/2}$		
$\delta_{t1}^\circ, \delta_{t2}^\circ, \delta_{t3}^\circ$	deflection of first, second, third element of slotted trailing-edge flap, positive trailing edge down, see Sketch 1.2 for double-slotted flap, Sketch 1.3 for triple-slotted flap	deg	deg
η	spanwise distance from wing centre-line as fraction of semi-span		
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		
$\bar{\eta}$	value of η at spanwise centre of pressure for loading due to angle of attack, see Item No. 83040		

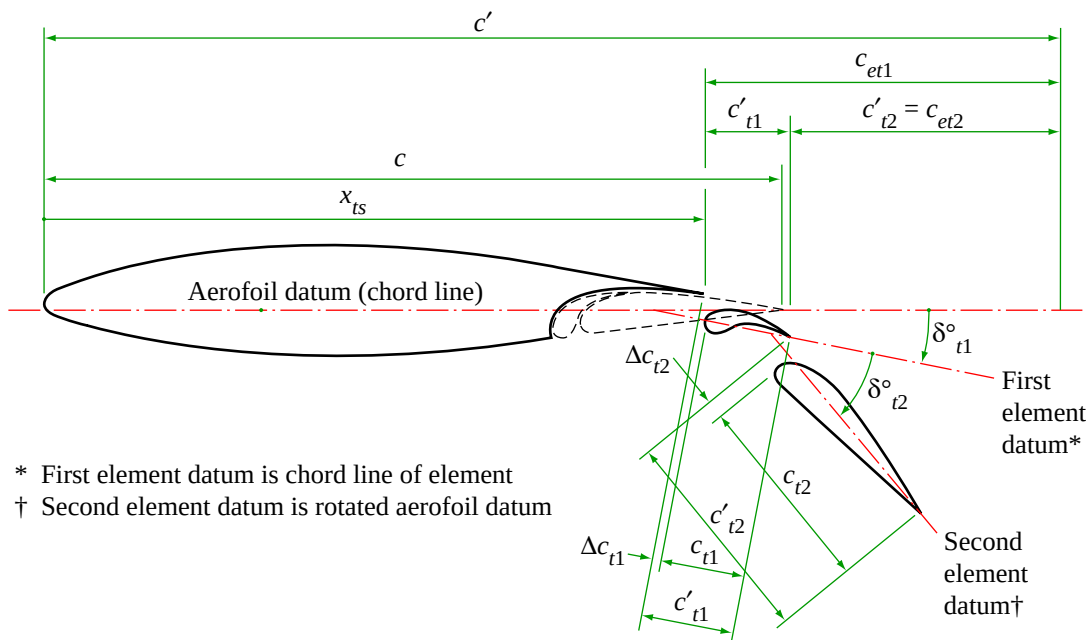
κ	wing taper parameter in Item No. 83040; $\int_0^1 (c/\bar{c})\eta d\eta$, giving $(1 + 2\lambda)/[3(1 + \lambda)]$ for straight tapered wing		
Λ_h	flap hinge-line sweep angle, see Section 4.1 and Sketch 1.1	deg	deg
Λ_0	wing leading-edge sweep angle, see Sketch 1.1	deg	deg
$\Lambda_{1/4}$	wing quarter-chord 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 flaps extending symmetrically from wing centre-line divided by lift coefficient increment due to full-span flaps at same flap setting and wing angle of attack		
Φ_i	value of Φ corresponding to η_i , Figure 7		
Φ_o	value of Φ corresponding to η_o , Figure 7		

Subscripts

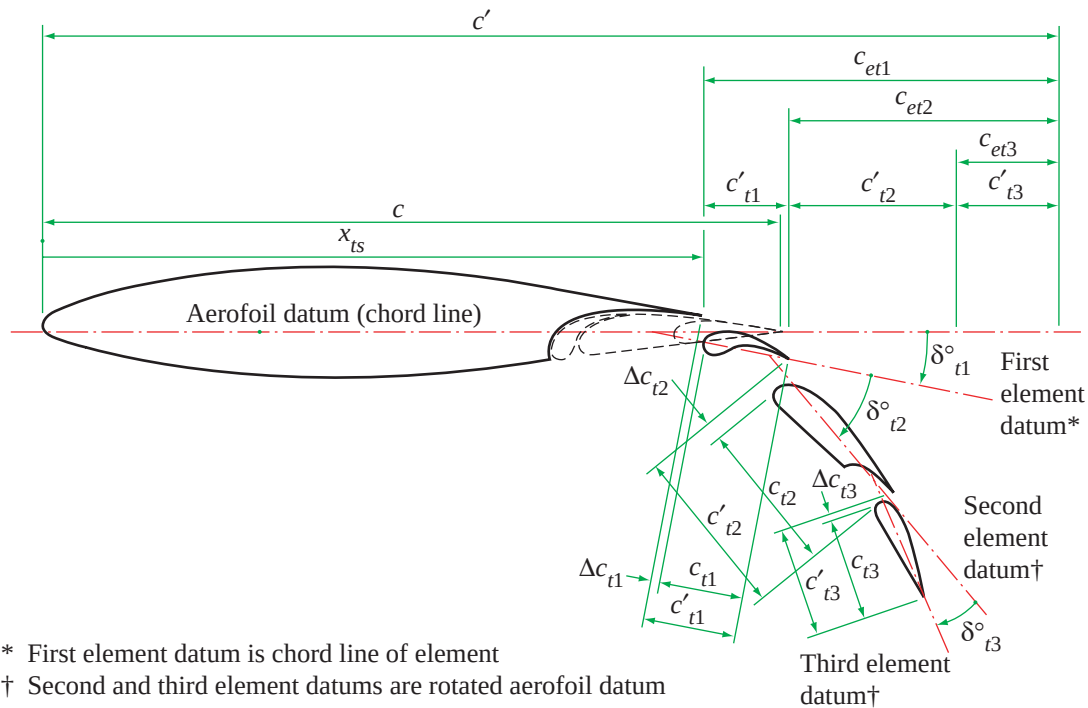
<i>full-span</i>	denotes full-span flap ($\eta_i = 0, \eta_o = 1$)
<i>part-span</i>	denotes part-span flap ($\eta_i(\geq 0) < \eta_o \leq 1$)
$()_{expt}$	denotes experimental value
$()_{pred}$	denotes predicted value



Sketch 1.1 Wing planform notation (flaps undeveloped)



Sketch 1.2 Deployed double-slotted flap notation (at section AA)



Sketch 1.3 Deployed triple-slotted flap notation (at section AA)

2. INTRODUCTION

This Item provides an empirical method for estimating the increment in wing lift coefficient at zero angle of attack, ΔC_{L0tw} , due to the deployment of a double-slotted or triple-slotted trailing-edge flap at low speeds. Item No. 93019 (Reference 16) deals with the case of single-slotted flaps. In the application of the method a number of other Data Items may be required, and these are listed in Section 3.

In Section 4, the value of ΔC_{L0tw} is derived from the value in two-dimensional flow, ΔC_{L0t} , for an aerofoil/flap combination that is representative of the wing/flap system. Values of ΔC_{L0t} are obtained using the method of Item No. 94031 (Derivation 4). For wings with full-span flaps a factor dependent on planform geometry is applied to ΔC_{L0t} to allow for three-dimensional effects. For wings with part-span flaps an additional factor, dependent on the flap spanwise extent and wing planform geometry, is required. The method is well validated for wings with double-slotted flaps; for the case of triple-slotted flaps, however, lack of test data prevents validation.

Section 5 addresses applicability and accuracy, Section 6 gives the Derivation and References and Section 7 presents a detailed worked example illustrating the use of the method.