MMM GROUP

Ventilation and Energy Efficiency in MURBs

Building Science, Ventilation code and Energy codes

COMMUNITIES
TRANSPORTATION
BUILDINGS
INFRASTRUCTURE

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Multifamily Buildings

Controlling Stack Effect-Driven Airflow

By Joseph W. Lstiburek, Ph.D., P.Eng., Fellow ASHRAE

The author is a proponent of the individual buildings and individual services and systems school (in addition to being a Red Sox fan). In the author's world, compartmentalization and the Red Sox rule. The most elegant argument for compartmentalization of apartment buildings comes from Handegord.[1]

Stack effect-driven airflows in tall buildings compromise smoke control and fire safety, adversely affect indoor air quality and comfort as well as increase operating costs for space conditioning energy (*Figure 1*). By isolating the units from each other and from corridors, shafts, elevators and stairwells, stack effect-driven interior airflows can be controlled (*Figures 2* and *3*).

To achieve compartmentali... airtightness should meet a m... sistance or air permeance of 75 Pa (0.4 cfm/ft² at 0.30 ... is the recommended min... of enclosure air barri... level of unit airtightn... control stack effect a... airflow from adja... contamination. ... should be locat...

About the Au...

Joseph W. L... cipal of Bui... ford, Mass.

Joseph W. Lstiburek

How Buildings Stack Up

BY JOSEPH W. LSTIBUREK, PH.D., P.ENG., FELLOW ASHRAE

We live at the bottom of an ocean of air. Each of us is carrying around 14.7 pounds per square inch when at the beach in Miami.* We are powerful creatures indeed. Imagine carrying around 101,000 Pascals on that beach. Or 1,010 millibars. As elevation increases, the weight of the air we are carrying around decreases. This decrease in weight with elevation is called the lapse rate (*Figure 1*).

The lapse rate thing gets interesting with buildings. In a heated building, the lapse rate inside is less than the lapse rate outside. This is due to the reduced density of heated air compared to unheated air. Check out *Figure 2*. The assumptions in this figure are important. There is only one hole in the building enclosure, and it is at the bottom. There are also no interior floors or partitions. So we have an airtight building (except for the one hole at the bottom) with no interior flow resistance. And, the building is heated. At the hole, the pressure inside equalizes with the pressure outside. As we go up with height, the pressure difference between the inside and outside gets bigger. This difference in pressure is called the stack effect.

The stack effect gets its name from the same phenomenon that causes hot combustion gases to rise in a chimney or chimney stack. A heated house or heated building can be considered a giant chimney that we live and work inside. The taller the building, the greater the stack effect. The colder the temperature, the greater the stack effect. So, in heated buildings, the air tends to flow out of the top of the building while inducing air to flow in at the bottom.

Now let's look at *Figure 3*. The hole is at the top of the building. All other assumptions are the same. Once again, at the hole, the pressure inside equalizes with the pressure outside. As we go down in height, the pressure difference between the inside and outside gets bigger—but it is in the opposite direction. Neat, eh? The interior pressure line (the interior lapse rate "line") moves laterally—horizontally shifts to the left from *Figure 2* to *Figure 3*. The "solid" line does not move. The "dotted" line moves. The slope of the "dotted" line does not change, it just shifts left.

What happens when we have two holes the same size? One at the top and one at the bottom? Check out *Figure 4*. The "dotted" line shifts right partially. It crosses the "solid" line smack dab in the center of the building elevation wise. Where the interior lapse rate line crosses the exterior lapse rate line, the pressure inside equals the pressure outside. No pressure difference exists. We call that the neutral

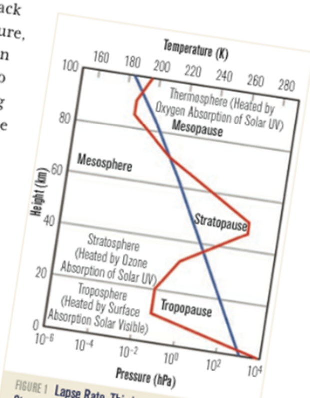


FIGURE 1 Lapse Rate. This is a chart of the U.S. Standard Atmosphere (1976). The red line is the temperature lapse rate. The blue line is the pressure lapse rate. The pressure lapse rate is around 12 Pa per meter or 3.6 Pa per foot.

*Why Miami? Ah, I am thinking warm thoughts. Any sea level location would have worked. Unfortunately, the International Civil Aviation Organization (ICAO) Standard Atmosphere assumes a temperature of 15°C (59°F). Not exactly bathing suit weather except for Canadians. It also assumes no water vapor. So it is a "dry cold."

High Rise Ventilation
– Opportunities for Improved Performance

Topics of Discussion:

- a little history
- the Building Science
- measurements from the real world
- what does the Ventilation Code actually say?
- compartmentalization as a solution
- building Energy Codes enforced in Canada
- case studies of buildings using balanced in-suite ventilation with exhaust air heat recovery

Short History

High rise ventilation went through stages

- Corridor ventilation for fire and smoke control
- Exhaust from kitchen & bathrooms
    - o Central exhaust stack ducts were tried
- Corridor ventilation as air make-up and odor control
- Larger and more exhaust appliances in-suite
- Tighter buildings, air conditioning, better heating options
- Ever increasing odor and noise complaints
- More diverse occupancy and luxury lifestyles

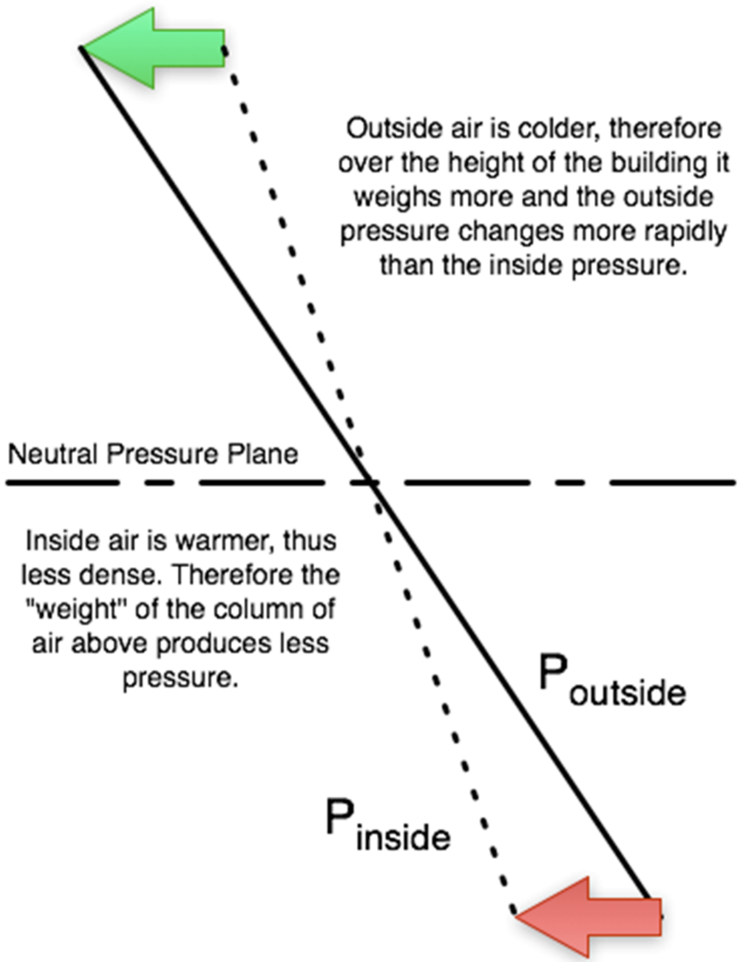
Airflow in Buildings

3 things are required to move air

- Pressure difference
- Path
- Um, errr…. Well air!

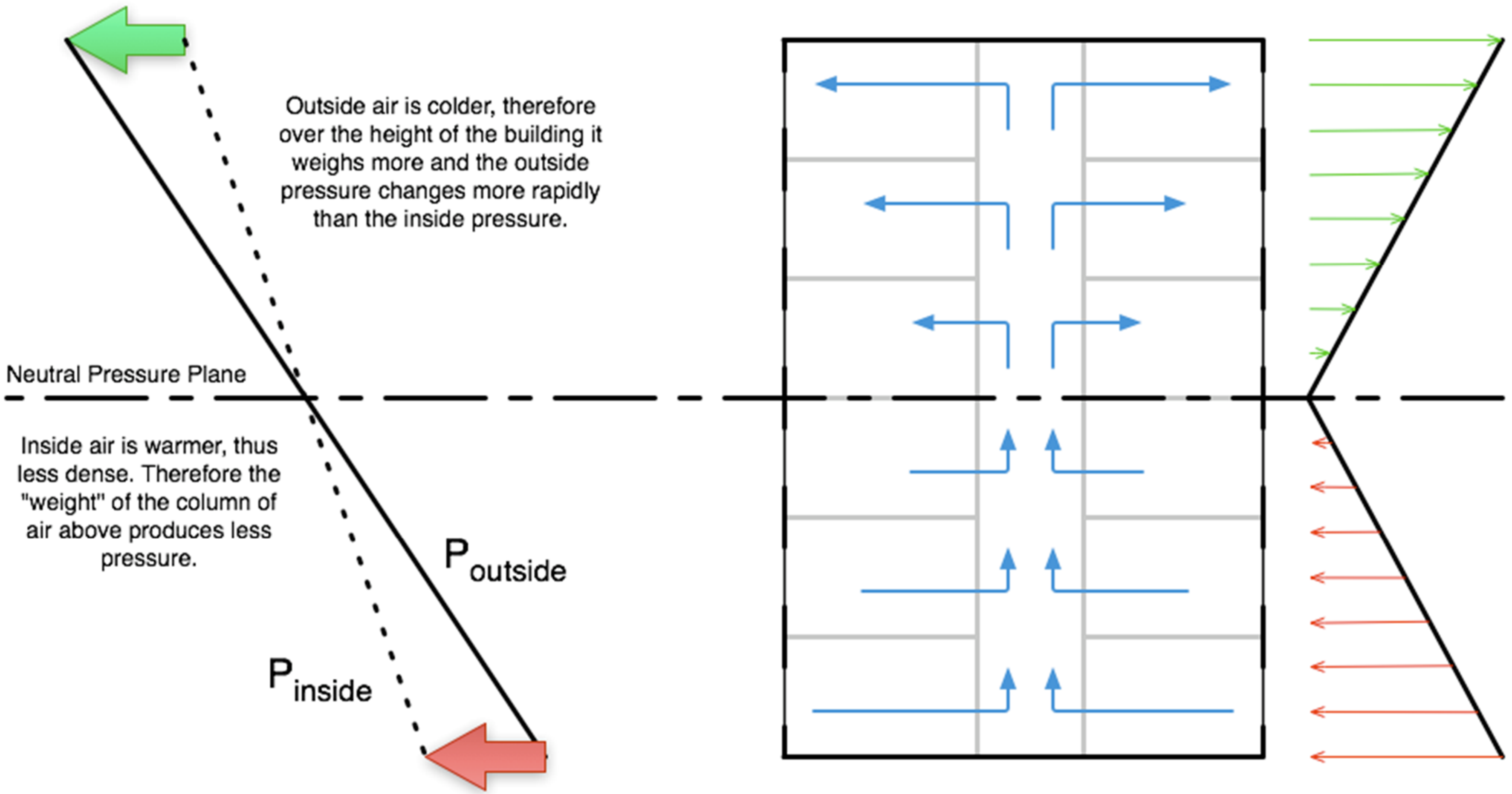
Buildings in winter are just hot air balloons

Stack Pressures acting on hi-rise buildings

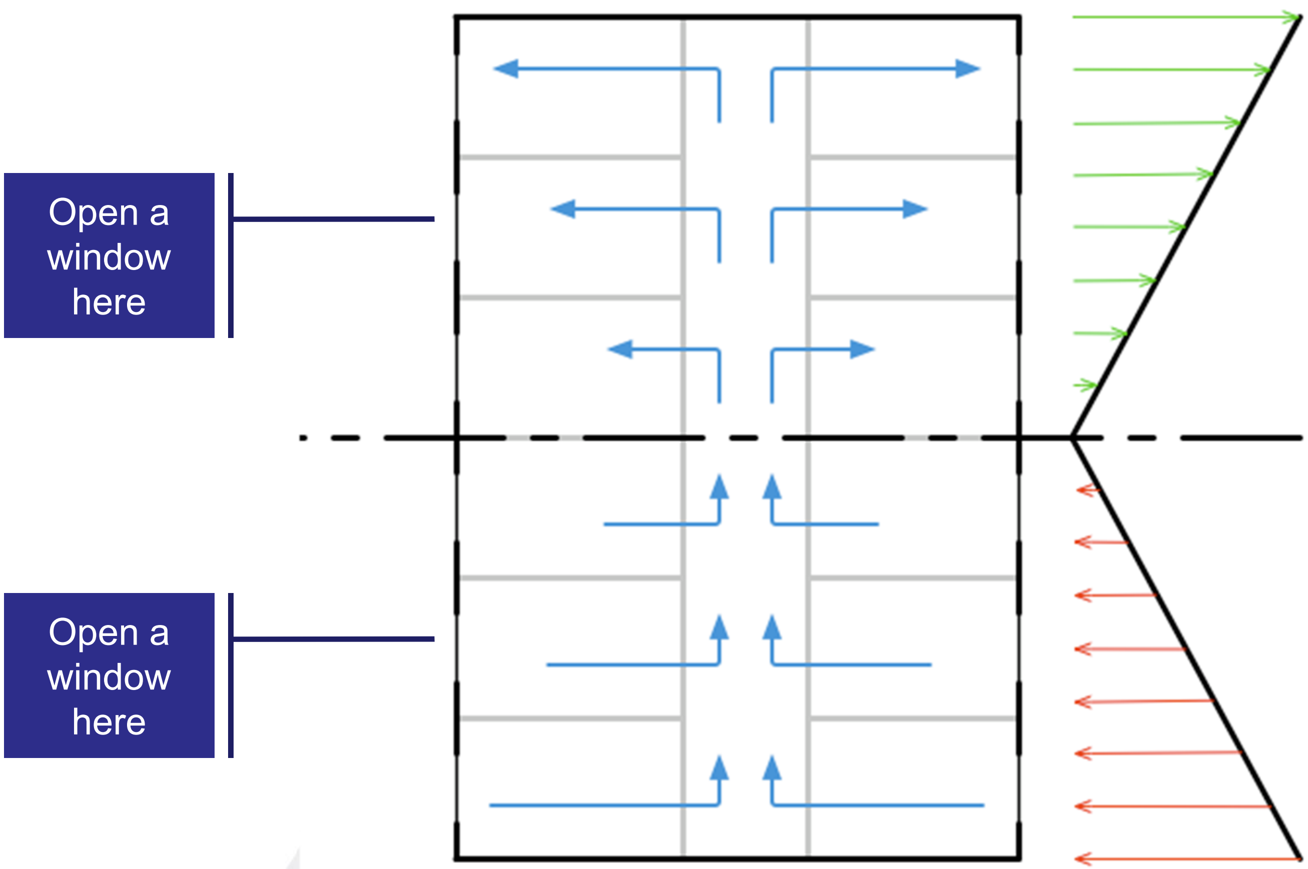


- the higher the building the greater the stack effect
- the colder it is outside the greater the stack effect
- warm air rising is an affect, the cause is colder denser air displacing it

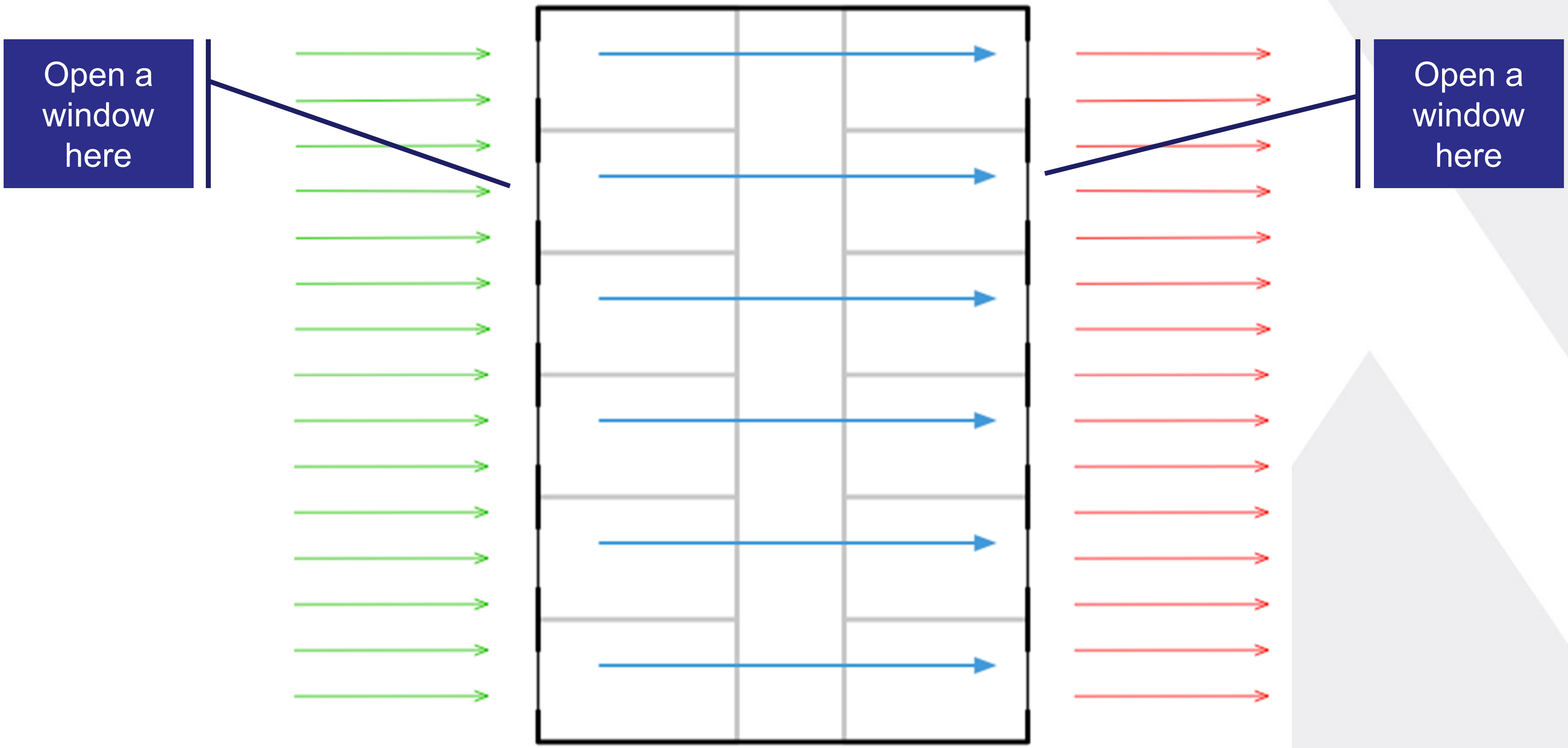
Stack Pressures acting on hi-rise buildings



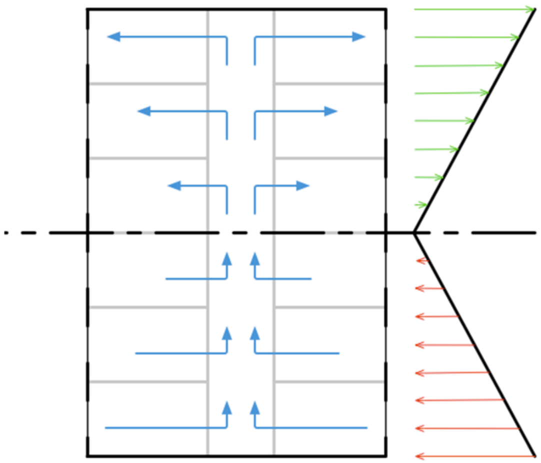
Stack pressure acting on hi-rise buildings

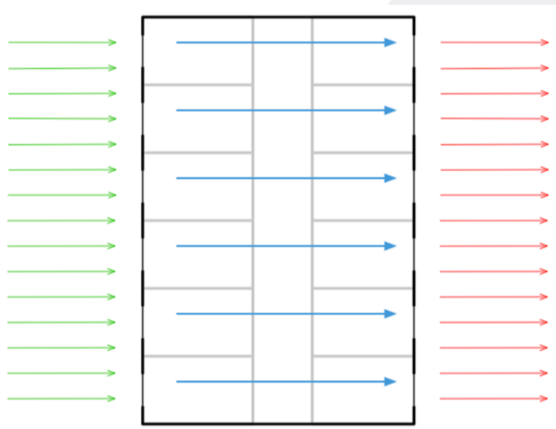


Wind Pressures acting on hi-rise buildings



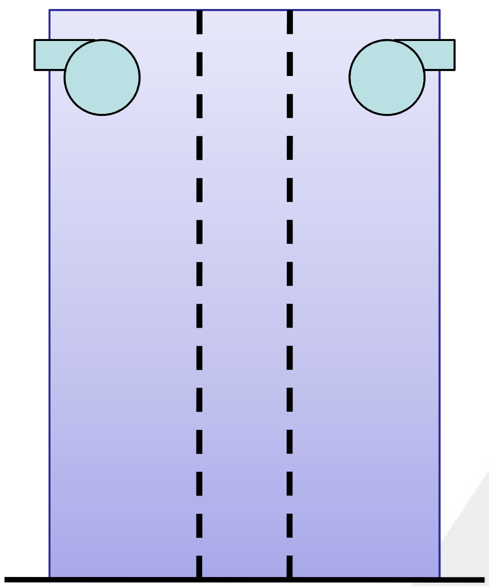
High Rise Technical Challenges



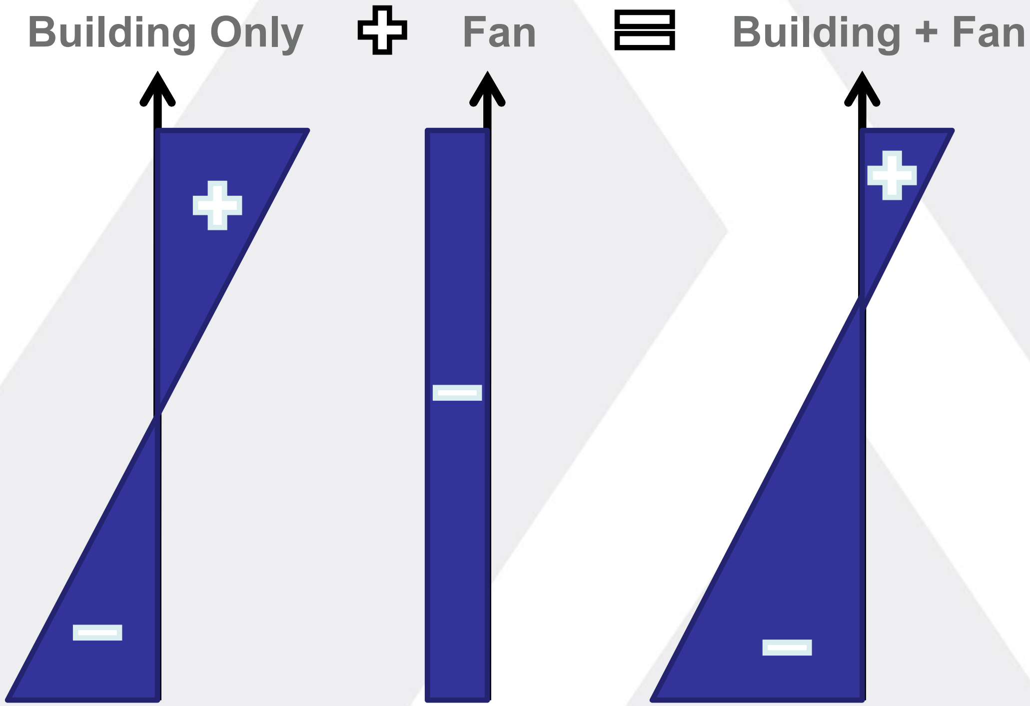


- Wind Pressure
  – up to 300 Pa
- Stack Pressure
  – up to 120 Pa
- Mechanical Pressures
  – typically 75 Pa
  - more and larger appliances
  - tighter buildings (this is a good thing)
  - residents want operable windows
- Higher energy costs
- Air conditioning

So how have we traditionally ventilated these buildings?



Exhaust only



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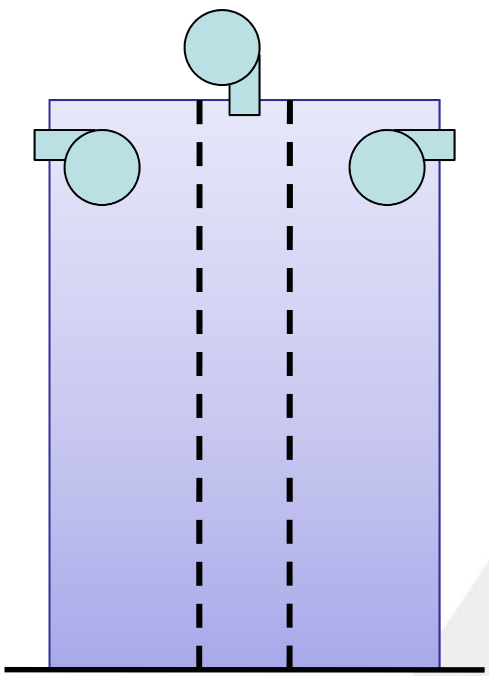
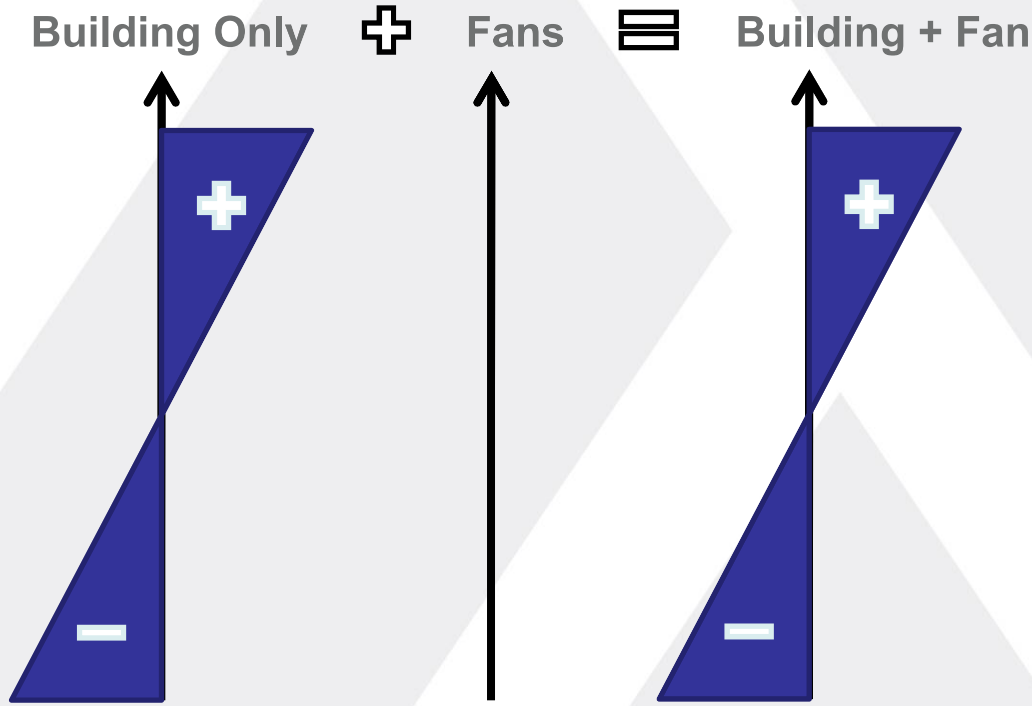


Exhaust and Pressurized Corridor



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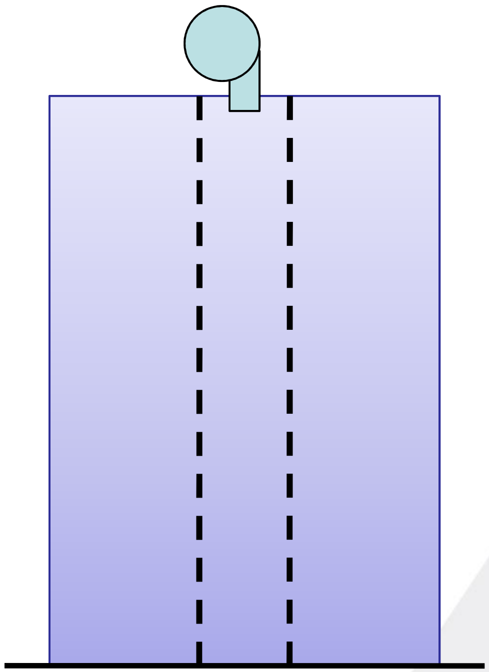
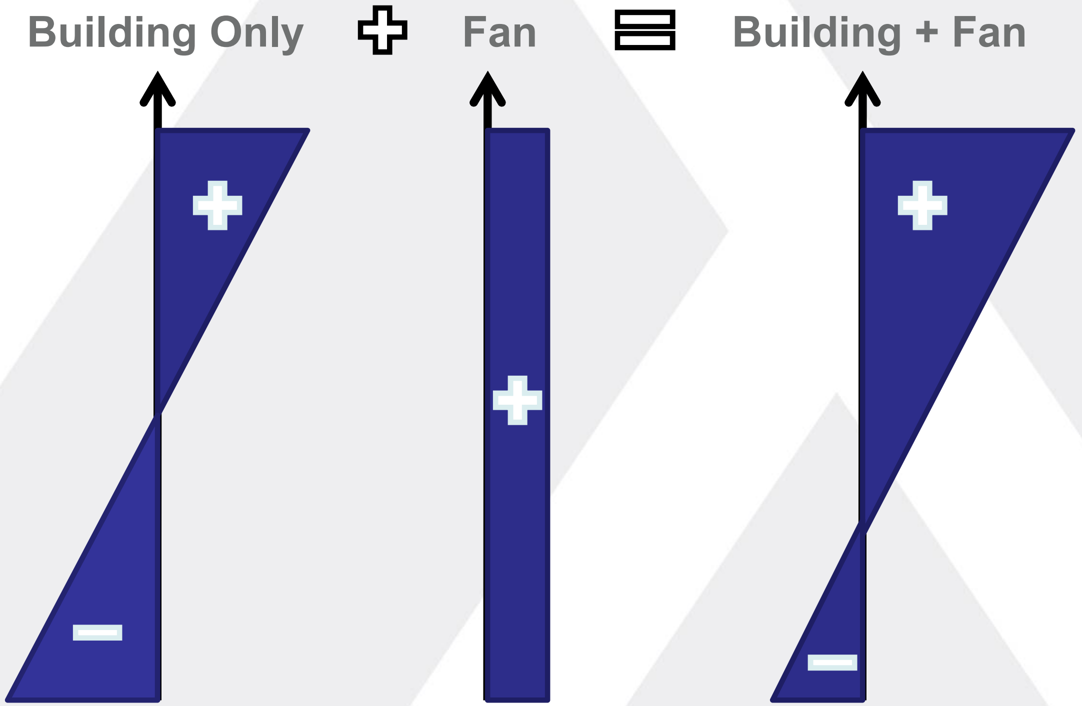


Pressurized Corridor Only – exhaust is off



The possible consequences?

- Canadian “toque” for buildings
- Mould issues on higher floors
- Hey I can smell what’s for dinner!

Translation…

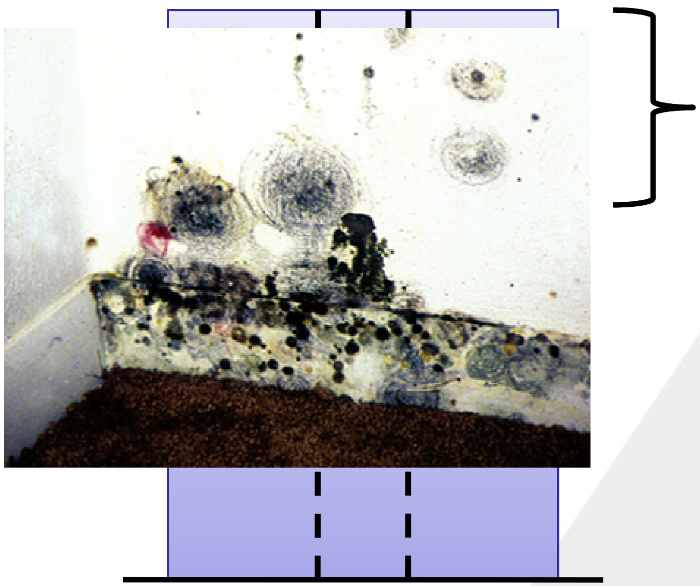
- Poor durability
- Poor air quality

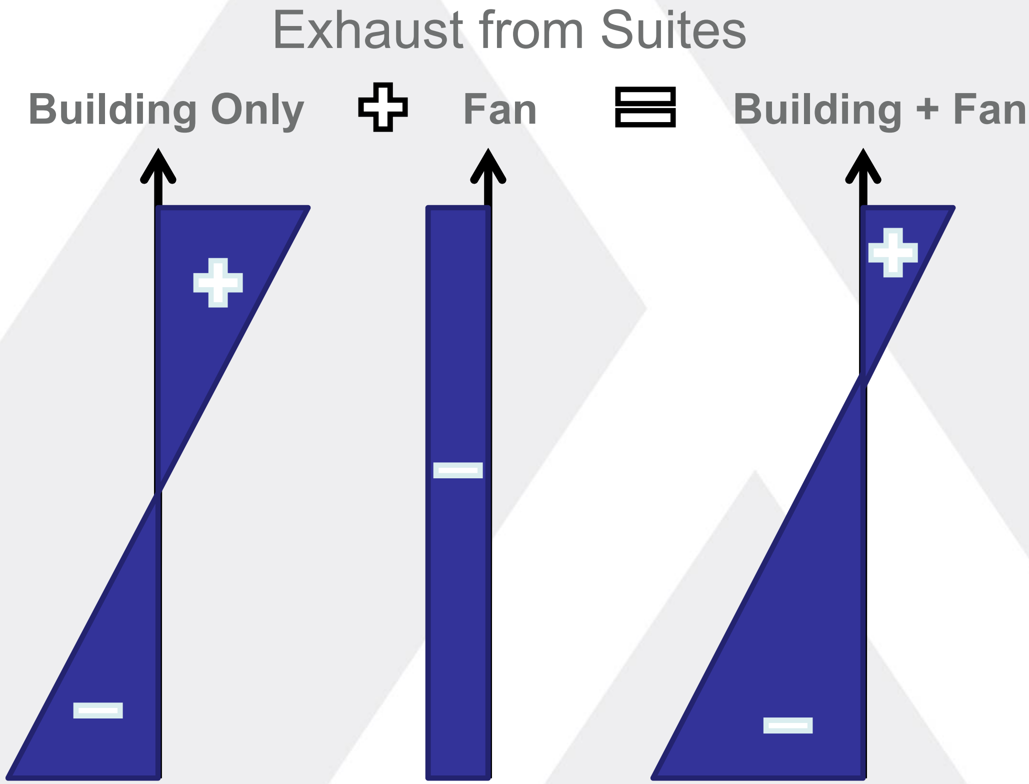
“My definition of cost effective is a fully occupied building—I want to be able to tell prospective buyers, who are moving from single family homes, that they will not perceive smells from their neighbors.”

-- condo developer

Air Quality – a real building

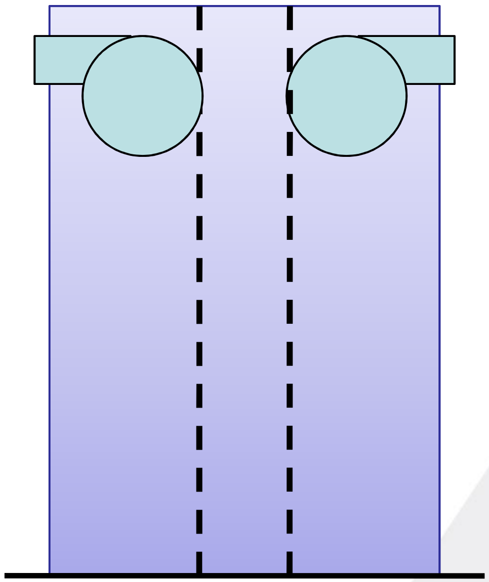
Mold growing on floors above neutral pressure plane



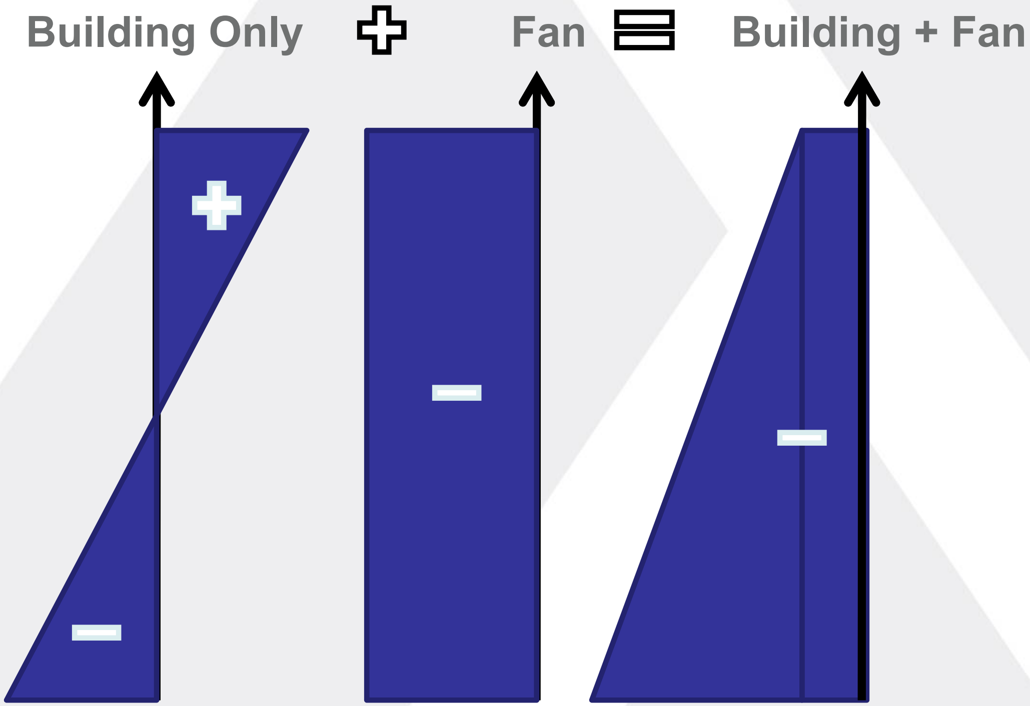


Air Quality – Renovation Solution

Big Fans

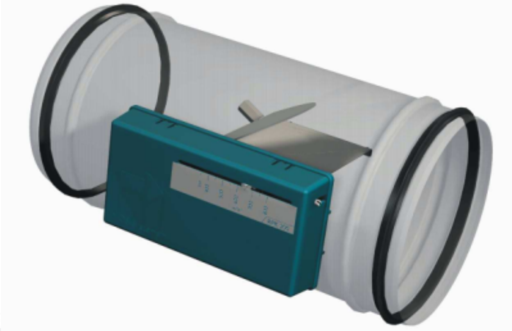


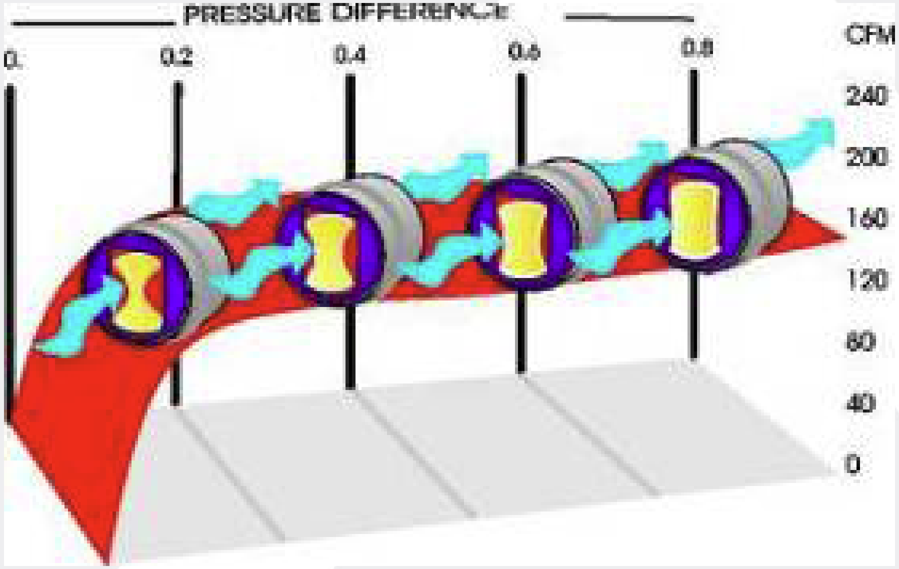
Exhaust from Suites



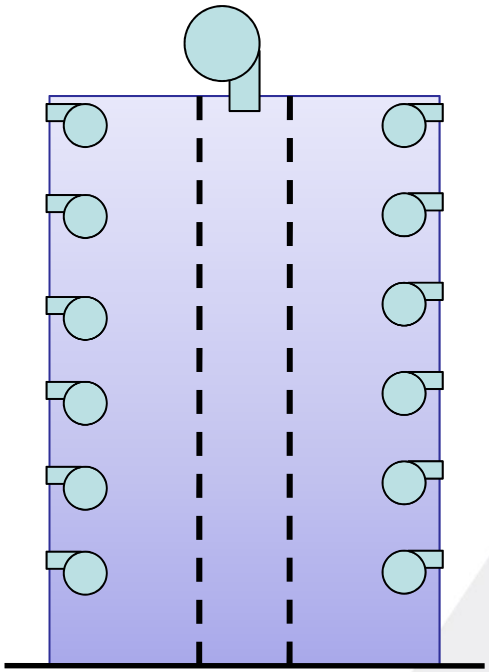
Air Quality – Renovation Solution

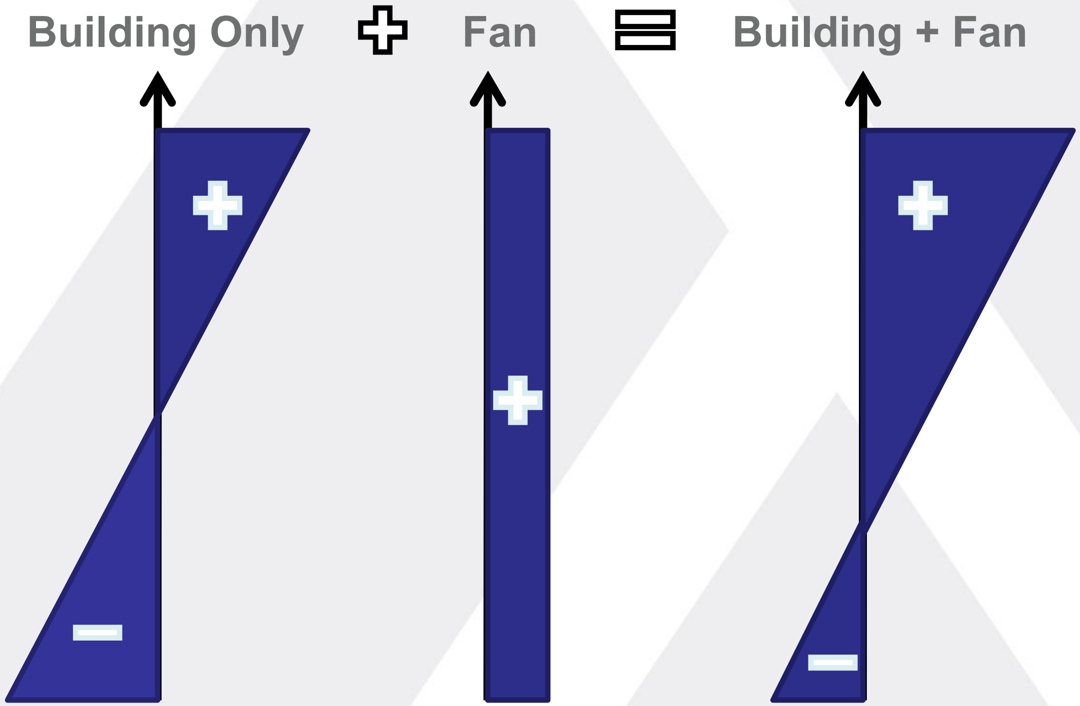
- But how to control exhaust air flow rate on each floor?
  - Constant flow regulators
  - Requires very airtight ductwork
- Corrected air quality problem… though was a high energy consumption solution





Real Word Measurement of Corridor Pressurization with Suite Exhaust…





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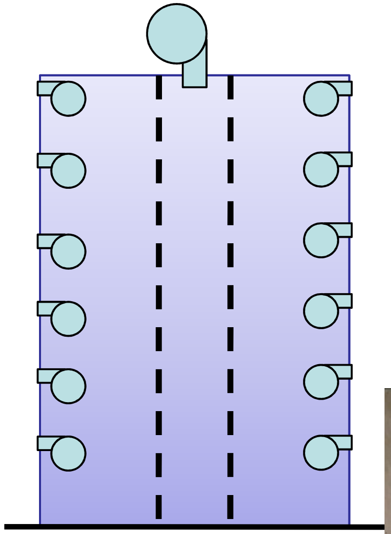
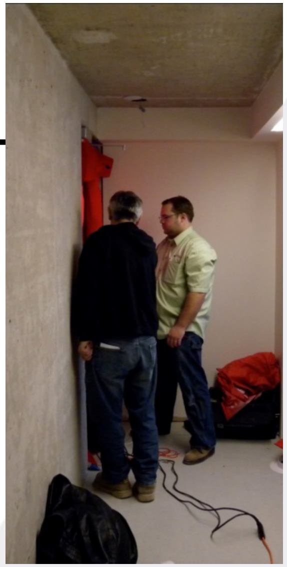


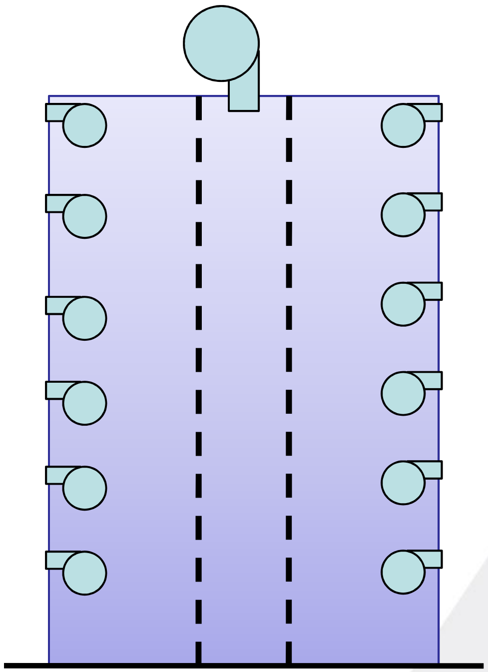


100 CFM / suite of pressurization provided

Measurements:

- with **exhaust fans operating** 40% of corridor air didn't reach the suites
- inadequate pressurization of corridor (under 5 Pa)
  - sealing suite doors increased corridor pressurization,
  - but reduced transfer of air to suites

Real Word <u>Measurement</u> of Corridor Pressurization with Suite Exhaust…



Conclusions

- corridor make-up air systems are wasting 40% of supply air
- sealing corridor increases pressurization
- ventilation needs to be provided directly to the suite

But before we get to that, what is involved in making corridor pressurization ventilation air code compliant?

Ventilate Right

- Ventilation Systems MUST be able to:
  - Exchange
  - Treat
  - Distribute and
  - Circulate
  - Test and Verify!

- … delivery of outdoor air to all habitable rooms in a building.

Ventilate Right

- What is the Quality of Corridor Air?
  - used by persons in corridor – respiration, smoking and other bodily effluents
  - proven interconnections to parking garages, garbage chute rooms, storage areas
  - cooking and other odours from other apartments often intrude into the corridor

ASHRAE 62.1-2007/2010 Ventilation Requirement in Breathing Zone

$$V_{bz} = R_p\,P_z + R_a\,A_z$$

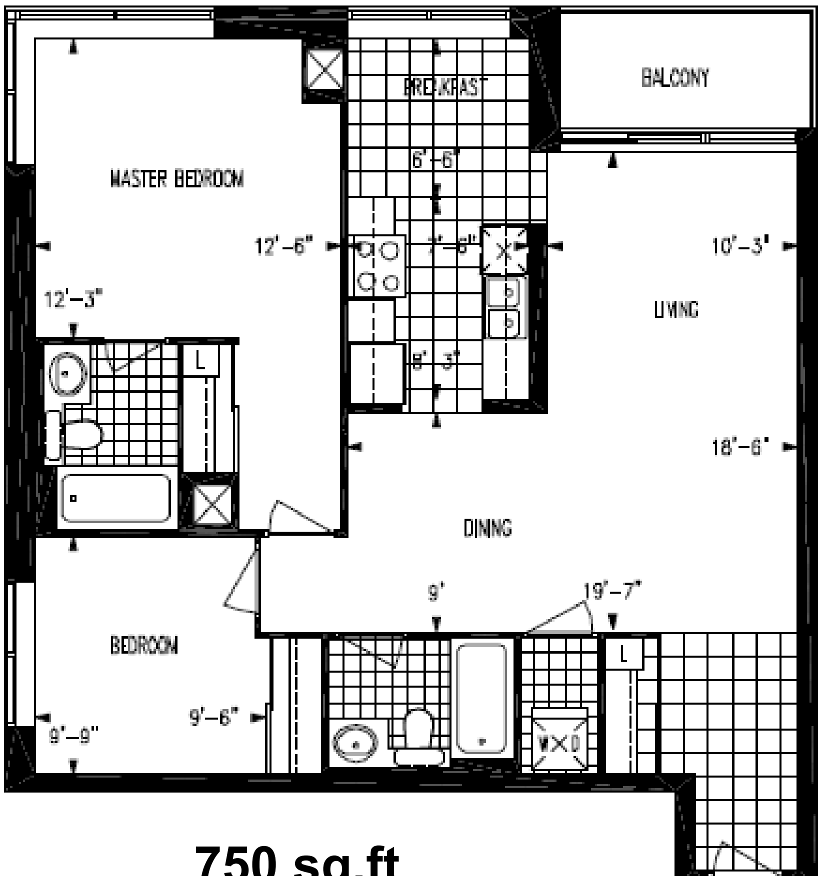
dilution of bioeffluents

dilution of background VOCs

- **Rp** outdoor air floor rate required per person
- **Pz** zone population: the number of people in the *ventilation zone* during **typical** usage
- **Ra** outdoor airflow rate required per unit area
- **Az** zone floor area: the *net occupiable floor area* of the *ventilation zone*

- **Ventilation zone:** any indoor area that requires ventilation
- **Net occupiable area:** the floor area of an occupiable space defined by the inside surfaces of its walls, but excluding shafts, column enclosures, etc.
  - in residential dwelling units – the entire floor area, excluding closets

Ventilate Right – ASHRAE 62.1-2007/2010



750 sq.ft.

	ASHRAE 62.1-2007/2010
Ra	0.06 CFM/ft²
Rp	5 CFM / person
Vbz	0.06 x 750 + 3 x 5 = 60 CFM
Kitchen Exhaust	50 CFM continuous or 100 CFM intermittent
Bathroom Exhaust	25 CFM continuous or 50 CFM intermittent
Total Exhaust	75 CFM continuous or 150 CFM intermittent

So we need 60 CFM with intermittent exhaust correct?

V_{bz} is ventilation requirement in "breathing zone"

$$V_{bz} = R_p P_z + R_a A_z$$

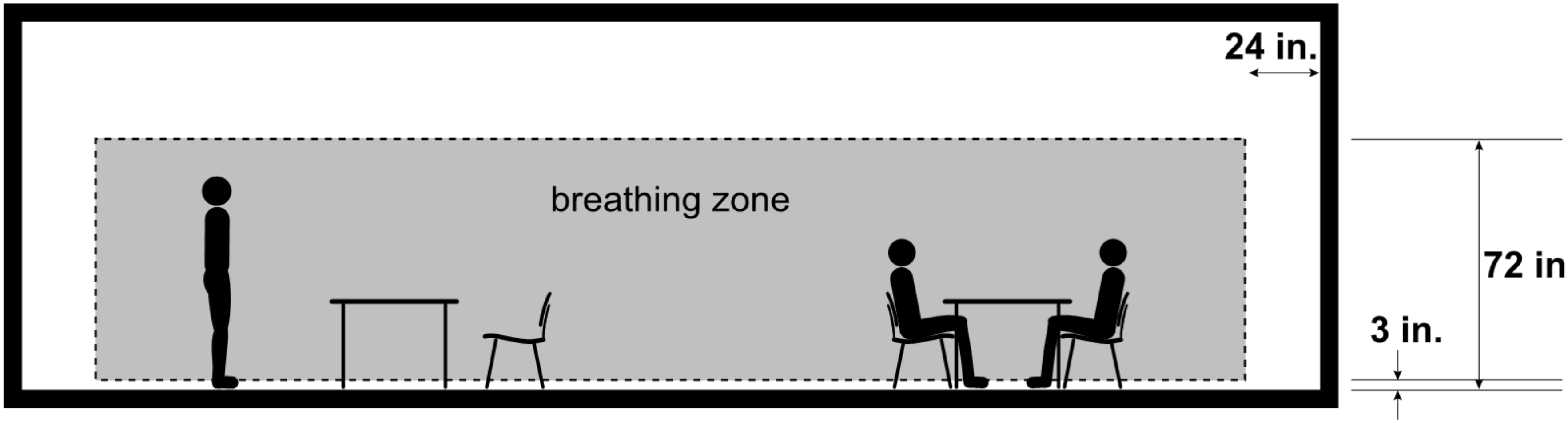


Figure 6-A—Breathing Zone

Note: Az is defined to the inside wall surface (do not subtract 24" x2 inches)

Breathing Zone (V_{bz})

- Zone occupied by people, where they notice "bad air quality"
- Goal is to deliver ventilation air for dilution of pollutants, into this breathing zone

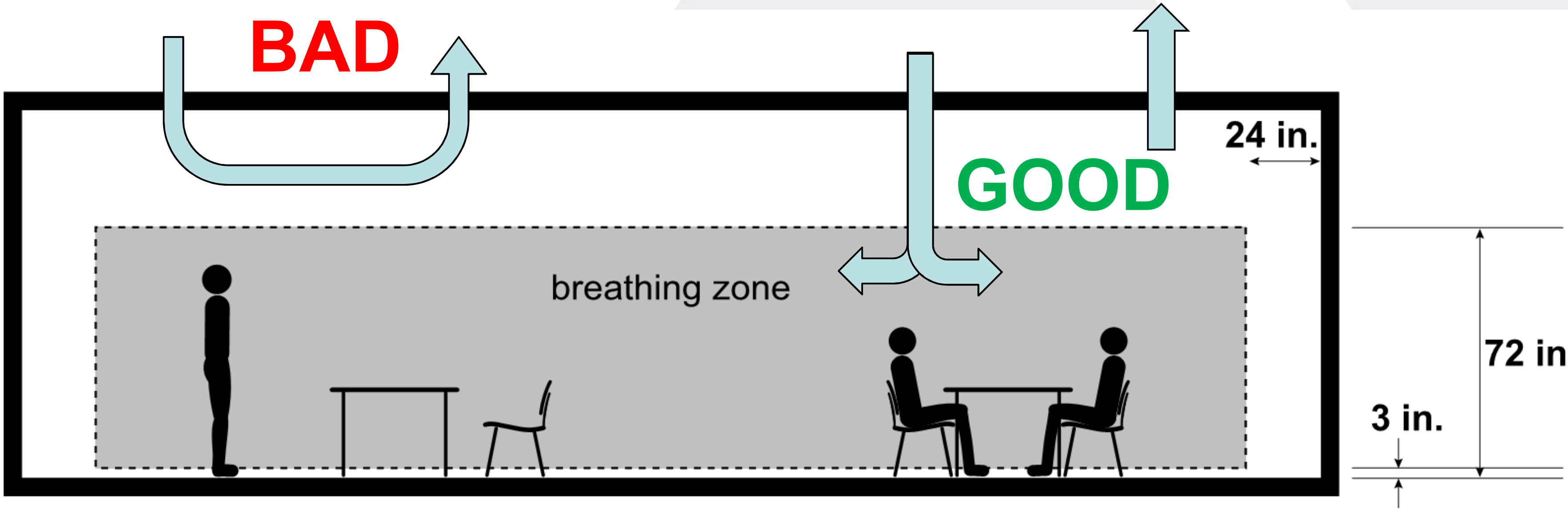


Figure 6-A—Breathing Zone

Zone Air Distribution Effectiveness (E_z)

- Zone Air Distribution Effectiveness (E_z) is metric on how well ventilation air is distributed to the breathing zone
- ASHRAE Standard 129 "Measuring Air-Change Effectiveness"
  - Ez can be between:
    - 0.0 – no ventilation air reaches the breathing zone and
    - 1.0 – perfect mixing of ventilation air in the space
    - 2.0 – perfect "plug flow"

$$V_{oz} = V_{bz} / E_z$$

- **V_{oz}** outdoor air provided to the ventilation zone (dwelling units)

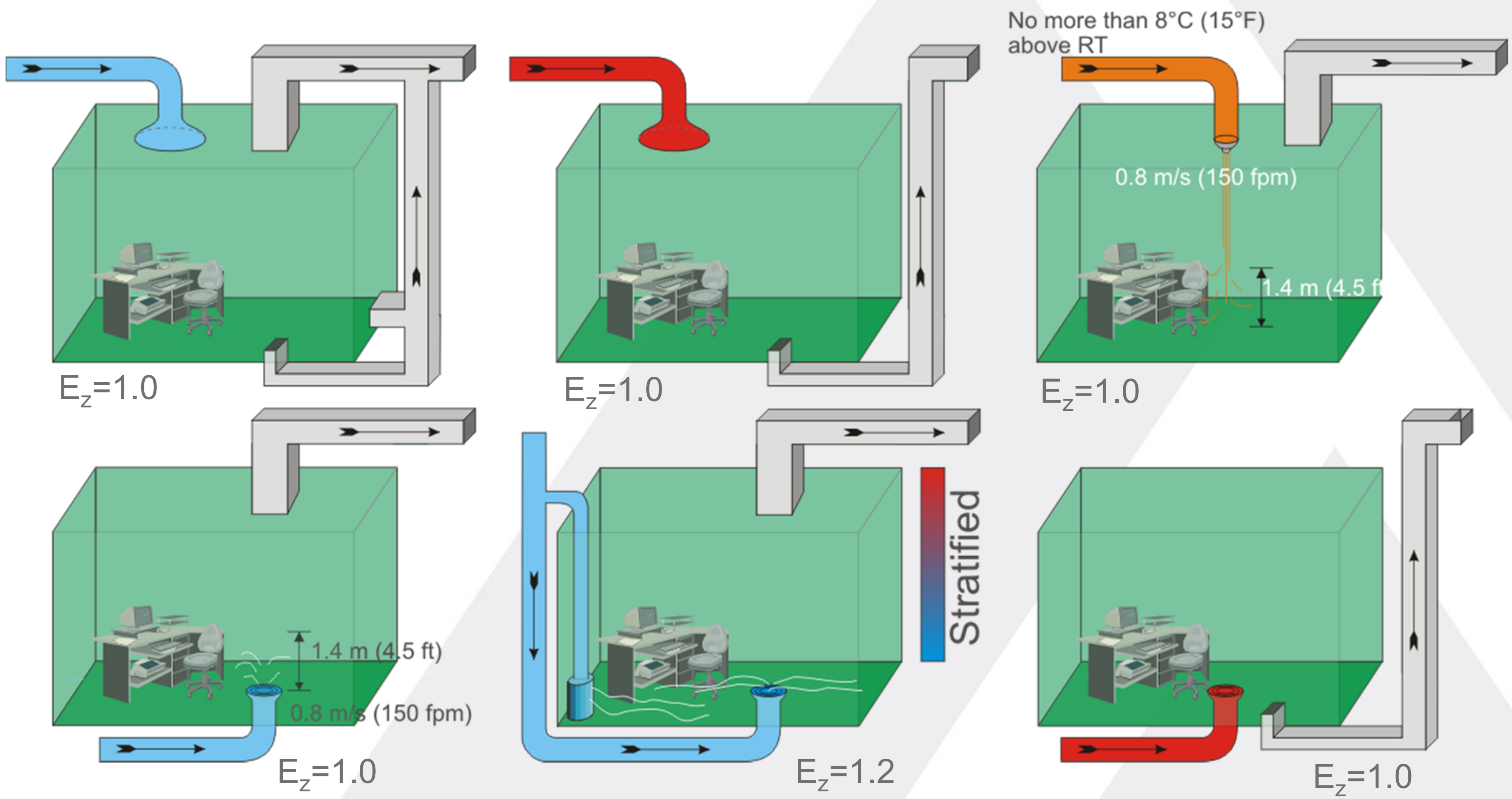
Zone Air Distribution Effectiveness

table of default values for Zone Air Distribution Effectiveness in Standard 62.1 (Table 6-2) is based on this research as well as engineering judgment for applications where research is less complete

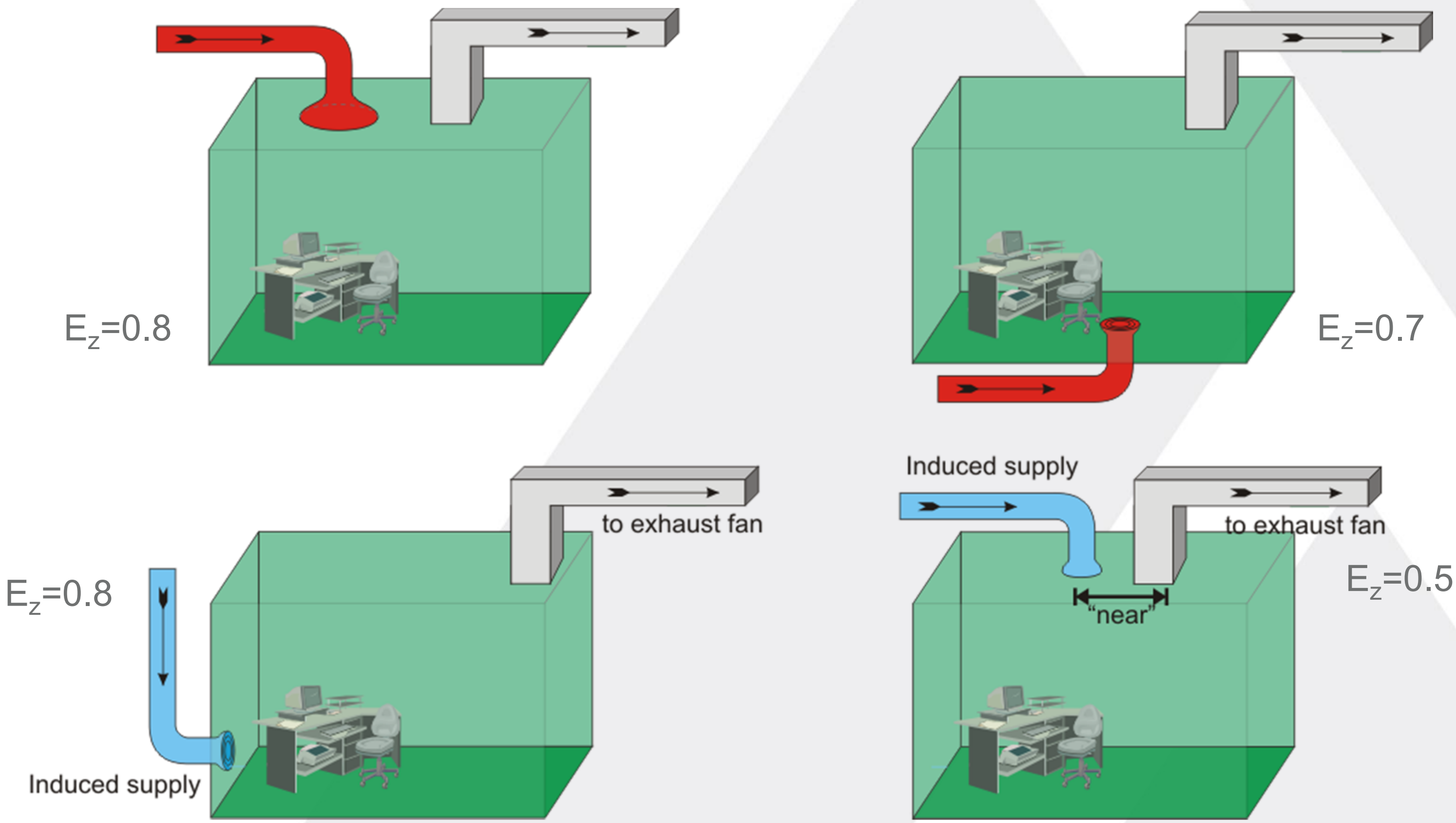
TABLE 6-2 Zone Air Distribution Effectiveness

Air Distribution Configuration	E_z
Ceiling supply of cool air.	1.0
Ceiling supply of warm air and floor return.	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return.	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level. ***Note:*** For lower velocity supply air, E_z = 0.8.	1.0
Floor supply of cool air and ceiling return provided that the 150 fpm (0.8 m/s) supply jet reaches 4.5 ft (1.4 m) or more above the floor. ***Note:*** Most underfloor air distribution systems comply with this proviso.	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification.	1.2
Floor supply of warm air and floor return.	1.0
Floor supply of warm air and ceiling return.	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust and/or return.	0.8
Makeup supply drawn in near to the exhaust and/or return location.	0.5

Good: E_z is 1.0 or greater…



Bad: E_z is less than 1.0…

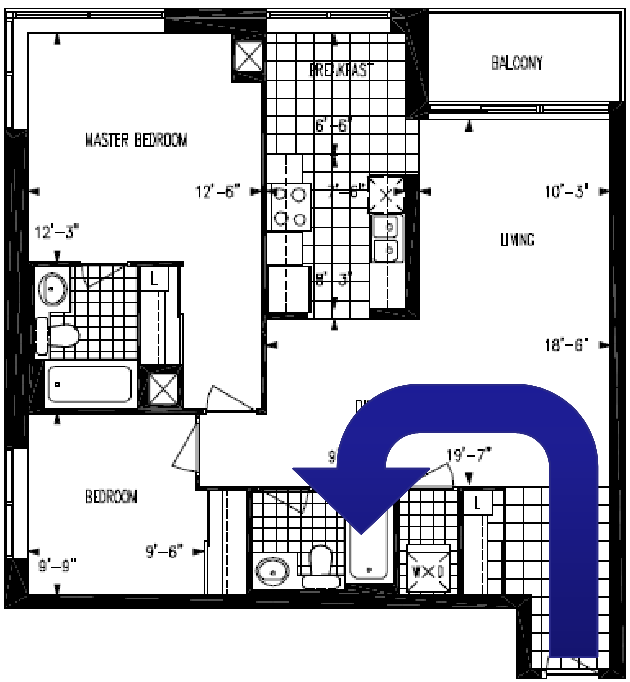


exhaust on opposite side of the room from "drawn" supply

Ventilate Right – ASHRAE 62.1-2007/2010

ASHRAE 62.1-2010 User Manual example for pressurized corridor and bathroom exhaust suggests

Ez = 0.5



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Ra	0.06 CFM/ft
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Total Exhaust	75 CFM continuous or 100 CFM intermittent

So we need 120 CFM with intermittent exhaust correct?

Ventilate Right – ASHRAE 62.1-2007/2010

ASHRAE 62.1-2007/2010 Clause 7.2.2

"**7.2.2 Air Balancing.** Ventilation system shall be balanced in accordance with ASHRAE Standard 111, SMACNA's HVAC Systems—Testing, Adjusting and Balancing, or equivalent at least to the extent necessary to verify conformance with the **total outdoor air flow** and **space supply air flow** requirements of this standard."

We know from trying to do this that over 40% of corridor air does not reach the suites, only 60% reached the suites….

120 CFM ÷ 60% becomes **200 CFM per suite** for a corridor system

Ventilate Right – ASHRAE 62.1-2007/2010

ASHRAE Interpretation 62.1-2007-20, Jan 29, 2011

Interpretation: It is my interpretation that ventilation air shall be supplied directly to the apartment, in one location, based on the total occupants and the combined bedroom/living area per Table 6-1.

Question: Is this interpretation correct?

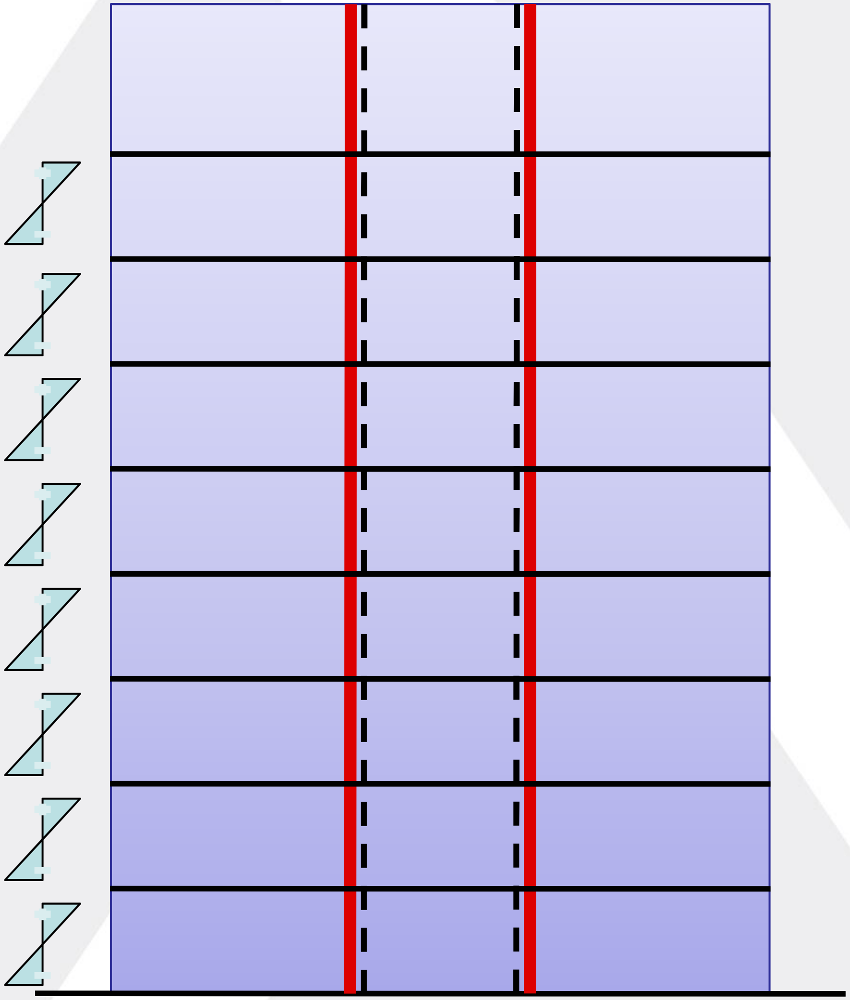
Answer: No

Comments: The occupancy category "Bedroom/living room" applies to a single-room configuration. The design must be such that the outdoor air (Vbz) will be supplied or distributed to the breathing zone in the occupiable space or spaces within a ventilation zone (see Section 6.2.2.1).

Suites using fan coils (or heat pumps) may be able to claim that air is distributed to all rooms…

But what about when there is no call for heat/cooling and fan coil is off?

Compartmentalizing is a solution – to many problems



Compartmentalization of Units

- In MURBs put “air lock” at suite doors
- Make suites “air tight”
  - Exterior walls are generally reasonably air tight already
  - Interior partitions are easily addressed
  - Weather strip suite doors

  - Solves air movement problems (odours, tobacco smoke)
  - Provides sound control between suite and corridor
  - Decreases pressures difference across building envelop, enabling exhaust devices to move air more reliably

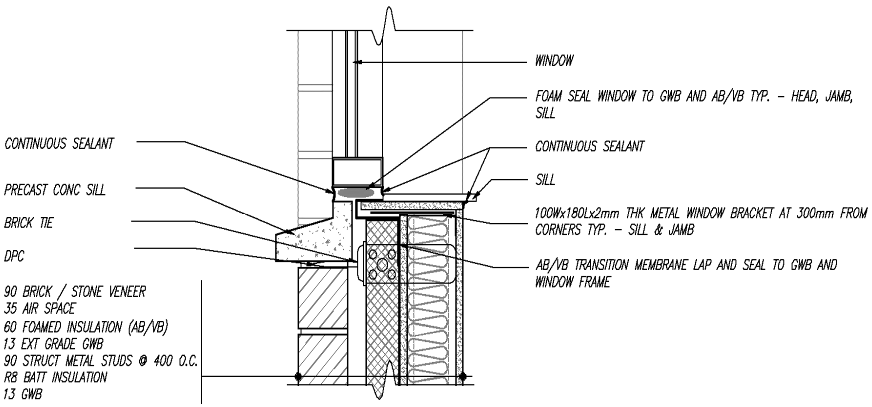
- But how to ventilate?

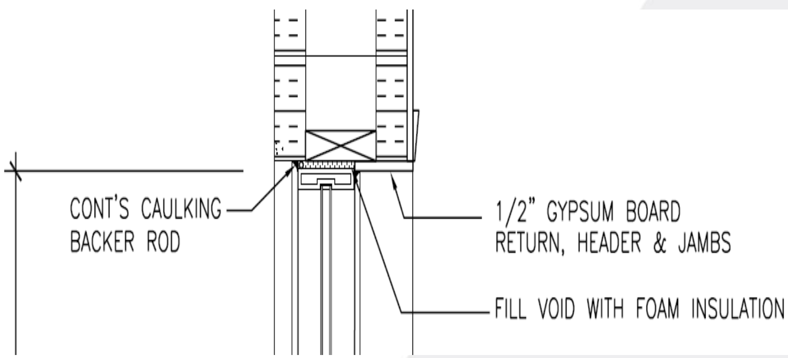
  have patience, I’m getting there

Designing for Air-tightness

- Show a continuous air barrier
  - Exterior walls and interior walls
- Concrete shear walls are excellent air barriers
- So is gypsum board
  - If top and bottom and exterior electrical boxes are sealed.
- Sweat the details!
- Verify with Mock-up suites and blower-door

Sweat the details





- M/E services through wall, roof, etc.
- Wall to window
- Wall to roof
- Wall to slab
- Wall to foundation
- Etc.

Verify with Blower Door

Air tightness targets…

- In "perfect" world zero leakage
- Real world
  - best we can do at a reasonable effort
- Targets have been "arbitrarily" picked based on experience and ability of market to achieve
  - R-2000 1.5 ACH @ 50
    - (was compromise between 1.0 and 2.0)
  - LEED: 1.25in²/100ft² NLA using ASTM (4 Pa)

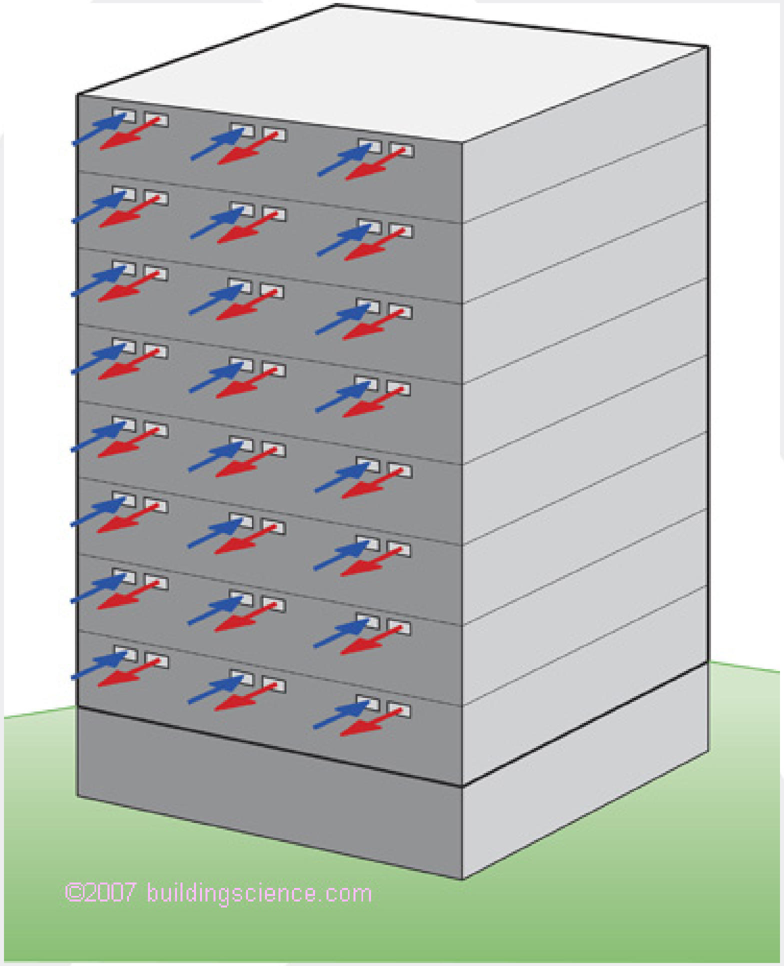
Air Tightness Targets and MMM Measurements Performance

	NLA – ASTM @ 4 Pa, Cd = 1.0.43 [in²/100ft²]	NLA – CGSB @ 10 Pa, Cd = 0.61 [in²/100ft²]	NLR @ 75 Pa [L/s-m² @ 75 Pa]
Target	**1.25**	**2.34**	**1.5**
Building A	0.60 – 0.84	1.13 – 1.58	0.72 – 1.01
Building B	0.36 – 0.73	0.68 – 1.37	0.43 – 0.88
Building C	0.23 – 0.76	0.43 – 1.43	0.28 – 0.92
Building D	0.55 – 0.75	1.03 – 1.40	0.66 – 0.90
Building E	0.67 – 1.33	1.26 – 2.50	0.81 – 1.6
Building F	0.439 – 0.867	0.826 – 1.63	0.53 – 1.04
CMHC Tests-Various buildings and units	0.291 – 0.838	0.546 – 1.58	0.35 – 1.01

Conclusion: air tightness targets for compartmentalization can be readily achieved. Requires attention to detail and quality assurance plan

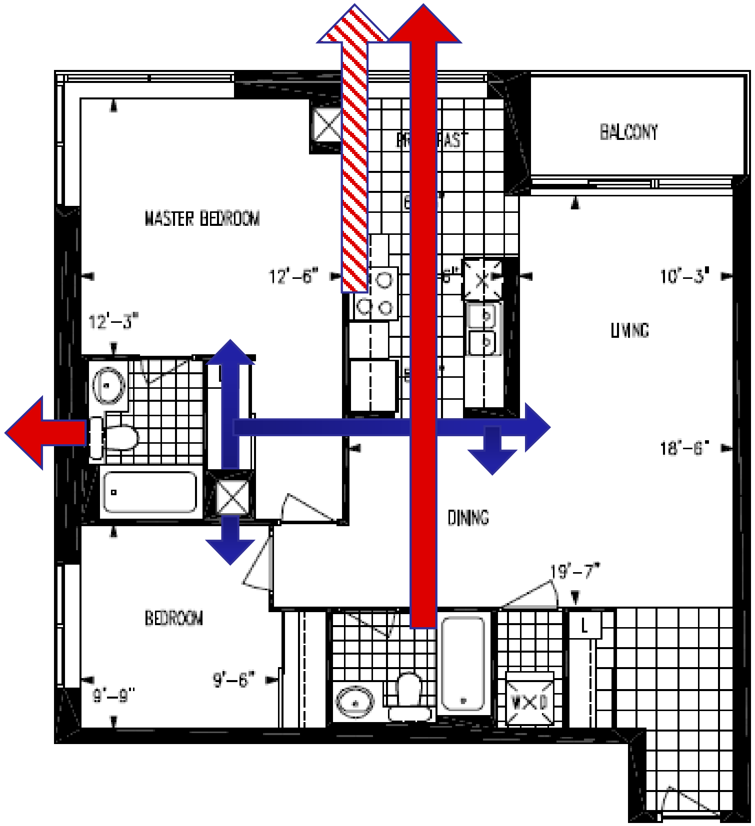
Distributed Ventilation

- Central systems defeat the intent of compartmentalization
  - difficult to balance through varying wind and stack effect pressures
- Central system with constant flow regulators
  - require high pressure
  - constant flow regulators are prone to clogging
- Solution – independent ventilation per suite



Ventilate Right – ASHRAE 62.1-2007/2010

using compartmentalization and per suite ventilation



	ASHRAE 62.1-2007/2010
Ra	0.06 CFM/ft
Rp	5 CFM / person
Vbz	0.06 x 750 + 3 x 5 = 60 CFM
Voz	**60 / 1.0 = 60 CFM**
Kitchen Exhaust	50 CFM continuous or 100 CFM intermittent
Bathroom Exhaust	25 CFM continuous or 50 CFM intermittent
Total Exhaust	75 CFM continuous or 100 CFM intermittent

60 CFM with constant bathroom exhaust and intermittent kitchen exhaust

Ventilation Comparison

	Total O/A supply to building
Common Practice (I haven’t read the code)	100 CFM / suite from corridor
Corridor Pressurization (I read ASHRAE 62.1)	120 CFM / suite from corridor
Corridor Pressurization, balanced and **verified** (I read **all** of ASHRAE 62.1)	~200 CFM / suite from corridor
Compartmentalization and per suite ventilation	60 CFM / suite in suite + 20 CFM / suite in corridor **80 CFM total / suite**

We’re energy and haven’t considered heat recovery yet!

But wait, can’t I rely on Natural Ventilation?

For example:

- 100 CFM per suite, of which **30 CFM** per suite corridor pressurization that reaches the breathing zone
- remainder from operable windows

Ontario Building Code Division B—6.2.2.2 Natural Ventilation

(1) Except as permitted by Sentence (2), the ventilation required by Article 6.2.2.1. **shall be provided by mechanical ventilation** except that it can be provided by natural ventilation or a combination of natural and mechanical ventilation in,

(a) *buildings* of **other than *residential occupancy*** having an *occupant load* of not more than one person per 40 m2 during normal use,

(b) *buildings* of *industrial occupancy* where the nature of the process contained in them permits or requires the use of large openings in the *building* envelope even during the winter, or

(c) seasonal *buildings* not intended to be occupied during the winter.

(2) Where climatic conditions permit, *buildings* containing ***occupancies* other than *residential occupancies***, may be ventilated by natural ventilation methods in lieu of mechanical ventilation where engineering data demonstrates that such a method will provide the required ventilation for the type of *occupancy*.

But wait, can't I rely on Natural Ventilation?

For example:

- 100 CFM per suite, of which **30 CFM** per suite corridor pressurization that reaches the breathing zone
- remainder from operable windows

ASHRAE 62.1-2010 (referenced by Ontario Building Code)

6.4 Natural Ventilation Procedure. Natural ventilation systems shall be designed in accordance with this section and shall include mechanical ventilation systems designed in accordance with Section 6.2 and/or Section 6.3.

Exceptions:

a. An engineered natural ventilation system, **when approved by the authority having jurisdiction, need not** meet the requirements of Section 6.4.

b. The **mechanical ventilation** systems are **not required** when:

   1. **Natural ventilation openings** that comply with the requirements of Section 6.4 **are permanently open** or have controls that **prevent the openings from being closed** during periods of expected occupancy, or
   2. The zone is not served by heating or cooling equipment.

WHAT ABOUT ENERGY EFFICIENCY?

Ontario Energy Code SB-10

Ontario SB-10 Energy Code requires a high performance enclosure

- High performance window (low-e and argon, double glazed)
- R-18 **effective** walls

NECB has similar and even more stringent requirements in colder climates

- R-27 **effective** wall in Winnipeg

- NECB is (will be) energy code in:
  - Nova Scotia
  - New Brunswick
  - Ontario (alternate path)
  - Manitoba
  - British Columbia (alternate path)

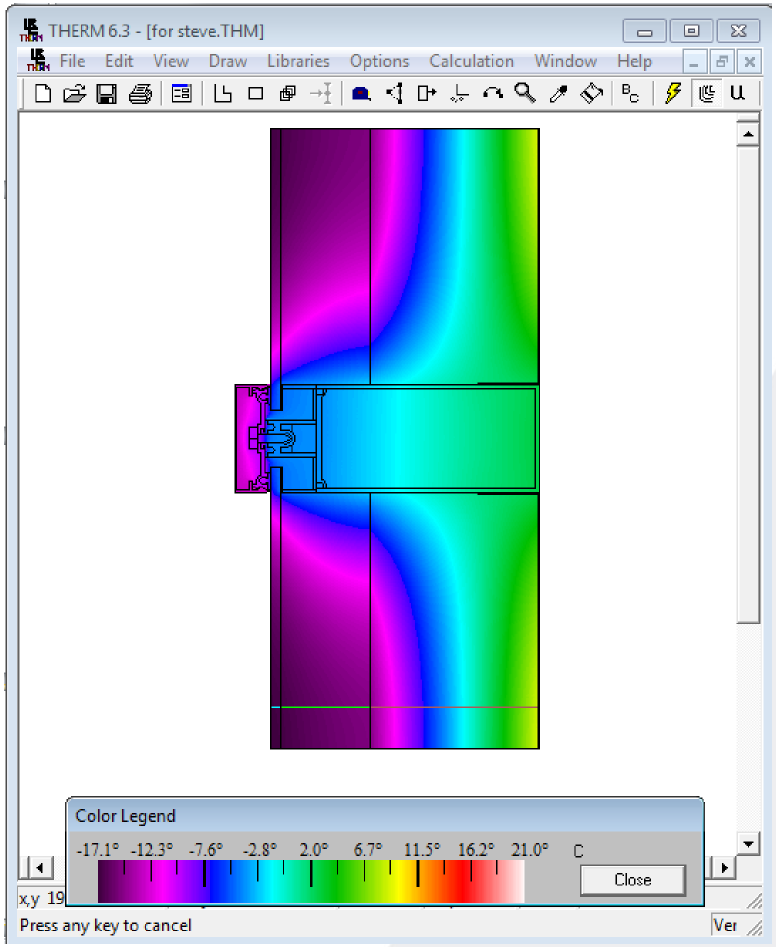
SB-10 Section 5 – Above Grade Wall Requirements (SB-10 revisions)

TABLE SB5.5-6 (See Appendix A.)
(Supersedes Table 5.5-6 in ANSI/ASHRAE/IESNA Standard 90.1)
Building Envelope Requirements for Climate Zone 6 (A, B) (I-P)

Opaque Elements	Nonresidential		
	Assembly Max. U	Insulation ·lation Min. R-Value	
Walls, Above Grade			
Mass	U-0.071	R-15.2 ci	
Metal Building	U-0.052	R-13.0 + R-13.0 ci	R-19 effective
Steel Framed	U-0.055	R-13.0 + R-10.0 ci	R-18 effective
Wood Framed and Other	U-0.045	R-13.0 + R-10.0 ci	R-22 effective

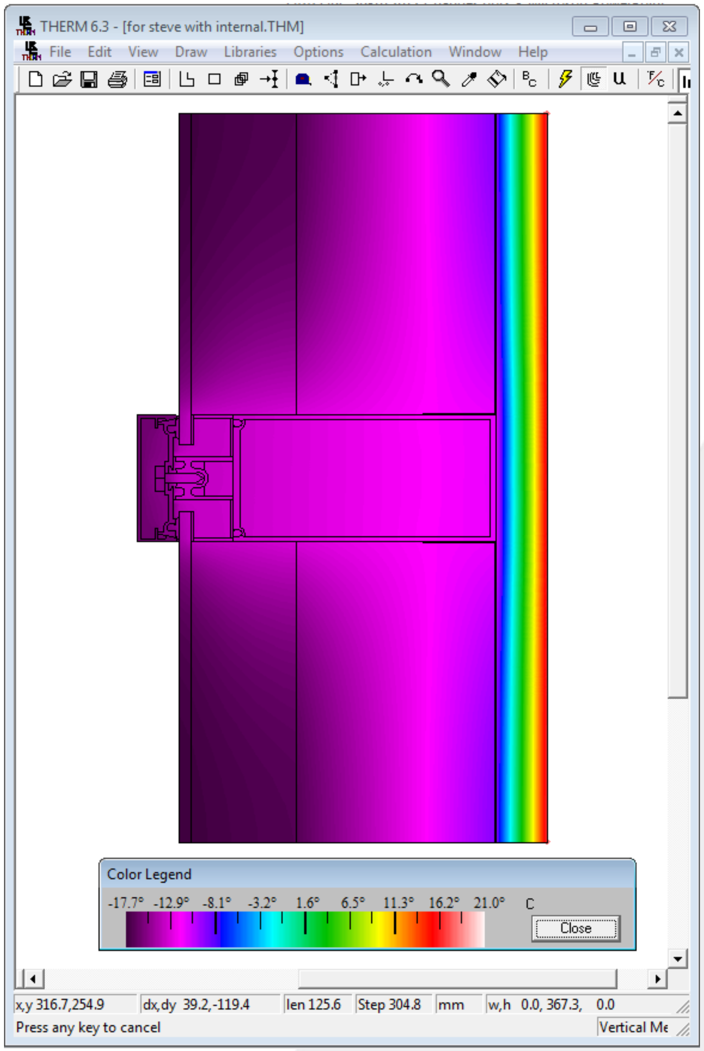
- Steel Framed Wall: Includes curtain-wall / window-wall **spandrel panel**

Spandrel in Window wall / Curtain wall ??



	R-value	U-value BTU/hr-ft²-° F
Nominal Performance	R-14	
Actual Performance	**R-4.0**	**0.25**
OBC Requirement	**R-18**	**0.055**

Spandrel will be challenging (condensation?)



With 1" XPS interior insulation

Nominal R-19

Actual R-9.1

OBC Requirement: U-0.055 BTU/hr-ft²-° F

Assembly: U-0.11 BTU/hr-ft²-° F

With 2" XPS interior insulation

Nominal R-24

Actual R-14.2

OBC Requirement: U-0.055 BTU/hr-ft²-° F

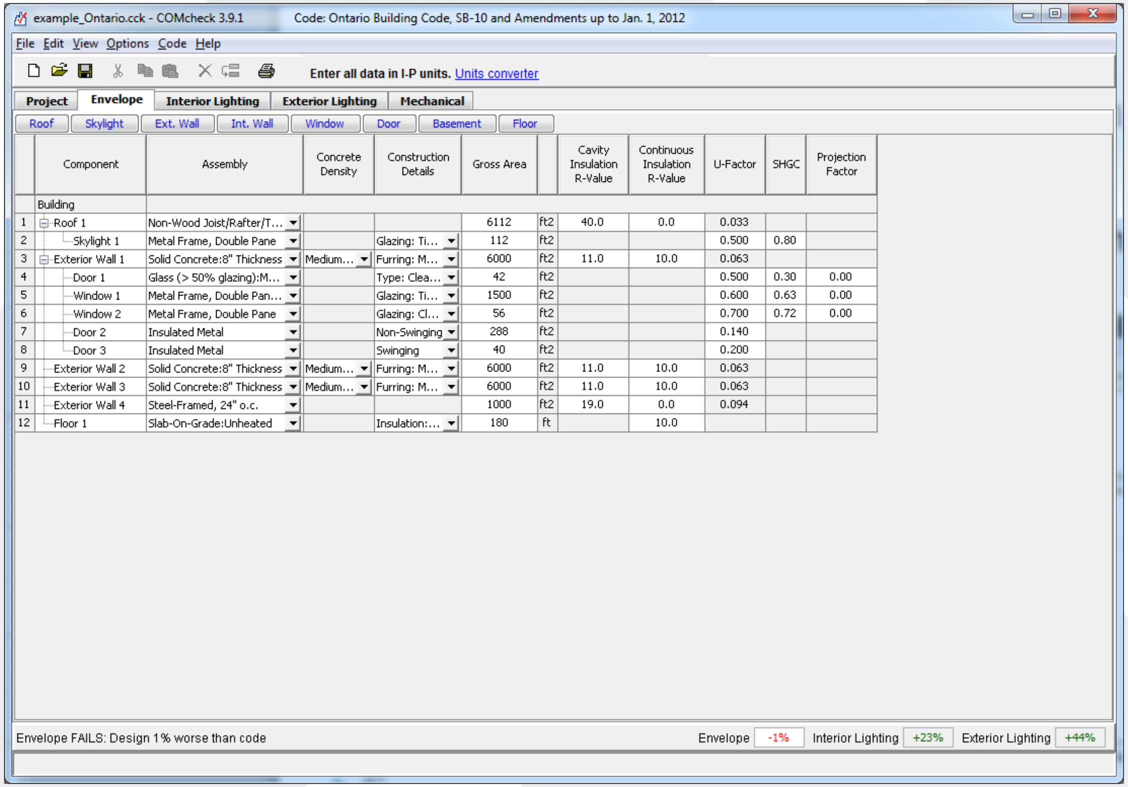
Assembly: U-0.070 BTU/hr-ft²-° F

Envelope Trade-Offs within Prescriptive Path – Building Envelope Trade-off

- 90.1 Section 5.6
  - comply with:
    - o 5.1General
    - o 5.4 Mandatories
    - o 5.7 Submittals
    - o 5.8 Product information and installation requirements
  - the *envelope performance factor* is less than or equal to budget building
    - o Appendix C calculations
      - Do not try this at home!
    - o Software Tool: ComCheck v3.9.1
      - OBC version now available
      - http://www.energycodes.gov/comcheck/

ComCheck Software (Version 3.9.1 Shown)

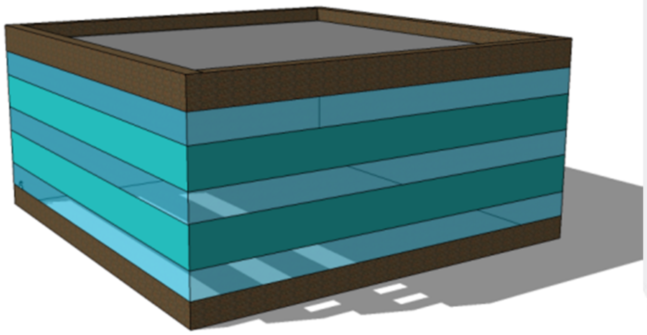
- OBC Version is available
- Exceeding 60% **fenestration** will still be a challenge with only envelope trade-offs



	Component	Assembly	Concrete Density	Construction Details	Gross Area		Cavity Insulation R-Value	Continuous Insulation R-Value	U-Factor	SHGC	Projection Factor
	Building										
1	Roof 1	Non-Wood Joist/Rafter/T...			6112	ft2	40.0	0.0	0.033		
2	Skylight 1	Metal Frame, Double Pane		Glazing: Ti...	112	ft2			0.500	0.80	
3	Exterior Wall 1	Solid Concrete:8" Thickness	Medium...	Furring: M...	6000	ft2	11.0	10.0	0.063		
4	Door 1	Glass (> 50% glazing):M...		Type: Clea...	42	ft2			0.500	0.30	0.00
5	Window 1	Metal Frame, Double Pan...		Glazing: Ti...	1500	ft2			0.600	0.63	0.00
6	Window 2	Metal Frame, Double Pane		Glazing: Cl...	56	ft2			0.700	0.72	0.00
7	Door 2	Insulated Metal		Non-Swinging	288	ft2			0.140		
8	Door 3	Insulated Metal		Swinging	40	ft2			0.200		
9	Exterior Wall 2	Solid Concrete:8" Thickness	Medium...	Furring: M...	6000	ft2	11.0	10.0	0.063		
10	Exterior Wall 3	Solid Concrete:8" Thickness	Medium...	Furring: M...	6000	ft2	11.0	10.0	0.063		
11	Exterior Wall 4	Steel-Framed, 24" o.c.			1000	ft2	19.0	0.0	0.094		
12	Floor 1	Slab-On-Grade:Unheated		Insulation:...	180	ft		10.0			

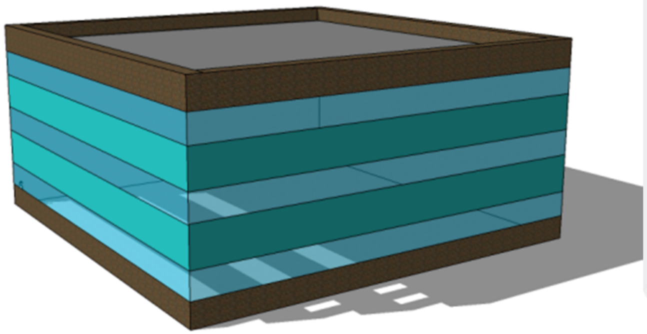
Complying with Prescriptive Envelope: Building Envelope Trade-Off: Curtain/Window Walls Only

Envelope	15,030		U-Factor	Reff
W1 Spandrel	9,030	60%	0.154	6.5
Code CW Window	6,000	40%	0.35	2.9
			-8% below code	
Envelope	15,030		U-Factor	Reff
W1 Spandrel	9,030	60%	0.154	6.5
Triple CW Window	6,000	40%	**0.19**	**5.3**
			-0.1% below code	
Envelope	15,030		U-Factor	Reff
W1 Spandrel, ~2" EPS	9,030	60%	**0.065**	**15.4**
Code CW Window	6,000	40%	0.35	2.9
			+0.1% above code	
Envelope	15,030		U-Factor	Reff
W1 Spandrel, ~1"EPS	**4,030**	**27%**	**0.087**	**11.5**
Triple CW Window	**11,000**	**73%**	**0.19**	**5.3**
			+0.1% above code	



Complying with Prescriptive Envelope: Building Envelope Trade-Off: Walls and Punched Window

Envelope	15,030		U-Factor	Reff
W1 Code Steel Frame	9,030	57%	0.055	18.2
Code Punched Window	6,400	43%	0.45	2.2
			+0.1% above code	
Envelope	15,030		U-Factor	Reff
W1 Code Steel Frame	5,430	36%	0.055	18.2
Hi-Perf Double Punched Window	9,600	**64%**	**0.32**	**3.1**
			+0.1% above code	
Envelope	15,030		U-Factor	Reff
W1 Code Steel Frame	1,530	10%	0.055	18.2
Triple Punched Window	13,500	90%	**0.22**	**4.5**
			+0.1% above code	



SB-10 and NECB Mechanical Requirements

- SB-10: 80% boilers
- NECB: 83-85% boilers

- Exhaust air heat recovery?
  - Yes but only if exhaust significant enough
  - you can design yourself out of the requirement

So not too stringent

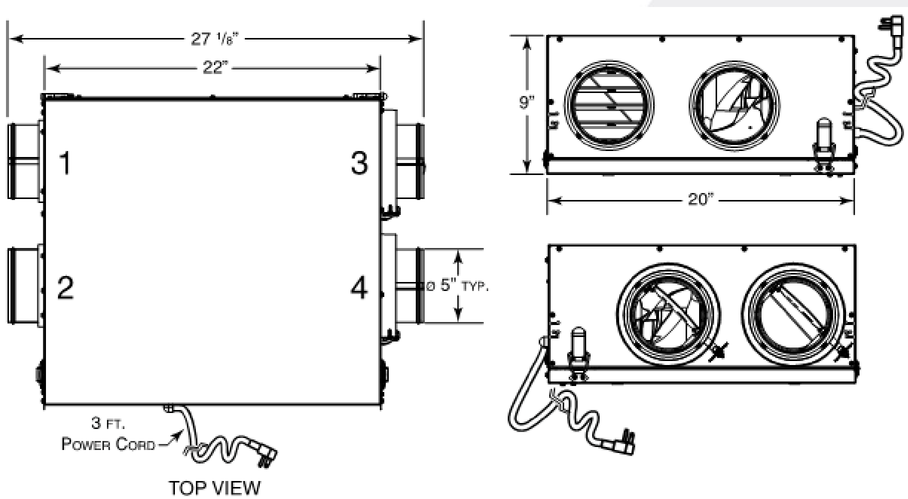
What if I still want my window-wall building?

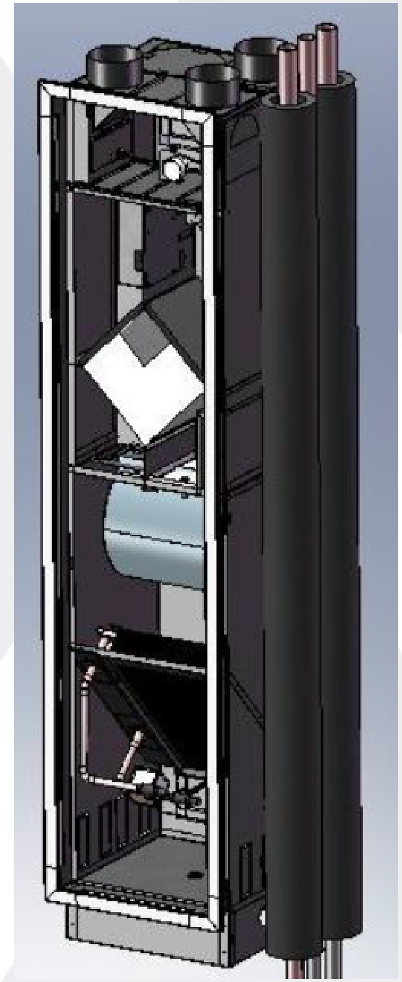
Mechanical Design Specification:

- **Heat Recovery ventilation, directly to each suite**
  - Typically 50-70 CFM per suite
  - Preferably with HRV/ERV in each suite
- Weather strip suite doors to the corridor
- Drop corridor ventilation to 20 CFM/suite
- Condensing efficiency boiler (>93%)
- Variable speed distribution pumps

- Above will typically exceed SB-10 by ~10%

What are the solutions for compartmentalized Ventilation?





Dundas Condominium - 1999

- Designed to CMHC IDEAS Challenge
- Combo space/ water heating
- In-suite HRVs
- Low-e fibreglass windows

Balanced In-suite Ventilation

- Compartmentalized suite
- HRVs provide required fresh air
- Lower energy cost

Impact of HRV

- Annual energy savings of $100/suite
- Installed cost of HRV is $1700 per suite, but saves…
    - Make-up air unit, reduction at $600/suite
    - Bathroom and kitchen exhaust fans at $500/suite
- Net cost of $600/suite

Dundas Findings

- Energy Performance Results
  - Target 125 ekWh/m2, Actual 137 ekWh/m2
    - MNECB 195 ekWh/m2,
      Typical 300 ekWh/m2
  - Electricity Use – 15 kWh/day/suite
  - Gas Use – 2.6 kWh/day/suite
- Water Use – 211 L/day/suite
- Air Tightness – 1.18 L/s/m2 @ 75 Pa

Dundas Findings (Cont'd)

- Ventilation Results
  - 0.28 to 0.40 ACH with HRV and HRV+AH and well distributed through suite
  - Some garage air entered corridors, but very little entered suites
  - Natural infiltration 0.06 ACH
  - Formaldehyde, particulate and VOCs well below Canadian Guidelines
    - "tested like a 10 year old building"
    - And then…. tenants moved in with new furniture

Other Projects – West Village

- University of MacMaster Residence (suites had full kitchens)
- Certified LEED Platinum
- Integrated fancoil + HRV

Other Projects – Chapelview Affordable Housing

- LEED Platinum Certified
- Occupied October 2010
- Integrated fan-coil + HRV

Other Projects – 60 Richmond Co-Op

- LEED Gold Certified
- Independent HRV

Closing Quotes

- Ludwig Wittgenstein
  (engineer, mathematician, philosopher)
  - “I don't know why we are here, but I'm pretty sure that it is not in order to enjoy ourselves.”
- W.H. Auden
  (poet)
  - “We are all here on earth to help others; what on earth the others are here for I don't know.”
- Kurt Vonnegut
  (writer)
  - "We are put on earth to fart around....don't let any one tell you any different."