

Thanks, Eric! how much money can you spare? {:>)

I don't really know the answer, doesn't seem unreasonable, but I think we can check that theory fairly easily.

Lets consider that point. Will IAS provide an indication of air mass flow if the IAS is the same at two different altitudes?

The same indicated air speed at any altitude implies that the dynamic pressure (as that is what the pitot tube measures) is the same. Again looking at our two equations we have

$$P_d = 1/2 * \rho * V^2 \quad (\text{dynamic pressure}) \quad \text{and} \quad W = \rho * V * A \quad (\text{for mass flow})$$

Where ρ is density and V velocity and A area of our duct (1 ft^2)

The density at sea level is $0.00237 \text{ Slug/ft}^3$ whereas the density at 20000 ft is $0.001267 \text{ slug/ft}^3$ according to the chart I have.

So if we have the same indicated airspeed at both altitudes then that means the dynamic pressure is the same at both altitudes. Dynamic pressure at sea level for 120 mph TAS (has to be true airspeed for V as that is the speed at which we are moving through the air mass) = $.00237 * (176 \text{ ft/sec})^2 = .00237 * 30976 = 73.41312 \text{ lbf/ft}^2 = 73.4/144 = 0.51 \text{ psi}$ dynamic pressure.

So 0.51 psi gives us an indicated airspeed of $X \text{ IAS}$ (would have to know, temperature, pressure altitude, instrument and installation errors to really get IAS from this) for 120 MPH TAS at sea level.

and at sea level the Mass flow = $0.00237 * (176 \text{ ft/sec}) * (1 \text{ ft}^2) = 0.41712 \text{ Slug/Sec}$

So lets now go to $20,000$ altitude.

Now while we don't know what $X \text{ IAS}$ was a sea level, but we know we want it to be the same so that means the same dynamic pressure has to be present in the pitot tube.

So $P_d = 0.51 \text{ psi} = 73.4 \text{ lbf/ft}^2$ has to be the same at $20,000$ as it was at sea level to give us the same IAS. So working backwards and recalling that the density is now $0.001267 \text{ slug/ft}^3$

$$P_d = 1/2 * \rho * V^2 \quad \text{and solving for } V^2 = 2 * P_d / \rho \quad \text{and } V = \text{Squareroot}(2 * P_d / \rho)$$

$$V \text{ (TAS)} = \text{Sqrt}(2 * P_d / \rho) = \text{sqrt}(2 * 73.4 \text{ lbf/ft}^2 / .001267 \text{ slug/ft}^3) = \text{sqrt}(115864) = 340 \text{ ft/sec} = 232 \text{ mph TAS.}$$

So to get the same indicated airspeed at sea level given by a true air speed of 120 mph we would have to be traveling at 232 MPH TAS at $20,000 \text{ ft}$.

So looking at our mass flow again at this true airspeed (232 mph) and air density ($.001267$)

$$W = .001267 \text{ slug/ft}^3 * (340 \text{ ft/sec}) * (1 \text{ ft}^2) = 0.4307 \text{ slug/sec of mass flow}$$

So comparing our sea level mass flow of 0.417 slug/sec with that at $20,000$ of 0.4307 slug/sec

there is only an approx 3% difference (could be I lost it rounding numbers, but in any case not significantly different)

So, unless I've screwed up the math badly, it does indeed appear that indicated airspeed provides a fairly good indication of mass flow at any reasonable altitude provided we are not so fast as to encounter compressibility.

Ed Anderson

Ed, I think you dropped a $\frac{1}{2}$ in the low level calculation. Let's try it this way.

Symbols

D = Dynamic pressure

ρ_l = density at low altitude

ρ_h = density at high altitude

V_l = Velocity at low altitude

V_h = Velocity at high altitude

If the IAS reads the same, then

$$D = \frac{1}{2} * \rho_l * V_l^2 = \frac{1}{2} * \rho_h * V_h^2$$

The $\frac{1}{2}$'s drop out, and we can solve for V_h

$$V_h = V_l * \text{SQRT}(\rho_l / \rho_h)$$

Substituting the values from your email above,

$$V_h = 120 * \text{SQRT}(0.00237 / 0.001267) = 164 \text{mph}$$

Mass Flows

$$W_l = \rho_l * V_l * A = 0.00237 * 120 * A = 0.2844A$$

$$W_h = \rho_h * V_h * A = 0.001267 * 164 * A = 0.207A$$

So the mass flow rate at altitude is $0.207A / 0.2844A = 72.7\%$ that of the mass flow at lower altitude.

Bill Schertz