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NORFOLK
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AIR BARRIER EDUCATION TRACKS FOR
THE CONSTRUCTION INDUSTRY

Whole Building Airtightness Testing of Industrial, Commercial and Institutional Buildings

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Whole Building Air Leakage Testing



- Introduction to Red River College
- Whole building airtightness testing principles
- Red River College whole building airtightness research programs
- Test standards
- Building codes
- Large building air leakage rate targets
- Summary and discussion



Whole Building Air Leakage Testing



Building Research at Red River College

Centre for Applied Research in Sustainable Infrastructure - CARSI

10,000 sq. ft. facility opened in 2007

College's first dedicated applied research centre



Whole Building Air Leakage Testing



NSERC Applied Tools and Instruments Grants

6-fan blower door system (~ 50,000 CFM capacity)

Capacity to test large buildings (depending on how leaky)

Smoke machines

Priority area of research identified by industry – air leakage in commercial buildings



Whole Building Air Leakage Testing



Manitoba Hydro Research Study

The 26 buildings in the overall sample were located across the province.

18 situated in Winnipeg.

They ranged in age from one to over 100 years.



Whole Building Air Leakage Testing



Test Methodology

ASTM E 779-03 Standard Test Method for Determining Air Leakage Rate by Fan Pressurization

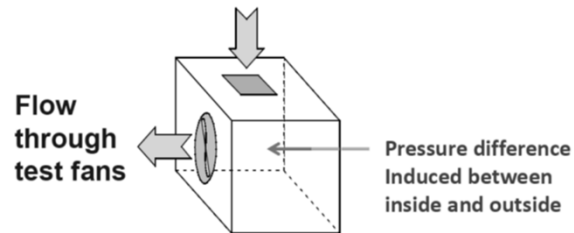
Air Leakage Test Protocol for Building Envelopes Version 3 published in 2012 by the U.S. Army Corps of Engineers and the Air Barrier Association of America USACE/ABAA).



Whole Building Air Leakage Testing



Fan Pressurization Airtightness Test Measures Two things



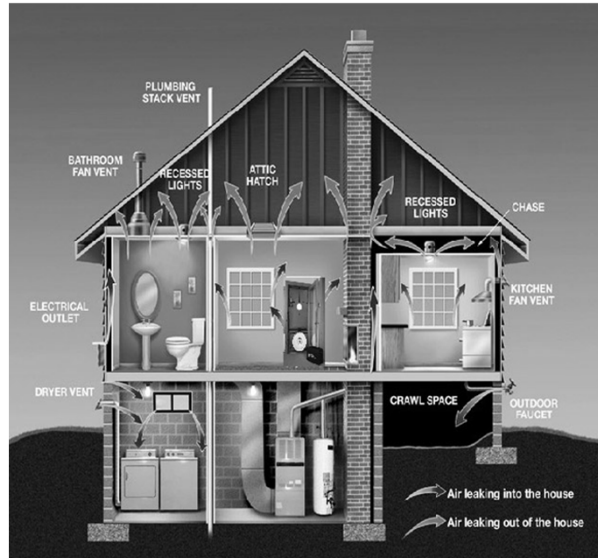
Standard Test Methods
ASTM E779 and E1827
Army Corps of Engineers
ISO 9972
CGSB 149.10
ATTMA TS1



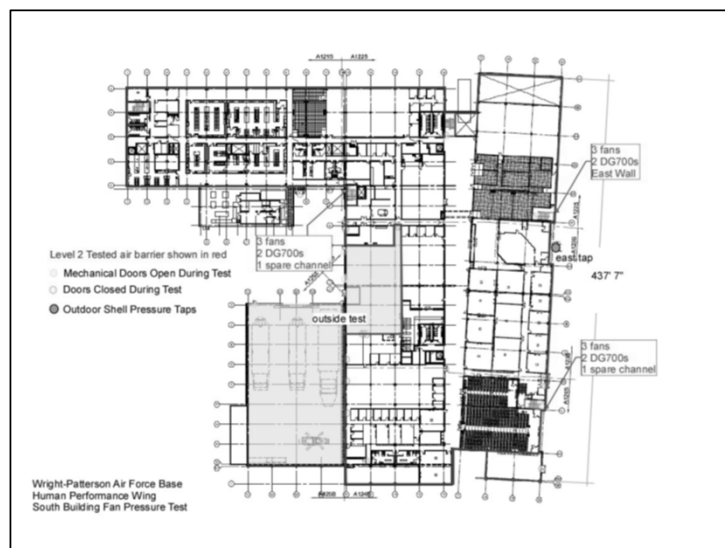
Whole Building Air Leakage Testing



Whole Building Air Leakage Testing

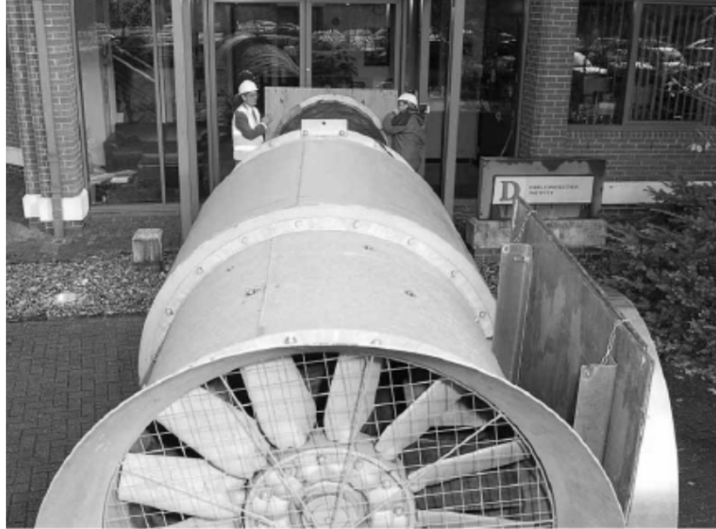


Whole Building Air Leakage Testing



Red River College © 2015

Whole Building Air Leakage Testing



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Whole Building Air Leakage Testing



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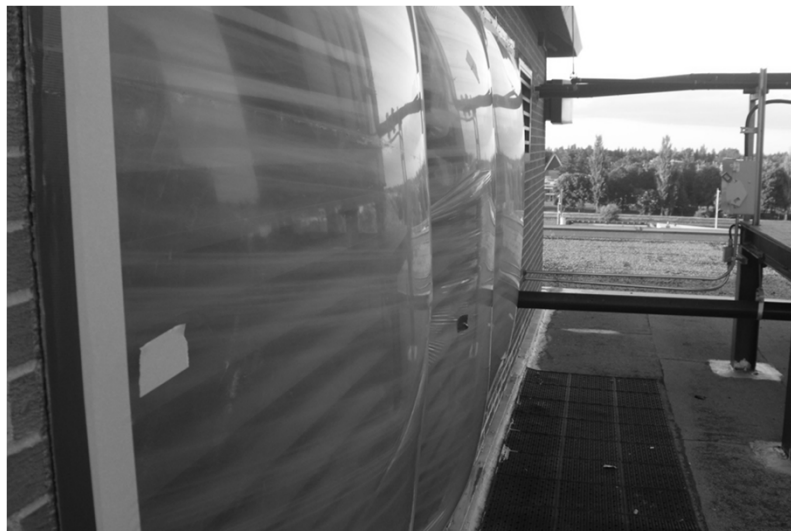
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Exterior Doors:

Closed & Locked



Whole Building Air Leakage Testing



Interior Doors:

Wedged open



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Whole Building Air Leakage Testing



Security and Safety Issues

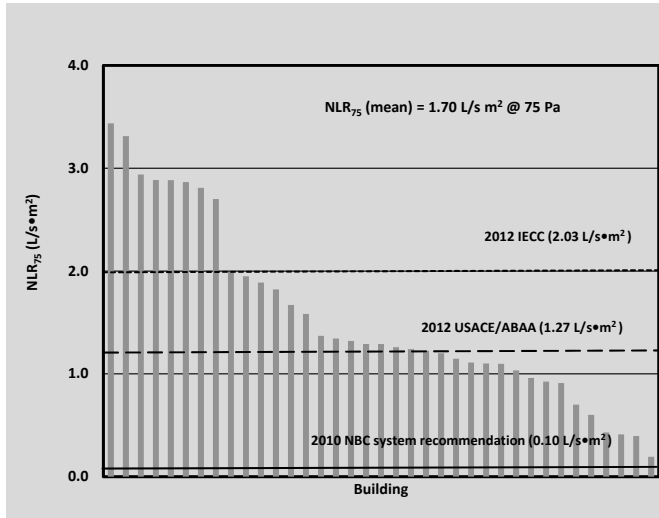


Red River College © 2015

Whole Building Air Leakage Testing



Whole Building Air Leakage Testing



Legend:

| | |
|------------------------------------|-----------|
| NBCC Assembly | ————— |
| 0.10 l/s•m ² @ 75Pa | |
| (0.02cfm/ft ² @ 75 Pa) | |
| USACoE | - - - - - |
| 1.25 l/s•m ² @ 75Pa. | |
| (0.25cfm/ft ² @ 75 Pa) | |
| IECC | - - - - - |
| 2 l/s•m ² @75Pa. | |
| (0.40 cfm/ft ² @ 75 Pa) | |

Whole Building Air Leakage Testing



What is possible with New Construction:

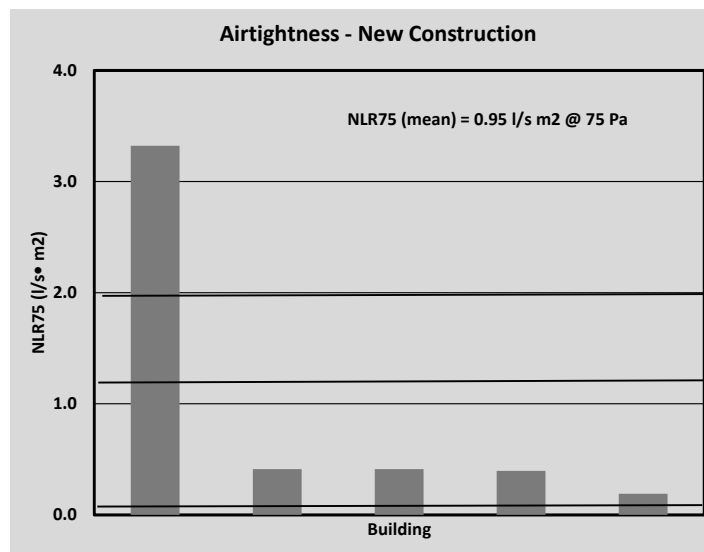
- 2010 NBC system NLR₇₅ recommendation - 0.10 L/s•m²
- Clearspring School whole building NLR₇₅ – 0.19 L/s•m²



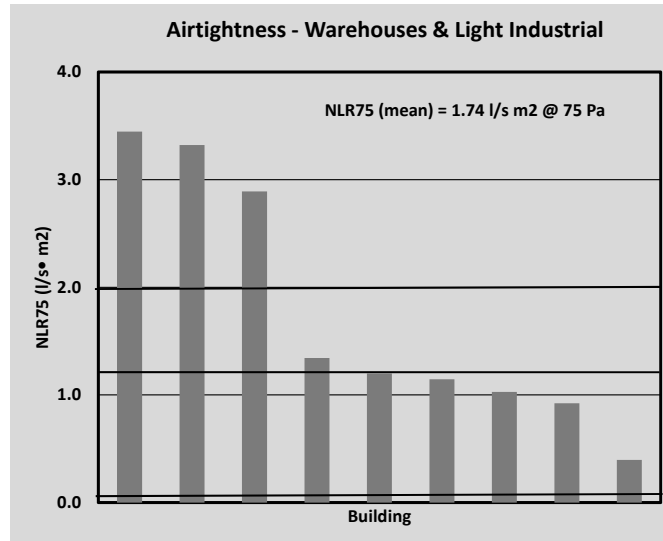
Whole Building Air Leakage Testing



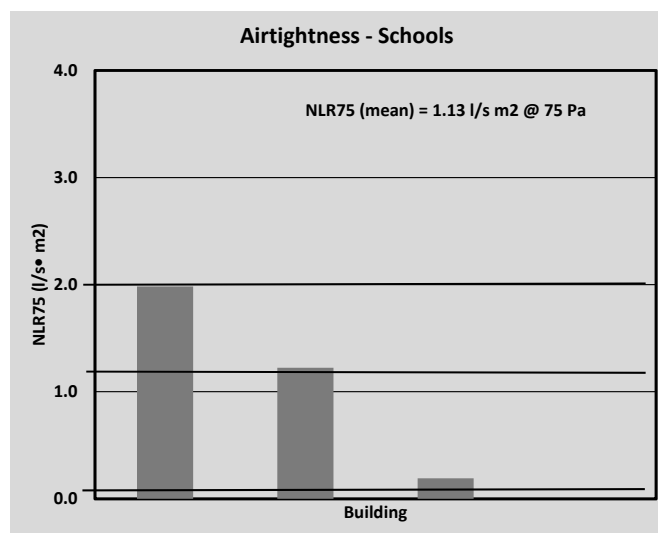
Whole Building Air Leakage Testing



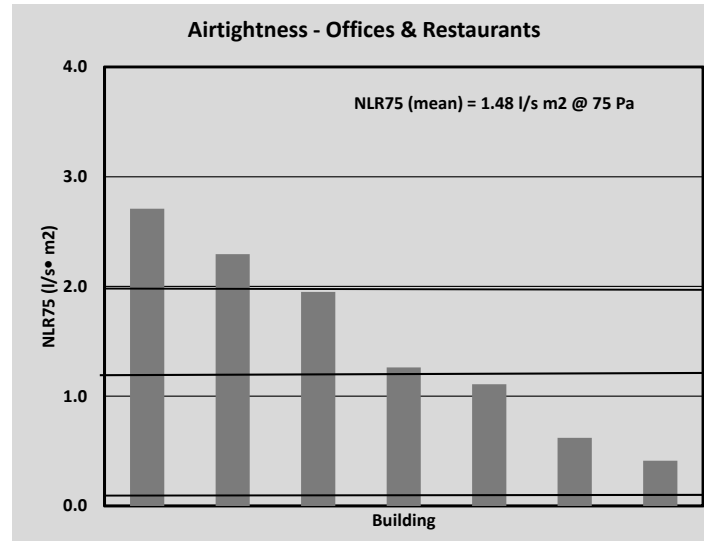
Whole Building Air Leakage Testing



Whole Building Air Leakage Testing



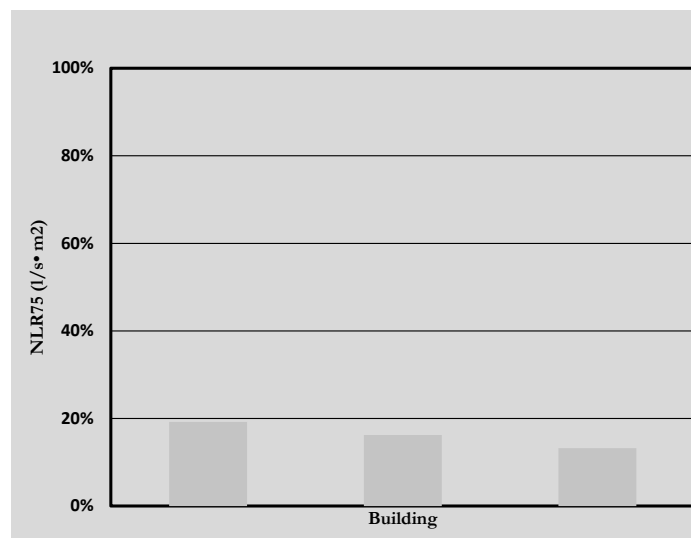
Whole Building Air Leakage Testing



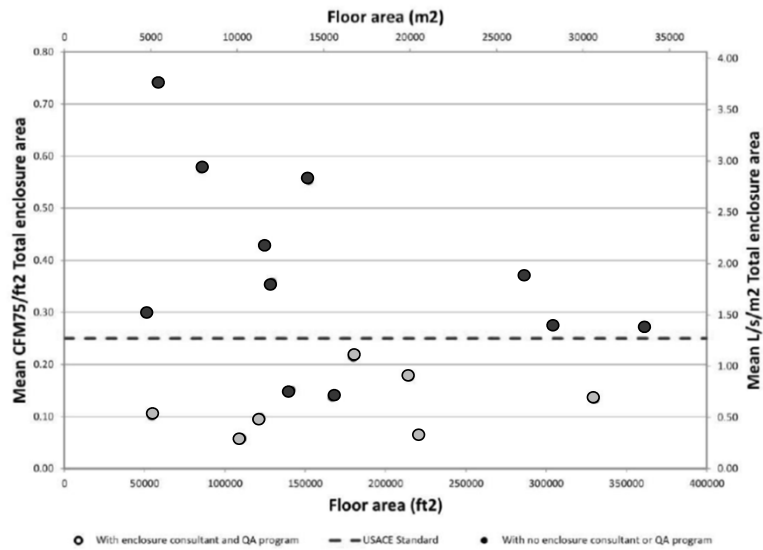
Whole Building Air Leakage Testing



Retrofits:
How Much
Can Leakage
Be Reduced?



Whole Building Air Leakage Testing



Whole Building Air Leakage Testing



CMHC Research Program Testing of Occupied MURBs

Develop appropriate protocols that address the challenges of testing an occupied multi-unit residential building.



Whole Building Air Leakage Testing



The Problem

Airtightness tests are normally conducted with the building's interior doors open (to create a single zone).

Occupied MURB's have lots of interior doors - which cannot be left open for extended periods.

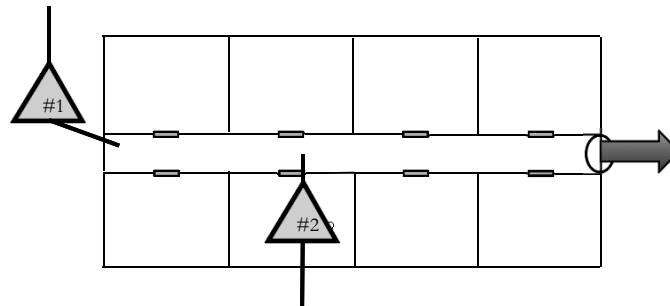
So, what to do?



Whole Building Air Leakage Testing



Conceptual Test Protocol



Whole Building Air Leakage Testing



The Solution

By measuring $\Delta\#1$ and $\Delta\#2$, we have the indoor-to-outdoor pressure differential and the pressure drop across the suite door.

We can then correlate the ratio $\Delta\#1/\Delta\#2$ between the test building and other buildings for which the impact of closed suite doors has been measured.



Whole Building Air Leakage Testing



CMHC Research Program

Testing of Occupied MURBs

Phase One

Field Trial of Test Protocol on Unoccupied MURBs

Modify the current test protocol to reflect a building in use



Whole Building Air Leakage Testing



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Test Standards

CAN/CGSB-149.10-M86 Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method

ASTM E779-10 Standard Method for Determining Air Leakage Rate by Fan Pressurization

2009 2011 U.S. Army Corps of Engineers Air Leakage Test Protocol for Measuring Air Leakage in Buildings

2012 U.S. Army Corps of Engineers/Air Barrier Association of America

2015 Air Barrier Association of America Standard Method for Building Enclosure Airtightness Compliance Testing



Whole Building Air Leakage Testing



Test Standards

**ASTM E3158-18 Standard Test Method for
Measuring the Air Leakage Rate of a Large or
Multi-zone Building**

Approved 24th October 2018



Whole Building Air Leakage Testing



Standard Test Method for Measuring the Air Leakage Rate of a Large or Multi-zone Building

A second test to evaluate the building true operational performance shall also be conducted with the building's intentional openings open. There are no prescribed airtightness rates but the results from this test shall be reported to the commissioning agent and/or consultant to help with the energy use.



Whole Building Air Leakage Testing



TABLE 1 Default Conditions for Building Preparation

| Intentional Openings | Building envelope test (HVAC-related openings excluded) | Operational envelope test (building envelope and HVAC-related openings included) |
|--|---|--|
| Doors, hatches, and operable windows inside the test envelope | Open | Open |
| Fire Dampers | Remain as found | Remain as found |
| Windows, doors, skylights, and hatches in the bounding envelope | Closed and latched | Closed and latched |
| Windows, doors, hatches, and operable windows in ancillary spaces as identified in section 9.13 | Treat in accordance with 9.13 | Treat in accordance with 9.13 |
| Dryer doors and air handler access panels | Closed and latched | Closed and latched |
| Vented combustion appliance | Off, unable to fire | Off, unable to fire |
| Pilot light | As found | As found |
| Chimney or outlet for vented combustion device in a separate mechanical room | As found | As found |
| B-vent or other insulated chimney serving a vented combustion appliance located within the test envelope | Sealed*, ** | As found |
| Solid fuel appliances (fireplaces, wood burning stoves, pellet stoves) | No fires; dampers closed; chimney sealed*, ** | No fires; dampers closed |
| Exhaust, outdoor air, make-up air fans, air handlers that serve areas inside and outside the test envelope | Off | Off |
| Clothes dryers | Off | Off |
| Air intake inlet with motorized dampers | Dampers closed and sealed*, ** | Dampers closed |
| Air intake inlet with gravity dampers | Sealed*, ** | As found |
| Air intake inlet with no dampers | Sealed*, ** | Open unless fan(s) serving inlet is operated greater than 8000 hours |



Whole Building Air Leakage Testing



Whole Building Air Leakage Testing



Whole Building Air Leakage Testing



Building Codes

The Evolution of Codes

How well are we doing

Where are/should we going with the leakage rates



Whole Building Air Leakage Testing



Building Codes

1995 NBCC Requirements:

- Airtightness
- Continuity
- Durable/serviceable
- Structural integrity



Whole Building Air Leakage Testing



Building Codes

Material Requirements

0.02 L/s.m² @75Pa

System Recommendations Class

Class 1 RH < 27% 0.15 L/s/m² @75Pa

Class 2 RH 27-55 0.10 L/s/m² @75Pa

Class 3 RH > 55% 0.05 L/s/m² @75Pa



No reference to Whole Building Airtightness

Whole Building Air Leakage Testing



Building Codes

2001 : Massachusetts - Energy Code Chapter 13

Air Barrier Requirement:

0.004 CFM/Ft² @ 1.56 Lb/Ft²

(0.02 L/s.m² @75Pa)



Whole Building Air Leakage Testing



Building Codes

2007: US Army Corps of Engineers

Air barrier material air permeance not to exceed 0.004 cfm/ft² at 0.3" wg (1.57 psf) (0.02 L/sm² @ 75 Pa)

Whole building's air leakage rate must not exceed 1.25 L/sm² @ 75 Pa (0.25 cfm/ft² at 1.57 psf) when tested according to ASTM E779



Whole Building Air Leakage Testing



Building Codes

Washington meeting with the General Services Administration (GSA) Sept. 4, 2007.

Materials (NBCC) 0.02 L/s.m²@75Pa
(0.004 CFM/Ft²@75Pa)

Systems X 10 0.2 L/s.m²@75Pa
(0.04 CFM/Ft²@75Pa)

Whole building X 10 2 L/s.m²@75Pa
(0.4 CFM/Ft²@75Pa)



Whole Building Air Leakage Testing



Building Codes

2011 ASHRAE 90.1 Addendum z. Standard 189

| | | |
|------------------|------|--|
| Materials (NBCC) | | 0.02 L/s.m ² @75Pa (0.004 cfm/ft ² @75Pa) |
| Systems | X 10 | 0.2 L/s.m ² @75Pa (0.04 cfm/ft ² @75Pa) |
| Whole building | X 10 | 2 L/s.m ² @75Pa (0.4 cfm/ft ² @75Pa) |



Whole Building Air Leakage Testing



Building Codes

IECC 2012 C402.4.1.2.1 Materials

Materials with air permeability
 0.004 cfm/ft² @75Pa (0.02 L/s.m² @75Pa) tested to ASTM E
 2178 @ 0.3 in wg (75Pa) pressure.



Whole Building Air Leakage Testing



Building Codes

IECC 2012 C402.4.1.2.2 Assemblies

Assemblies of materials/components have average air leakage $\leq 0.04 \text{ cfm/ft}^2 @75\text{Pa}$ ($0.2 \text{ L/s.m}^2 @75\text{Pa}$) tested to ASTM E 2357, ASTM E 1677 or ASTM E 283 @ 0.3 in/75Pa pressure.



Whole Building Air Leakage Testing



Building Codes

2012 IECC allow options for complying with the continuous air barrier requirements

Compliance by Materials and Assemblies

Compliance by Whole Building Test

Documentation will need to be submitted to demonstrate that the building envelope meets the maximum air leakage requirement of $0.40 \text{ cfm/ft}^2 @75\text{Pa}$ ($2 \text{ L/s.m}^2 @75\text{Pa}$)



Whole Building Air Leakage Testing



Building Codes

2015 the General Services Administration

Facilities Standards for the Public Buildings Service

Tier 1 High Performance: Maximum air leakage rate
 0.25cfm/ft^2 @ 75 Pa ($1.25\text{ l/s}\cdot\text{m}^2$ @ 75Pa.)

Tier 2 High Performance: Maximum air leakage rate
 0.15cfm/ft^2 @ 75 Pa ($0.75\text{ l/s}\cdot\text{m}^2$ @ 75Pa.)

Tier 3 High Performance: Maximum air leakage rate
 0.10cfm/ft^2 @ 75 Pa ($0.50\text{ l/s}\cdot\text{m}^2$ @ 75Pa.)



Whole Building Air Leakage Testing



Building Codes

Vancouver the Energy Modelling Guidelines,

BC Building Code air leakage rate of 2.0 L/s m^2 at 75 Pascals shall be used for design purposes during the initial energy modelling of the building.

Further, the Step Code requires all MURBs up to 6 stores to be tested along with a target airtightness rate of 2.0 L/s m^2 at 75 Pascals.



Whole Building Air Leakage Testing



Building Codes

AIR TIGHTNESS TESTING REQUIREMENTS

Requiring buildings to conduct whole building air tightness testing helps to improve the quality and airtightness of the building envelope, as well as the performance gap between building design and performance.



Whole Building Air Leakage Testing



Building Codes

AIR TIGHTNESS TESTING REQUIREMENTS

While Toronto requires a test to be conducted, it does not specify a target level of airtightness to be achieved. The rationale is that this will allow the building industry the necessary time to develop capabilities to design and construct low-leakage buildings and also develop an airtightness testing infrastructure, while still providing information about typical air leakage rates of Toronto buildings.



Whole Building Air Leakage Testing



Building Codes

The National Master Specification (NMS) For Building Enclosure Performance Testing

Requires quantified whole building testing in accordance with ASTM E 779 or the USACE/ABAA protocol. As a Specification it will not have a defined target for the airtightness requirement but a placeholder bracket for the specifier to reference the correct leakage rate for the project.



Whole Building Air Leakage Testing



Building Codes

GREEN BUILDING PROGRAM

Technical Update: 2017-07-11

Airtightness and Water Penetration Testing for Residential Buildings



Whole Building Air Leakage Testing



Building Codes

Section 3: Air & Water tightness (overall)

Purpose: Fan pressurization tests measure the amount of air leakage across the building's envelope. Air leakage rates are used to determine the required amount of mechanical ventilation for proper indoor air quality.

| Air & Water Tightness Testing (Overall) When project is complete | PART 3: Residential Buildings Testing standard & Protocol | PART 9: Residential Buildings Testing standard & Protocol |
|--|--|--|
| *USACE Air Leakage Test Protocol For Building Envelopes version 3. *This will be superseded by ASTM WK35913 Standard Test Method for Determining the Air Leakage Rate of Large or Multi Zone Buildings upon publication. | Application 3.1 | NA |
| CGSB 149.10 – Determination of the Air tightness of Building Envelopes by the Fan Depressurization Method | NA | Application 3.1 |
| AAMA 501.1- Standard Test Method for Water Penetration of Windows, Curtain Walls, and Doors Using Dynamic Pressure | Application 3.1 | Application 3.1 |



Whole Building Air Leakage Testing



Building Codes

| | NBCC, Part 5, Appendix Recommendations | Enhanced Life Service >=50 Years | Fundamental Life Service <50 Years |
|--|--|--|--|
| Warm side relative humidity at 21 C | Recommended maximum system air leakage rate, L/(s • m ²) at 75 Pa | Recommended maximum Whole Building Airtightness. L/(s • m ²) at 75 Pa | Recommended maximum Whole Building Airtightness, L/(s • m ²) at 75 Pa |
| Class 1 RH < 27% | 0.15 L/s/m ² | x 5 = 0.75 L/(s • m ²) | x 10 = 1.50 L/(s • m ²) |
| Class 2 RH 27-55% | 0.10 L/s/m ² | x 5 = 0.50 L/(s • m ²) | x 10 = 1.00 L/(s • m ²) |
| Class 3 RH > 55% | 0.05 L/s/m ² | x 5 = 0.25 L/(s • m ²) | x 10 = 0.50 L/(s • m ²) |



Whole Building Air Leakage Testing



The intent to adopt into the 2020 National Energy Code of Canada



Whole Building Air Leakage Testing



Most current studies on the airtightness of large industrial, commercial and Institutional

RDH Study of Part 3 (NBCC) Buildings Airtightness 2015,

Wiss Janney Elstner Associates Inc./ASHREA 1478 2014
Measuring Airtightness of Mid- and High-Rise Non-Residential
Buildings and

Red River College 2015 An Investigation of Airtightness in
Manitoba's Commercial Building Sector



Whole Building Air Leakage Testing



Most current studies on the airtightness of large industrial, commercial and Institutional

RDH Study of Part 3 (NBCC) Buildings Airtightness 2015,
Four different types commercial, institutional, military and MURBs

142 Commercial Buildings from (1875 only one building included 3.5 L/s/m²) 1964 to 2015 including industrial, offices, warehouses, and retail

51 Institutional buildings from 1990 to 2014



Whole Building Air Leakage Testing



Most current studies on the airtightness of large industrial, commercial and Institutional

Wiss Janney Elstner Associates Inc./ASHREA 1478 2014
Measuring Airtightness of Mid- and High-Rise Non-Residential Buildings

Sixteen buildings between four and fourteen stories, built since the year 2000



Whole Building Air Leakage Testing



Most current studies on the airtightness of large industrial, commercial and Institutional

Red River College 2015 An Investigation of Airtightness in Manitoba's Commercial Building Sector

26 commercial buildings heights ranged from one to 16 stories'
The buildings tested comprised of office buildings, schools, warehouse and light industrial buildings, churches and greenhouses. ranged in age from 1 to over 100 years.
Also included an additional 20+ buildings tested to date



Whole Building Air Leakage Testing



Most current studies on the airtightness of large industrial, commercial and Institutional

| Studies | High | Low | Mean | Median |
|----------------|---|------|------|--------|
| RDH | $\text{l/s}\cdot\text{m}^2 @ 75\text{Pa}$ | | | |
| Commercial | 19.04 | 0.29 | 3.52 | 2.75 |
| Institutional | 8.16 | 0.2 | 2.61 | 1.84 |
| WJE/ ASHREA | 3.76 | 0.31 | 1.47 | |
| RRC | 3.44 | 0.19 | 1.70 | 1.30 |



Whole Building Air Leakage Testing



| | NBCC, Part 5, Appendix Recommendations | Enhanced Life Service >=50 Years | Fundamental Life Service <50 Years |
|--|---|---|---|
| Warm side relative humidity at 21 C | Recommended maximum system air leakage rate, L/(s • m²) at 75 Pa | Recommended maximum Whole Building Airtightness, L/(s • m²) at 75 Pa | Recommended maximum Whole Building Airtightness, L/(s • m²) at 75 Pa |
| Class 1 RH < 27% | 0.15 L/s/m² | x 5 = 0.75 L/(s • m²) | x 10 = 1.50 L/(s • m²) |
| Class 2 RH 27-55% | 0.10 L/s/m² | x 5 = 0.50 L/(s • m²) | x 10 = 1.00 L/(s • m²) |
| Class 3 RH > 55% | 0.05 L/s/m² | x 5 = 0.25 L/(s • m²) | x 10 = 0.50 L/(s • m²) |

| Studies | High | Low | Mean | Median |
|---------------|-------|------|------|--------|
| RDH | | | | |
| Commercial | 19.04 | 0.29 | 3.52 | 2.75 |
| Institutional | 8.16 | 0.2 | 2.61 | 1.84 |
| WJE/ ASHREA | 3.76 | 0.31 | 1.47 | |
| RRC | 3.44 | 0.19 | 1.70 | 1.30 |



Whole Building Air Leakage Testing



Summary



Whole Building Air Leakage Testing



Summary



Whole Building Air Leakage Testing



Summary



Whole Building Air Leakage Testing



Summary

Canadian Codes, AHLs and Specifiers to adopt air leakage rates that are based on the buildings operation, climate and service life

Current New Construction **0.02 to 4.00 l/s·M²**

Current Codes & Standards **0.25 to 2.00 l/s·m²**

Future Codes say – **0.25 to 1.50 l/s·m²**



Whole Building Air Leakage Testing



Summary

Airtightness rates in Codes should reflect the building type and live service

The project highlighted the significant differences between testing commercial/large buildings and houses.

Building Owners and AHJ have to be able to identify qualified testing agencies that can perform the whole building airtightness test.



Whole Building Air Leakage Testing



Summary

Training on the use of the test equipment is offered by blower door manufactures but training on the execution of the test should also be a prerequisite for individuals working in the field,

Commercial building airtightness testing requires significant planning, coordination and manpower resources.



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