A Test Procedure for Assessing Envelope Leakage in Commercial Buildings: The Issues, the Process and the Results

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The Building Envelope …

… Making a Statement about the Building and its Owner

- Aesthetics and visual appeal are key drivers
- Origins in the early phases of design

The Building Envelope …

… An Essential Component of the Building Environmental Control System

- Resist energy transfer
- Resist mass transfer
  - Water
  - Air
- Allow occupant access

These functions evolve later in the design process

Envelope Details …

…Impact HVAC Performance

- Thermal implications
- Humidity implications
- Pressure implications

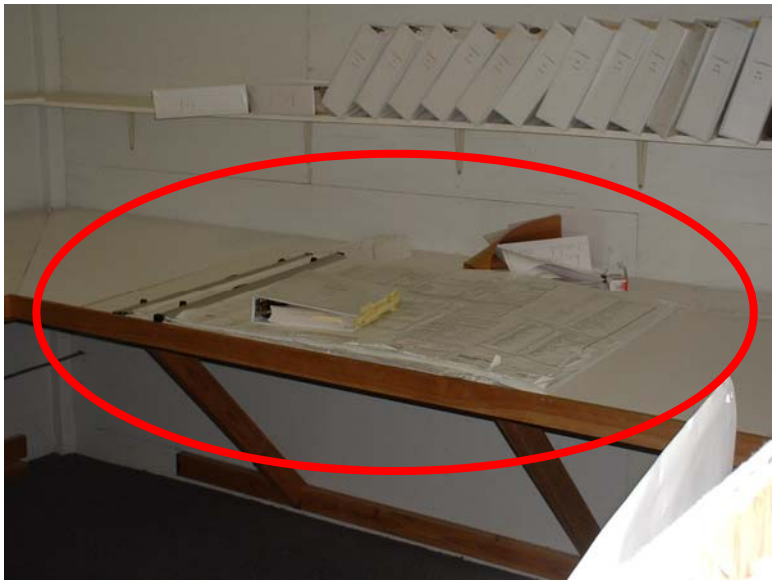
It Takes A Lot of Detail ….

… to Assemble a Building Envelope

Shop drawing sets that define the curtain wall and window system for a 400 foot tall high-rise

The Contract Documents for the Same Project

The Architectural Contract Documents



The Mechanical Contract Documents

Perhaps a clue about why there may be a few problems and where they are going to occur?

Envelope Design Realities

- Multiple panels = Multiple joints
- Different materials = Different physical characteristics
- Different characteristics = Joint movement
- Building movement = Joint movement
- Entrances and exits = Envelope breaches
- Building height = Stack effect

Envelope Fabrication Realities

- Construction timeline = Seasonal variations
- Different materials = Multiple trade specialties
- Architectural features = Hidden joints and construction
- Plenums = Heightened performance requirements from standard construction techniques
- Special products = Special handling
- Special products = Special installation processes in a less than optimal environment

Detection By Inspection is Increasingly Difficult as Construction Progresses

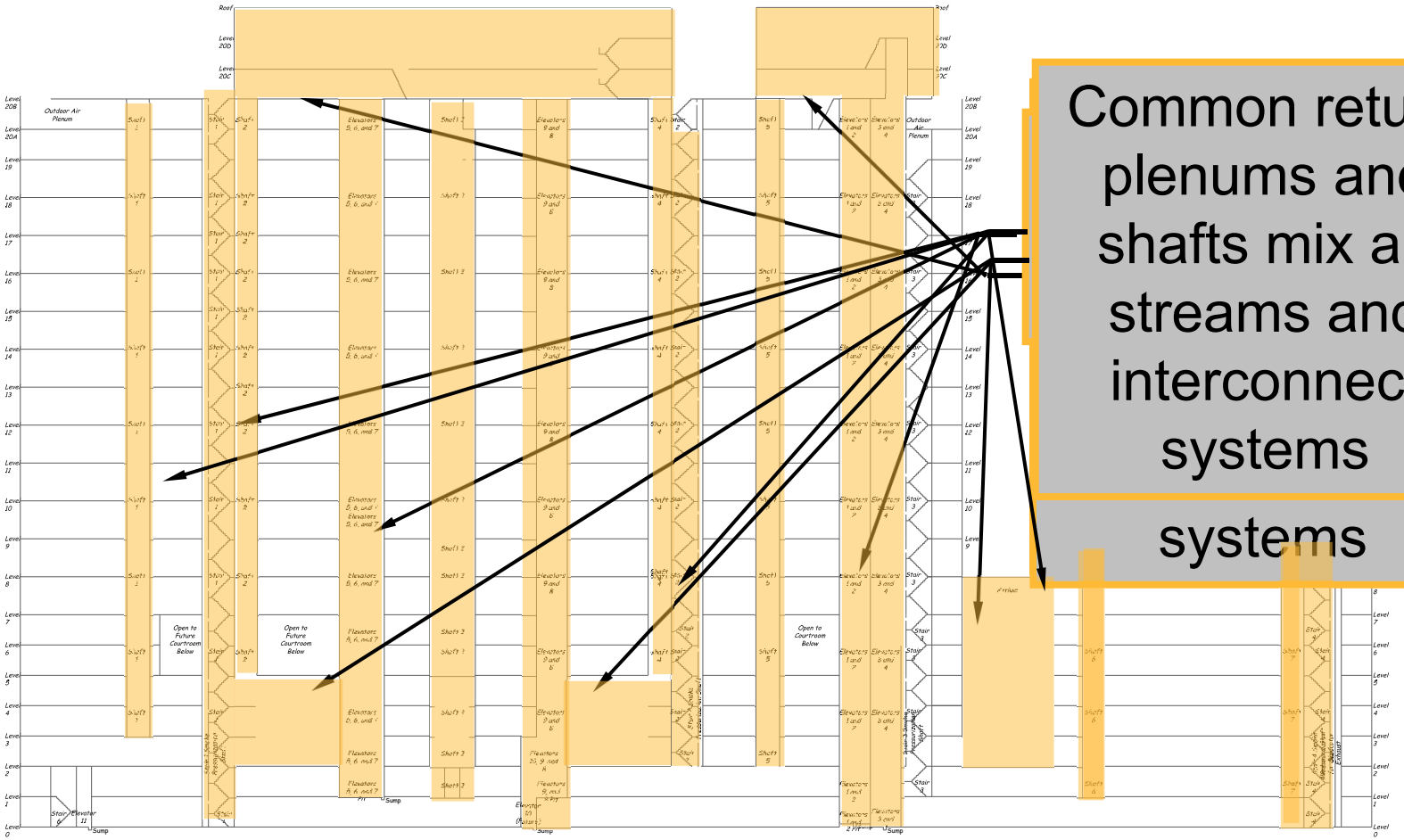
Finishes make assessment from the interior virtually

Elevation makes impossible assessment

Design and Fabrication Realities Lead to Operating Realities

- A weather tight building is not air tight
- Uncontrolled, unanticipated air leakage leads to:
  - Comfort problems
  - Energy waste
  - Catastrophic events
    - Indoor air quality failures
    - Piping failures

Complex Geometry Compounds the Problem



Common return plenums and shafts mix air streams and interconnect systems

systems

HVAC Modifications May Or May Not Be Able To Mitigate Air Leakage Problems …

… Understanding the problem is the key first step to developing a solution

Assess air leakage:

- Magnitude
- Location
- Significance relative to other openings
  - Entrances
  - Loading docks
  - Relief systems

Many Procedures Available

ASTM Standard E 779 (ASTM 1992) - *Standard Test Method For Determining Air Leakage Rate By Fan Pressurization*

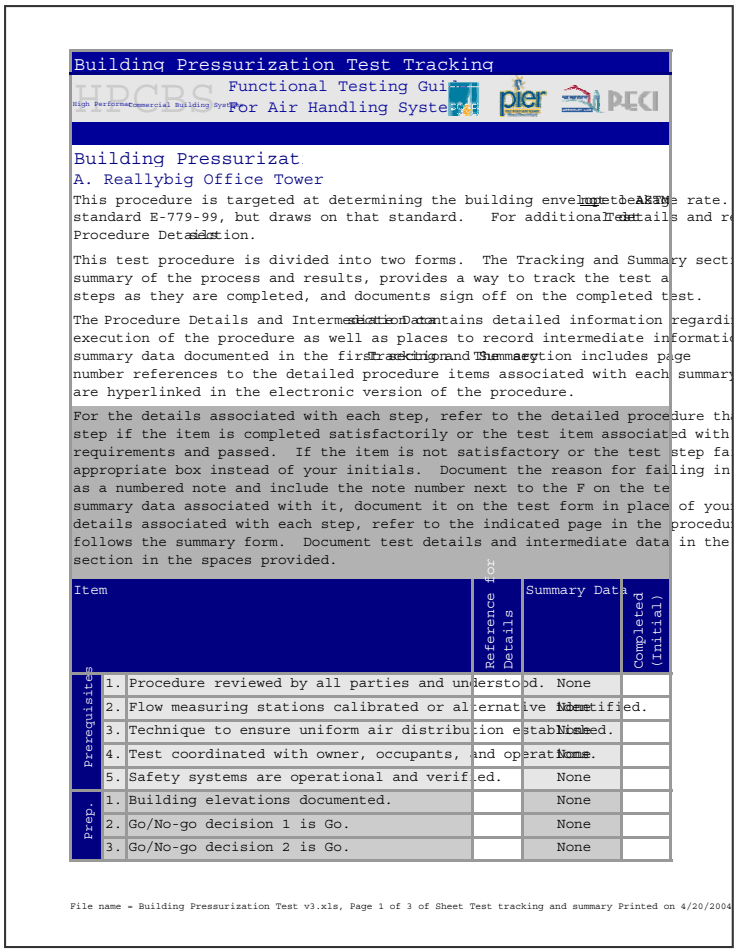
- Uses HVAC fans or an independent test fan
- Documents ambient conditions
- Documents pressures on all faces
- Documents pressures on multiple floors
- Steps pressures up in small increments (0.02 – 0.04 inc.w.c.)
  - Documents flow rates at each test pressure
  - Tests up to 0.25 in.w.c.
- Collects data during pressurization and depressurization

Limited Published Data From Commercial And Institutional Buildings

Myths About Building Envelopes in the March 1999 ASHRAE Journal documents DOE study results

- 139 commercial and institutional buildings assessed
- World-wide assessment
- Multiple uses (offices, schools, retail, industrial)
- Surprising results
  - No correlation to age
  - No correlation to type
  - No correlation to wall construction

The Authors' Test Procedure



Building Pressurization Test Tracking

Functional Testing Gui
For Air Handling Syste

Building Pressurizat
A. Reallybig Office Tower

This procedure is targeted at determining the building envelope leakage rate. standard E-779-99, but draws on that standard. For additional Procedure Details section.

This test procedure is divided into two forms. The Tracking and Summary sect summary of the process and results, provides a way to track the test a steps as they are completed, and documents sign off on the completed test.

The Procedure Details and Intermediate Data contains detailed information regardi execution of the procedure as well as places to record intermediate informatic summary data documented in the first section and the Summary section includes page number references to the detailed procedure items associated with each summary are hyperlinked in the electronic version of the procedure.

For the details associated with each step, refer to the detailed procedure th step if the item is completed satisfactorily or the test item associated with requirements and passed. If the item is not satisfactory or the test step fa appropriate box instead of your initials. Document the reason for failing in as a numbered note and include the note number next to the F on the te summary data associated with it, document it on the test form in place of you details associated with each step, refer to the indicated page in the procedu follows the summary form. Document test details and intermediate data in the section in the spaces provided.

		Item	Reference for Details	Summary Data	Completed (Initial)
Prerequisites	1.	Procedure reviewed by all parties and understood.		None	
	2.	Flow measuring stations calibrated or alternative identified.		None	
	3.	Technique to ensure uniform air distribution established.		None	
	4.	Test coordinated with owner, occupants, and operations.		None	
	5.	Safety systems are operational and verified.		None	
Prep.	1.	Building elevations documented.		None	
	2.	Go/No-go decision 1 is Go.		None	
	3.	Go/No-go decision 2 is Go.		None	

File name = Building Pressurization Test v3.xls, Page 1 of 3 of Sheet Test tracking and summary Printed on 4/20/2004

- Based on ASTM E 779
- Limited number of pressures documented
  - Fewer floors
  - Fewer faces
- Larger pressure steps
- Pressurization cycle only checked
- Assesses known penetrations

Equipment

- Pressure meter for low air pressures
  - 0.30 in.w.c. maximum reading
  - Resolve 0.01 – 0.05 in.w.c.
- Air flow measurement capability
  - Installed flow meters
  - Shortridge™ meter with Velgrid™ attachment to traverse filter bank, intake louver or coil face

Acceptance Criteria

- Information gathering
- Anticipate leakage based on DOE study
  - The average leakage rate varied from 0.1 - 6.8 cfm/sq.ft.
  - The average leakage rate for the high-rise buildings in the data was approximately is 150,210 cfm at a 0.1 in.wc.

Precautions

- Introducing large volumes of outdoor air
  - HVAC capacity vs. load at ambient conditions
  - Assess penalties for loss of control
    - Temporary loss of building environmental control
    - Condensation damage
    - Frozen piping
    - Frozen coils
- Over pressurization
  - Tends to blow doors open
  - 0.20 in.w.c. generates about 25 pounds of force on a typical lobby door

Prerequisites

- Establishing uniform air distribution ensures that the entire envelope influences leakage rate
- Techniques
  - Fully open all VAV terminals
  - Open doors between zones
  - Open stairwell doors

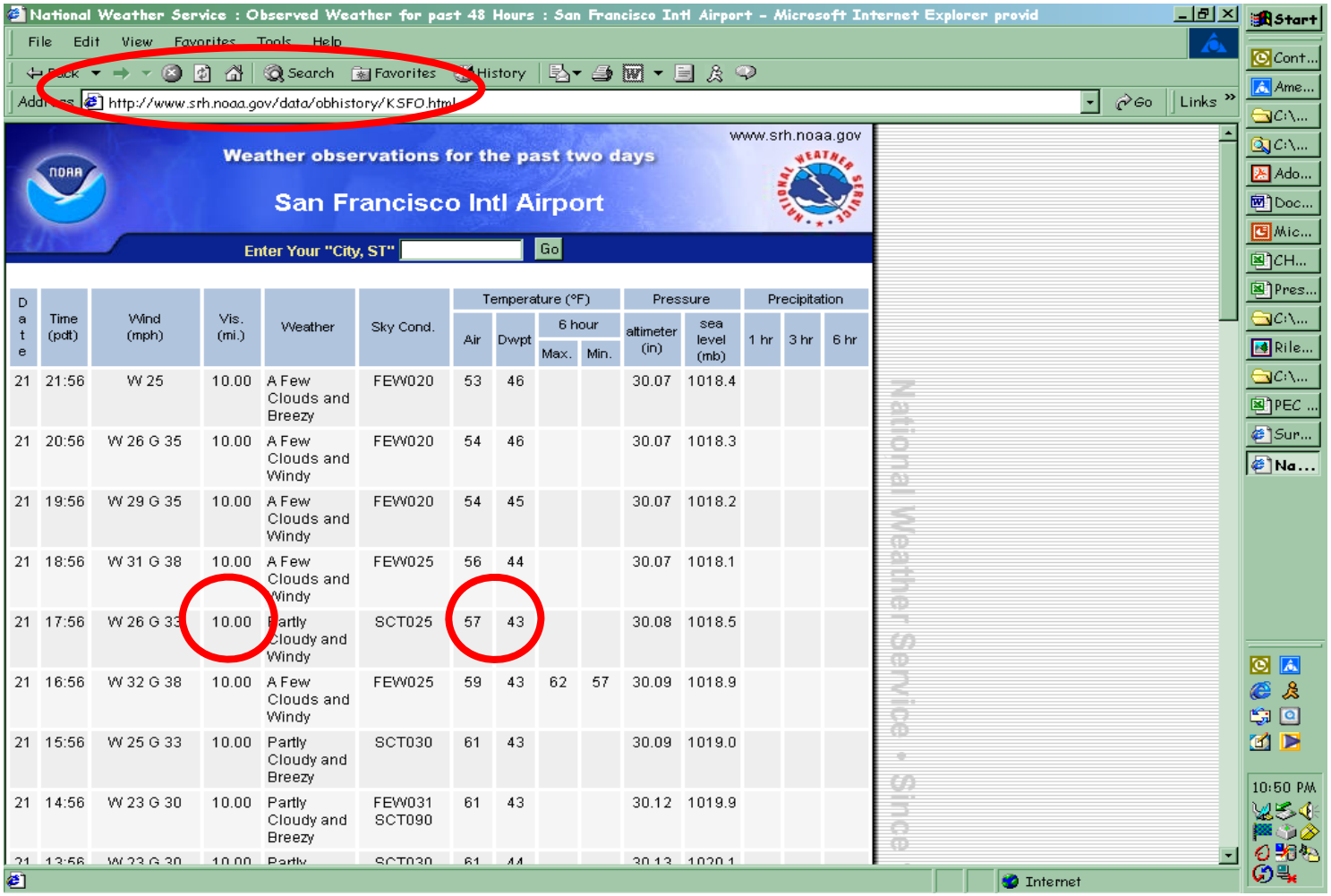
Preparation

- Go/No Go decisions from ASTM procedure
- Go/No Go decision 1
  - Assesses stack effect
  - If indoor/outdoor temperature differential times building height exceeds 1,180 ft.-ºF, consider waiting
- Go/No Go decision
  - Assesses wind effects
  - If wind is steady or gusting over 9 mph, consider waiting

Procedure

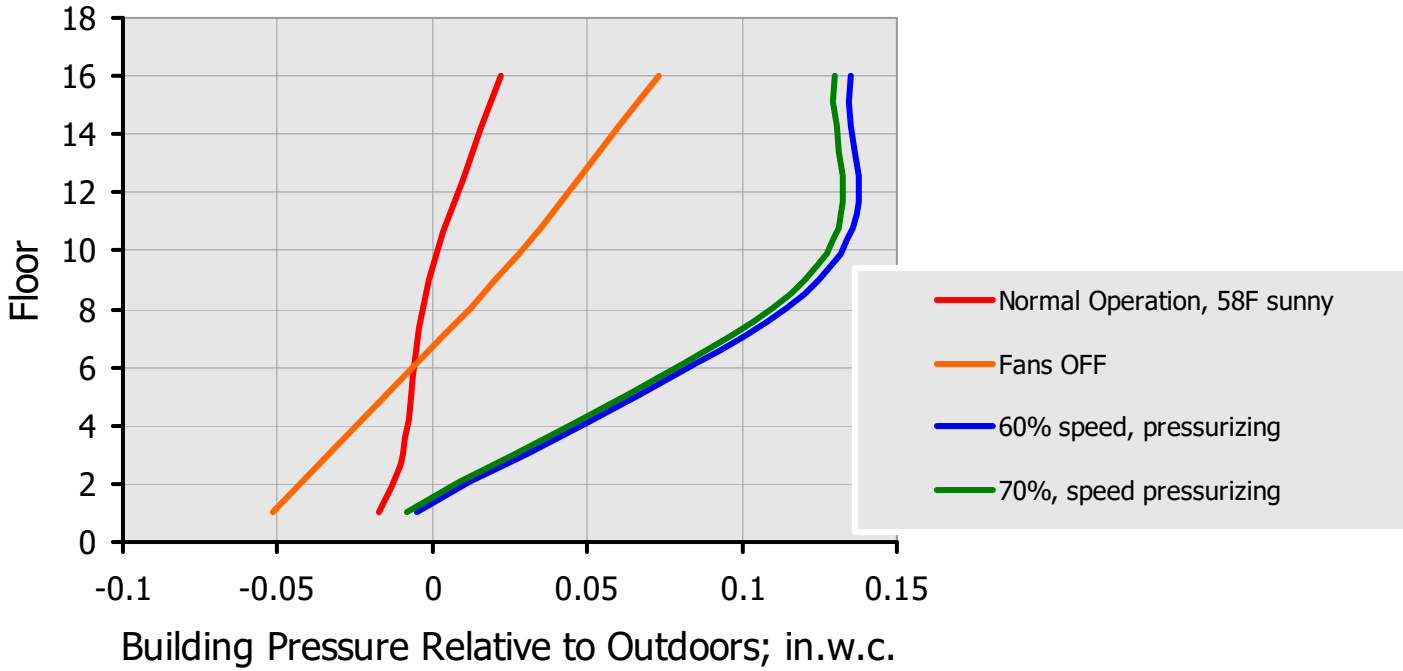
- Configuring the air handling unit and system
  - Set up uniform air distribution
  - Configure AHU dampers for 100% outdoor air, no return, and no relief
  - Best done with the unit off line
- Place units in manual control and ramp up while watching them
- Visual verification of damper position is desirable

Return to Normal and Follow Up



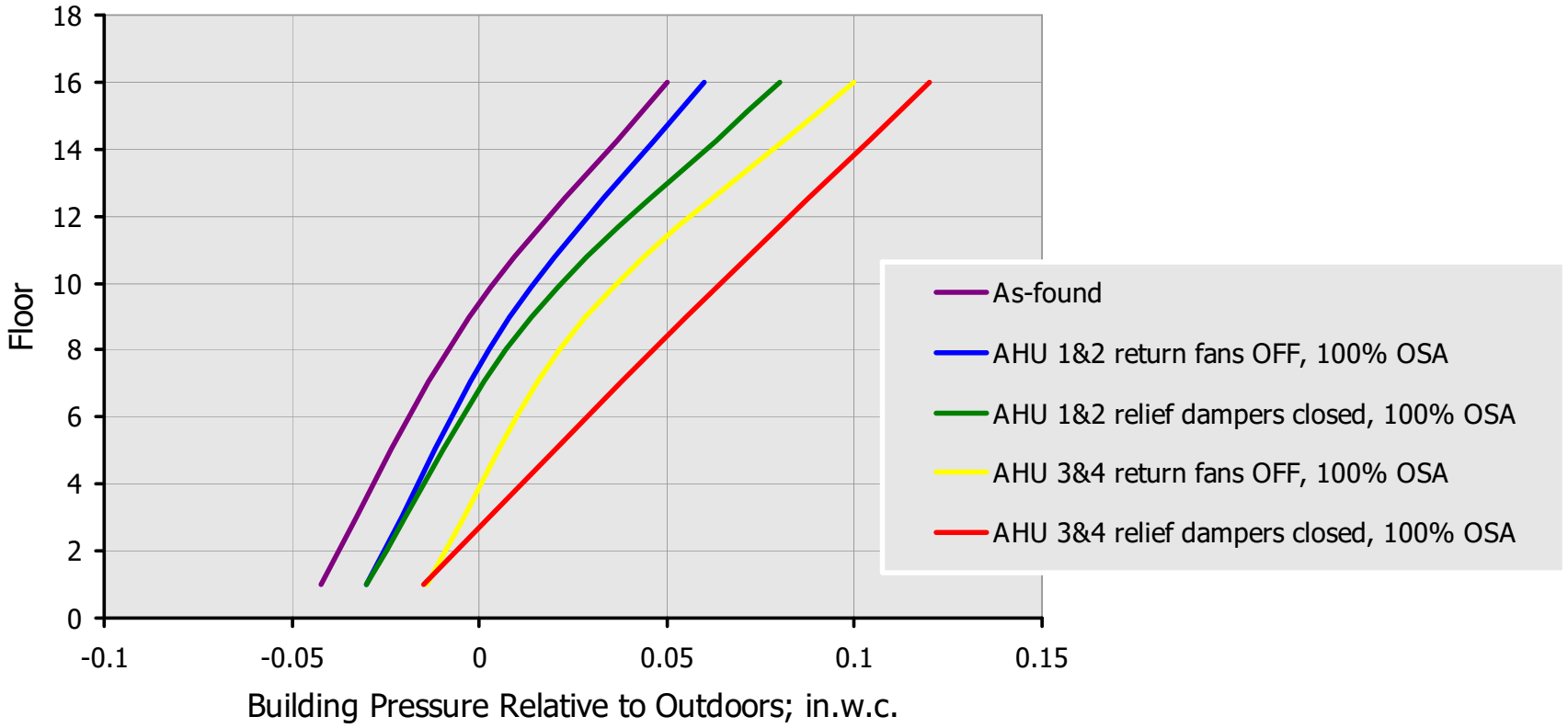
Date	Time (pdt)	Wind (mph)	Vis. (mi.)	Weather	Sky Cond.	Temperature (°F)				Pressure		Precipitation		
						Air	Dwpt	6 hour Max.	6 hour Min.	altimeter (in)	sea level (mb)	1 hr	3 hr	6 hr
21	21:56	W 25	10.00	A Few Clouds and Breezy	FEW020	53	46			30.07	1018.4			
21	20:56	W 26 G 35	10.00	A Few Clouds and Windy	FEW020	54	46			30.07	1018.3			
21	19:56	W 29 G 35	10.00	A Few Clouds and Windy	FEW020	54	45			30.07	1018.2			
21	18:56	W 31 G 38	10.00	A Few Clouds and Windy	FEW025	56	44			30.07	1018.1			
21	17:56	W 26 G 33	10.00	Partly Cloudy and Windy	SCT025	57	43			30.08	1018.5			
21	16:56	W 32 G 38	10.00	A Few Clouds and Windy	FEW025	59	43	62	57	30.09	1018.9			
21	15:56	W 25 G 33	10.00	Partly Cloudy and Breezy	SCT030	61	43			30.09	1019.0			
21	14:56	W 23 G 30	10.00	Partly Cloudy and Breezy	FEW031 SCT090	61	43			30.12	1019.9			
21	13:56	W 23 G 30	10.00	Partly	SCT030	61	44			30.13	1020.1			

The Hatfield Courthouse Results



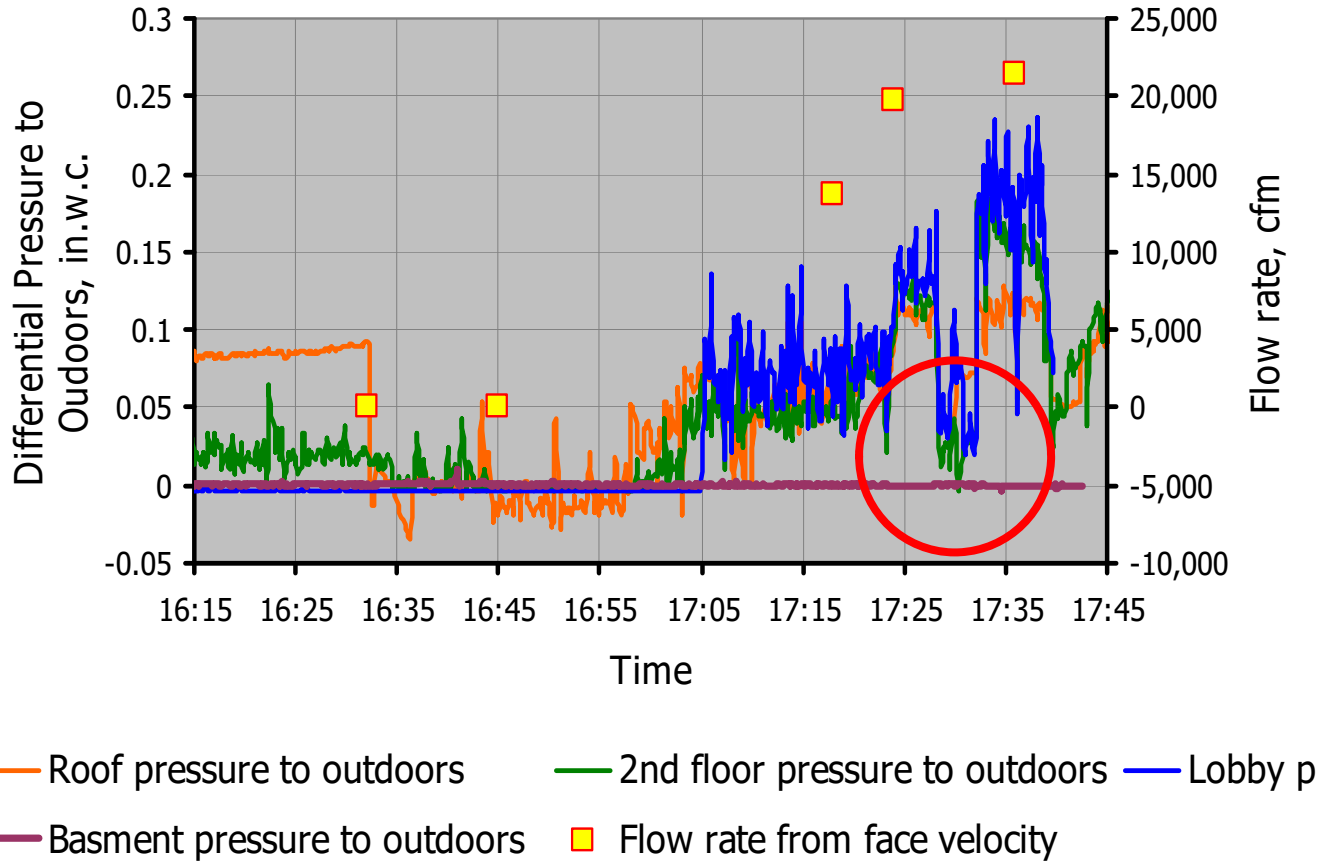
Projected leakage rate range from DOE study - 41,597 to 1,918,061 cfm @ 0.10 in.w.c.

Using the Hatfield Envelope Leaks as a Relief System

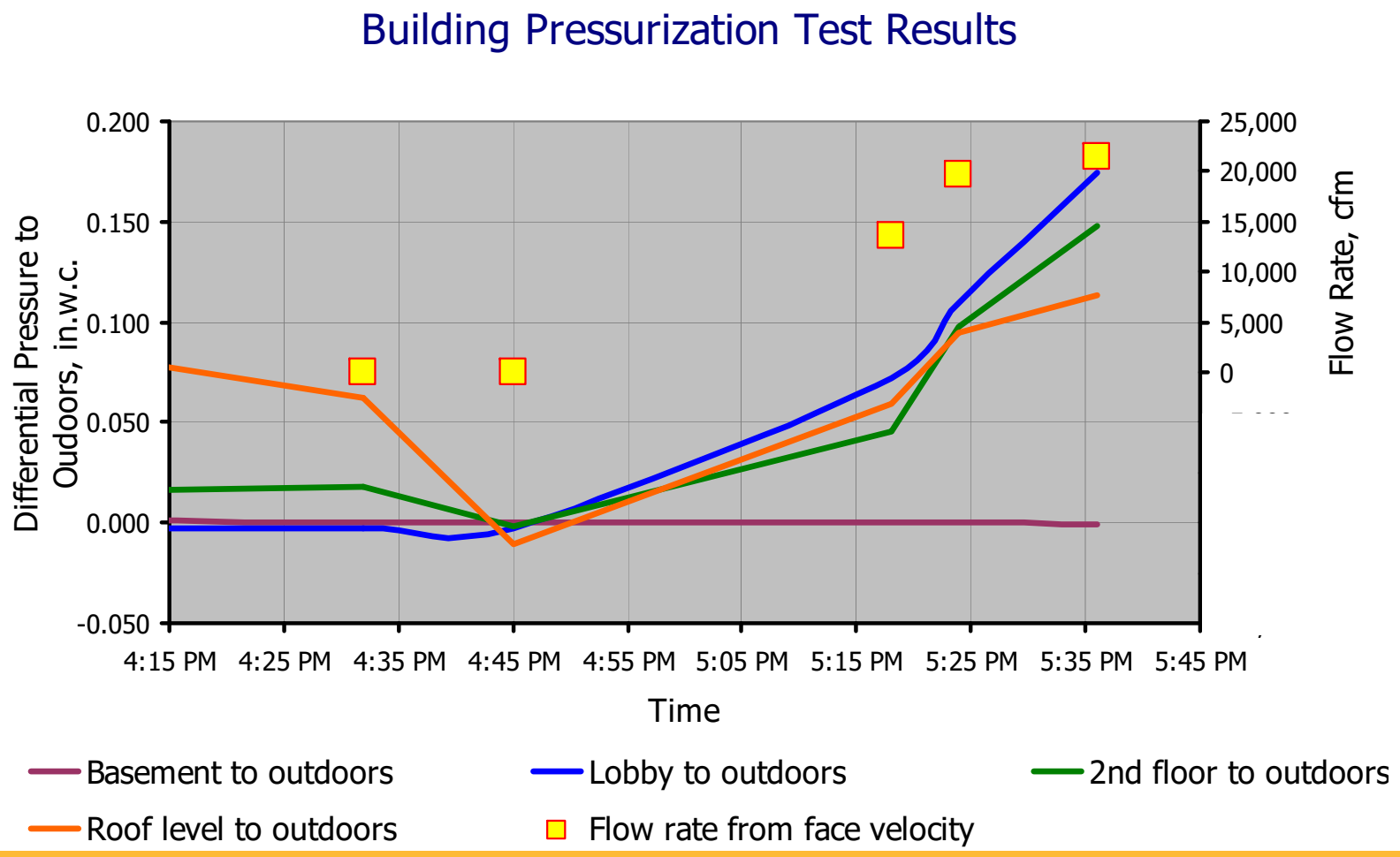


The Pacific Energy Center Results

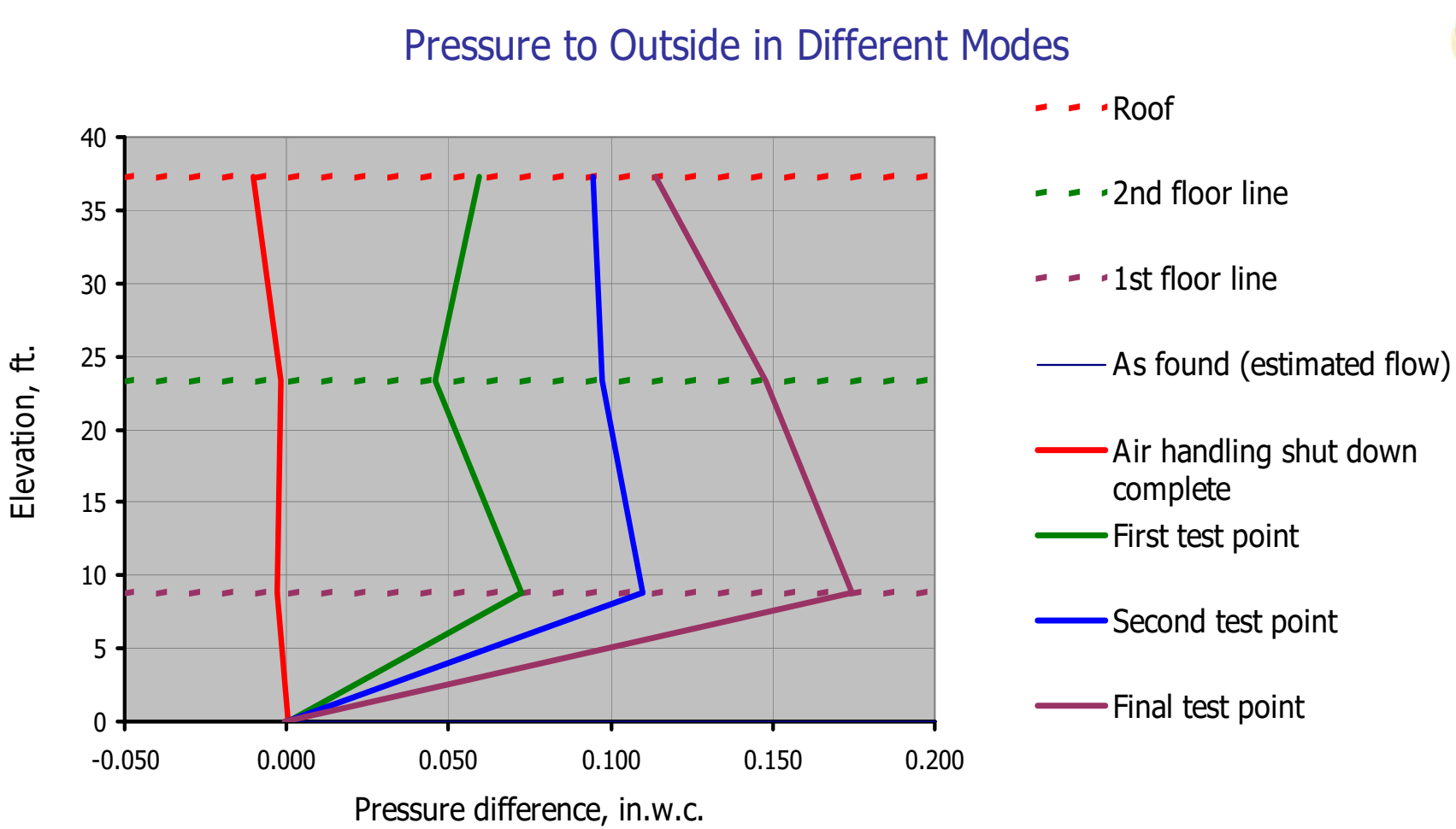
Building Pressurization Test Results



Removing Some of the Spikes



The PEC Pressure Gradient



Conclusions

- Buildings are generally not air tight
- Commissioning efforts can mitigate the effect with the HVAC systems in some cases
- In some cases, the leakage can overwhelm any practical HVAC mitigation
  - Target and repair the leaks as a first step
  - Provide additional HVAC based mitigation if necessary as a final step

Recommendations

- Assume buildings will leak
  - Develop design and operating strategies to allow HVAC systems to cope
  - Target during design phase Cx efforts
  - Target during start up phase Cx efforts
  - Target during RCx efforts
- Endeavor to build leak free buildings

Key Design Points to Consider

- Consider decoupling the temperature control and building pressure control functions associated with the economizer.
- Provide vestibules on lobbies
- Provide supplemental heat and draft protection at workstations located in the lobby.
- Provide an independent HVAC system for the lobby in high-rise and complex buildings