Airtightness Testing of Large Buildings

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Why are we testing?

- To meet building regulation for air tightness requirements
  - To limit air flows that
    - Increase energy use
    - Lead to moisture issues and other building failures
    - Prevent proper HVAC operation, e.g., maintaining building pressurization
  - To assess construction quality and identify flaws during construction process
- Typical metrics:
  - Air flow at fixed pressure m^3/h (cfm or L/s) at 50 Pa or 75 Pa
  - Normalized by surface area: $m^3/h/m^2$ (cfm/ft^2) at 50 or 75 Pa
- Examples: CO0
  - ASHRAE 90.1 in US: 0.40 cfm/ft^2 at 75 Pa (7 $m^3/h/m^2$)
  - International Green Construction Code: 0.25 cfm/ft^2 at 75 Pa (4 $m^3/h/m^2$)

スライド 2

CO0 Formatting issue: this bullet does not fit on screen for me
Collin Olson, 2023-05-08T19:17:26.859

Large Building Testing Issues

- Pressure uniformity
  - Resistance of interior air flow paths
  - Wind and stack effects
- Moving enough air
  - Need a lot of fans or one really big one
  - Safety issues – noise, slamming doors, high air speeds, opening fire doors
  - Power (independent circuits, generators or battery capacity)
- What about occupants? Can we only test when empty?
- Operation of other air moving systems and general building control
  - Building HVAC system
  - Building zones

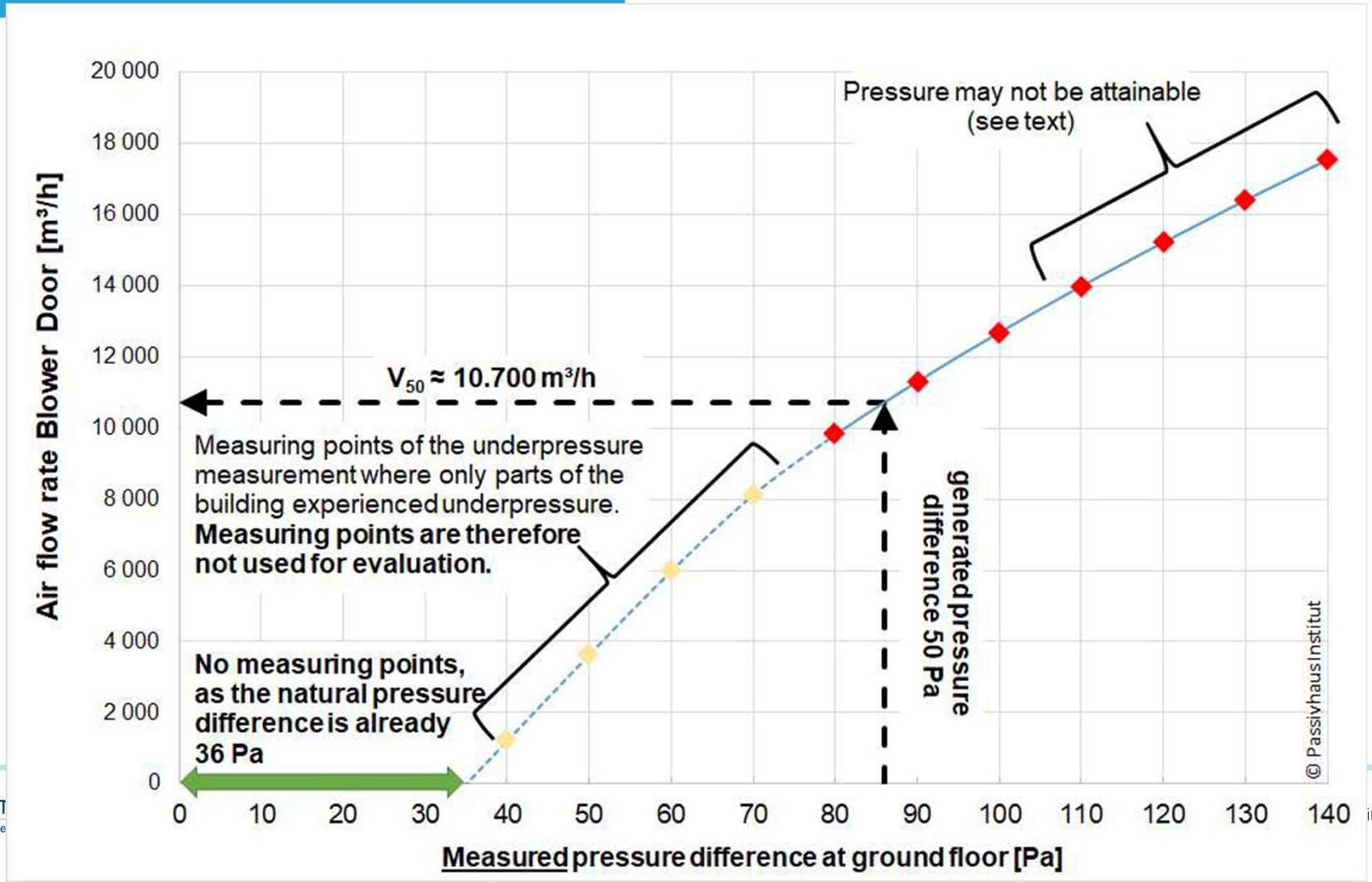
Background – Current Test Methods

- ISO 9972 & EN 13829
  - has requirement for <10% pressure difference variation
  - Lowest measuring point > 5 times natural pressures: this gets unfeasibly high
  - Multipoint testing at several induced envelope pressures
- ASTM E779
  - "Single Zone" if internal pressure differences < 5% of inside to outside pressure difference
  - Limits height x temperature difference to 200 mK
  - Multipoint testing at several induced envelope pressures
- ASTM E3158 Standard Test Method for Measuring the Air Leakage Rate of a Large or Multizone Building
  - Instructions for building preparation
  - Pressure uniformity if internal openings > $2m^2$ and flow less than 2800 L/s.
  - Multipoint testing at several induced envelope pressures + single point testing (50 or 75 Pa)
  - Internal pressure differences <10% of induced envelope pressure
- PassivHaus Guideline:
  - Considers deviating from standard test procedures:
  - Changing measurement pressures so that they all have the same sign: either the whole building is pressurized or the whole building is depressurized (Not very satisfactory because different parts of the building are at different pressures and traditional analysis assumptions are invalid?)

CO0

CO0 Maybe not, granted, but modeling suggests this is a good rule
Collin Olson, 2023-05-08T19:25:24.886

Example from PassivHaus Guideline



Ideas for large/tall building testing

- Use many fans at different locations
- Measure pressure differences at multiple locations
- Wait for favorable weather: small temperature differences and not windy
- Test when unoccupied for window/door/HVAC control
- Need data automation: multiple air flow and pressure location measurements need to be combined

Tall Building Example – Three towers in Austria

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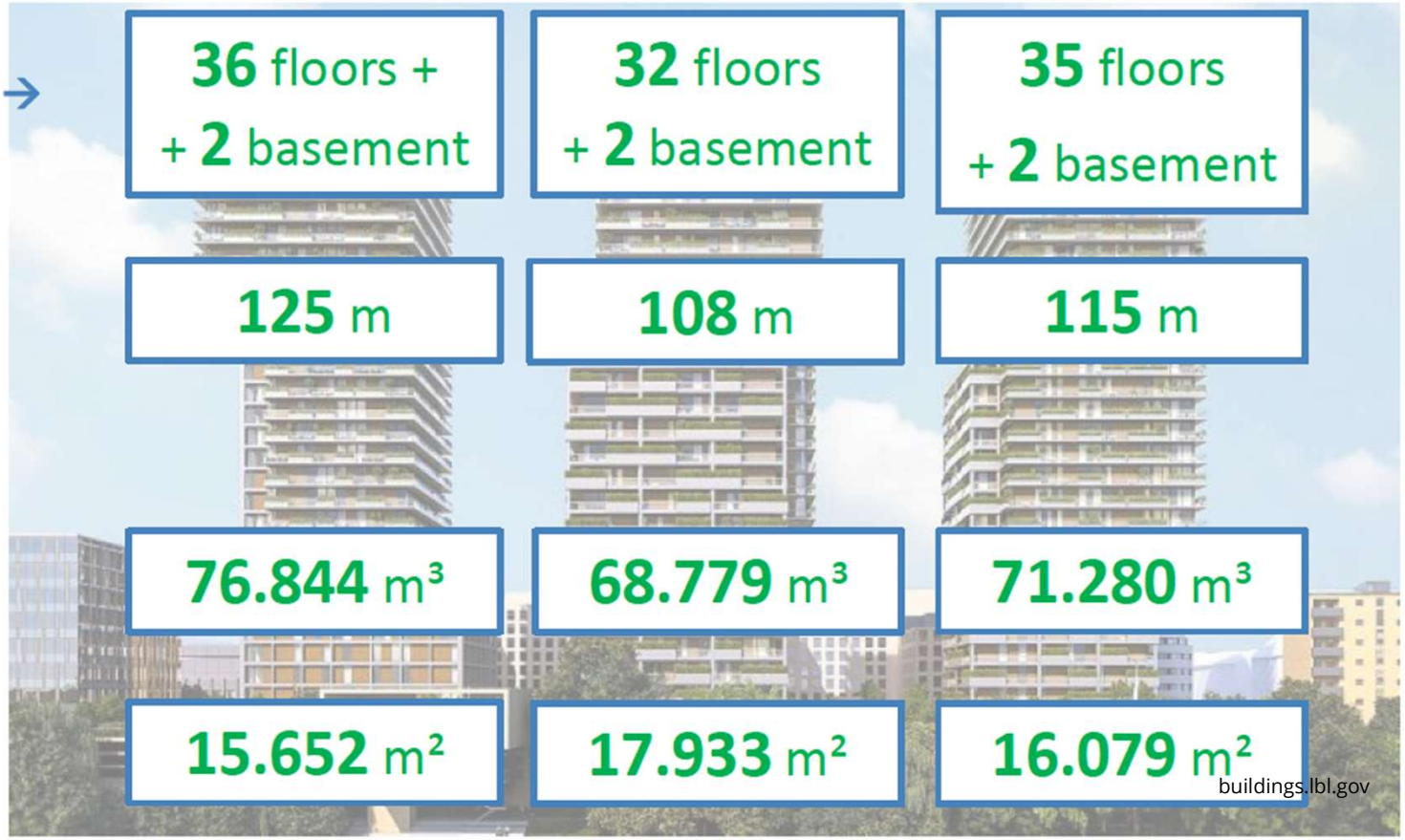


	Tower 3	Tower 2	Tower 1
Floors →	36 floors + + 2 basement	32 floors + 2 basement	35 floors + 2 basement
h →	125 m	108 m	115 m
V →	76.844 m³	68.779 m³	71.280 m³
A_E →	15.652 m²	17.933 m²	16.079 m²

Where to install fans?

Estimate that 18 fans will be needed
120,000 m^3/h

Example fan locations

34. Floor

22. Floor

12. Floor

Ground Floor

31. Floor

18. Floor

Ground Floor

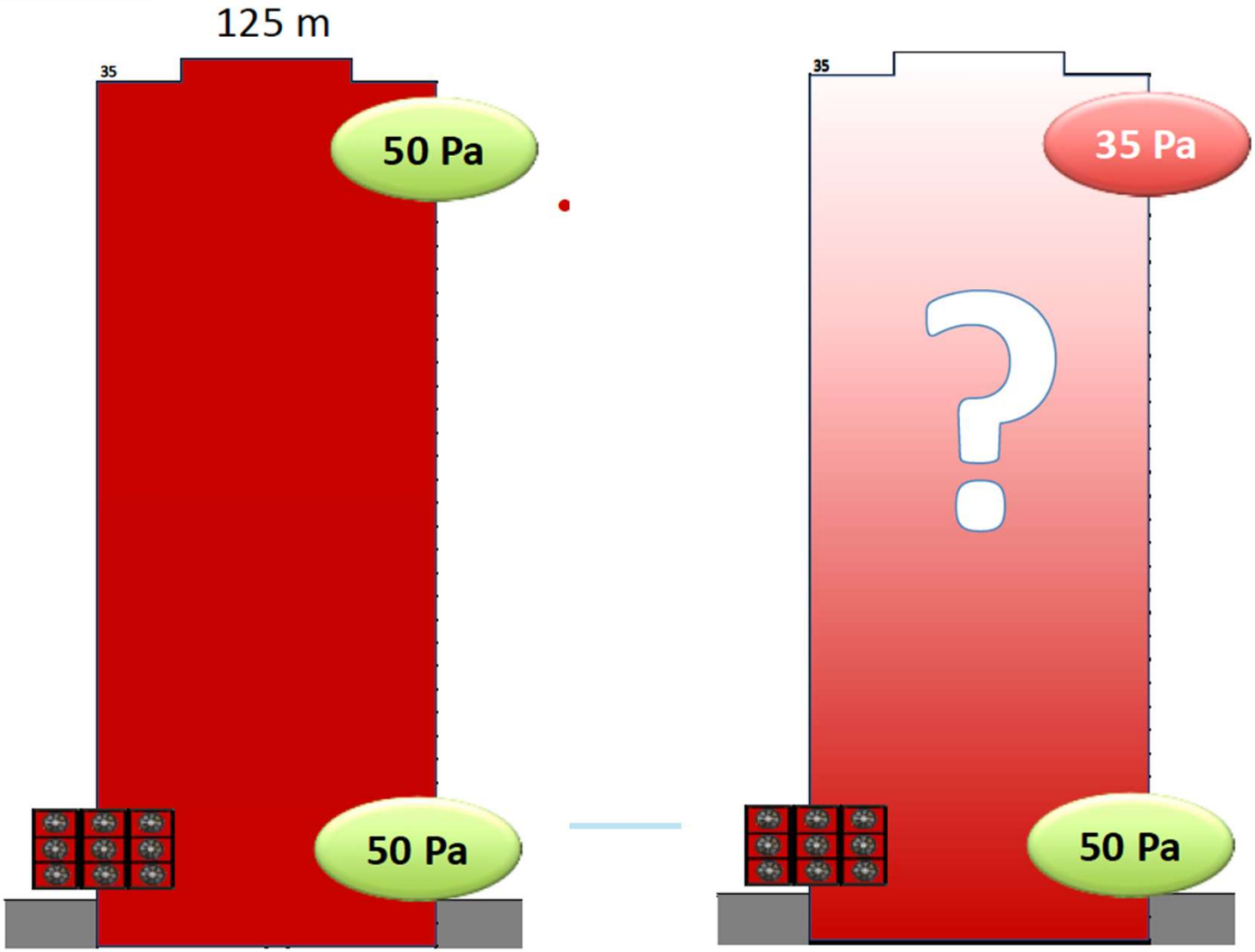
34. Floor

20. Floor

2. Floor

Ground Floor

Uniform Pressure Difference?

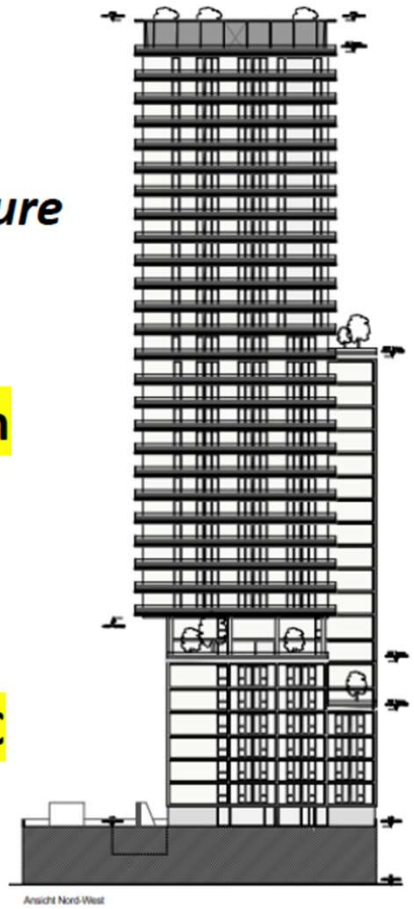


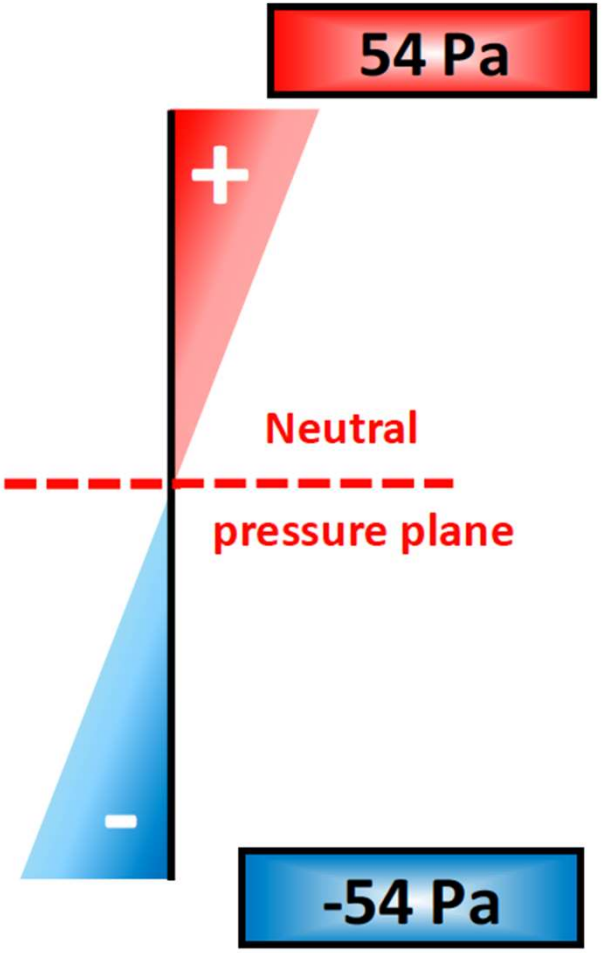
Stack Effect – a significant challenge

Tower 3, Test in Feb. 2021

Estimation of *natural building pressure* some weeks BEFORE the test

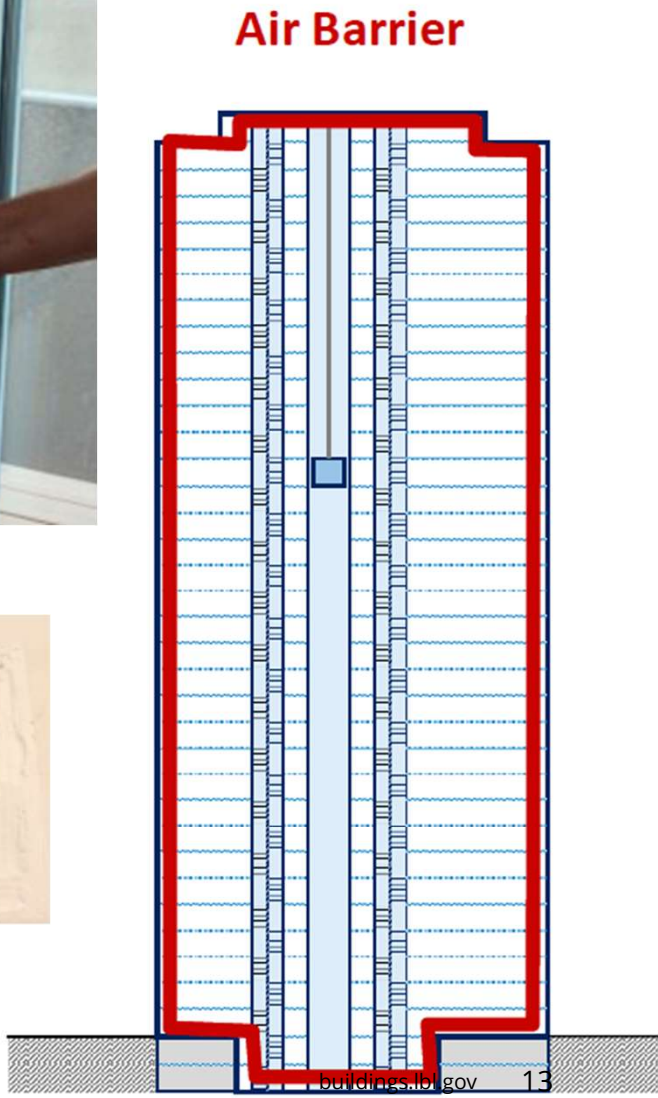
- building height **125 m**
- inside temperature **20°C**
- outside temperature **-1,5°C**





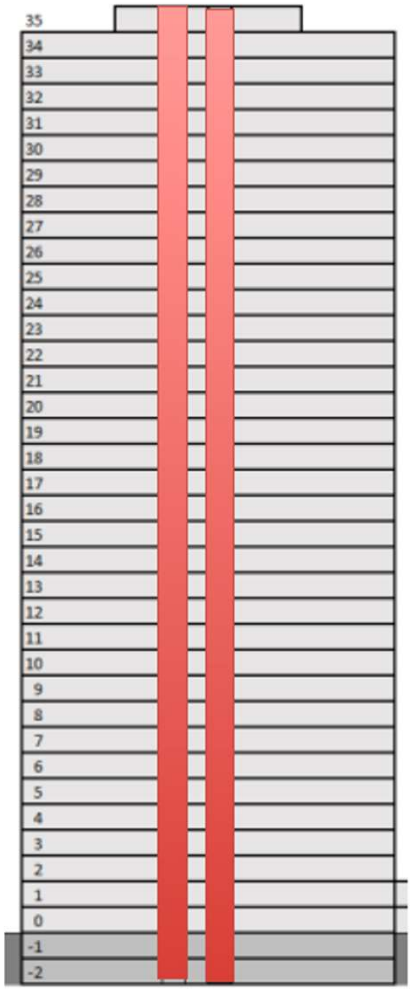
Building Preparation

- Close all exterior doors and windows
- Fill all drains for sinks, showers, toilets
- Dampers in ventilation system
- Dampers in ducts for fire control
- Open all interior doors
  - 1200 wedges!



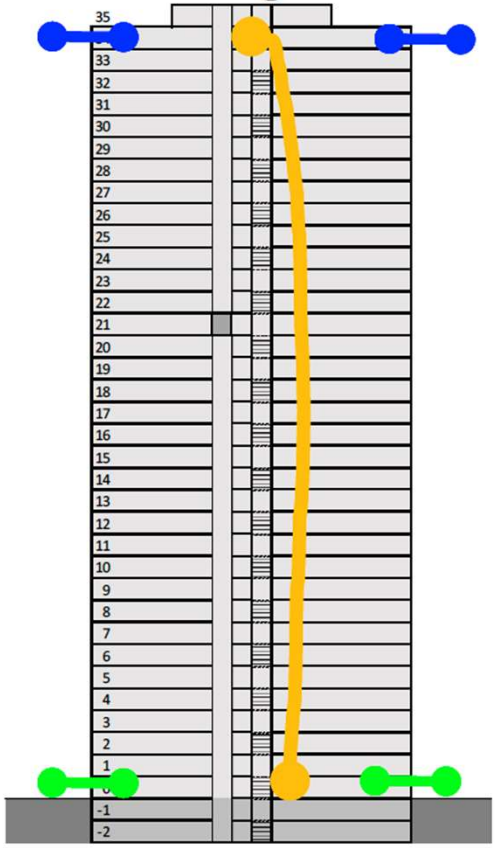
Internal air flow paths

- Stairs – narrow and only 2 or 3 doors/flo
- Lift Shaft – fall protection + other safety



Measure pressures at multiple locations

Measuring stations for the building pressure differences



34. Floor

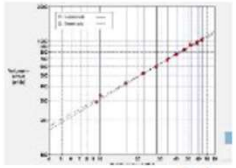
4x building press. difference
between inside / outside
on 4 sides of the building

Intern

pressure difference between two points inside of the building
to see if there is a pressure drop of induced pressure

Ground Floor

3x building press. difference
between inside / outside
on three sides of building



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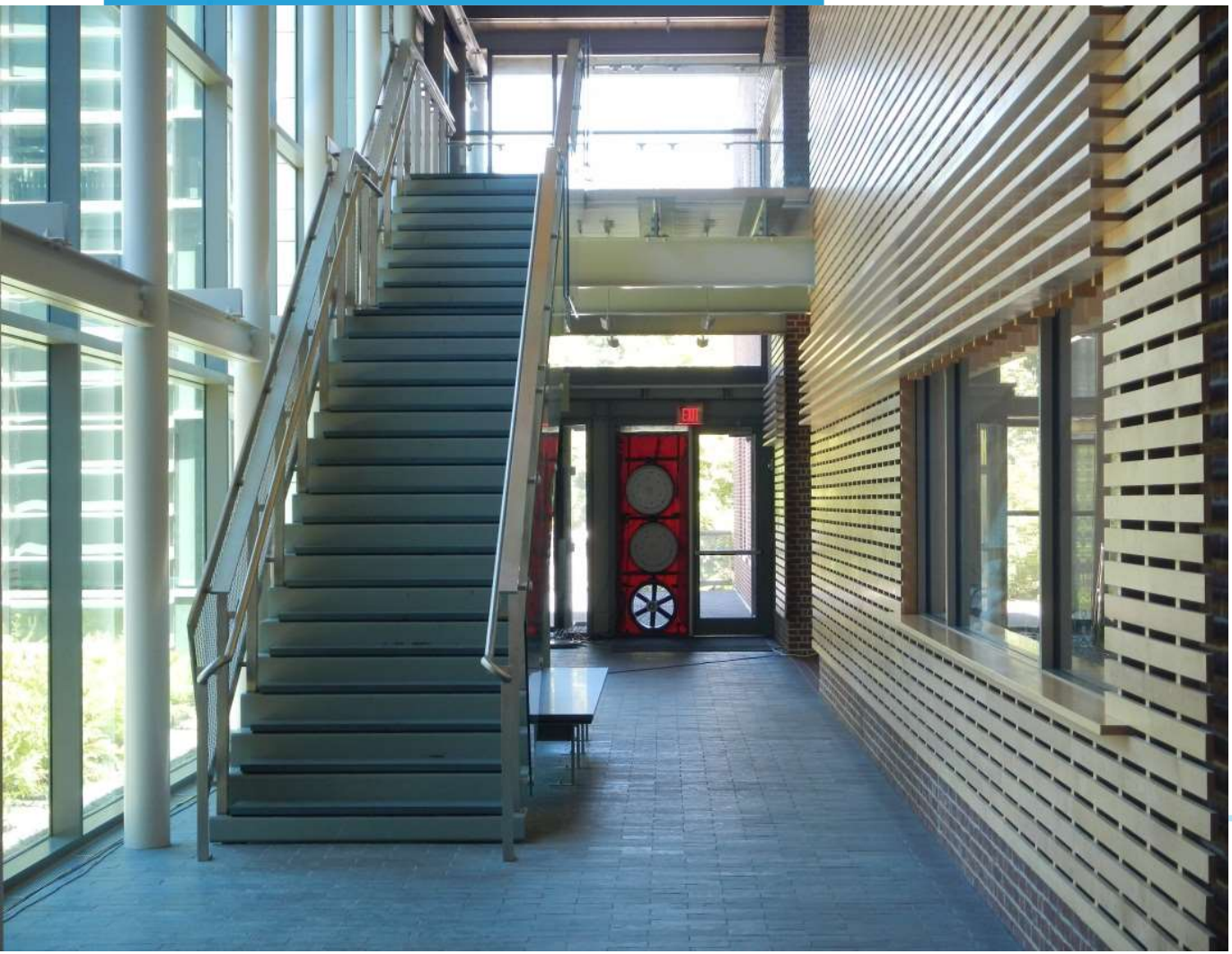
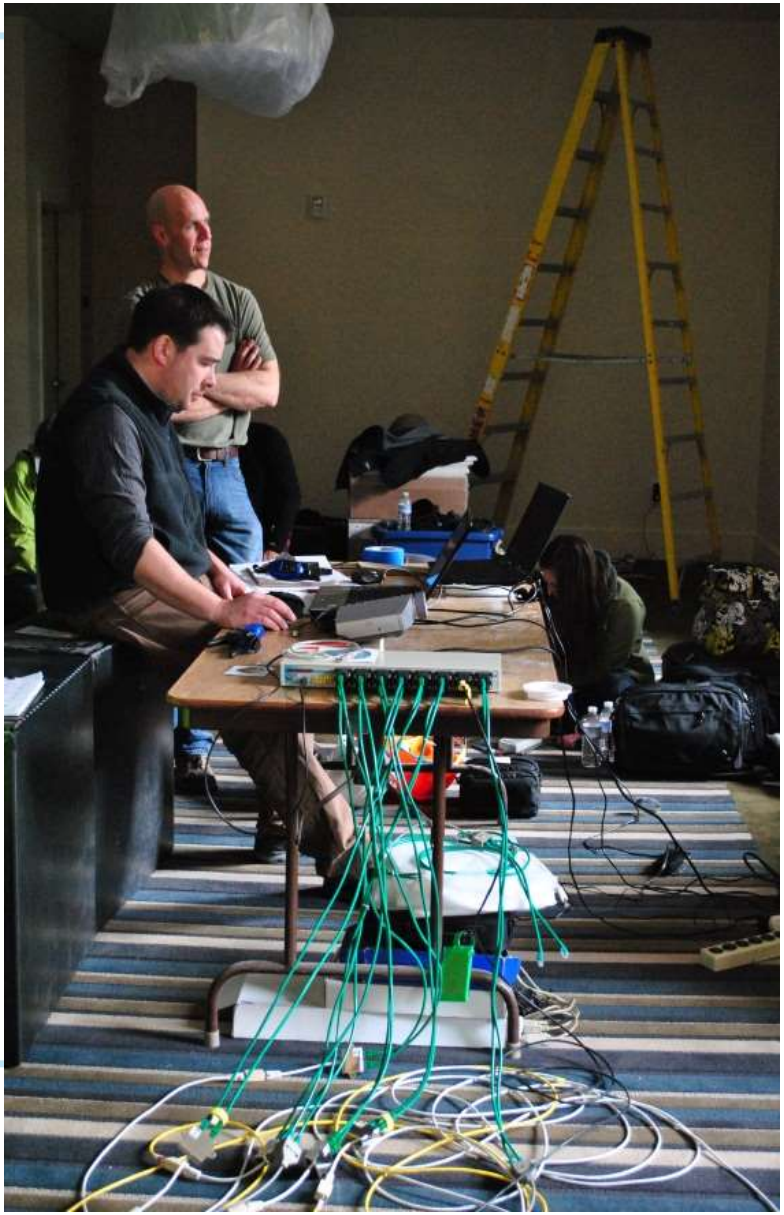
What sort of results do we get?

Table 2: Results of the Airtightness Measurements

	Tower 3	Tower 2	Tower 1
q_{50} depressurization	52,700 m³/h	75,970 m³/h	69,937 m³/h
q_{50} pressurization	66,800 m³/h	75,760 m³/h	69,222 m³/h
q_{50} average	**59,750 m³/h**	**75,865 m³/h**	**69,580 m³/h**
n_{50} air change rate	**0.78 h^{-1}**	**1.10 h^{-1}**	**0.98 h^{-1}**
q_{E50} air permeability	3.8 m³/hm²	4.2 m³/hm²	4.3m³/hm²

Example #2 ASHRAE RP 1478

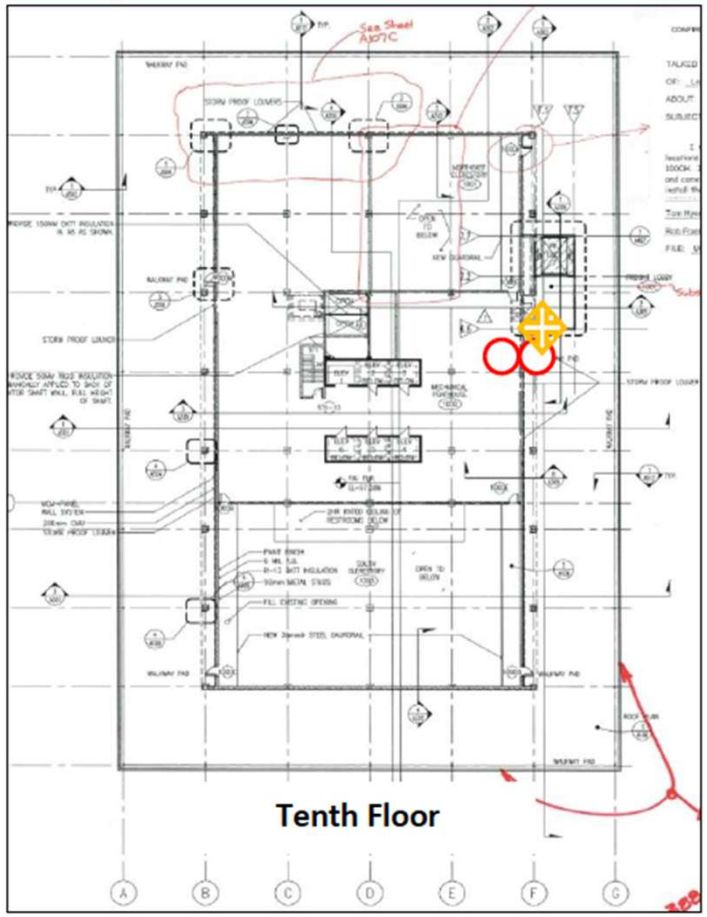


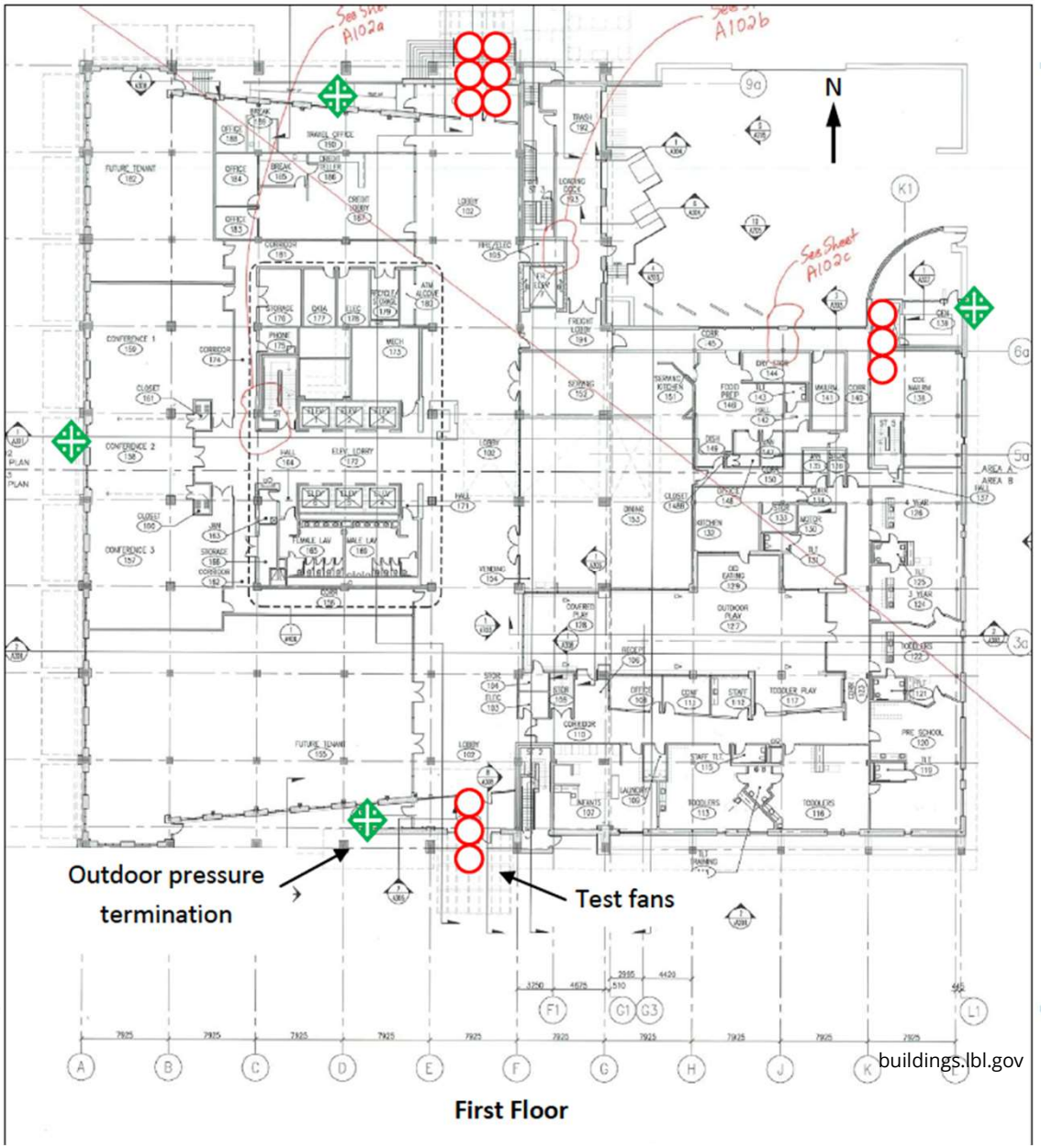


Building Types

- 16 buildings
- 4 to 14 stories
- 7,000 to 24,000 m^2
- Offices, university buildings, public buildings, food and retail
- Use modified ASTM E779 using multiple fans

Building Complexity a Major Challenge





CO0

- One building was also pressurized and depressurized using the building HVAC system. How easy is it to control the HVAC system? CO1
- Measuring surface area for normalization not obvious: 2-15% difference between testing team and independent 3rd party
- Enclosure pressures measured on upper floors need not be included in the baseline or test point calculations because they have little effect on the average and significantly increase wind noise CO2
- Questions about what is inside/outside the pressure boundary; e.g., what to do about mechanical rooms?
- Sealing HVAC system openings is very important and attention must be paid to HVAC system dampers – particularly gravity dampers that can open and close at different test pressures.

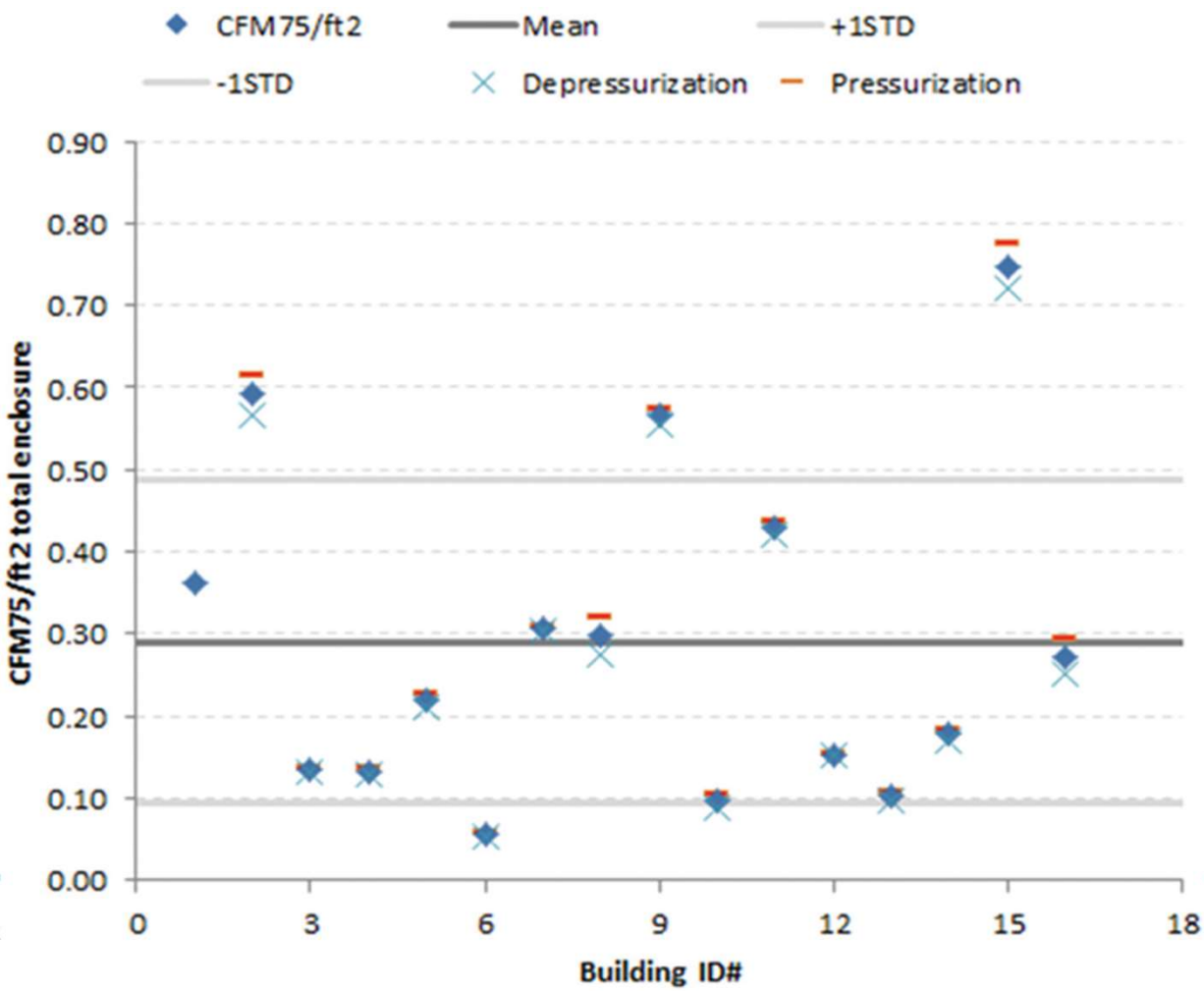
スライド 20

CO0 Title needed
Collin Olson, 2023-05-08T19:31:19.278

CO1 I can talk about that one. We had an interesting event which caused the building to reach + 160 Pa.
Collin Olson, 2023-05-08T19:32:04.528

CO2 Uniform INDUCED pressures is ensured if pressure differences measured internally stay near zero.
Collin Olson, 2023-05-08T19:33:16.420

Lots of building to building variability



Recommendations

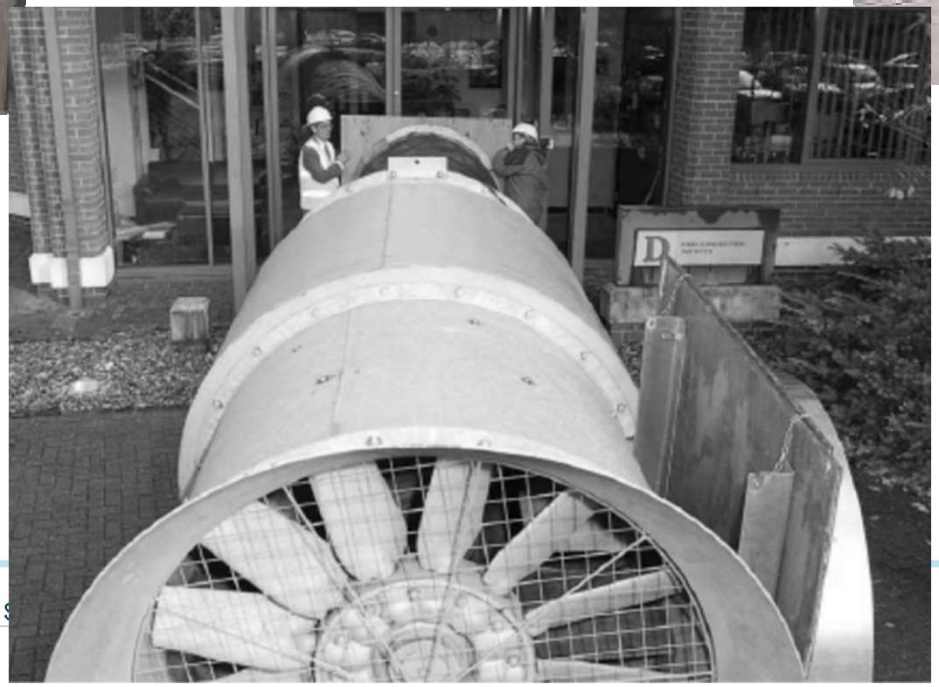
- General
  - Use multiple fans and pressure measurement locations
  - Whole building needs to be positive or negative pressure
  - Test both pressurization and depressurization
  - Need careful envelope and HVAC system preparation
- Austria three towers:
  - A temperature difference from 8 K-10 K should not be exceeded for buildings with a height of up to 125 meters - this corresponds to 1000 mK to 1250 mK. NOTE: ASTM E 779 has a limit of 200 mK
  - While testing, the wind speed should be equal or below 3 on the Beaufort scale.

Thanks to...

Stephanie Rolfsmeier, Emanuel Mairinger, Johannes Neubig, Thomas Gayer. 2022. Measuring airtightness of 100-meter high-rise buildings (lessons Learned). Proc. AIVC Conference 2022.

Terry Brennan, Gary Nelson, Wagdy Anis and Collin Olson. 2013. ASHRAE 1478: Measuring Airtightness of Mid- and High-Rise Non-Residential Buildings

Comments and Questions



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