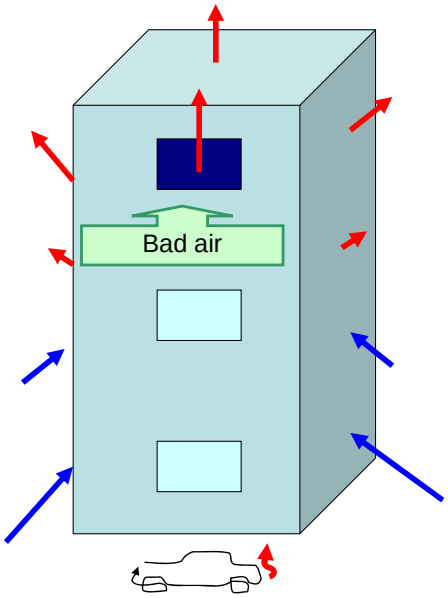
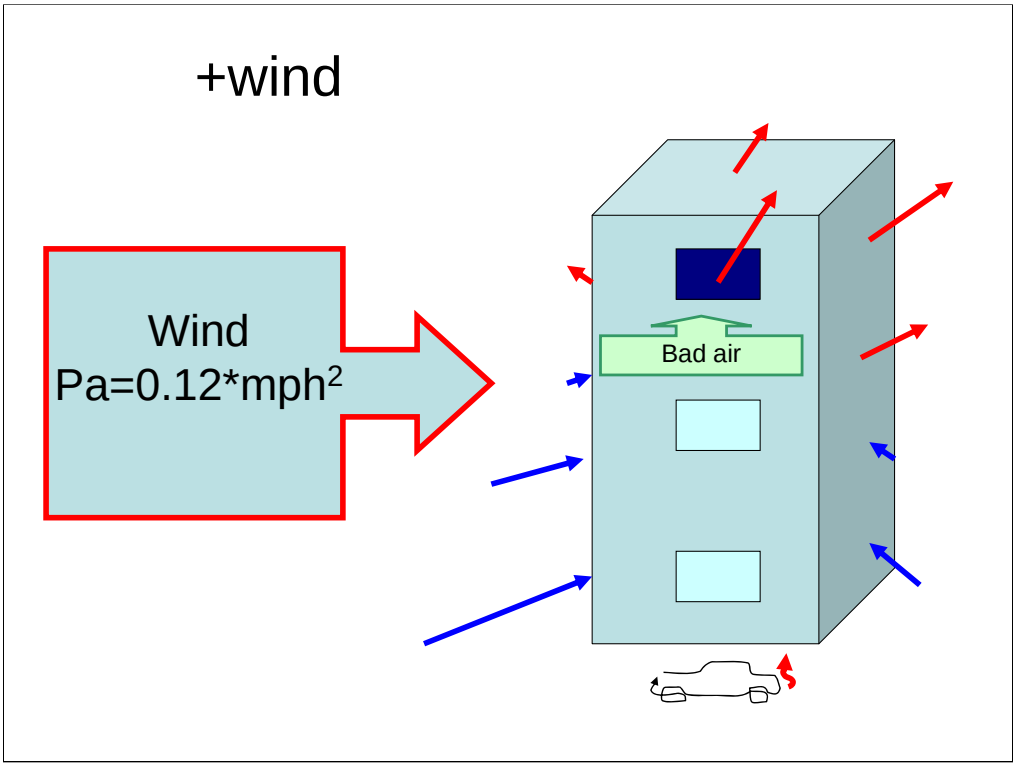
High Rise Energy Testing

Chimney Effect



Warm air shown in red rises and leaves the upper half of the building causing cold air shown in blue to enter the lower half. As the air rises, it becomes more polluted with household /or office odors and chemicals. The most polluted air pools outdoors at the lowest levels; this is the same air that gets pulled in. Underground garages supply vehicle exhaust to the mix.

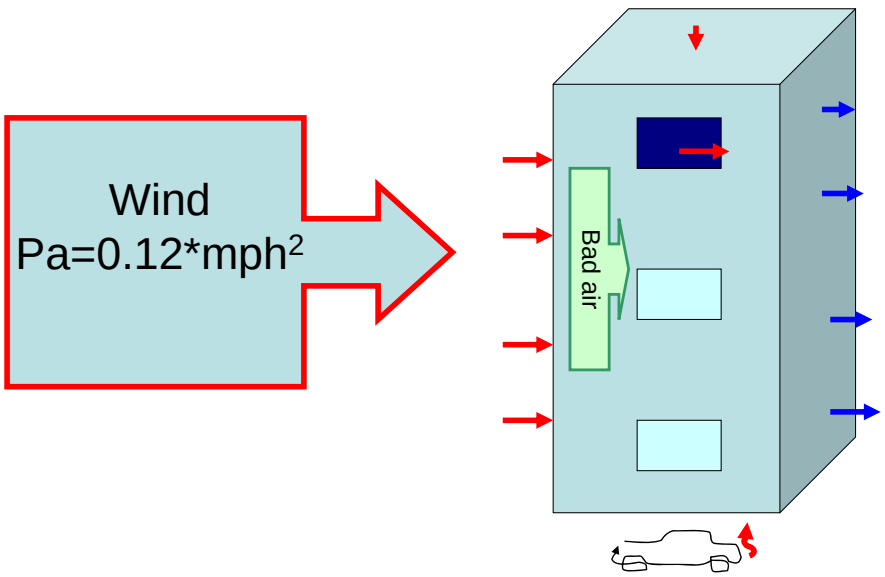


Wind shifts the movement patterns; creating more horizontal flows through the building.

Cold Climates

- Slab and shaft leaks critical

Hot climates

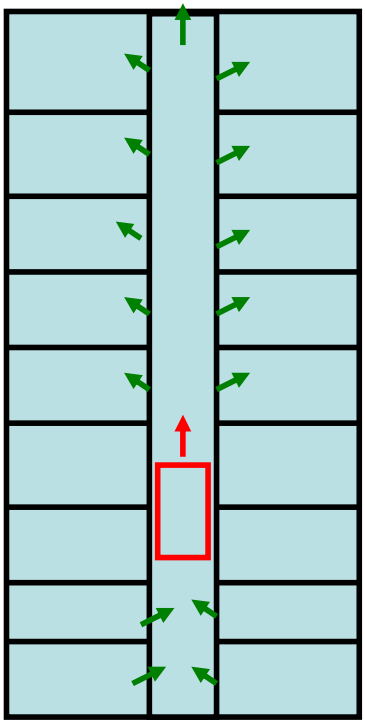


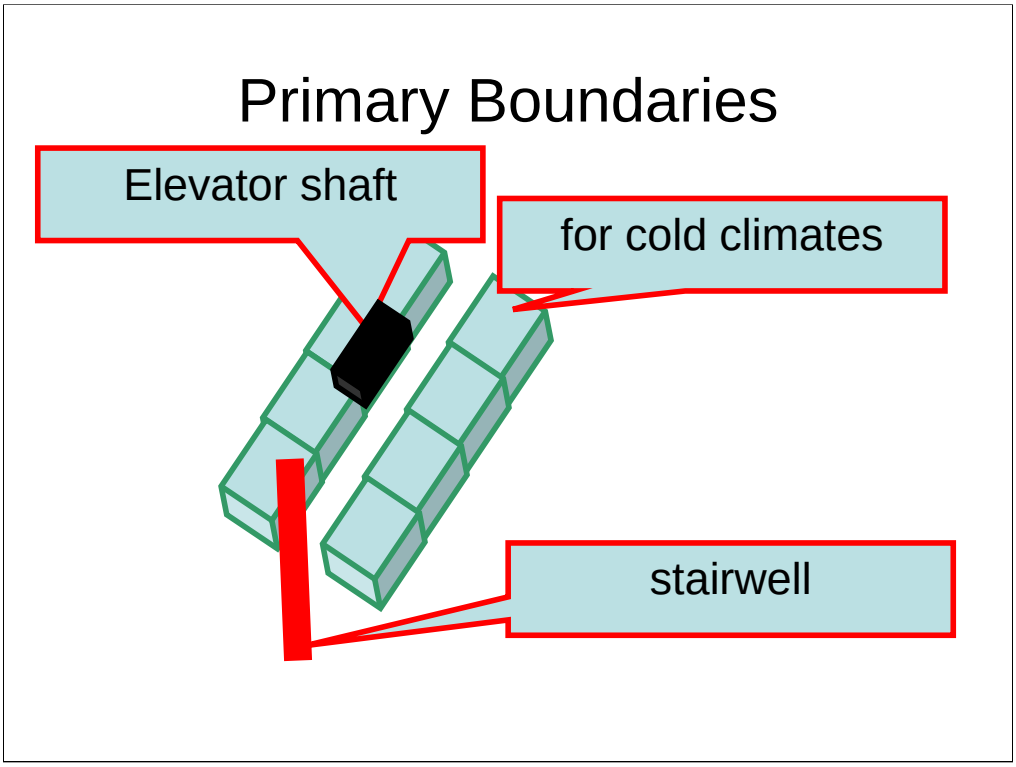
Hot climates

- Party & hallway walls critical

All Climates

Elevator piston effect





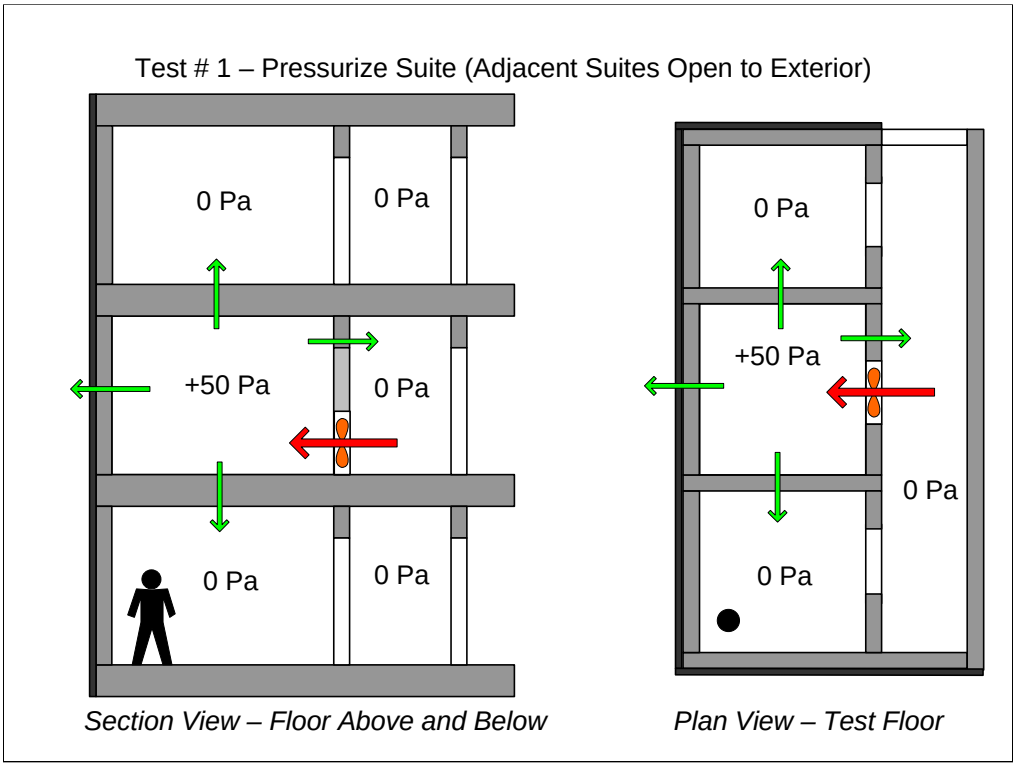
Where opening windows are present, the exterior of the envelope cannot be well controlled making vertical shafts and horizontal slabs the key components whose job it is to control the chimney effect.

This is one of the buildings that was tested.

And another,

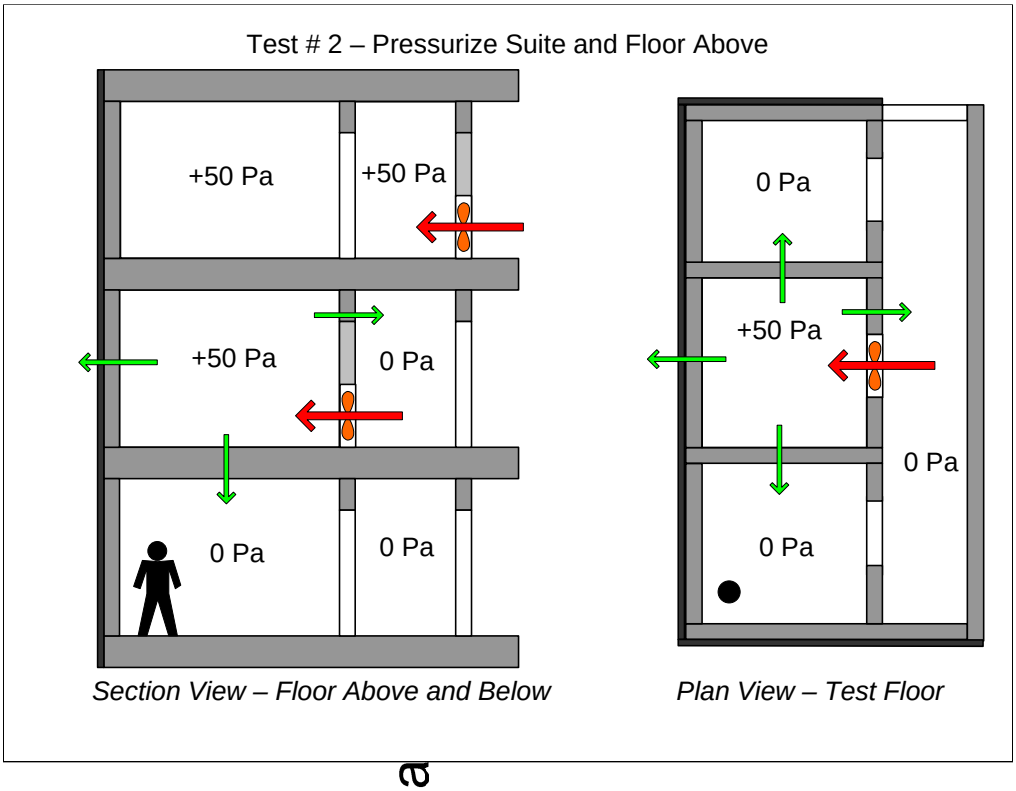
And another,

And another,



Apartments or individual offices can easily be tested on all 6 side simultaneously.

Exterior = 0 Pa

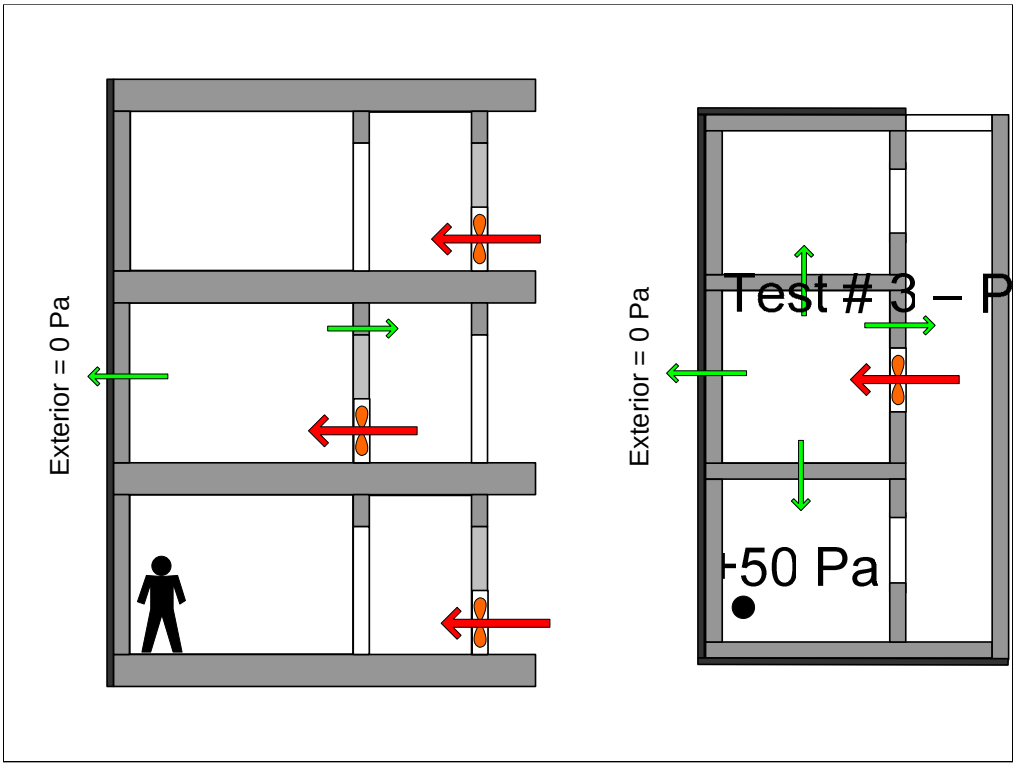


Exterior = 0 Pa

Adding another blower door to the floor above allows the leakage to that floor to be measured.

Floor to floor leakage concern Large leaks between floors:

- Increases energy losses due to increased stack pressures
- Is an IAQ concern since it allows indoor pollutants, cooking odors, cigarette smoke etc to move upward between apartments.
- Is a safety concern in fires since it will allow smoke to permeate upper floor in a fire.
- Is a comfort concern since it will make upper floors hot and humid causing window openings and will cause lower floors to become dry and cold in winter.
- Is a noise concern since it will allow for the transmission of noise from one floor to the next.

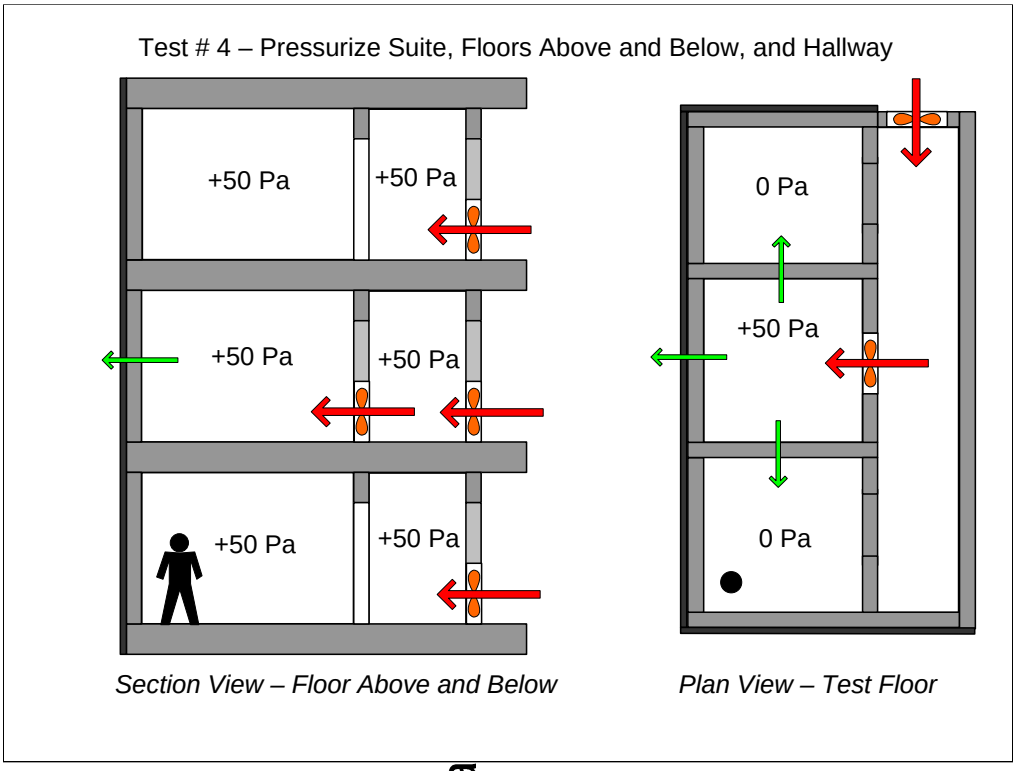


Adding a third blower door to the floor below allows the leakage to the floor below to be measured.

+50 Pa 0 Pa

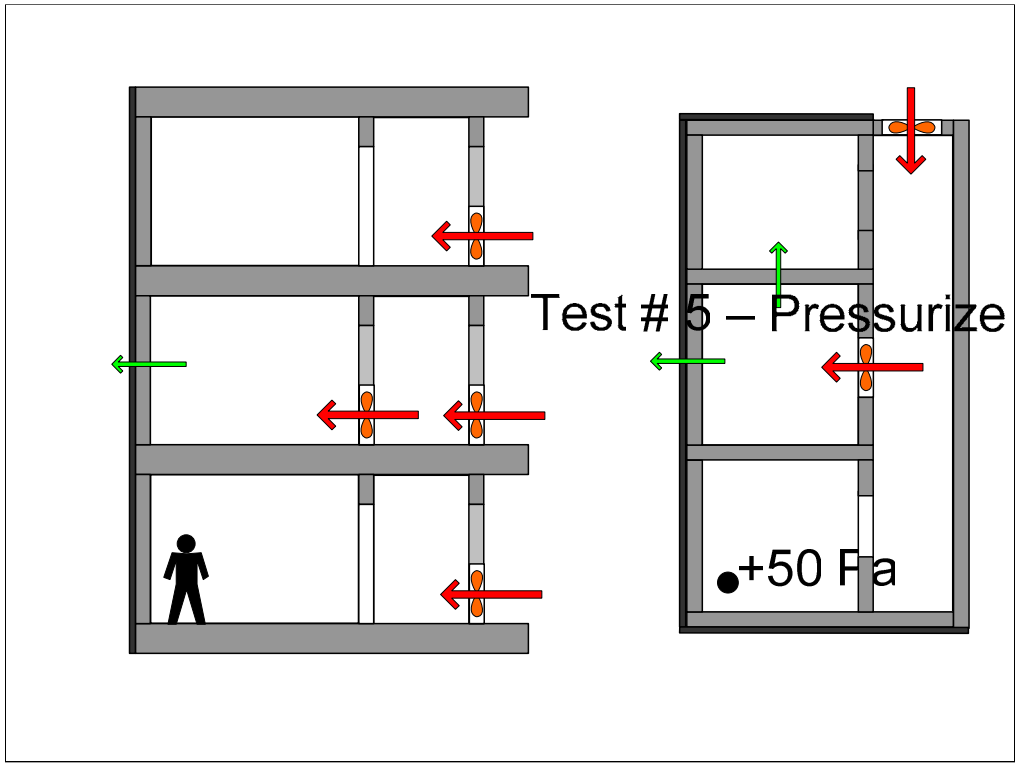
+50 Pa +50 Pa

Section View – Floor Above and E

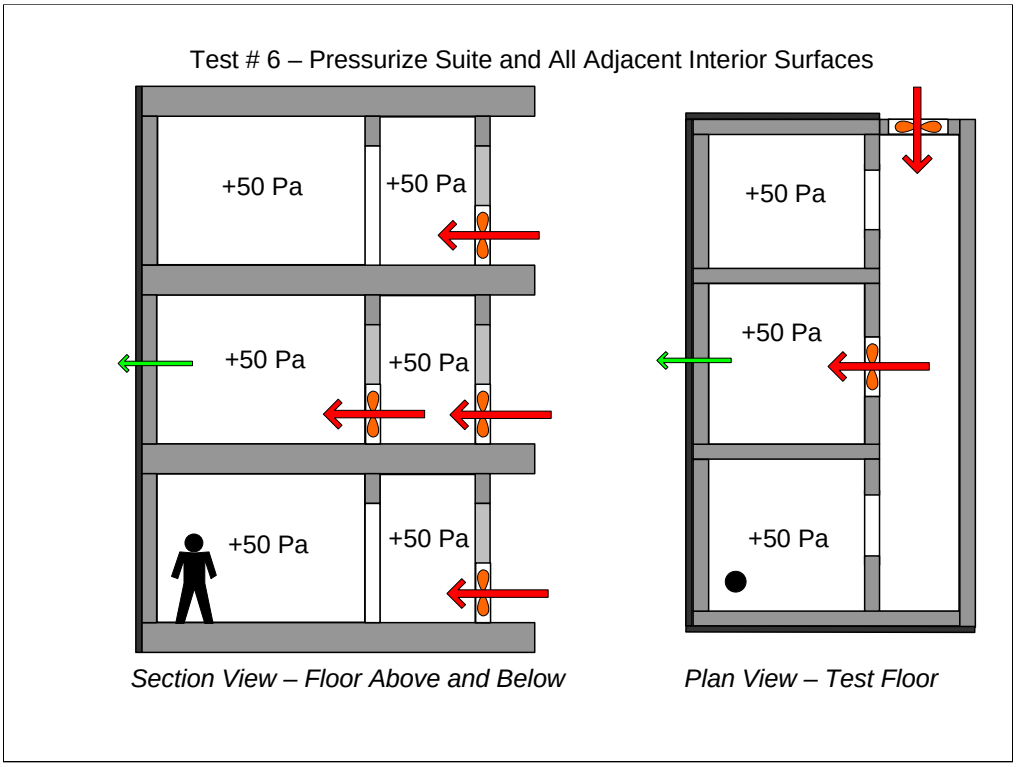


Exterior = 0 Pa

Adding a fourth blower door to the hallway allows the leakage to the hallway to be measured.



Opening the door to the apartment on the left, allows the leakage to the adjacent apartment to be measured.



Exterior = 0Pa

Opening the door to the apartment on the right, allows the leakage to the adjacent apartment on the other side to be measured.

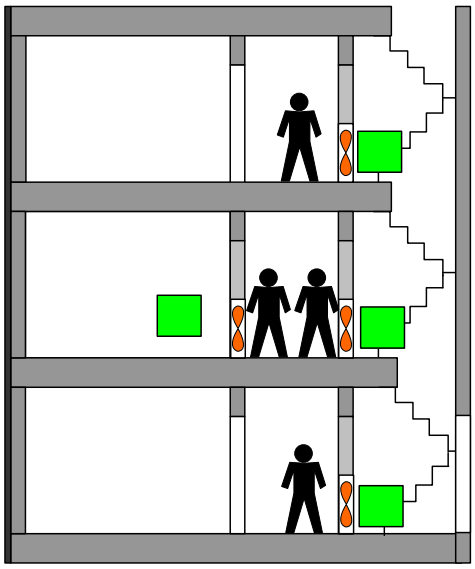


Figure 1-1: Door-fan test setup for isolation of individual test suite

Normally a stairwell is used to gain access to the floors above and below.

Bonus:

•not only do we measure the entire envelope leakage in this way but we learn what each floor leaks. If one floor has much more leakage than another it may indicate a problem peculiar to that particular floor.

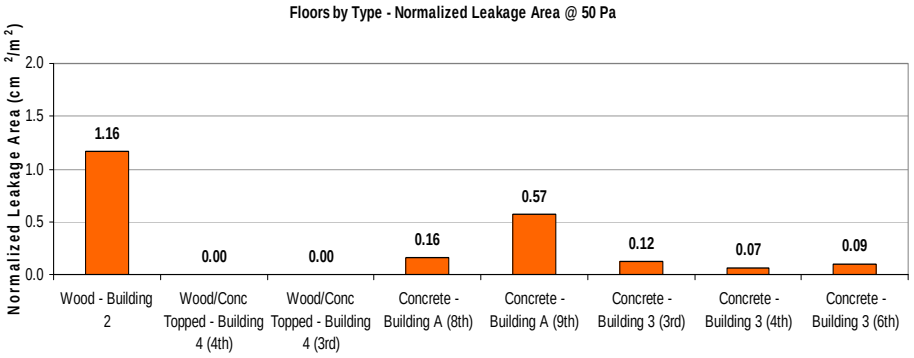
•We get the floor to floor leakage allowing us to identify indoor pollution transmission routes. Useful for solving cigarette smoke and cooking odor problems so prevalent in high rise buildings.

Various Standards

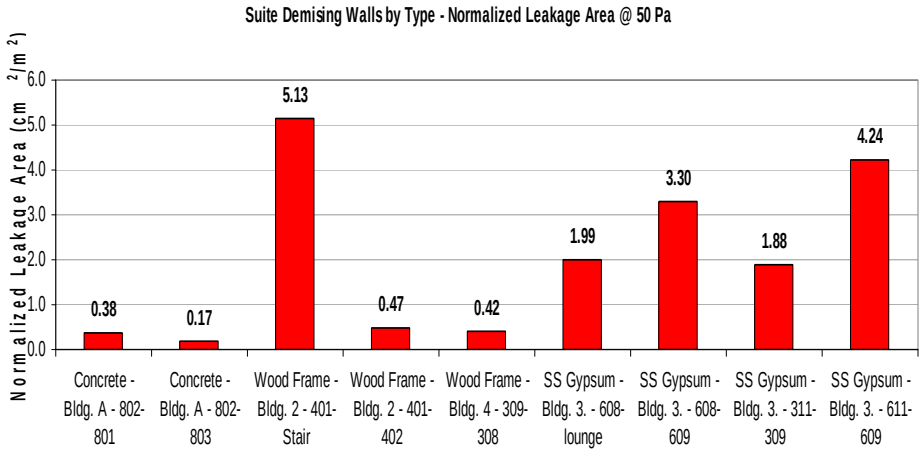
	EqLA, cm^2/m^2	at	
LEED standard is 1.25 in^2 EfLA / 100 sq ft envelope is	**1.4**	4Pa	
IECC standard is 0.4 cfm at 75Pa is	**1.9**		n=0.65
UK 5 m^3/hour/m^2 Best practice is	**1.6**		n=0.65
US Army standard is 0.25 cfm at 75Pa is	**1.2**		n= 0.65

Various Standards require similar levels of tightness.

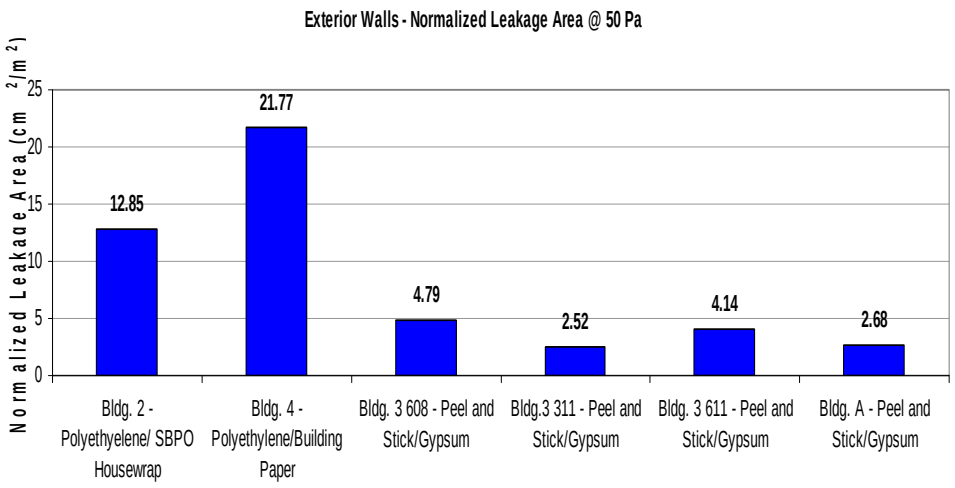
Floor Leakage



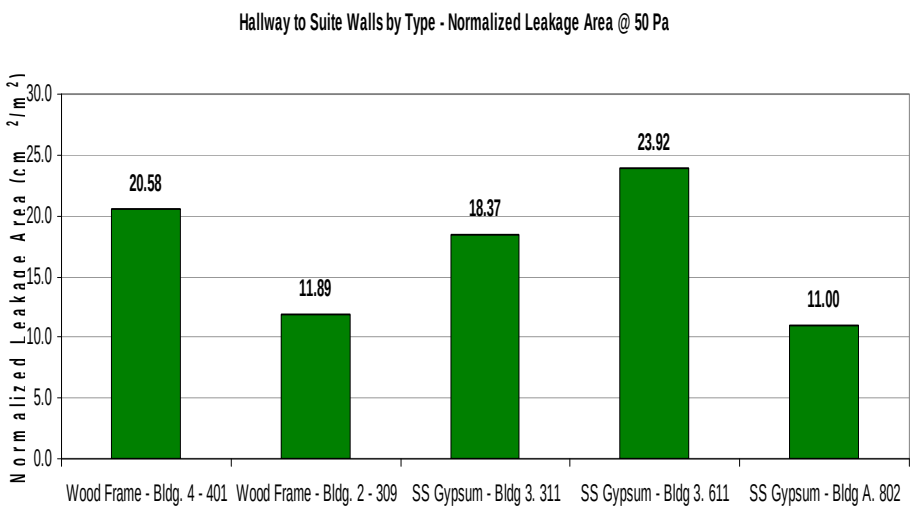
Party Walls


Suite Demising Walls by Type - Normalized Leakage Area @ 50 Pa
Normalized Leakage Area (cm²/m²)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.38
0.17
5.13
0.47
0.42
1.99
3.30
1.88
4.24
Concrete - Bldg. A - 802-801
Concrete - Bldg. A - 802-803
Wood Frame - Bldg. 2 - 401-Stair
Wood Frame - Bldg. 2 - 401-402
Wood Frame - Bldg. 4 - 309-308
SS Gypsum - Bldg. 3. - 608-lounge
SS Gypsum - Bldg. 3. - 608-609
SS Gypsum - Bldg. 3. - 311-309
SS Gypsum - Bldg. 3. - 611-609

Exterior Walls

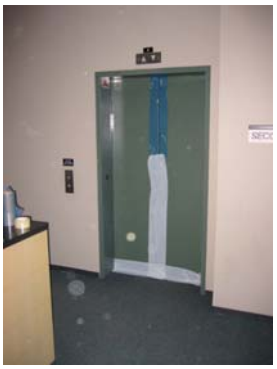


Hallway Walls



Elevator Shaft test in Dam

Lobby Test



Elevator lobbies could provide excellent containment of the connecting affect of the shaft. By providing slab to slab walls, the floor could be protected from energy loss and air qualities problems caused by a floor's connection to the elevator shaft.

			Envelope		*Leakage*	*SLA*	*Driving*	*Min. Egress*
Type	Description	*Ht.*	*area*	*Vol.*	*Area*		*Force*	*Time*
	-all concrete	m	m^2	m^3	cm^2	cm^2/m^2	Pa	min
Hydro Dam	Elevator shaft	80	1210	1000	5483	**4.53**	100	0.08
Hydro Dam	stairwell	80	1015	800	3113	**3.07**	100	0.11
Hydro Dam	stairwell	80	915	800	2361	**2.58**	100	0.14
Hydro Dam	stairwell	80	1412	800	5270	**3.73**	100	0.06
Hydro Dam	stairwell	80	1015	800	2509	**2.47**	100	0.14
Hydro Dam	Elevator shaft	60	1003	800	12110	**12.1**	75	0.03
Hydro Dam	stairwell	60	1015	800	3597	**3.54**	75	0.11
Hydro Dam	stairwell	60	1015	800	1738	**1.71**	75	0.23
Office Tower	2nd floor	4	4600	7200	4664	**1.01**	10	2.07
Office Tower	2nd floor, lower slab	4	1800	7200	152	**0.08**	10	63.46
Office Tower	elevator lobby, 2nd flr	4	480	576	4305	**8.97**	10	0.18
Office Tower	elevator doors, 2nd flr	30	4	180	145	**36.3**	25	1.05

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UBC 905 stnd	walls	4	2500	4000	25000	**10.00**	10	0.21
UBC 905 stnd	exit enclosures	4	2500	4000	8750	**3.50**	10	0.61
UBC 905 stnd	other shafts	4	2500	4000	37500	**15.00**	10	0.14
UBC 905 stnd	floors and roofs	4	2500	4000	12500	**5.00**	10	0.43
NFPA2001	fm200 protected	4	2500	4000	10000	**4.00**	10	0.54
Computer flr	lower slab and walls	5	7000	11000	4164	**0.59**	15	2.89
House	R-2000 maximum	3	725	900	225	**0.31**	10	5.10
PFEER stnd	Oil Platform	3	350	560	14	**0.04**	10	55.60
Apartment	8+9th floor, lower slab	6	1656	3024	1300	**0.79**	8.1	2.2
Apartment	6+7th floor, lower slab	6	1656	3024	1600	**0.97**	8.1	1.8
Apartment	4+5th floor, lower slab	6	1656	3024	1100	**0.66**	8.1	2.6
Apartment	2+3th floor, lower slab	6	1656	3024	1000	**0.60**	8.1	2.9

Problem: sufficient power to test one floor with one fan

Solution: 2 HP fan on Variable Frequency Drive

Problem: manual control of gauges impossible

Solution: Set Pressure control

One our initial test rigs used many years ago the resulted in our newly designed gauge that solves all those problems. The largest one was being able to automatically control fans from large distances.

Problem: adjusting a fan on one floor affects the pressure on another

Solution: Retrotec's new digital gauge with built in PID controller will control each fan separately so it stays at the ideal test pressure which appears to be 50 Pa.

Problem: gathering information from 3 fans

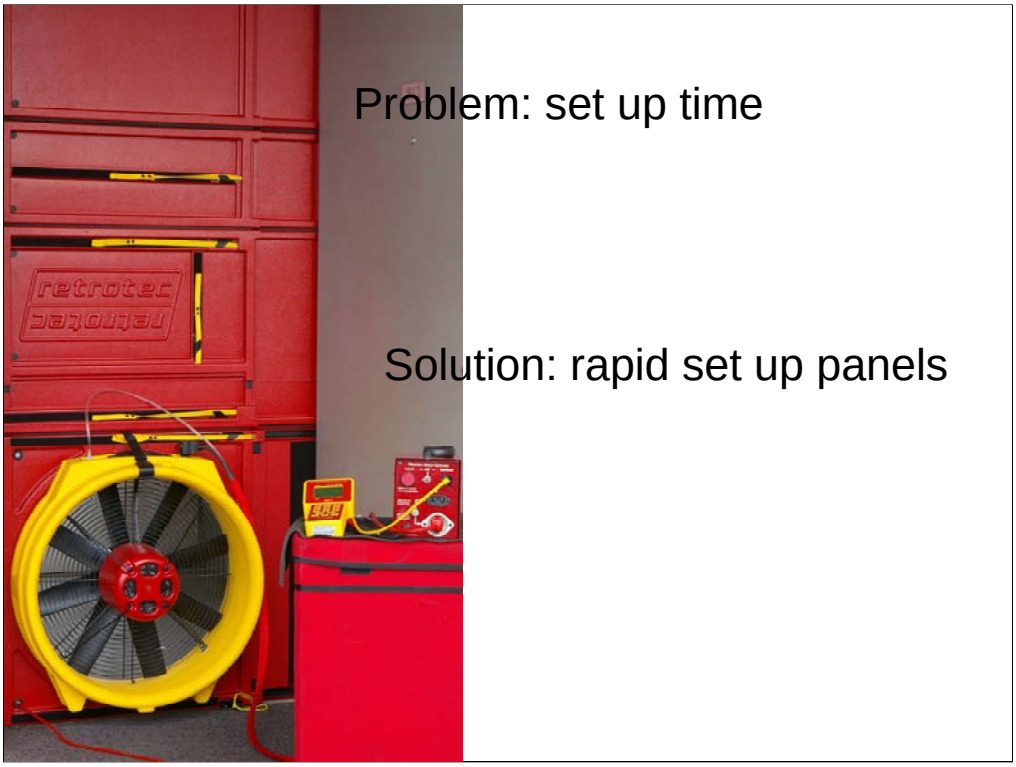
Solution: Monitor all from one location

Laptops were tried to log the data but were found unnecessary and slowed down the testing process a lot.

Problem: time to set up laptop

Solution: read cfm at 50 or ELA directly

We now keep our controlling gauges on one floor so we can read all gauges simultaneously.



Problem: limited time to perform tests, people moving about building

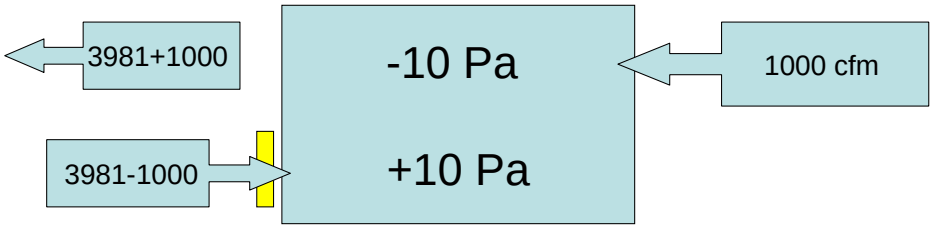
Solution: rapid set up panels install and remove in seconds. Allow operators to pass through 24 inch port without removing the panel.

Problem: Typical 0.75 horsepower House testing fans don't have enough power

Solution: Retrotec's new 2 horsepower commercial fans are normally enough to test an entire floor.

Error caused by flow that creates 1 Pa

n	C	cfm	at		error PR	error DP
0.6	1000	1000	1	Pa		
0.6	1000	3981	10	Pa	34%	20%
0.6	1000	10456	50	Pa	11%	9%

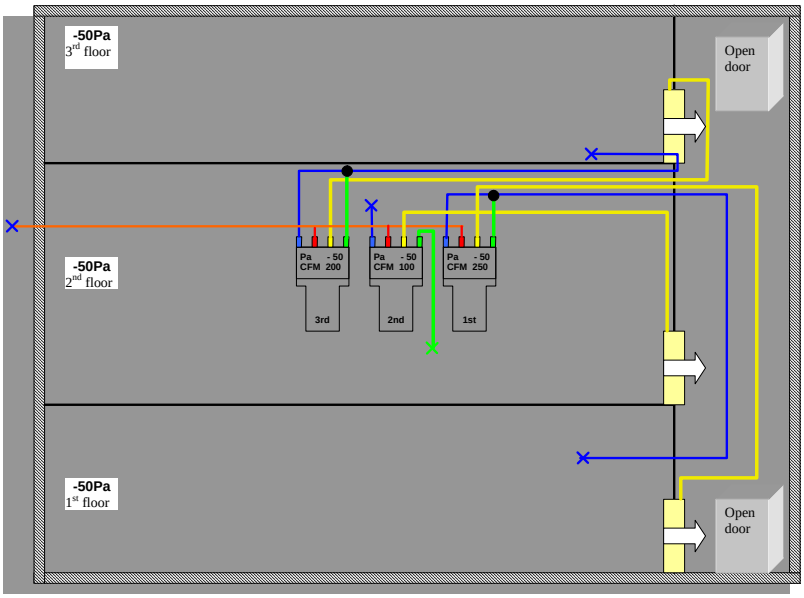


Small unaccounted for flows can produce large errors. Testing in both directions, solves that problem.

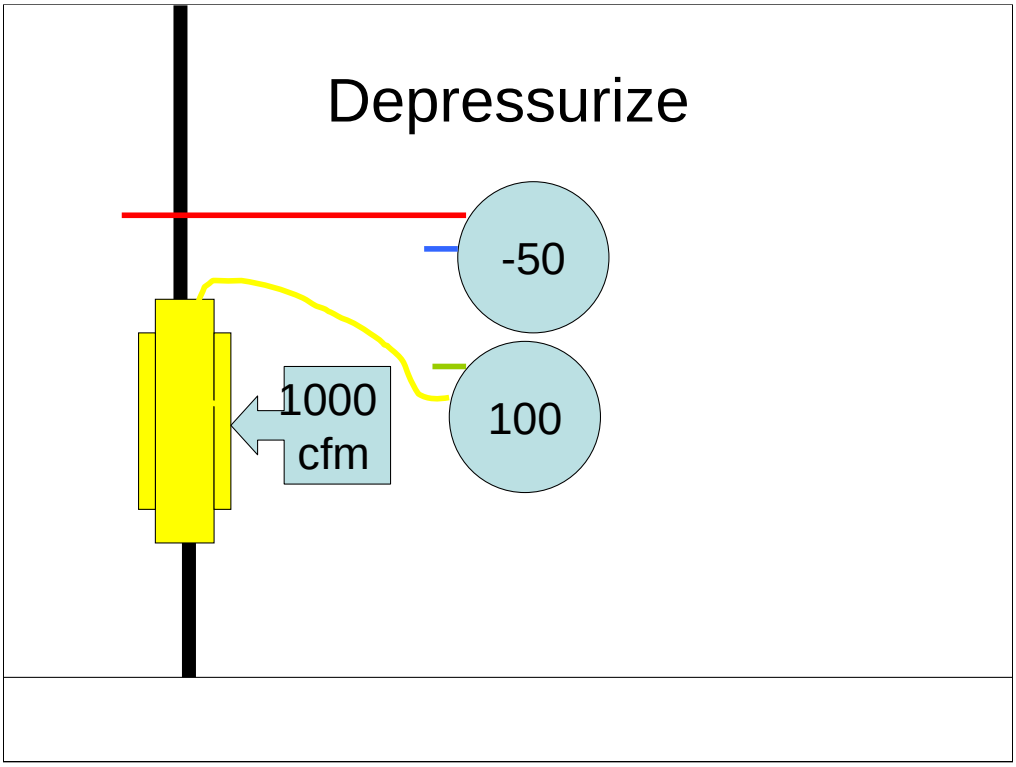
Problem: testing in one direction, either pressurize or depressurize does not give and accurate picture of high rise leaks. Large static pressures due to wind, stack and HVAC systems can produce offsets that are not properly accounted for. Simply subtracting static pressures, common in house testing, can throw off high rise readings by 25%. Static pressures can result from pressure shifts or airflow. Static shifts can be subtracted linearly but static pressures caused by HVAC flows have a square root relationship meaning that if for example the flow required to go from 0 to 1 Pa is 100 cfm then the flow required to go from 49 to 50 is only 7 cfm. Clearly, just adding 1 Pa to the test pressure does NOT compensate for a 1 Pa static pressure if it is induced by flow versus a static shift.

Solution: Testing in both directions does a good job on negating static shifts no matter how they are produced ensuring repeatable results in alll weahter conditions. If an hallway pressurization fan cannot be turned off as we would strongly recommend. for the test, testing both ways will do a good job of negating it.

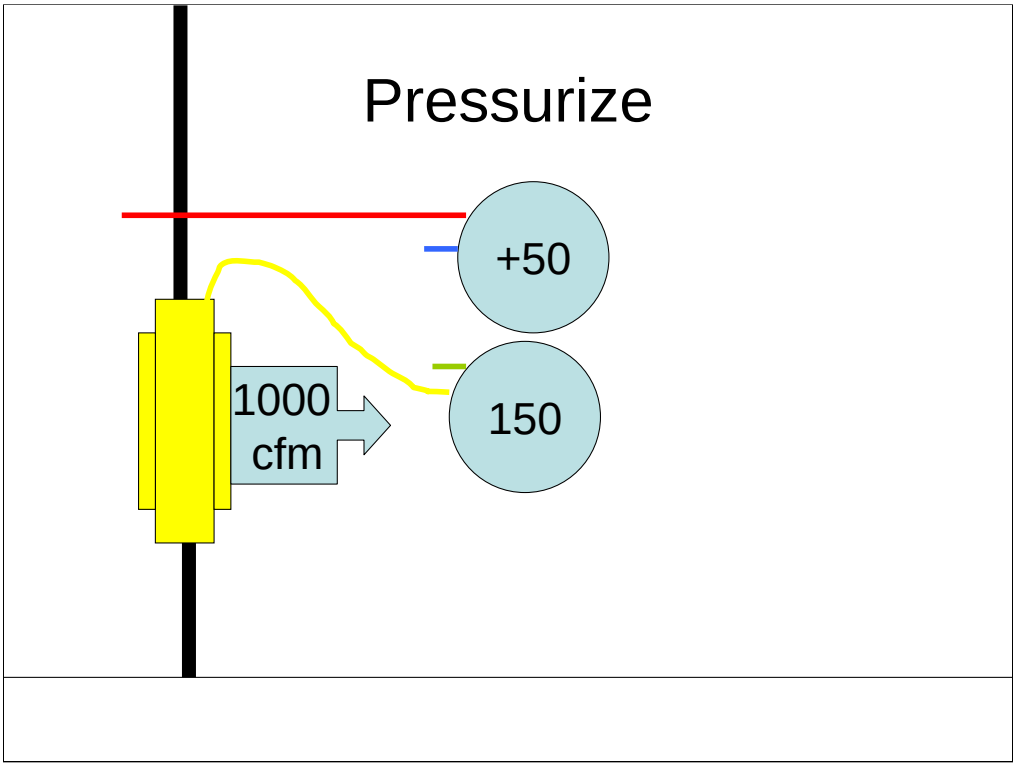
Problem: Proper reference of flow pressure

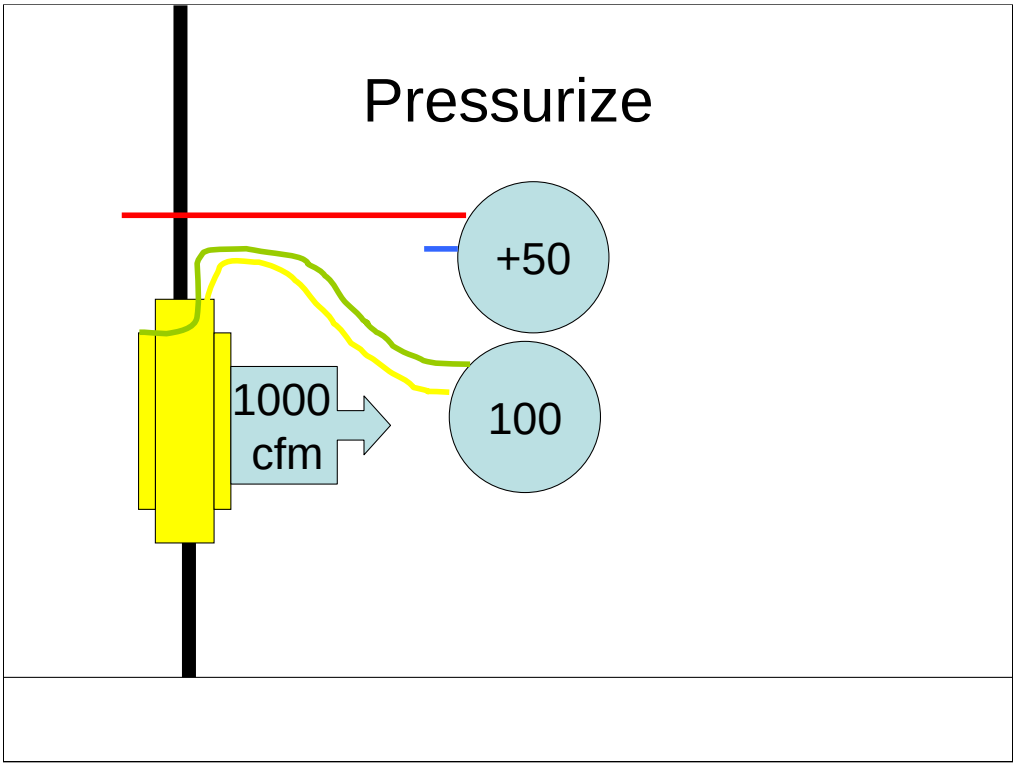


Running a common outside pressure tube is essentially for maintaining the same reference pressure on each fan.

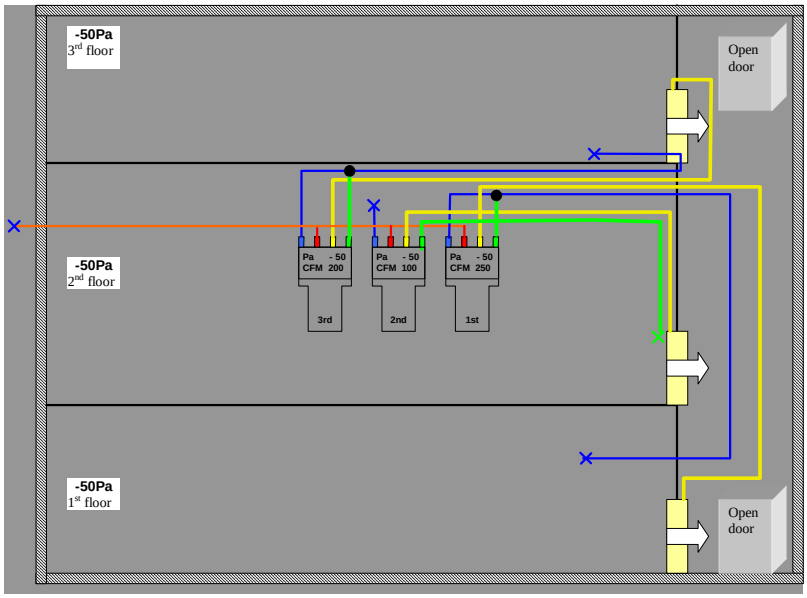


The next 3 slides shows the massive error that can be produced by improperly referencing fans.


Pressurize
+50
150
1000
cfm


Pressurize
+50
1000
cfm
100

Solution: Run reference tube in each umbilical



Our latest fans use the green reference hose on each fan. Newer yet, custom fans have a self referencing port built into the fan so mistakes can never be made.

Testing Problem…….Solution

Stack	Test both ways
Exhaust flows	Test both ways
Wind	Time average

We strongly recommend high rise buildings be tested in the positive and negative directions because stack pressures, wind pressures and HVAC flows can drastically shift results by as much as 20% from test to test. One way leaks such as flaps add minor errors too. Testing both directions takes care of all these errors and makes results much more repeatable. If fresh air supply fans are running, testing only one way can skew results by 40% in extreme cases; testing both ways will eliminate most of this but will still skew results by 5 to 10%. Best is to shut off ventilation fans to get the most accurate measurement of shell leakage.

Method

Test both ways, +50 and -50 Pa
Common outdoor reference tubes
Monitor all gauges simultaneously
Record values in in^2 /100 ft^2 or cm^2 / m^2
Use @50Pa setting to extrapolate
Reference ports on fans

Setup the Door-Fans Secure all doors where fans are mounted so they will not slam shut over the fan; use door stops and tape doors in place. Remove mats, papers etc that could get sucked into or blown away by the 30 mph fan blast.
Install Fan Install fans. Run tubes and cables per the diagram. Set all the digital gauges on one floor or in one location in the stairwell.
Post Floor watch If the building is occupied, have at least one person per floor to ensure no one tampers with or is endangered by fan operation. Watch for elevator, window and hallway door opening. If not occupied, check these openings when the fans are running to ensure they stay closed.
Fan Checkout Run each fan separately till the pressure rises to 15 Pa to checkout individual operation.

Initiatives

- Complaint driven, IAQ mostly
- UK shell of ALL buildings, ENERGY
- LEED, 1.25 in^2 /100 ft^2 of apt, IAQ

Recent LEEDS building standards and increasing indoor air quality problems in high rise buildings have encouraged Retrotec to develop equipment and procedures for testing high rise buildings.

Needed; way to test a high rise without testing entire building at one time.
Problems;

-requires too much blowing power, high air velocities

-Can’t get enough air to upper floors

Benefits

- Smoke control
- IAQ
- Longevity of structure, moisture problems
- Comfort

Needed, Design

- Minimize slab leakage
- Elevator lobbies
- Elevator Shaft seal
- Stairwell seal
- Exterior wall not as important

Needed, Construction

- Test as floors are completed
  - Wall to slab joints with flexible seal
  - Partition walls
  - Exhaust fan capacity
  - Zero slab leakage
- Flexible seal elevator lobbies, shafts

Needed, Retrofit

- Cost 10 to 1000 times more !
  - Wall to slab joints with flexible seal
  - Partition walls
  - Exhaust fan capacity

Conclusions

- Leakage of any surface can be tested
- Easiest fix is during construction
- Combined benefits
  - energy + smoke+ IAQ + longevity
- LEED is only a start
  - 1.25 in^2 /100 ft^2 @4 Pa
- recommend EqLA at 50 Pa = 2 in^2 /100 ft^2
- If >, test all 6 sides to locate problems

Benefits Quantify high rise shell leakage for energy conservation purposes. Reduce wind noise. Locate leakage sites.
Application LEEDS energy efficiency rating.
Contam W NIST software requires accurate leakage number to predict contaminant movement; both IAQ and smoke from fires.
UK standards for energy efficiency of commercial buildings
Uniform Building Code requirements for building leakage for passive smoke control

End