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Tel: 519.823.1311
Fax: 519.823.1316
Rowan Williams Davies & Irwin Inc.
901 King Street West, Suite 400
Toronto, Ontario M5V 3H5
Email: solutions@rwdi.com

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To: Mike Singleton, Sustainable Buildings Canada Email: mike-singleton@rogers.com

From: Brandon Law, RWDI Email: brandon.law@rwdi.com

Mike Williams, RWDI mike.williams@rwdi.com

**RE: Accounting for Infiltration in Savings by Design Energy Models**

## OVERVIEW

Air leakage through the envelope can have a significant impact on the energy use of a building, particularly in heating dominated climates.

However, it is RWDI's experience that infiltration is not given an appropriate amount of attention by most projects during the design stage of a development. There are several possible reasons for this, including:

- Determining exactly what infiltration rate to apply to an energy model is difficult and requires detailed calculations, computational fluid dynamics models, or on-site testing.
- The most commonly used energy codes in Canada (e.g. ASHRAE 90.1, NECB 2011) do not allow savings to be directly claimed for technologies and strategies that reduce infiltration.

The consequence is that infiltration rates used in energy models are often just a 'best guess', which in turn leads to a reduced understanding of the project's expected performance. The overarching intent of this document is to inform this 'best guess', and to encourage a more consistent representation of infiltration across projects that go through the SBD program.

It is important to note that this document is by no means an all-encompassing guide to accurately determining and modelling infiltration. Infiltration is a very complicated variable that is influenced by several factors (e.g. wind pressure, outdoor / indoor temp differences, humidity, stack pressure, internal partitions, mechanical systems and their scheduling, building geometry, orientation, amongst others) outside of the scope of this study and summary document. Instead, a level of simplicity and brevity was maintained in an effort to encourage more widespread adoption, with methods recommended that are expected to lead to satisfactory correctness without placing excessive additional requirements on development teams in terms of additional, and perhaps costly studies. However and crucially, professional discretion should be used before using any variables or methods referenced in this document. While recommendations are made in this document, they should be interpreted as guidance only; the decision regarding how to model infiltration should always be left to the discretion of the engaged energy modeller and supporting development team.

## ACCOUNTING FOR UNCONTROLLED AIR LEAKAGE IN AN ENERGY MODEL

Depending on the energy simulation program, there are a variety of methods for modeling infiltration. For example:

- EnergyPlus requires the user to input a design infiltration rate defined as a volumetric flow for each conditioned zone in the model. A schedule can then be assigned to this rate. The software then uses wind speed to vary infiltration, but does not have a wind direction component to it.
- eQuest allows the user to input a constant infiltration rate based on $cfm/ft^2$ of envelope area when within the Design Development Wizard, but once in Detailed Data Edit mode, the input changes to $cfm/ft^2$ of floor area. A schedule can then be assigned to this rate.
- IES Virtual Environment can model both infiltration and exfiltration according to wind speed and wind direction if the MacroFlow module is turned on and appropriate schedules are assigned within the module. Otherwise, a constant infiltration rate can be applied based on $L/(s \cdot m^2)$ of exterior envelope. A schedule can then be assigned to this rate.

In reality, infiltration in commercial buildings will vary depending on HVAC system operation. For example, if a building is pressurized when the HVAC system is operating, infiltration may be significantly reduced during this time (although exfiltration would then increase). Nevertheless, in order to maintain consistency across all modelling software, we recommend that a fixed infiltration rate be applied to all energy models for the SBD program. This constant value method aligns with the modelling requirements of the National Energy Code for Canada for Buildings 2011 (NECB), as outlined in Sentence 3.3.4.9.(6) and Sentence 8.4.3.4.(3).

## Range of Appropriate Infiltration Rates

There have been dozens of infiltration studies conducted and published over the past few decades (see references at end of document), and several organizational and governmental policies from around the world addressing maximum whole building infiltration rates. Several of the rates from these studies are provided in the below table. All of these rates are all provided in L/(s·m²) of exterior envelope area, which as per the NECB should include the gross area of exterior walls/windows, roofs/skylights, and exposed floors, but exclude slabs on grade and interior partitions. When reviewing these studies it is important to note that the rates are provided at two different pressures:

**75 Pascals**

Actual infiltration in an existing building is often measured using a blower-door test where the building is pressurized with a fan and the leakage is measured by the volume of air the fan sends into the building to maintain that pressure. These tests are usually conducted at pressures between 50 and 300Pa; the 75Pa is simply among one of the most common pressures used. Because these high pressures are not typical of most commercial building's operating conditions, flow rates at these high pressures are rarely appropriate inputs for an energy model.

**5 Pascals**

5Pa is referenced in the NECB as typical pressurization of a commercial building at normal operating conditions. The flow rate at this 5Pa is therefore the value that would be a more appropriate input for an energy model.

One can convert air leakage rates between different pressures using the below formula:

$$Q_2 = \left(\frac{Q_1}{(\Delta P_1)^n}\right)(\Delta P_2)^n$$

**ΔP1 =** Pressure #1 (Pa)
**Q1 =** Flow Rate per m2 of wall, when tested at ΔP1 ((L/s)/m2)
**n =** Pressure exponent (typically 0.65 for cracks smaller than 1 mm width)
**ΔP2 =** Pressure #2 (Pa)
**Q2 =** Flow Rate per m2 of wall, when tested at ΔP2 ((L/s)/m2)

The range of possible infiltration rates that we recommend considering for the SBD program have been colour-coded below, with 0.09 L/(s·m²) @ 5Pa at the low end, and 0.52 L/(s·m²) @ 5Pa at the high end.

| | Reference | Whole Building Rates per m² of Exterior Envelope | |
|---|---|---|---|
| | | L/s/m² @ 75 Pa | L/s/m² @ 5 Pa |
| | American Architectural Manufacturers Association (2011) | 0.30 | 0.05 |
| Recommended Range for SBD Program | ASHRAE Fundamentals - Chapter 16, Tight Building (2013) | 0.50 | 0.09 |
| | United Kingdom Building Regulations (2006) | 0.76 | 0.13 |
| | U.S. Army Corps of Engineers (2012) | 1.27 | 0.22 |
| | National Energy Code for Buildings 2011 (Sentence 3.3.4.9.(6) and 8.4.3.4.(3)) | 1.45 | 0.25 |
| | ASHRAE Fundamentals - Chapter 16, Average Building (2013) | 1.50 | 0.26 |
| | Air Barrier Association of America's recommendation (2016) | 2.00 | 0.34 |
| | **RDH & RWDI's Recommended Starting Point for SBD Program Modelling** | **2.03** | **0.35** |
| | ASHRAE 90.1-2013 (Sentence C.3.5.5.3) | 2.03 | 0.35 |
| | RDH Database, Survey of 87 Canadian buildings | 2.93 | 0.50 |
| | ASHRAE Fundamentals - Chapter 16, Leaky Building (2013) | 3.00 | 0.52 |
| | Emmerich and Persily's study of 200 buildings in the US (2005) | 7.75 | 1.33 |
| | Conglomeration of several studies referenced in Chapter 16 of ASHRAE Fundamentals (2013) | 7.88 | 1.36 |

## RECOMMENDED INFILTRATION MODELLING PROCEDURE FOR SBD CHARRETTES

### Infiltration Rate

Sentence 3.3.4.9.(6) and Sentence 8.4.3.4.(3) of the NECB require that air leakage be set to a constant value of 0.25 L/(s·m²) of gross above-ground wall and roof areas. Because of the NECB's ability to be an Authority Having Jurisdiction for building code compliance energy models, this rate is likely to be among the most defensible infiltration assumptions available to Canadian energy modellers today. Given that many of the energy models used in the SBD program may also be adapted for building permit submission, the importance of a "defensible" infiltration assumption is acknowledged.

However, RDH and RWDI's research to date has indicated that this NECB value, while achievable, is a fairly aggressive performance target. From RDH's research, a rate of 0.35 L/(s·m²) at 5Pa has been identified as a value that is reflective of known air tightness values for large commercial buildings, while still being conservative. This value also aligns with ASHRAE 90.1-2013, Sentence C3.5.5.3 where the same rate is recommended for use.

Given the above, we offer the following recommendations in regards to the modelling of infiltration at the start of every SBD charrette:

- The NECB constant rate of **0.25 L/(s·m²)** at 5 Pa be an *allowable* rate to use.
- A constant rate of **0.35 L/(s·m²)** at 5Pa be the SBD Program's *preferred* rate to use.

### Evaluating Improvements in Infiltration

It is recommended that at the start of each SBD charrette, the same infiltration rate and method be applied to both the Proposed and Reference buildings. This aligns with Sentence 8.4.4.4.(6) of the NECB, which requires that air leakage rates for the Reference building be modeled as being identical to those used for the Proposed building.

We also recommend, however, that the SBD program encourage infiltration rates in the Proposed building to be reduced to at least as low as the U.S. Army Corps of Engineers' requirement of 0.22 L/(s•m²) at 5 Pa during SBD charrettes to gauge the impact of infiltration reduction measures on the anticipated energy use of the project. This recommendation is based on the success of the U.S. Army Corps of Engineers' air tightness program, which has demonstrated that this level of air tightness can be achieved across a wide range of building types, contractors, and locations.

Utilizing this U.S. Army Corps of Engineers value of 0.22 L/(s•m²) at 5 Pa would therefore represent a 37% improvement over the 0.35 L/(s•m²) at 5 Pa rate referenced above.

Development teams at the charrette should be encouraged to explore even lower infiltration rates, but be made aware the significant attention during design, construction and commissioning phases of their project will be required to achieve such targets. We recommend that the U.S. Army Corps of Engineers' protocol be the starting point for any team considering the pursuit of lower infiltration rates for their project.

## CLAIMING SAVINGS FOR INFILTRATION REDUCTION AFTER THE CHARRETTE

We recommend that the SBD program allow projects to claim savings for infiltration reduction as long as, at a minimum, the following procedure is followed:

1. The Reference building's infiltration is modelled no higher than 0.35 L/(s•m²) at 5Pa.

2. Design teams engage a building science professional early on in the project to conduct a detailed design review to focus on building air tightness.

3. By the Issued for Construction Energy Model submission: the project must commit to a high performance infiltration target by working at least the following into their Issued for Construction project specifications:
    a. Require whole building air tightness testing at substantial completion that follows the U.S. Army Corps of Engineers Air Leakage Test Protocol for Building Envelopes.
    b. Establish a high performance whole building infiltration target that is better than the 0.35 L/(s•m²) at 5Pa rate.
    c. Require that corrective action be taken by General Contractor as necessary to achieve the high performance whole building infiltration target that has been established.

4. By the As-built Energy Model Submission: the project must provide the SBD Program Administrators evidence of this whole building air tightness testing, demonstrating achievement of a high performance whole building infiltration rate.

Should the above procedure be successfully implemented, we recommend that applicants be able to attribute energy savings to reductions in infiltration equivalent to the improvement they were able to achieve over the starting point of 0.35 L/(s•m²) at 5Pa.

## DISCLAIMER

Although this documents reflects RWDI and RDH's current knowledge, it is provided for general information purposes only. Any reliance or action taken based on the information, materials and techniques described are the responsibility of the user. Users are advised to consult appropriate professional resources to determine what is suitable in their particular case. RWDI and RDH assume no responsibility for any consequence arising from use of the information, materials and techniques described.

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