

ESTIMATION OF DRAG DUE TO INOPERATIVE TURBO-JET AND TURBO-FAN ENGINES USING DATA ITEM NOS 81009 AND 84004

1. NOTATION AND UNITS*

The estimation method of this Item is self contained to the extent that the user need only refer to the numerical data in Item Nos 81009 and 84004. However, to achieve this, it is necessary to introduce a full Notation section.

		SI	British
$\mathcal{A}$	airflow function for inoperative engine (definition given in Item No. 81009 but unnecessary here)		
A	cross-sectional area* of streamtube entering cowl, see Sketch 1.1	m ²	ft ²
A_c	intake capture area (= A_1 for axisymmetric intake), see Sketch 1.1	m ²	ft ²
A_1	intake cross-sectional area at cowl lip (or highlight)	m ²	ft ²
A_2	cross-sectional area at engine face	m ²	ft ²
$[A/A_c]$	mass flow ratio, $\dot{m}/\rho A_c V (= \mathcal{A} A_2/A_c)$, see Item No. 81009, Equation (A4.12))		
$[A/A_c]_{sep}$	separation mass flow ratio (defined in Section 3.2 of Item No. 84004)		
$[A/A_c]_{sep,basic}$	value of separation mass flow ratio at $M = 0.6$, $\sigma = 0$		
$C_{D_{spill}}$	spillage drag coefficient, $D_{spill}/qA_c (= D_{spill}/qA_1$ for axisymmetric intake)		
$C_{D_{theory}}$	theoretical internal drag coefficient of inoperative engine (defined in Equation (A4.13) of Item No. 81009)		
$C_{D_{wm}}$	windmilling drag coefficient		
C_F	mean skin friction coefficient (flat plate)		
D_{max}	maximum diameter of axisymmetric cowl	m	ft
D_{spill}	spillage drag, per intake, (definition in Section 3.1 of Item No. 84004)	N	lbf
D_{wm}	windmilling drag, per engine (= $C_{D_{wm}} \times qA_2$)	N	lbf

* No subscript is used when considering ambient, freestream or upstream infinity conditions.

D_1	intake diameter at lip (or highlight) of axisymmetric cowl	m	ft
$[f_N / \dot{w}]_{s,o}$	design specific thrust at maximum rating at ISA sea-level static conditions	s	s
L_f	length of cowl forebody	m	ft
M	Mach number*		
$\dot{m}$	mass airflow entering cowl and inoperative engine, see Section 5.1	kg/s	slug/s
p	static pressure*	N/m ²	lbf/ft ²
q	kinetic pressure* , $0.7pM^2$	N/m ²	lbf/ft ²
Re_f	Reynolds number based on cowl forebody length, L_f		
R_f	initial radius of curvature of cowl forebody, see Sketch 1.2 and Table 8.2 of Item No.84004	m	ft
S	reference wing area	m ²	ft ²
V	true airspeed	m/s	ft/s
x	cowl longitudinal co-ordinate with $x = 0$ at cowl lip, see Sketch 1.2 of Item No 84004	m	ft
$\Delta[A/A_c]_{sep,M}$	correction to $[A/A_c]_{sep}$ for Mach numbers other than 0.6		
$\Delta[A/A_c]_{sep,\sigma}$	correction to $[A/A_c]_{sep}$ for incidence angles other than $\sigma = 0$		
ΔC_D	contribution to aircraft drag coefficient due to an inoperative engine, ($= \Delta D/qS$), see step 6 of Table 7.1		
$[\Delta C_D]_{spill,att}$	contribution to spillage drag coefficient associated with increasing thickness of attached boundary layer and evaluated at $[A/A_c]$ or $[A/A_c]_{sep}$, whichever is the greater		
$[\Delta C_D]_{spill,sep}$	contribution to spillage drag coefficient due to flow separation , when $[A/A_c] < [A/A_c]_{sep}$,		
$\Delta C_{D_{wm}}$	incremental windmilling drag coefficient, $\Delta C_{D_{wm}} = C_{D_{theory}} - C_{D_{wm}}$		
ΔD	contribution to aircraft drag due to an inoperative engine ($= D_{wm} + \Delta D_{spill,sep} + \Delta D_{spill,att}$), see step 6 of Table 7.1	N	lbf

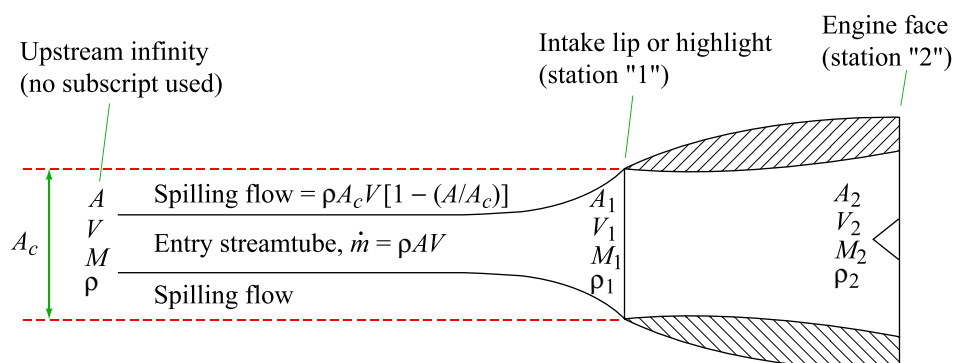
For footnote refer to end of Notation

$\Delta(D/q)$	contribution to aircraft drag parameter due to an inoperative engine, see step 6 of Table 7.1	m ²	ft ²
$\Delta D_{spill,att}$	contribution to spillage drag associated with increasing thickness of attached boundary layer and evaluated at $[A/A_c]$ or $[A/A_c]_{sep}$, whichever is the greater, ($= \Delta C_{D_{spill, att}} \times q A_c$)	N	lbf
$\Delta D_{spill,sep}$	contribution to spillage drag due to flow separation when $[A/A_c] < [A/A_c]_{sep}$, ($= \Delta C_{D_{spill, sep}} \times q A_c$)	N	lbf
δ_f	cowl forebody angle, defined between stations $x = 0.01 D_1$ and $x = 0.05 D_1$ aft of the cowl lip, see Sketch 1.2 and Table 8.2 of Item No. 84004	deg	deg
ρ	density of air*	kg/m ³	slug/ft ³
σ	incidence angle, <i>i.e.</i> angle between local flow direction and cowl axis of symmetry ($= \sin^{-1}[1 - \cos^2 \alpha \cos^2 \beta]^{1/2}$, where α = angle of attack, β = angle of sideslip, see Item No. 79018 for definitions)	deg	deg

Subscripts *

f	denotes cowl forebody
σ	denotes value at incidence angle, σ
1	denotes value at cowl lip (or highlight)
2	denotes value at engine face

* No subscript is used when considering ambient, freestream or upstream infinity conditions.



Sketch 1.1 Illustration of intake flow parameters for axisymmetric cowl