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Pitot and static errors due to non-steady flight



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PITOT AND STATIC ERRORS DUE TO NON-STEADY FLIGHT

1. NOTATION, UNITS, CONSTANTS AND DEFINITIONS

1.1 Notation and Units

		SI	British
a	speed of sound	m/s	ft/s
A	aspect ratio of static port	—	—
A_r	reference area (see Appendix A)	m ²	ft ²
A_{sp}	total area of static system sensor port(s)	m ²	ft ²
C_m	coefficient of mass flow in a static pressure system, (dm_s/dt)/($\rho_a A_{sp} V$)	—	—
f	denotes functional relationship of type f[...]	—	—
f_x	reading of a body-mounted accelerometer aligned with fuselage longitudinal datum and expressed in units of g_0 , $(-\ddot{x}_{in}-g\sin\theta)/g_0$ (see Section 5 of Reference 11 for accelerometer equations and associated sign convention)	—	—
g	acceleration due to gravity	m/s ²	ft/s ²
H_p	pressure height	m	ft
k	volumetric proportion of a pressure system within pressure shell of aircraft	—	—
l	length of pipe from pressure sensor port(s) to the transducer in a pressure system	m	ft
l_x	effective length of a pressure system as derived for inertial corrections, i.e. distance from transducer to pressure sensor port(s) projected on to fuselage longitudinal datum (forward is positive)	m	ft
M	Mach number, V/a	—	—
m	mass of air in a pressure system	kg	slug
p	pressure (absolute) in a pressure system	N/m ²	lbf/ft ²
p_a	ambient static pressure (absolute)	N/m ²	lbf/ft ²

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p_p	fully corrected value of pitot pressure (absolute) in pitot system in steady-level-flight conditions	N/m ²	lbf/ft ²
p_p'	pitot pressure (absolute) corrected for non-steady flight effects (steady-level-flight corrections still to be made to get p_p)	N/m ²	lbf/ft ²
$(p_p)_i$	value of pitot pressure (absolute) registered (indicated) by transducer (note for steady level flight, $(p_p)_i = p_p'$)	N/m ² , mb	lbf/ft ²
p_s	sensed static pressure (absolute) in static system in steady-level-flight conditions	N/m ²	lbf/ft ²
$(p_s)_i$	value of static pressure (absolute) registered (indicated) by transducer (note for steady level flight, $(p_s)_i = p_s$)	N/m ²	lbf/ft ²
Q	relevant internal volume of an instrument or transducer in a pressure system	m ³	ft ³
R	gas constant for air	N m/(kg K)	lbf ft/(slug K)
r	mean internal radius of pipes in a pressure system	m	ft
T	temperature of air in a pressure system	K	K
T_a	ambient temperature	K	K
t	time from start of "ramp" change in pressure	s	s
V	true airspeed	m/s	ft/s
V_x	component of true airspeed along fuselage longitudinal datum	m/s	ft/s
Vol	air-volume within a pressure system	m ³	ft ³
$\ddot{x}$	acceleration along fuselage longitudinal datum relative to inertial frame of reference	m/s ²	ft/s ²
α	angle of attack (angle between projection of true airspeed vector on to aircraft plane of symmetry and angle of attack datum)	degree	degree
β	angle of sideslip (angle between true airspeed vector and its projection on to aircraft plane of symmetry)	degree	degree
γ	ratio of specific heat capacity at constant pressure to that at constant volume	—	—
δp	contribution to pressure error in a pressure system, $(p_i - p)$	N/m ²	lbf/ft ²

θ	inclination angle, <i>i.e.</i> pitch attitude of fuselage longitudinal datum to horizontal plane	degree	degree
θ_f	setting of fuselage datum relative to angle of attack datum	degree	degree
λ	lag time constant for a pressure system	s	s
μ	coefficient of dynamic viscosity	N s/m ²	lbf s/ft ²
ρ	density of air	kg/m ³	slug/ft ³
$\Sigma(\delta p_p), \Sigma(\delta p_s)$	summation of pitot, static pressure errors	N/m ²	lbf/ft ²
τ	acoustic lag time constant for a pressure system	s	s
ϕ	transformation of Mach number (see Equation (4.3))	—	—

Subscripts

a	denotes ambient conditions
$crit$	denotes a critical condition for pipe-flow to be in a state of transition between laminar and turbulent
$flight$	denotes flight conditions
$ground$	denotes conditions for ground (“hangar”) calibration of pressure system
i	indicated (registered) value of a quantity that is subject to corrections to arrive at true value (see Section 1.3)
in	denotes either: inertial error in pressure system or: value relative to inertial frame of reference
int	denotes interference flow error
lag	denotes lag error
ns	denotes non-steady flight conditions
p	denotes pitot-pressure system
s	denotes static-pressure system
sf	denotes steady-level-flight conditions
std	denotes value of parameter in International Standard Atmosphere, ISA, conditions
0	denotes conditions at sea level in ISA

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1.2 Constants

The conversion factors in the following table have been taken from Reference 11.

a_0	340.294 m/s	1116.45 ft/s
g_0	9.80665 m/s ²	32.1740 ft/s ²
R	287.05287 N m/kg K	3089.8114 ft lbf/slug K
γ	1.4	1.4

1.3 Definitions of Indicated or Registered Quantities

“Indicated” or “registered” values of height, Mach number and airspeed are those provided by transducers (instruments) which are assumed to be free of any calibration or other inherent errors. The transducers (instruments) are responding to the registered or output pressure(s) of the static and/or pitot pressure system(s). True values of height, Mach number and calibrated airspeed may be derived by making corrections for:

- (i) air-data system pressure errors due to non-steady flight effects, the subject of this Data Item,
- (ii) aerodynamic errors due to the aircraft flow field at the sensor and, on occasions, due also to the orientation of this sensor (see Reference 14).