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Reduction of take-off and landing measurements to standard conditions

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REDUCTION OF TAKE-OFF AND LANDING MEASUREMENTS TO STANDARD CONDITIONS

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REDUCTION OF TAKE-OFF AND LANDING MEASUREMENTS TO STANDARD[†] CONDITIONS

1. NOTATION AND UNITS

		<i>SI</i>	<i>British</i>
a	acceleration	m/s ²	ft/s ²
$\bar{a}$	mean acceleration	m/s ²	ft/s ²
B	constant: 0.5144 (m/n.m)/(s/h); 0.2778 (m/km)/(s/h); 1.688 (ft/n.m)/(s/h)		as shown
C_L	lift coefficient, $L/(\rho \mathbf{B}^2 V^2 S/2)$	–	–
D	drag	N	lbf
d	distance covered horizontally during airborne phase to/from screen height, h_{screen} , or any part thereof	m	ft
F	thrust (positive or negative)	N	lbf
F'	thrust at V'	N	lbf
g	acceleration due to gravity (standard sea-level values are 9.80665 m/s ² , 32.1740 ft/s ²)	m/s ²	ft/s ²
h_{screen}	screen height measured above lift-off or touch-down point	m	ft
L	lift	N	lbf
L'	lift at V'	N	lbf
S	wing area	m ²	ft ²
s	distance covered during ground run or any part thereof between prescribed speeds V_A and V_B	m	ft
t	time	s	s
V	true airspeed	kn	kn
V'	true airspeed at which $\bar{a}$ or $\bar{\gamma}_a$ occurs for a phase or any part thereof	kn	kn
V_A	true airspeed at beginning of a part of a phase	kn	kn
V_B	true airspeed at end of part of a phase	kn	kn
V_l	true airspeed corrected to standard C_L	kn	kn
V_w	surface headwind component (see Section 4)	kn	kn

[†] The words “standard conditions” denote those conditions to which it is required to correct a set of measured values – these might, more appropriately, be described as “datum” or “reference” conditions. The corrections are not necessarily made to ISA conditions.

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V'_w	headwind component during airborne phase, appropriate to heights considered	kn	kn
W	aircraft weight	N	lbf
x	mean runway gradient taken positive upwards, <i>i.e.</i> height change during ground run or part thereof divided by distance covered	rad	rad
γ	instantaneous climb or descent angle (positive for climb)	rad	rad
$\bar{\gamma}$	mean angle of climb or descent applying to airborne phase or part thereof (positive for climb)	rad	rad
$\bar{\gamma}_a$	mean value of $(F - D)/W$ during airborne phase or part thereof	rad	rad
ΔC_L	(standard [†] C_L) – (test C_L)	–	–
$\Delta F'$	(standard [†] thrust) – (test thrust)	N	lbf
Δs_x	correction to ground run for lift coefficient (see Sections 6.1 and 6.2)	m	ft
ΔW	(standard [†] weight) – (test weight)	N	lbf
$\Delta \mu$	(standard [†] μ_{eff}) – (test μ_{eff})	–	–
$\Delta \sigma$	(standard [†] σ) – (test σ)	–	–
μ_{eff}	effective coefficient of rolling or braking friction	–	–
ρ	density	kg/m ³	slug/ft ³
σ	relative density, ρ/ρ_0	–	–

Subscripts

f	denotes that distances d or s have been corrected [‡] to standard values of thrust, weight, density and effective coefficient of friction
gc	denotes quantities applying at ground contact point (touch-down or take-off)
l	denotes that distances d or s have been corrected [‡] to standard value of C_L
$screen$	denotes value at screen height, h_{screen}
w	denotes that distances d or s have been corrected [‡] to zero wind
x	denotes that distance s has been corrected [‡] to zero runway gradient
0	denotes conditions in International Standard Atmosphere, ISA

[†] The words “standard conditions” denote those conditions to which it is required to correct a set of measured values – these might, more appropriately, be described as “datum” or “reference” conditions. The corrections are not necessarily made to ISA conditions.

[‡] The subscripts w , x , l and f , applied to distances d or s , denote that the distances have been corrected successively to zero wind, zero runway gradient, standard C_L and to standard values of thrust, weight, density and effective coefficient of friction, respectively.

2. INTRODUCTION

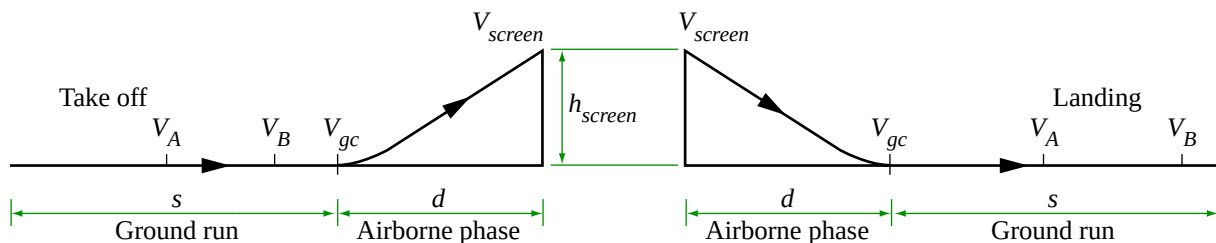
The methods presented in this Data Item are suitable only in the early stages of a design project. It is also assumed that the tyre-runway friction interaction is dealt with in an approximate way using gross assumptions: other Items in the Performance Series provide more comprehensive methods (see, for example, ESDU 05011, Reference 1).

This Data Item provides simple methods for the reduction of take-off and landing measurements, *i.e.* the incremental adjustment of distances and speeds measured in “test” conditions to values applicable in some desired “standard” or “datum” conditions (see Reference 2).

The Item deals more particularly with aircraft that may be termed “conventional” and treats only of what are believed to be the main corrections. It neglects the influence of changes in the vertical thrust component in the reduction process. In deriving C_L it is assumed that $L = W$, *i.e.* the vertical acceleration and vertical thrust component are neglected.

3. BASIS OF METHODS

The take-off or landing distance of an aircraft over a screen of height h_{screen} consists essentially of two phases as shown in Sketch 3.1.



Sketch 3.1 Representation of take-off and landing manoeuvres in two phases

Corrections are given for non-standard values of

wind (in Section 4),
runway gradient (in Section 5),
speeds (in Section 6)

and thrust, weight, density and effective coefficient of friction (in Section 7).

Corrections are made separately for each phase of the take-off or landing and each correction is determined by assuming all the other variables for which corrections are to be applied in the reduction process are held constant. The order in which the corrections are made may have some effect on the final answer and to promote consistency of reduction a fixed order should be used. The above order is believed to be reasonable and coincides with that of Reference 3. It should be noted that when there is a discontinuity during a phase as, for example, when reversed thrust is applied for only part of the landing ground run or there is a deliberate change of angle of attack (see example of ESDU PERF EG 6/4, Reference 4), it is necessary to divide the phase in question into parts and to apply corrections to each part separately (see Section 7.2).

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