Low Leakage Air Handler

Derivation of Duct Leakage Percentage for ASHRAE Standard 193 M.O.T. Test Pressure

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Key to Document: *Italicized Text* – *added by M. Brook*
Regular Text – extracted from E-Mail from Iain Walker to CEC Staff, and formatted for clarity by M. Brook

Explanation of how the proposed requirement of 1.4% air handler leakage at 0.5" w.c. was derived as equivalent to the current requirement of 2% air handler leakage at 1" w.c.:

For fluid flow along a streamline, the Bernoulli equation can be used if the following assumptions are met: (1) steady flow; (2) incompressible flow; and (3) frictionless flow.

We expect air flow through duct leakage to be steady and incompressible for the following reasons (it isn't frictionless - the friction is what makes all this happen - or a combination of the first and second law of thermodynamics if you want to get really, really *[get]* down to nuts and bolts) :) - however, if by friction you mean viscous effects in which the flow and pressure are linearly related, then see below.)

- The flow will be steady because we are operating a fan at a fixed air flow so we have fixed air flows and pressures in the duct system. So there is no issue regarding accelerating flows. There will be some turbulence - but at the low flows we are measuring the effect will be negligible.

- The flow will be incompressible because we are operating far, far away from sonic velocities and compression ratios where this could be an issue. The air velocities in the 1-2 m/s range are less than 1% of sonic velocity in air. The approx. 100Pa in static pressure we are talking about is 1/1000 of an atmosphere. These are negligible effects.

If anyone asks, it is trivial to find references for the speed of sound in air and atmospheric pressure.

You should only read further if you want to know more than any one person should have to know about air flow in cracks....

Walker, I.S. and Sherman, M.H. 1997. A comparison of the power law to quadratic formulations for air infiltration calculations. Energy and Buildings. Vol. 27, No.3, pp. 293-299. Elsevier Science. LBNL 41447.
This paper looked at flow through cracks typical of building envelopes, but their fundamental analysis applies to equipment leakage, too.

The key part is to look at the work originally outlined in Baker, P.H., Sharples, S. and Ward, I.C. 1987. Air Flow Through Cracks.
Building and Environment, Vol. 22, No.4, pp. 293-304 that separated out the linear and non-linear parts of air flow through cracks as

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follows:

dP=AQ+BQ^2 Equation 1.

Where A= 12*mu*z/L*d^3 and B = rho*Y/2*d^2*L2;
where:
mu = dynamic viscosity of air (1*10^-5),
z = distance in flow direction (crack length , typically 10 mm or 0.01m),
L is crack width (say 0.2 m),
d is the gap thickness (typically 0.5 mm or 0.005 m for a furnace blower access leak),
rho is fluid density (1.2 kG/m^3 for air), and
Y is an experimentally determined geometry factor that is about 1.5 for a straight crack (or higher for more complex air flow paths).

If we substitute these values we get A = 48 and B=900,000.

At typical furnace air flows of 1-2 m^3/s we can easily see that the term in equation 1 that dominates is the second term by a factor of 10,000 or so.

Therefore it is reasonable to approximate the relationship between pressure and flow for a furnace leak using dP=kQ^2

For knock-outs in furnaces we have a much more familiar situation of a sharp-edged orifice and standard orifice equations apply and dP=kQ^2.

If you plug numbers into Eq. 1 you will find that dP=kQ^2 is even more true for a sharp edged orifice.

Q.E.D.

- Iain

Based on this explanation, k = dP/Q^2 and solving for k at the original test conditions of 1" w.c. and 2% yields 0.25. Therefore the new percent leakage at 0.5" w.c. is: SQRT(dP/k) = SQRT(0.5/0.25) = 1.4%