

An Examination Of Envelope Pressure Differential Behaviour In Multi-Unit Residential Buildings

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Uncontrolled Building Air Leakage Can Cause A Variety Of Problems

- Envelope damage due to air exfiltration/moisture deposition
- Increased energy costs
- Decreased occupant comfort
- Pollutant transfer
- Transmission of outdoor noise into the building
- Inadequate smoke control

A Surprising Amount Of Our Understanding Of Large Building Air Leakage Performance Is Based On Theory - Blissfully Unchallenged By Actual Data



The Project...

- Initiated by Canada Mortgage and Housing Corp.
- Undertaken with the assistance of Manitoba Housing
- Objective: to improve our understanding of air pressure and air movement patterns in MURB's
- Consisted of a variety of measurements and observations on two Winnipeg MURB's (15 and 18 stories)
- Tests performed during the winter, summer and shoulder seasons

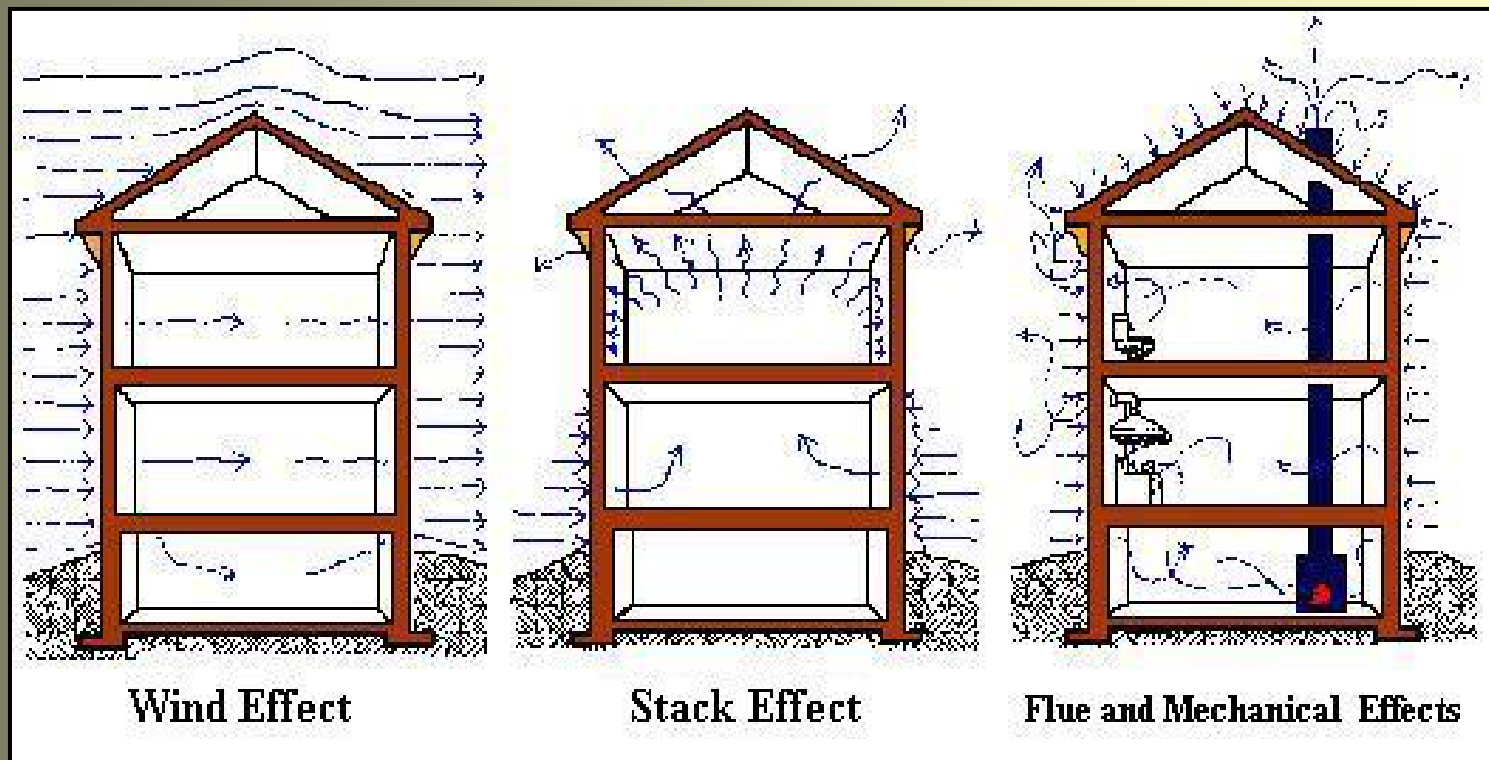
Issues Studied...

- Envelope pressure regimes
- Neutral Pressure Plane Behaviour
- Compartmentalization
- Building airtightness (in the real world)

Envelope Pressure Regimes

What Causes Air Leakage?

- Three driving forces can create pressure differences across the envelope
- Pressure differences + cracks and holes = air flow



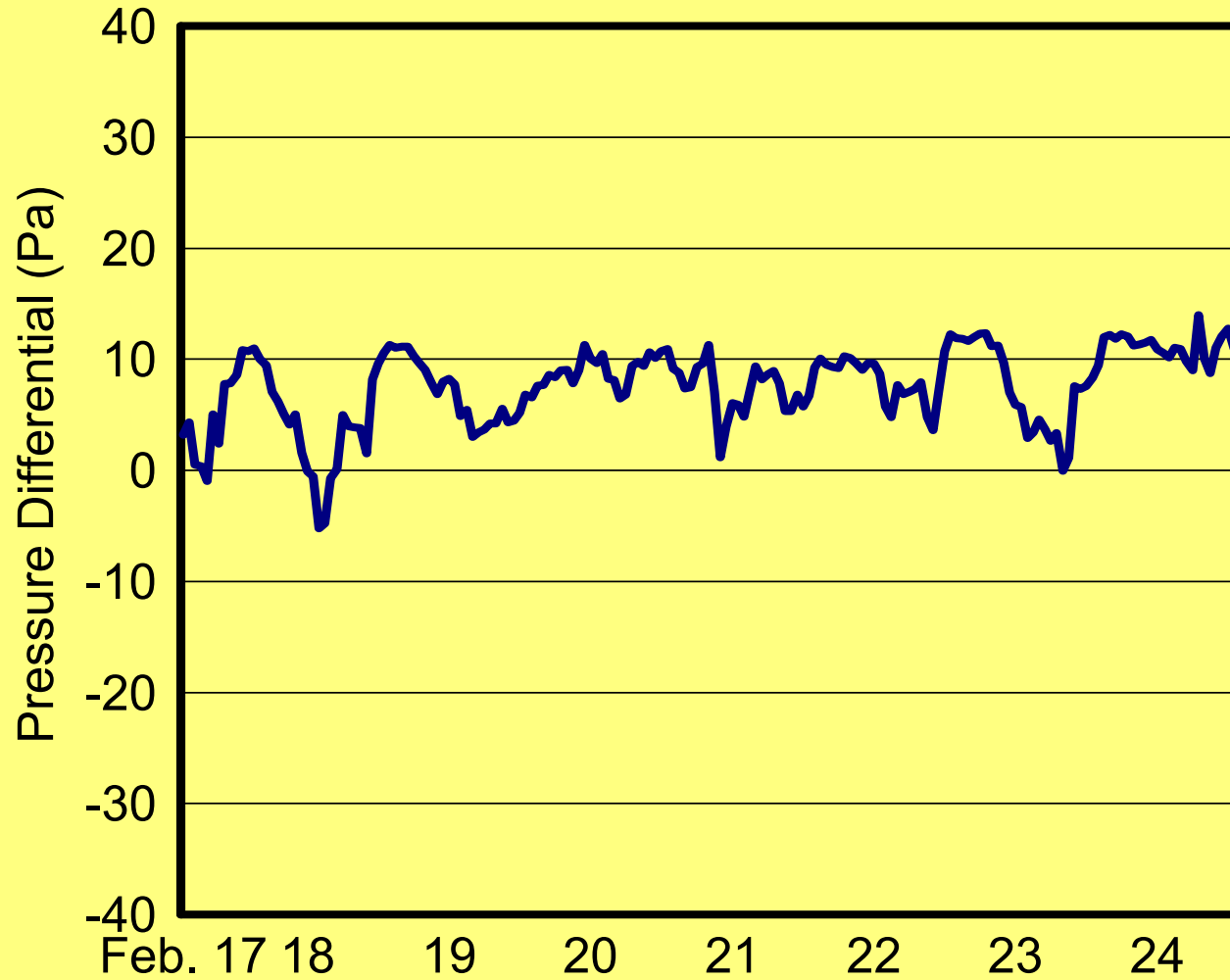
Measuring Envelope Pressure Differentials



Exterior Wall Pressure Differential 3rd Floor, Winter



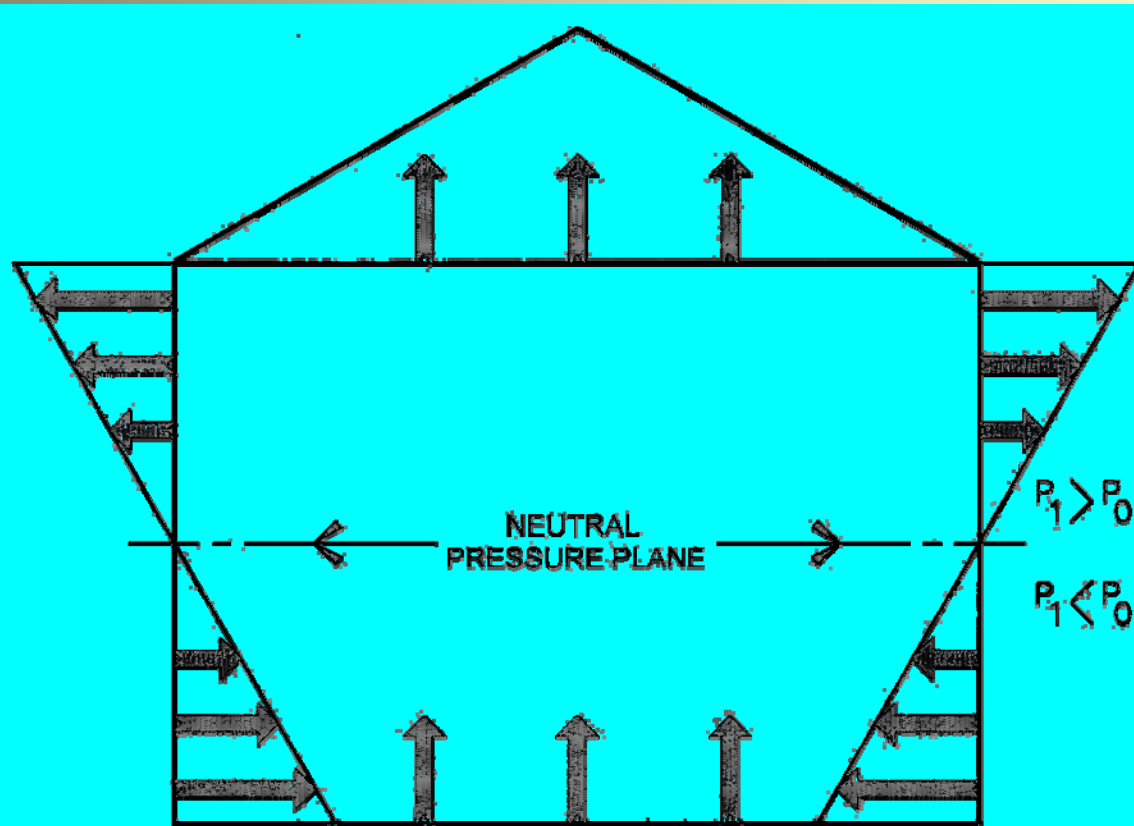
Exterior Wall Pressure Differential 16th Floor, Winter



Neutral Pressure Plane (NPP) Behaviour

Neutral Pressure Plane (NPP)

- The locus of points on the building envelope at which the indoor-to-outdoor pressure differential equals zero.
- Its position changes constantly.
- In the absence of wind and mechanical systems, the NPP would be located at the mid-height of the building under winter conditions.



NO WIND

NOTE: ARROWS INDICATE MAGNITUDE AND DIRECTION OF PRESSURE DIFFERENTIAL.

FIG. 1

Measuring The Location Of The Neutral Pressure Plane

- By measuring the indoor-to-outdoor pressure differential at the top and bottom of the building, the position of the NPP can be determined.
- Synchronized, hand-held data loggers can be used to measure and record the pressure differentials.
- Usually expressed in relation to the building's height, i.e. H_{npp}/Height .
- Easy to do.

Why Is The Neutral Pressure Plane Important?

- It determines whether each spot on the envelope will be subject to air infiltration or air exfiltration.
- Air infiltration means potential drafts, pollutant entry and higher energy costs.
- Air exfiltration means potential envelope moisture damage.

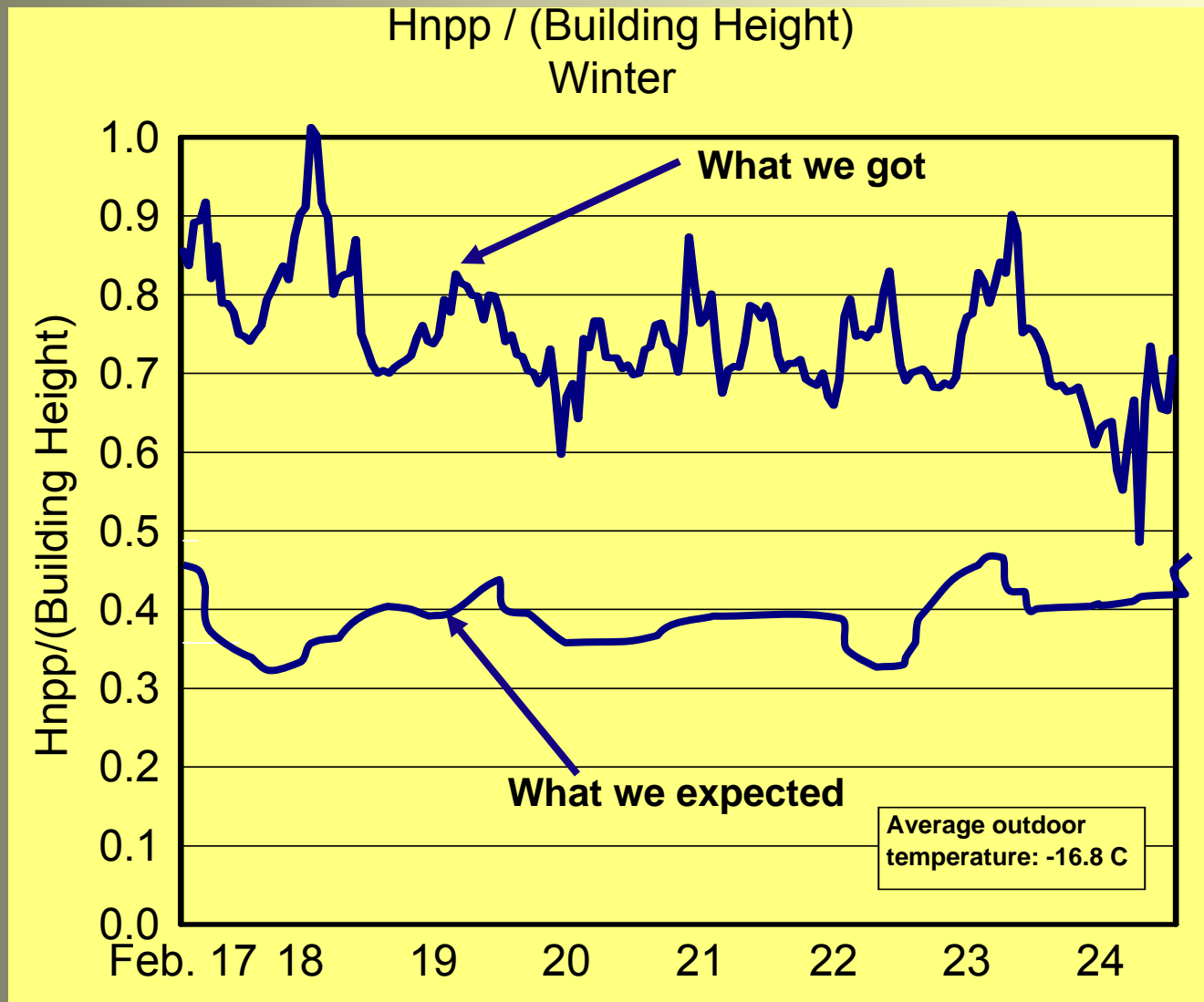
Neutral Pressure Plane Behaviour

- In an electrically heated MURB, with a corridor pressurization system, you would expect the NPP to be below the building's mid-height.
- But, we also know that the NPP tends to move towards holes (such as open windows); the bigger the hole, the more it moves.

So....What Happens When You Open A Bunch Of Holes In The Upper Part Of The Envelope?



This...



Lessons Learned: Envelope Pressure Regimes And NPP Behaviour

- Measured envelope pressure regimes were significantly different from those expected – especially during winter.
- Occupant-controlled use of windows had a major impact on the pressure regimes experienced by the envelope.
- Exfiltration forces were moderated by the prevalence of open windows in the two buildings (i.e. open windows may be saving the building envelope from serious damage in many buildings).

Compartmentalization

Compartmentalization

- By increasing the airtightness of internal partitions within the building, the pressure differentials across the building envelope are reduced.
- This has the same effect as making the envelope more airtight...less air leakage occurs.
- Compartmentalization can be a relatively cheap way to reduce air exfiltration/moisture deposition into the envelope.

Consider these internal air leaks pathways...



Horizontal pathways



How Do You Measure Compartmentalization?

- By using the “Thermal Draft Coefficient” (TDC).
- Defined as...

Sum of the actual top & bottom pressure differentials

Total theoretical pressure differential

- For a building with no internal partitions, $TDC = 1$.
- For a building with airtight internal partitions, $TDC \rightarrow 0$.
- So, we want the TDC to be as low as possible.

TDC Under Winter Conditions



What Does This Tell Us?

- Remember,
 - For a building with no internal partitions, $TDC = 1$.
 - For a building with airtight internal partitions, $TDC \rightarrow 0$.
- So, given that our real buildings seemed to operate with TDC values of about 0.5 to 0.8 during winter, there is lots of room for improvement (which is good news).

Could This Behaviour Been Caused By...

- A preponderance of leaks at the top of the building, such as a leaky elevator penthouse? – No, calculations showed that with observed open window areas of 10 to 39 m², the measured behaviour would require not merely a leaky penthouse, but a *missing* penthouse.
- Mechanical depressurization? – No, with the observed window usage patterns, the impact of the mechanical ventilation system on the overall building pressure differential was estimated to range from 0.2 to 0.4 Pa.

Airtightness Of Large Buildings

**“You Don’t Understand Something Until
You Can Quantify It”**

Large Building Airtightness

- Relatively limited data is available.
- One of the largest study to date has documented the results for 192 buildings in Canada, the United States, Great Britain and Sweden.
- Test is done with all doors and windows closed.
- Results are typically expressed using the Normalized Leakage Rate @ 75 Pa (NLR_{75})

$$= \frac{\text{(Total Leakage at 75 Pa)}}{\text{Envelope Area}}$$

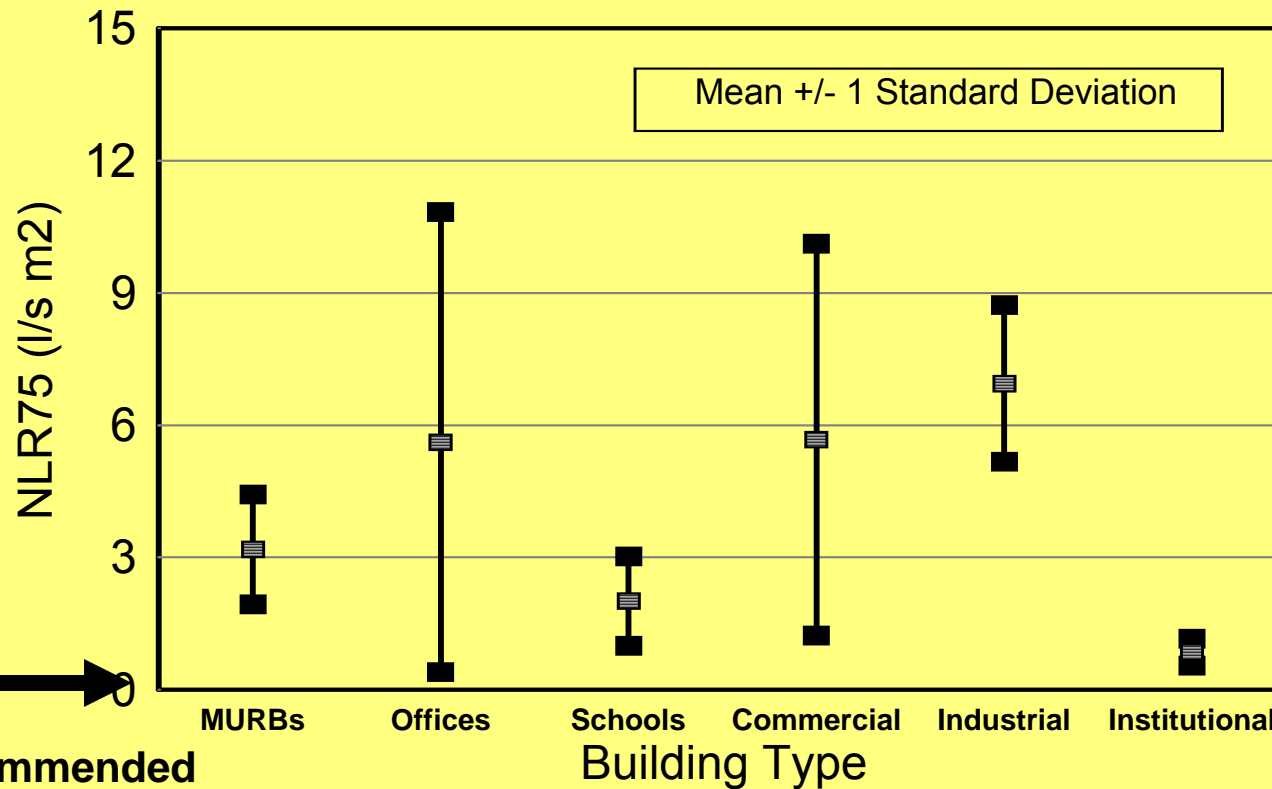
How Tight Should A Building Be???

- Good question.
- For example, the 2005 National Building Code of Canada offers a *recommended* (not mandatory) level of airtightness:

Warm Side R/H	Maximum NLR_{75}
<27%	0.15
27% to 55%	0.10
>55%	0.05

How Leaky Are Large Buildings?

Impact Of Building Type
(Type 1 Data Only)



NBC - Recommended
Airtightness Level

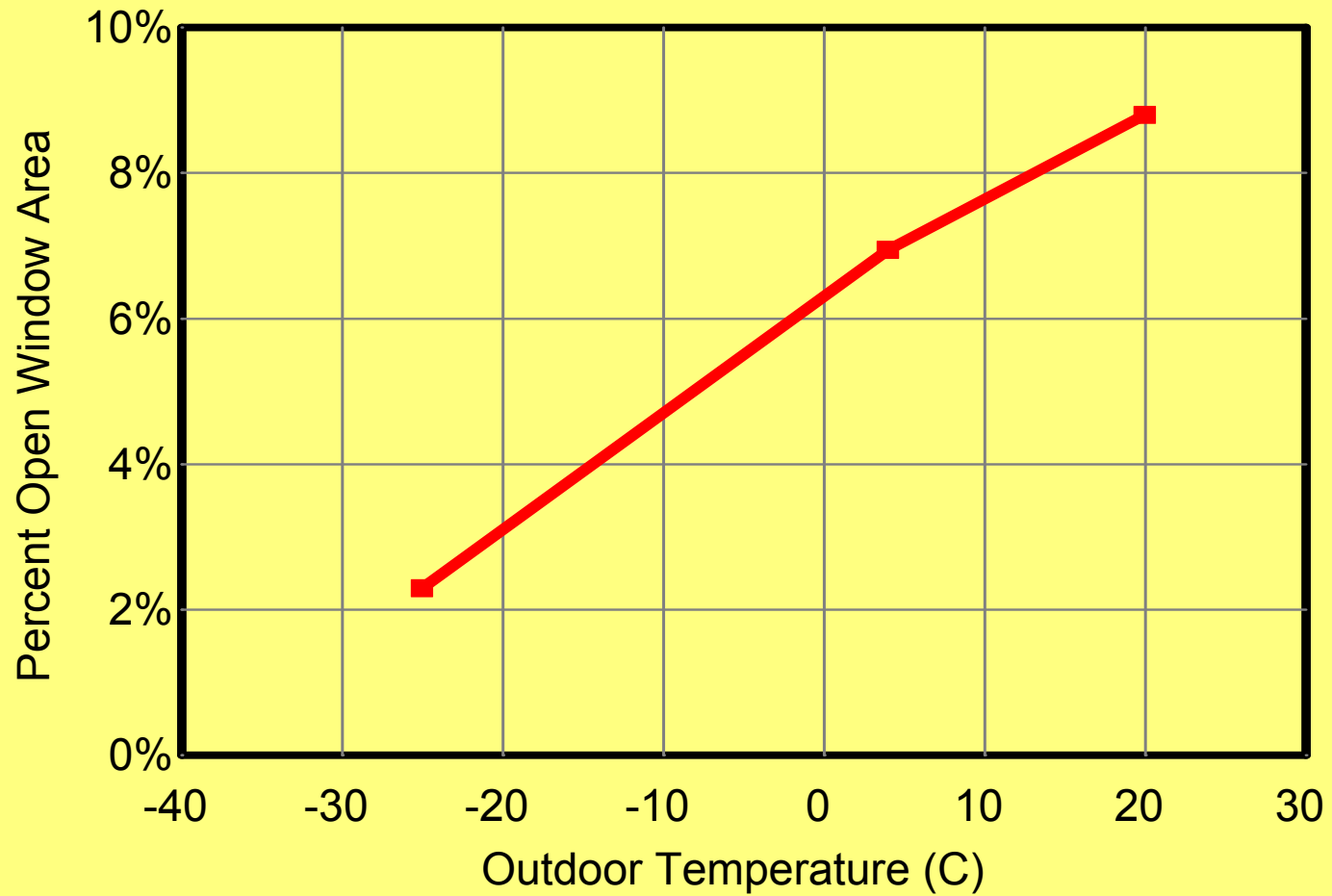
But...

Remember how an airtightness test is performed (with doors and windows closed).

**A Typical Winter Day In Winnipeg,
Lots Of Open Windows At -25 °C**



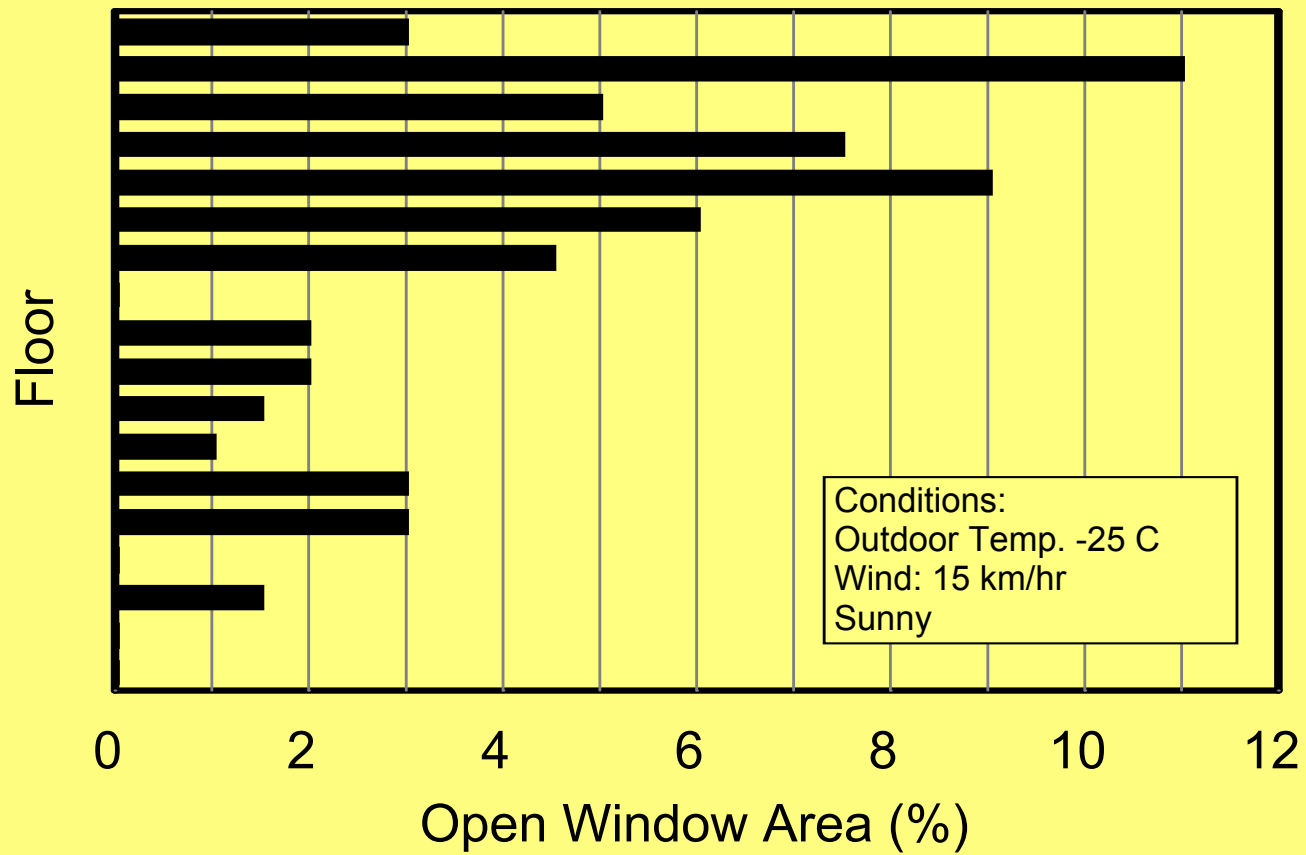
Window Usage vs. Temperature



In fact...

Open windows were observed in both buildings at -40 C.

Window Usage, Building #2



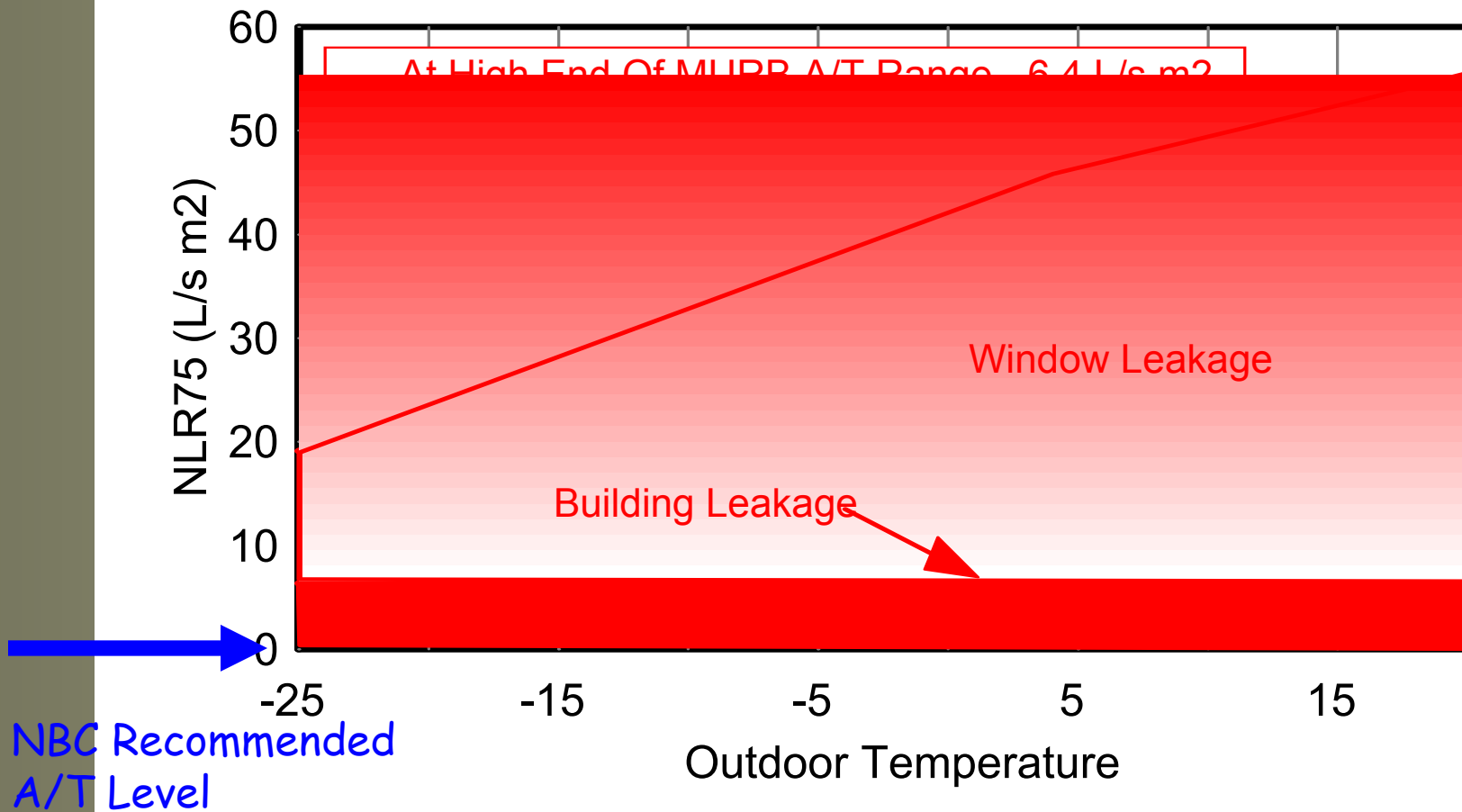
Air Leakage Through An Open Window

- If we can estimate the area of open windows, we can estimate the amount of air leakage which occurs through them. The biggest problem is accounting for the influence of insect screens. Fortunately, the greenhouse industry has spent a lot of time worrying about this and have produced methods to estimate the impact of screens on air flow through large openings.

$$Q_s / Q_{us} = \varepsilon (2 - \varepsilon) \quad \text{where } \varepsilon = \text{screen porosity}$$

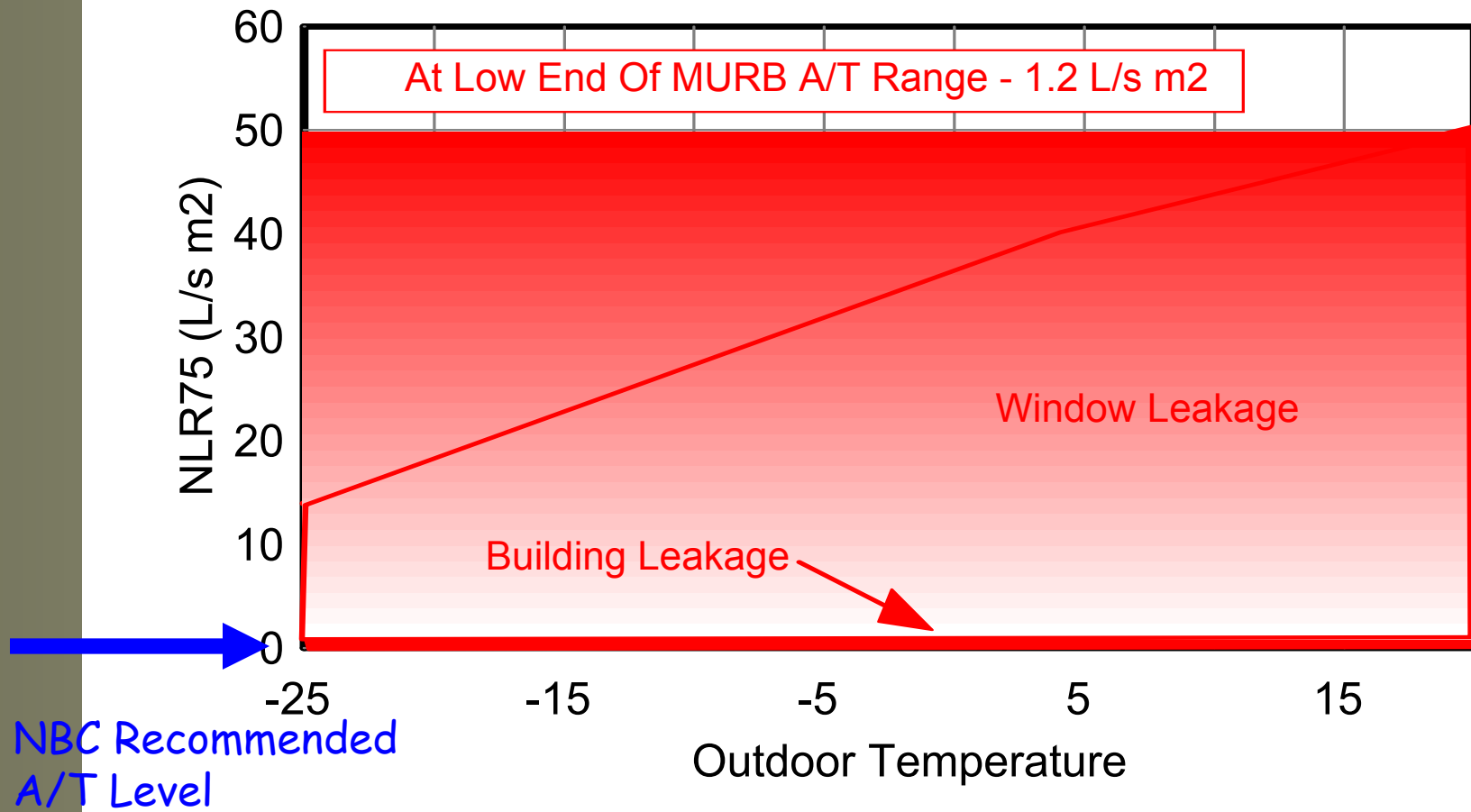
Using this info, we can factor window air leakage into the NLR_{75} leakage into the NLR_{75} and compare the result to existing airtightness data and recommended values. What does this look like.....

Impact Of Windows On Airtightness



**And, these effects become more pronounced
as the building envelope becomes tighter.**

Impact Of Windows On Airtightness



Lessons Learned: Envelope Airtightness

- Occupant-controlled window usage had a major impact on the overall airtightness and performance of the two buildings.
- Basically, the “effective airtightness” of the buildings was controlled by the occupants and their use of the windows.

Lessons Learned: Envelope Airtightness

- Many of our existing buildings are currently being protected (unintentionally) by their occupants whose use of windows raises the NPP thereby increasing the percentage of the envelope which is subjected to infiltration forces and reducing the magnitude of the exfiltration forces on the upper portion.
- This effect has been observed in other buildings in which some suites, where the windows were kept open 5 to 10 cm, suffered no envelope damage while others (on the same or lower floors) displayed more pronounced damage.

Lessons Learned: Envelope Airtightness

- Basically, opening a window in one suite of a MURB drops the indoor-to-outdoor pressure differential to zero and protects that suite from moisture damage caused by air exfiltration/moisture deposition.

Lessons Learned (con't)...

- One implication is that if MURB's are to operate with low levels of natural air leakage, then improved HVAC strategies will be required – if people open windows on a regular basis (to lower the temperature, reduce odours, etc.), then the airtightness and air movement patterns will be controlled by window usage.