


AIR TEST CALCULATION METHODOLOGY

Produced by:
Marc Cowlin – Compliance Manager

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INTRODUCTION

This document has been compiled to explain how the figures and results are derived within Stroma air tightness test report. The process explains how pressure readings are corrected for on-site conditions for building pressures by means of the zero-flow correction, and the volumetric flow rates correcting for local air densities, and the derivation of the air flow.

CALCULATION OF THE VOLUME AIR FLOW RATE THROUGH BUILDING

From the fan off pressures recorded pre-test and the post-test determine

the pre-test average of the positive values of zero-flow pressure difference, $\Delta p_{0,1}$

the pre-test average of the positive values of zero-flow pressure difference, $\Delta p_{0,2}$

Subtract the average zero-flow pressure difference (offset) from each of the measured pressure differences, *Δp_m,* to obtain the induced pressure differences, *Δp,* using Formula (1).

$$\Delta p = \Delta p_m - \frac{\Delta p_{0,1} + \Delta p_{0,2}}{2} \quad (1)$$

First, convert the volume flow readings, *q_r*, of the air flow rate measuring system into measured air flow rates, *q_m,* at the temperature and pressure at the flow measuring device:

$$q_m = f(q_r) \quad (2)$$

Then, convert the air flow rates, *q_m,* to air flow rates, *q_{env},* through the building envelope for depressurization test using Formula (3), for pressurization test using Formula (4).

$$q_{env} = q_m \left(\frac{\rho_{int}}{\rho_e}\right) \approx q_m \left(\frac{T_e}{T_{int}}\right) \quad (3)$$

$$q_{env} = q_m \left(\frac{\rho_e}{\rho_{int}}\right) \approx q_m \left(\frac{T_{int}}{T_e}\right) \quad (4)$$

where

ρ_{int} *is the internal air density, in kg per cubic meters;*
ρ_e *is the external air density, in kg per cubic meters;*
T_{int} *is the internal air absolute temperature, in K;*
T_e *is the external air absolute temperature, in K.*

The relationship between pressure difference and the corresponding volumetric flow rate through the building is governed by Formula (5):

$$q_{env} = C_{env} (\Delta p)^n \quad (5)$$

where

n *is the air flow exponent;*
Δp *is the induced pressure difference, in Pa;*
q_{env} *is the air flow rate through the building envelope, in cubic meters per hour.*

Using $x_i = \ln(\Delta p_i)$ and $y_i = \ln(q_{env\ i})$ for i = 1…*N*, where *N* is the total number of test readings. Formula (5) then transforms into Formula (6).

$$y = \ln(C_{env}) + nx \quad (6)$$

The following statistical values (Formula (7) to (11)) are determined, to allow the flow exponent, *n* and air flow coefficient, C_{env} to be calculated using a least squares technique:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (7)$$

$$\bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i \qquad (8)$$

$$s_x^2 = \frac{1}{N-1}\sum_{i=1}^{N} (x_i - \bar{x})^2 \qquad (9)$$

$$s_y^2 = \frac{1}{N-1}\sum_{i=1}^{N} (y_i - \bar{y})^2 \qquad (10)$$

$$s_{xy} = \frac{1}{N-1}\sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y}) \qquad (11)$$

The best estimate for the flow exponent, *n* is given by Formula (12):

$$\mathrm{n} = \frac{s_{xy}}{s_x^2} \qquad (12)$$

The best estimate for the air flow coefficient, C_{env} is given by Formula (14):

$$\ln(C_{env}) = \bar{y} - n\bar{x} \qquad (13)$$

$$C_{env} = \mathrm{e}^{(\bar{y} - n\bar{x})} \qquad (14)$$

C_{env}, *n* and r^2 is calculated separately for pressurization and depressurization data

The air leakage coefficient, C_L, is obtained by correcting to the air flow coefficient, C_{env}, to standard conditions [20°C and 1,013 x 10^5 Pa], using Formula (15) for depressurization and Formula (16) for pressurization:

$$C_L = C_{env}\left(\frac{\rho_e}{\rho_0}\right)^{1-n} \approx C_{env}\left(\frac{T_0}{T_e}\right)^{1-n} \qquad (15)$$

where

ρ_0 is the air density at standard conditions, in kg/cubic meters;
T_0 is the air absolute temperature at standard conditions, in K.

$$C_L = C_{env}\left(\frac{\rho_{int}}{\rho_0}\right)^{1-n} \approx C_{env}\left(\frac{T_0}{T_{int}}\right)^{1-n} \qquad (16)$$

The air leakage rate, q_{pr}, at the reference pressure difference, Δp, expressed in m³/h, is determined using Formula (17):

$$q_{pr} = C_L(\Delta p_r)^n \qquad (17)$$

The pressure reference for the air leakage rate is usually equal to 50 Pa.

e.g. $q_{50} = C_L(50Pa)^n$

CALCULATION OF DERIVED QUANTITIES FOR BUILDING LEAKAGE RATES

Air permeability for UK & Ireland building regulation requirements is required at a pressure bias of 50 Pa, and is determined by dividing the air leakage rate, q_{50} by the envelope area, A_E, as per Formula (18) giving a result in cubic meters per hour, per square meter at 50Pa:

$$q_{E50} = \frac{q_{50}}{A_E} \tag{18}$$

where

A_E is the surface area of the exterior exposed elements of the zone of test, which does not include abutting walls/floors/soffits of extensions, or party walls/floors/soffits of zones, in square meters.

Air change rate is determined by dividing the air leakage rate at a specific pressure (normally 50Pa), by the volume, *V*, as per Formula (21) giving a result in number of air changes per hour at the specified reference pressure:

$$n_{pr} = \frac{q_{pr}}{V} \tag{19}$$

where

V is the internal volume enclosed within the extent of the tested zone.
Note: inclusion volume occupied by internal walls and floors is dependent upon the requirement of the testing.

AIR DENSITY CALCULATION

The air density, ρ, expressed in kilograms per cubic metre, at a temperature, θ, expressed in degrees Celsius, barometric pressure, p_{bar}, expressed in Pascal, and the relative humidity, φ, expressed in percent, can be obtained by Formula (20):

$$\rho = \frac{p_{bar} - 0.37802\, p_v}{287.055(\theta + 273.15)} \qquad (20)$$

where

p_v is the partial water vapour pressure in air calculated using Formula (21).

$$p_v = \varphi\, p_{vs} \qquad (21)$$

where

p_{vs} is the saturation water vapour pressure in air at a temperature, θ, obtained using Formula (*22*).

$$p_{vs} = \mathrm{e}^{\left[59.484058 - \frac{6790.4985}{\theta + 273.15} - 5.02802\,\ln(\theta + 273.15)\right]} \qquad (22)$$

Relative humidity is set to 0% (dry air) for BS EN 13829 / BS EN ISO 9972 and 50% for the ATTMA test standards.

CONFIDENCE INTERVAL OF AIR LEAKAGE CHARACTERISTICS

An estimate of the confidence intervals of C_{env} and n can be determined as follows.

The standard deviation of n is given by Formula (23):

$$s_n = \frac{1}{s_x}\left(\frac{s_y^2 - n s_{xy}}{N-2}\right)^{\frac{1}{2}} \quad (23)$$

The estimate of the standard deviation of ln(C_{env}) is given by Formula (24):

$$s_{\ln(C)} = s_n\left(\frac{\sum_{i=1}^{N} x_i^2}{N}\right)^{\frac{1}{2}} \quad (24)$$

If $T(P, N)$ is the confidence limit of the two-sided student's t distribution for a probability P on N events, then half the length of the confidence intervals at that probability for In(C_{env}) and n is given by Formula (25) and Formula (26), respectively:

$$I_{\ln(C)} = s_{\ln(C)} T(P, N-2) \quad (25)$$

$$I_n = s_n T(P, N-2) \quad (26)$$

The values of the two-sided confidence limits *T(P,N) are from a* student's t distribution

This means that with a probability, P, the air flow exponent, n, lies in the confidence interval $(n - I_n, n + I_n)$ and the air leakage coefficient, C_{env}, lies in the confidence interval given by Formula (27):

$$\left\{Ce^{[-I_{\ln(C)}]}, Ce^{[I_{\ln(C)}]}\right\} \quad (27)$$

The estimate of the standard deviation around the regression line [Formula (6)] at the value x is given by Formula (28):

$$s_y(x) = s_n\left(\frac{N-1}{N} s_x^2 + (x - \bar{x})^2\right)^{\frac{1}{2}} \quad (28)$$

Half of the length of the confidence interval in the estimate of y using Formula (6) at any x is given by Formula (29):

$$I_y(x) = s_y(x) T(P, N-2) = I_y(\ln(\Delta p)) \quad (29)$$

Therefore, the air flow rate, q, predicted by Formula (5) at any pressure difference, Δp, with a probability, P, lies in the confidence interval given by Formula (30):

$$\left\{q\ e^{[-I_y \ln(\Delta p)]}, q\ e^{[I_y \ln(\Delta p)]}\right\} \quad (30)$$