Pressure and Temperature Correction for BSL4- Pressure Decay Test

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Introduction

The standard BSL4 pressure testing method is to negatively pressurize the room to 2" H_2O, and then measure the pressure decay. The requirement for BSL4 lab is to maintain a pressure higher than 1" H_2O after 20min.

It has been proven that due to the tightness of the room, the flow through the cracks of BSL4 labs is laminar. Therefore, the following equation applies

$$Q = c\Delta p^n \tag{1}$$

for laminar flow *n*=1, therefore,

$$Q = c\Delta p \tag{2}$$

However, in real testing environment, the barometric pressure and room temperature changes over time. These variables may affect the leakage via changed Δp.

Using the measurement data without correction might lead to wrong conclusion about room's tightness.

Examples of Uncorrected Results

For example, imaging a room with a relatively large opening, at time=0, Δp=2" H_2O. The pressure dipped to 1.6" H_2O at t=1 min, but barometric pressure reduced 1.6" right after 1min. Since there is no Dp anymore, there will be no leakage, hence the room pressure stay the same until the end. If barometric pressure return back to its previous level at the end of 20min, so Δp=1.6"H_2O again, the room will be pass the test. Obviously, this is an extreme case but it does illustrate the need for corrections of the measurement data.

Correction Method

The goal of the correction method is to find the pressure decay of the room in the idealized environment, namely, in an environment with unchanged barometric pressure and room temperature.

Assuming the room air temperature is uniform and obeys ideal gas law, therefore

$$P_{room} = \rho RT \tag{3}$$

The room pressure change over time can be then expressed as

$$\frac{dP_{room}}{dt} = \frac{dM}{dt}\frac{RT}{V} + \rho R\frac{dT}{dt} = \rho Q\frac{RT}{V} + \rho R\frac{dT}{dt} \tag{4}$$

Adding barometric pressure change in equation (4)

$$\frac{d(P_{room} - P_{baro})}{dt} = \rho Q\frac{RT}{V} + K \tag{5}$$

Where

$$K = \rho R\frac{dT}{dt} - \frac{dP_{baro}}{dt} \tag{5'}$$

Substitute *Q* with equation (2), we can have

$$\frac{d\Delta p}{dt} = \rho c\Delta p\frac{RT}{V} = -C\Delta p + K \tag{6}$$

Assuming K is a constant in one particular time interval, the solution of equation (6) is

$$\Delta p_{t+\Delta t} = (\Delta p_t - \frac{K}{C})\exp(-Ct) + \frac{K}{C} \tag{7}$$

or

$$C[\Delta p_{t+\Delta t} - \Delta p_t \exp(-Ct)] = K[1 - \exp(-Ct)] \tag{8}$$

Note in equation 7, constant C calibrates a room's leakage: the larger of C, the larger of the opening. Equation 7 also applies to any time interval that environmental pressure and room temperature remains steady, therefore, under the ideal environment, for a room to pass the standard test, the C value has to be less than

$$C = \frac{\ln(\frac{\Delta p_0}{\Delta p_t})}{t} <= \frac{\ln(2)}{20} = 0.03466(1/\min) \tag{9}$$

The physical meaning of this number is the inverse of room 'time constant'.

Equation (8) includes all the effects of environmental changes. It has to be solved numerically to find the root. Once a root is find, the leakage characteristic can be determined.

Correction Procedure

1/ Obtain test data following standard test procedure, note, the data must include barometric pressure measurement and room temperature measurement at each data point.

2/ Calculate C value using equation (8), where t is the measurement interval in minutes.

3/ Average C values in all 'accepted' points, compare it with 0.03466. If C>0.03466, the room passes the test, otherwise fails.

4/Alternatively, a 'corrected' room Δp can be presented using averaged C value and equation (7) along with measured data. If the corrected Δp shows less than 1" H_2O pressure differential at 20 min, the room will fail.

Nomenclatures

P	Absolute Pressure (inch of water)
Δp	Pressure differential between room and environment (P_{room}-P_{baro}) (inch of water)
ρ	Air Density
R	Gas constant for air
T	Room temperature (K)
C	Flow constant of the room crack
n	Flow exponent of the room crack
Q	Volume flow rate due to leakage
V	Room volume
M	Room air mass
C	Room constant (1/min)
T	Time
Δt	A small time increment, or measurement interval (min)
Subscript	
room	Room condition
baro	Barometric condition