

VARIABILITY OF STANDARD AIRCRAFT PERFORMANCE PARAMETERS

1. NOTATION AND UNITS*

D	drag	
D_b	basic drag, airframe drag at nominal V_e	
EPR	engine pressure ratio (hot stream)	
F	thrust	
F_b	basic thrust, value at nominal engine setting	
H_p	pressure height	ft
$IEPR$	integrated engine pressure ratio (hot and cold streams)	
N	engine rotational speed expressed as per cent of nominal value	
p_a	ambient static pressure	
V_e	equivalent airspeed	kn
V_{e_2}	take-off safety speed (equivalent airspeed)	kn
W	weight	
Z_t	geometric height of aircraft above runway threshold during landing	ft
γ	angle of climb (gradient, in per cent, is $100 \tan \gamma$ or, for small values of γ , 100γ)	rad
γ_{test}	observed value of γ	rad
Δ	denotes increment in affixed parameter	
ΔV_c	airspeed indicator error	kn
θ_r	angle between runway centre line and horizontal (runway gradient, in per cent, is $100 \tan \theta_r$ or, for small values of θ_r , $100\theta_r$)	rad
μ_B	coefficient of braking friction	
μ_R	coefficient of rolling friction	
ξ_D	influence coefficient, $[D/\gamma][\partial\gamma/\partial D]$, for effect on γ of small change in D	

* The units quoted are those for which numerical values are given in this Data Item. In general, however, quantities in this Item are expressed in percentage or other non-dimensional forms.

ξ_F	influence coefficient, $[F/\gamma][\partial\gamma/\partial F]$, for effect on γ of small change in F
ξ_N	influence coefficient, $[N/F][\partial F/\partial N]$, for effect on F of small change in N
ξ_{V_e}	influence coefficient, $[V_e/D][\partial D/\partial V_e]$, for effect on D of small change in V_e
ξ_W	influence coefficient, $[W/\gamma][\partial\gamma/\partial W]$, for effect on γ of small change in W
σ_D	standard deviation of D due to σ_{D_b} and $\sigma_{D_{V_e}}$
σ_{D_b}	standard deviation of D_b at nominal value of V_e
$\sigma_{D_{V_e}}$	standard deviation of D due to σ_{V_e}
σ_{EPR}	standard deviation of EPR (system and setting errors)
σ_F	standard deviation of F due to σ_{F_b} and σ_{F_N}
σ_{F_b}	standard deviation of F_b at nominal value of N
σ_{F_N}	standard deviation of F due to σ_N
σ_N	standard deviation of N
σ_{p_a}	standard deviation of p_a
σ_{V_e}	standard deviation of V_e
σ_W	standard deviation of W
σ_γ	standard deviation of γ
σ_{γ_D}	standard deviation of γ due to σ_D
σ_{γ_F}	standard deviation of γ due to σ_F
σ_{γ_W}	standard deviation of γ due to σ_W

2. INTRODUCTION

The Report of the ICAO Standing Committee on Performance (Reference 2) is the basis from which the Civil Airworthiness Performance Requirements of References 3, 4 and 5 were derived and contains some statistical data that is useful in a wider context. This Data Item presents extracts from the ICAO Report, plus more recent information on the variability of turbo-fan engine performance and provides an example (in Section 5) of how these data may be used to estimate the variability of aircraft performance parameters. An introduction to statistical techniques for use in analysis of aircraft performance data is given in Data Item No. 91017 (Reference 1).

3. THE DATA

Table 3.1 of Reference 2 provides the following data on civil aircraft and engine performance variability.

Parameter	Standard deviation	Remarks
D_b (Flaps up)	2.0% of nominal value	Flap fully retracted
D_b (Intermediate flap)	2.5% of nominal value	Take-off or approach flap
D_b (Landing flap)	2.2% of nominal value	Flap fully extended
F_b	2.25% of nominal value	At nominal N
N	0.5% of nominal value	Mainly setting error
p_a	1.0% of nominal value	En-route (cruise)
V_e (Climb)	2.5% of nominal value	
V_e (Landing threshold)	6.0% of nominal value	
W	1.5% of nominal value	
Z_t	11 ft	
ΔV_c	0.5% of nominal value	
θ_r	0.1% gradient	
μ_B	13% of nominal value	
μ_R	0.0035	

However, the data in Reference 2 are based on research carried out in the early 1950s and, particularly as regards engine performance, are somewhat remote from current designs. The following data are presented as being more appropriate to turbo-fan engines with bypass ratios in the region of 5 and with more modern engine control systems.

Parameter	Range of uncertainty
EPR (hot stream; system error)	$\pm 0.6\%$
N (system error)	$\pm 0.1\%$
F_b (at constant EPR)	+ 2.2 to 0%
F_b (at constant N)	+ 3.6 to 0%

These latter data would be more usable if presented in the same form as the earlier ICAO data (*i.e.* in the form of standard deviations rather than ranges) and this can be achieved by use of Equation (3.3) from Reference 1 to infer approximate standard deviation values from the ranges quoted above. In addition, the standard deviation of N , quoted as 0.5% in the ICAO data, contains an allowance for thrust setting errors as well as system errors and account needs to be taken of this.

From the table above the range of system error in N is $\pm 0.1\%$ which implies a system error standard deviation (using Equation (3.3) of Reference 1) of

$$\frac{0.1}{2.5} = 0.04\%.$$

Equation (3.2) of Reference 1 allows the implied standard deviation of error in the setting N to be calculated as

$$\text{setting error standard deviation} = (0.5^2 - 0.04^2)^{1/2} = 0.498\%, \quad (3.1)$$