This functional testing guidance is designed to aid in developing test procedures for a specific project by describing the steps involved in testing. The guidance should be adapted as necessary to address the control sequences, configuration, and performance requirements of the particular system being tested. Additionally, codes may require specific testing procedures that may not be addressed in this document. All tests based on this guidance should be reviewed carefully to ensure that they are complete and appropriate.

Test Procedure: Envelope Leakage Test

Overview

This test is designed to help diagnose and quantify the airtightness of the whole envelope by putting air handling systems in 100% outdoor air mode to pressurize the building. The test guidance is intended to help commissioning providers develop their own building pressurization test for a specific building. Except for spaces requiring negative pressure, building pressure should be maintained at a slightly positive pressure. However, in tall, leaky buildings, maintaining positive pressure may be impossible without correcting envelope deficiencies. This test determines the magnitude of envelope leakage so that the cost-effectiveness of correcting these envelope deficiencies can be assessed. Additionally, the pressure profile determined through testing can help uncover which floors have leaks.

This guidance on performing a building pressure test is based on ASTM Standard E-779-99, but this test guidance is less rigorous in order to be more practical to perform outside a research setting. Preparation is essential when performing a building pressure test. The Precautions section and the Prerequisites section describe the most important considerations, including verifying safeties, selecting appropriate test conditions, finding pressure measurement locations, and setting up the building's HVAC systems for the test. After the test is performed, the Acceptance Criteria and the Analysis of Test Data sections help quantify the energy impact of leaks and provides avenues to address problems with air tightness that are identified.

Example Tests

The following test forms were created using this guidance document. They are available at www.ftguide.org/ftct/testdir.htm.

- Envelope Leakage Test - High Rise. ID#: 1013
- Envelope Leakage Test - Low Rise. ID#: 1014

Test Equipment

The following equipment list applies to this test procedure.

- Air flow multi-meter for verification of air flow station calibration or use during test if no air flow stations are installed. Also doubles as the digital pressure gauge.
- Borazine gun, handkerchief, or paper for observing air flow direction and leakage at cracks and other openings. Use of smoke stix or other opaque fume-based products is not advised and extreme caution should be taken if these devices are used to prevent a false trip of the fire/life safety system.
- Datalogger(s) (desirable, but not mandatory) with a bi-directional very low pressure input may be used instead of the hand-held digital pressure gauge. Range of +/- 0.3 in. w.c.

Acceptance Criteria

Acceptance criteria for a building pressure test will be specific to the building type and the desired airtightness. Currently, few standards exist for the desired airtightness of commercial buildings. (The term airtightness refers to the leakage rate of a building relative to its surface area.) A reasonable standard for a building should be based on code requirements (if they exist), owner's project requirements, the building construction type, and the sensitivity of the building occupants or processes to envelope leakage.

Test results from research projects have found a range of leakage rates, which can set expectations for air leakage at the building under test. Table 1 summarizes the latest research on testing and standards for airtightness. Since it may be difficult to achieve 0.2 in. w.c. without blowing doors open or reaching the maximum capacity of the air handling units, it may be preferable to test to 0.1 in. w.c. Applying the square law between pressure and flow allows approximation of the leakage rate at other test pressures, as seen in Table 1.

Table 1. Airtightness for Commercial Buildings (192 buildings tested)

Test Pressure (in. w.c.)	State of the Art [ii] (CFM50/ft^2)	Current Guidelines[iii] (CFM50/ft^2)	Typical Commercial U.S. (CFM50/ft^2)	Notes
0.2	**0.15**	**0.26**	**0.93**	**(Fennell and Haehnel, 2005)**
0.1	*0.11*	*0.18*	*0.66*	*Application of square law to data and recommendations for 0.2 in. w.c.*
0.05	*0.08*	*0.13*	*0.47*	*Application of square law to data and recommendations for 0.2 in. w.c.*

i CFM50/ft^2 is a standard unit of airtightness, defined as the cfm of leakage at 50 Pa (0.2 in. w.c.) per square foot of exterior building surface area (above ground).

ii State of the Art airtightness value of 0.15 resulted from a survey of high-performance buildings and high performance building standards (Fennell and Haehnel, 2005).

iii Current Guidelines airtightness value of 0.26 resulted from research on a number of different organizations' guidelines, recommendations, and in-house standards (Fennell and Haehnel, 2005).

The ASHRAE Journal paper titled "Myths About Building Envelopes" (Persily, 1999) provides more insight into the range of airtightness values found in building research:

- An air leakage rate of 0.1-6.8 CFM75/ft^2, with an average of 1.5 CFM75/ft^2 was found for 139 commercial buildings tested (where CFM75/ft^2 is the cfm of leakage at 75 Pa (0.3 in. w.c.) per square foot of exterior building surface area above ground).
- For buildings greater than 15 stories, the mean leakage rate was approximately 0.5 CFM75/ft^2 for 8 buildings tested.

As more commercial building pressure tests are performed, airtightness acceptance criteria for certain building types in certain climates may be developed.

Precautions

1. **100% Outdoor Air:** The test will involve running the system on 100% outdoor air mode to pressurize the building envelope. The following criteria should be met in order to avoid damage to the HVAC equipment and/or building envelope.
   - Testing should not occur under freezing conditions due to this potential to freeze coils (and due to increased stack effect). Also, the heating coil may not be designed to safely handle 100% outside air.
   - If the test is performed when the dew point is above 60ºF - 65ºF, the cooling coil should have adequate capacity to cool and dehumidify 100% outdoor air at these conditions. If the cooling coil is not actively maintaining discharge temperature in the normal operating range, there is potential for condensation damage in the duct system and on building furnishings.
2. **High Static Pressure Interlocks:** It is essential that the operating team has confidence that the high static pressure interlocks will shut the system down if static pressure exceeds the high limit cut-out setpoint. If the high static pressure interlocks have not been tested recently, it would be desirable to have the operating staff verify them prior to the test date. The interlocks must function regardless of the position of the selector switches at the fan starters and drives because the air handlers will be operated manually or by overriding the controls during the test. In other words, the interlocks should shut down the system if the fan is in Hand, Auto, Inverter, or Bypass.
3. **Ventilation During Test:** Performing this test will involve shutting down all of the building air handling equipment for a period of time (less than an hour), then starting up the systems in manual mode for the test. Ventilation rates in some portions of the building will be below what is required for occupancy, although the overall average ventilation rate may be above design since the systems that are operated during the test will be on 100% outdoor air. During the period of the test, temperature, humidity and pressure relationships in the building will not be controlled and air flow patterns will vary from normal operation.
4. **Fire/Smoke Damper Operation:** If the fire control panel in the Fire Command Center is used to position terminal units and fire/smoke dampers to 100% open during the test (see step 1.5.3 for details), the potential exists for a fan to start or run against a flow restriction or a totally obstructed flow path if fire/smoke dampers close. If this method is used, it is essential that the operating team has confidence in the fire/smoke damper operation.
5. **Exterior Door Opening:** Obtaining positive building pressures at the ground floor during the test has the potential to blow exterior doors open in upper floors if the stack effect is present, or blow open exterior doors on any floor if building pressures reach higher levels during the test. Open doors can skew the test results, so ensure that all exterior doors are fully closed when pressure readings are taken.
6. **Exhaust Fan Openings:** Backdraft dampers may need to be fixed in a closed position for the test.

Test Procedure Outline:

1. Prerequisites: Checklist Prior to Test Date

1.1 Discuss Process

1.2 Determine appropriate outdoor conditions

1.3 Schedule test time

1.4 Ensure accurate air flow measurement

1.5 Check smoke damper position/status

1.6 Ensure air is distributed uniformly throughout the building during test

1.7 Determine locations for differential pressure readings relative to the outdoors

1.8 Document the elevations of the levels at which pressure measurements will be taken

1.9 Specify test participants and roles/responsibilities

2. Determine an appropriate test day

2.1 Assess Go/No-Go Parameter 1: Stack effect criteria

2.2 Assess Go/No-Go Parameter 2: Wind speed criteria

3. Building Pressurization Test Procedure

3.1 Document the outdoor conditions at the beginning of the test

3.2 Document the status of the air handling equipment

3.3 Confirm that all stair and elevator pressurization fans are off

3.4 Close all garage and loading dock doors

3.5 Measure as-found operating pressures

3.6 Shut down all air handling equipment

3.7 Document stack effect with all air handling systems off

3.8 Place fans in manual control

3.9 Ensure air is distributed uniformly throughout building during test

3.10. Pressurize to 0.05 in w.c. and measure building pressures

3.11. Pressurize to 0.10 in w.c. and measure building pressures

3.12. Pressurize to 0.15, 0.20, and 0.30 in w.c. and measure building pressures

3.13. Test garage doors

3.14. Test loading dock doors

4. Return to Normal

4.1 Ramp all fan speeds down to 0 and shut them down

4.2 Return the building systems to their normal condition and status

4.3 Document the outdoor conditions at the end of the test

4.4 Re-enable all alarms that were disabled during the test

4.5 Retrieve the hourly weather data for the test day

5. Analysis of Test Data

6. Example Test Results

1. Prerequisites: Checklist Prior to Test Date

1.1 **Discuss process.** Everyone participating in the procedure is familiar with the test process.

1.2 **Determine appropriate outdoor conditions.** When the stack effect and winds are strong, achieving accurate pressure test results is difficult. The test date should be targeted for a time of year and day when the stack effect is minimized (when indoor and outdoor temperatures are approximately equal) and when winds are low (to avoid the higher pressures on the side of the building facing the wind). The intent of the test is to isolate airflow due to building leakage, not stack or wind effects.

The ASTM Standard for determining air leakage by fan pressurization provides a calculation to assist in determining if the stack effect is too great to achieve accurate results (see Step 2.1 for ASTM calculation method). Practically speaking, it may be difficult to schedule the test to meet this criterion, since for high rise buildings, the pressure test would need to occur when outdoor air temperature was within a few degrees of the indoor temperature. If the test is performed when the stack effect is apparent, the magnitude of stack effect must be taken into account when interpreting test results (See step 5 for interpreting test results).

Per the ASTM standard, the maximum ranges of test conditions are as follows:

Outdoor air temperature: 41°F to 95 ºF

Wind Speed: 0 to 9 mph

1.3 **Schedule test time.** Ideally, the test should be performed when the building is complete but not yet turned over for occupancy because space temperatures and pressures can be adjusted to execute the test without causing inconvenience to occupants. If the building is occupied when the test is performed, the test should begin towards the end of occupied mode in order to collect data on the "as-found" condition. It may be useful to extend the occupied schedule for that day. Alternatively, the test may be run immediately after occupied mode but before the building indoor temperature has changed significantly. The building pressurization portion of the test is recommended to occur when the building is unoccupied to minimize disruption to tenants and allow for measurements to be taken with all air handlers turned OFF. With the building unoccupied, temperature control is less important as long as there is no potential to freeze the coils with 100% outside air during the test. Keep in mind that the indoor and outdoor temperatures should be as close together as possible during the test in order to avoid the stack effect influencing test results.

1.4 **Ensure accurate air flow measurement.** Performing this test will require documenting the flow through various air handling systems while the building is at different test pressures. A hand-held air flow meter (ex., Shortridge multimeter with the Velgrid probe) can be used to traverse the filter banks and provide this information. If the fans are equipped with accurate differential pressure-based air flow measuring stations, they can be used during the building pressure test to save time. Before the test, verify the accuracy of the flow measuring stations. Alternatively, the flow measuring stations can be calibrated prior to the test.

Verifying flow measuring station at each air handling unit

1.4.1 Traverse the filter bank with a hand-held airflow meter and compare the reading (convert average velocity to flow using the duct area) with the flow measuring station meter. Alternatively, perform a duct traverse to determine flow. Traversing the filter bank is preferable to a duct traverse because velocity measurements are taken throughout the entire duct area.

1.4.2 Perform this verification at minimum fan speed and at a fan speed above 60%.

1.4.3 If the flow station and the meter readings are within 10%, then the flow stations can be used for the test measurements. Otherwise, they should be calibrated prior to testing or the flows documented in the test should be read using the hand-held airflow meter.

1.5 **Check smoke damper position/status.** Confirm via testing or discussion with the building operating staff that the indicator lights and selector switches on the graphic panel in the Fire Command Center accurately indicate the status of the fire and smoke dampers. All fire/smoke dampers must be open.

1.6 **Ensure air is distributed uniformly throughout building during test.** For this test to accurately reflect the building leakage rate, the air handling systems must distribute the air fairly uniformly and without much restriction between building compartments. To accomplish this, ensure that all of the smoke and fire dampers are open and that the terminal units are at or near maximum flow. These issues are described below: Terminal units set to maximum regulated flow (not necessarily 100% open). Use the easiest procedure to achieve this. Example procedures are described below.

1.6.1 **During unoccupied system status, terminal units may default to 100% open position.** If this is the case, then run the building pressure test in unoccupied mode and override the supply fans ON.

1.6.2 **Set up a global command that sets all terminal units to the maximum regulated flow position without affecting other operation.** If all terminal units cannot be set to the maximum regulated flow, then temporarily block all doors in all stairwells open. This will tend to help short circuit the floors to each other at several locations, compensating for the terminal units not being wide open at all locations.

1.6.3 **Use Fire Command Center to command terminal units to max flow.** The control drawings may indicate that if a floor is placed in the pressure mode, then the boxes on that floor will be commanded to the maximum regulated flow position, which is the condition desired for the pressure test. But the control sequence may also place the terminal unit dampers on the other floors in the closed position, which is not the condition needed for the test. It may not be clear if the pressure mode affects the return air fire smoke dampers, or if these dampers are only impacted by the purge position of the selector switch. Confirm via testing and/or discussions with the operators that placing all of the floors in the pressure mode will command all of the terminal units to the maximum flow position; i.e. placing a floor in pressure mode overrides the close command to the terminal units from an adjacent floor being in pressure mode. Also verify what happens to the fire/smoke dampers in the return shaft when the selector switch is in pressure mode. If it closes them, performing the test may still be feasible since having all of the terminal units open 100% should allow fairly uniform air distribution even without the return shaft fire/smoke dampers open. If the return dampers can be kept open as well, all of the floors would be short-circuited together via the return shaft.

1.7 **Determine locations for differential pressure readings relative to the outdoors.** Finding locations for measuring differential pressure with respect to the outdoors may be difficult in a sealed building. Locations such as doors to balconies may be used (pitot tube slipped underneath the door or door opened a crack) or perhaps an operable window. Building staff can help find appropriate locations, so it is important to identify all pressure measurement locations in advance of test day. If an outdoor reference is absolutely unavailable, the only option may be to take absolute measurements of both outdoor and indoor air pressure and use these values to calculate pressure differential. In a high rise building, there should be a minimum of 3 differential pressure readings relative to the outdoors.

- **Ground floor pressure** (magnitude and +/- relative to outdoors): Always measure ground floor pressure, since the lobby generally has the lowest pressure due to the stack effect. This is often the easiest pressure measurement to take because the pitot tube can be slipped under a door to the outside.
- **Top floor pressure** (magnitude and +/- relative to outdoors): Measuring the pressure at the top floor in addition to the lobby will document the stack effect during the test.
- **Pressure at middle of building** (magnitude and +/- relative to outdoors): Taking pressure measurements at the middle of the building will help determine the location of the neutral plane.
- **Additional pressures** (magnitude and +/- relative to outdoors): Additional pressure measurements beyond the three listed above can help narrow down the location of major leaks, but are not absolutely necessary for the test. Without multiple digital pressure gauges or dataloggers, it can be time-consuming to take measurements at many locations.

1.8 **Document the elevations of the levels at which pressure measurements will be taken in preparation for calculating Go/No-Go parameter (Step 2.1).** Usually, this information can be found in the architectural drawings. If it is not available, estimate it by measuring floor-to-floor heights between landings in a stairwell.

1.9 **Specify participants and roles/responsibilities.** The testing guidance provided in this document can assist in verifying proper system performance in both new construction and existing building applications. The following people may need to participate in the testing process. Refer to the *Functional Testing Basics* section of the Functional Test Guide for a description of the general roles and responsibilities of the participants. These roles and responsibilities should be customized based on actual project requirements.

New Construction Project	Existing Building Project
Commissioning Provider Mechanical Contractor Control Contractor	Commissioning Provider Building Operating Staff Controls Contractor

2. Determine an appropriate test day

Appropriate test conditions are 41°F-95°F outside air dry bulb and below 9 mph winds. The following Go/No Go parameters will help determine the best day for test.

2.1 Go/No-Go Parameter 1: Stack effect criteria

Absolute value of indoor/outdoor temperature difference multiplied by the building height in feet. (Units: °F-ft)

If the calculated parameter exceeds 1,180 ft-ºF, then consider postponing the test because the impact of the stack effect could be significant enough to skew the interpretation of the results (parameter per the ASTM Standard Test Method E 779). The taller the building, the narrower the testing window becomes because stack effect can skew the results. For tall buildings, the typical indoor temperature must be within a few degrees of the outdoor temperature to meet the ASTM parameter, which is typically not practical to achieve. The test may still proceed if the calculated parameter exceeds 1,180 ft.-ºF, however, the results will need to be analyzed with this in mind. For instance, during cold temperatures, the stack effect requires the supply fan to move even more air to create a positive pressure in the lobby. Therefore, the leakage found during test needs to be derated based on the severity of the stack effect. (See Step 5 Test Results Analysis for more information).

2.2 Go/No-Go Parameter 2: Wind speed criteria

Document the current wind conditions based on data from weather sites (See Step 4 for websites) or a measurement made with the air flow meter or other source.

Wind speed -	_____	mph	(document source)
Direction the wind is blowing from -	_____	(N,W, SE, etc.)	
Wind gusts -	_____	Yes or No	
Wind gust magnitude -	_____	mph (if available)	

If the wind speed exceeds 9 mph, either continuously or at peak gust, consider postponing the test because the impact of the wind on building pressure could be significant enough to skew the interpretation of the results. However, if testing in a location where typical average wind speed is higher than 9 mph, testing under this average wind speed condition is acceptable.

3. Building Pressurization Test Procedure

3.1. **Document the outdoor conditions at the beginning of the test.**

Outdoor air temperature -	_____	°F	(document source)
Outdoor air relative humidity -	_____	_____	(document units and source)
Cloud cover -	_____	(Sunny, partly cloudy, overcast, etc.)	
Precipitation -	_____	(None, showers, steady rain, etc.)	

3.2 **Document the status of the air handling equipment.** Supply and return fan speeds, outdoor/return/relief damper positions, and exhaust fans status are documented so that the as-found building pressures can be assessed with the system operating mode in mind.

Note other conditions that could impact the building pressure like open doors or windows or open loading dock doors. Where analog data is available, provide it, otherwise simply note general state (off, on, active, etc.). The idea here is to get a general picture of what is going on, but it is not worth hours of effort.

3.3 **Confirm that all stair and elevator pressurization fans are off.**

3.4 **Close all garage and loading dock doors.**

3.5 **Measure as-found operating pressures.** Document the pressure relative to the outdoors at a minimum of three locations at the "as found" operating condition in occupied mode. Connecting the outside pressure to the common reference port of the digital pressure gauge allows the pressure to be read directly as positive or negative as long as a common outside air reference is kept. The scheduled hours of operation may need to be extended for this test, but remember to return the schedule back to normal at the end of the test. Take an average of several readings if the signal is unstable. (With a Shortridge multimeter, taking an average is a standard feature. Don't forget to clear memory before taking readings at a new location or for a different test.)

Cross check the direction of air flow between the location and outside using a Borazine gun, a handkerchief, or piece of paper. It is not recommended to use a smoke stix or other opaque fume-based products since these devices may trip the fire alarm. This can be extremely problematic if the building is occupied during the time of the test. Document the equipment used to measure pressure.

Example documentation of pressures:

Lobby pressure (magnitude and direction of air flow)	_____	in.w.c.
Level 8 pressure (magnitude and direction of air flow) Measure at the door from the public lobby to the roof terrace.	_____	in.w.c.
Level 16 pressure (magnitude and direction of air flow) Measure at the door from the reception area at the judges chambers.	_____	in.w.c.

3.6 **Shut down all air handling equipment.**

3.7 **Document the stack effect with all air handling systems off.** Document the pressure and direction of air flow at the locations indicated relative to the outdoors. This will document the contribution of the stack effect and will be used to augment the data collected later in the test. Base the number recorded on the average of several readings if the signal is unstable.

3.8 **Place fans in manual control.** All supply fans in air handlers with outside air capabilities will be operated to pressurize the building for the test (but not stairwell or elevator pressurization fans). All air handlers are being used to ensure that air is distributed to all portions of the building. All fans are being used to eliminate any inaccuracy attributable to backflow through an inactive fan. To prepare for the next step in which fans are ramped up in speed, proceed as follows (Visually verify all damper positions after forcing them to the required position):

Manually control or override the following at the operator workstation:

3.8.1 Supply fans Off

3.8.2 Return fans Off

3.8.3 Outdoor air dampers 100% open

3.8.4 Return air dampers 100% closed

3.8.5 Relief air dampers 100% closed

3.8.6 Exhaust fan dampers 100% closed (this may require fixing backdraft dampers in the closed position)

3.8.7 Hot water coil controls active (only if the unoccupied building will get too cold during testing using 100% outside air)

3.8.8 Chilled water coil controls active (only if cooling or dehumidification of outside air is necessary to protect from moisture damage or uncomfortable conditions during testing)

3.9 **Ensure air is distributed uniformly throughout building during test.** Force the terminal units open or use some other technique to short circuit the floors together. (See Step 1.5 for details.)

3.10 **Pressurize the ground floor (when outdoor temperature is below indoor temperature – stack effect) or an upper floor (when outdoor temperature is above indoor temperature – reverse stack effect) to 0.05 in w.c. and measure building pressures at all test locations.**

3.10.1 Place all supply fans in operation and gradually ramp the speed up until the lobby pressure is 0.05 in.w.c. positive relative to the outdoors.

3.10.2 For each supply fan, document fan speed (note fan speed units; i.e. hz, % etc.).

3.10.3 Document supply air flow at each measuring station.

3.10.4 Document the building pressure and direction of air flow relative to the outdoors at each measurement location (lobby, middle floor(s), top floor).

3.11 **Pressurize ground floor to 0.10 in w.c. and measure building pressures at all test locations**.

3.11.1 If the supply fans are not already at 100% speed (or if fans haven't tripped out on static pressure safeties), gradually ramp up the fans until the lobby pressure is 0.10 in.w.c. positive relative to the outside.

3.11.2 For each supply fan, document fan speed (note fan speed units; i.e. hz, % etc.).

3.11.3 Document air flow at each measuring station.

3.11.4 Document the building pressure relative to the outdoors at each measurement location (lobby, middle floor(s), top floor).

3.12 **Repeat Step 3.11 for 0.15 in.w.c., 0.20 in.w.c., and 0.30 in.w.c.** Depending on the stack effect and airtightness of the building, it may not be possible to achieve these pressures. See Acceptance Criteria for details.

3.13 **Test Garage Doors.** Without changing fan speed from the final test point, open the garage doors. Document supply air flow at each measuring station. Document the building pressure and direction of airflow relative to the outdoors at the lobby only. This test is to determine if the garage door position has significant effect on building pressure.

3.14 **Test Loading Dock Doors.** Without changing fan speed from the final test point, close the garage doors and open the loading dock doors. Document supply air flow at each measuring station. Document the building pressure and direction of airflow relative to the outdoors at the lobby only. This test is to determine if the loading dock door position has significant effect on building pressure.

4. Return to Normal

4.1 **Ramp all fan speeds down to 0 and shut them down.**

4.2 **Return the building systems to their normal condition and status.**

4.2.1 Occupancy schedule returned to normal.

4.2.2 Fire and smoke dampers returned to normal status.

4.2.3 Fire Command Center graphics control panel selector switches returned to normal (if applicable).

4.2.4 If stair well doors were blocked open, verify all blocks removed and doors closed.

4.2.5 Terminal units are returned to a normal operating mode.

4.2.6 Supply and return fan VFDs are returned to auto/normal control mode.

4.2.7 Outdoor air, return air, exhaust, and relief air dampers are returned to auto/normal control mode. Visually verify positions.

4.2.8 Hot water and chilled water coil controls are returned to auto/normal control mode.

4.3 **Document the outdoor conditions at the end of the test (outdoor temperature, relative humidity, cloud cover, precipitation, wind assessment).**

4.4 **Re-enable all alarms that were disabled during the test.**

4.5 **Retrieve the hourly weather data for the test day.** Temperature, relative humidity, wind speed, and other information for United States cities can be found using the map on http://faa.gov/asos/map/map.htm. It provides 24-hour weather data by the hour, which may be useful in subsequent analysis.

5. Analysis of Test Data

The following steps will help interpret the results of the building pressure test and help determine when action may be necessary to find and fix envelope leakage.

5.1 **If the building was able to positively pressurize to at least +0.05" w.g., compare the test airflow (at the maximum pressure achieved during the test) to the acceptable airtightness at this same test pressure (see Acceptance Criteria on page 2 for a summary of guidelines):**

- Sum the air flow delivered by all supply fans during the pressurization test.
- Multiply the approximate surface area of the building and the acceptable airtightness (cfm/sq ft surface area) to determine the acceptable airflow for the test conditions. Acceptable airtightness criteria depends on the building application, but guidelines can be found in Acceptance Criteria on page 1.
- The difference between the acceptable airflow and the test airflow is the approximate excess leakage rate. If the excess leakage rate is unacceptable, then finding and fixing envelope leakage may be warranted. Fixing leaks will allow a building pressure control strategy to be more effective and reduce energy usage by allowing fans in a VAV system to turn down. Fixing leaks will also decrease the outdoor air necessary to positively pressurize the building, resulting in decreased central plant energy usage since less air must be conditioned.

5.2 **If the building was not able to positively pressurize the lobby to approximately +0.05 in. w.g. (or was not able to positively pressurize at all), then the building has significant envelope leakage problems.** Areas with potentially large leaks can be identified through discussion with building operators or tenants about perimeter areas (or near elevator shafts) that typically have cold calls during the winter. Building thermography is another method for locating leaks, which is best performed during cold weather.

5.3 **Estimate the energy waste from infiltration loads to determine cost-effectiveness of reducing building leakage.**

5.3.1 Determine the excess airflow (excess leakage) in cfm. This is the difference between the acceptable airflow at the test pressure and the measured test airflow. See Section 5.1 above for details.

5.3.2 If stack effect was significant during the test conditions, derate the total airflow used to pressurize the building during the test. Take into consideration the location of the neutral plane under the normal operating condition on the test day. For example, if the neutral plane is at the middle floor of the building during the test, assume that half of the excess airflow is the net perimeter infiltration load. This is only an estimate to be used to determine the approximate energy savings achievable. (Ideally, the building pressure test is performed with no stack effect so that the volume of air used to pressurize the building is truly for pressurization rather than overcoming the stack effect).

5.3.3 Determine the bin occupied hours per year during perimeter heating load conditions (for example perimeter heating load exists when outdoor air temperature is less than 55°F).

5.3.4 Determine heating fan (if applicable) and heating fuel savings due to potentially eliminating this infiltration load by fixing the leaks.

5.3.5 If it is not feasible to fix the leaks, assess the ability to reducing infiltration by altering HVAC strategies.

- Determine if it is possible to maintain a slightly positive pressure through modifications to the building pressurization control strategy. Consider the energy implications of the revised control strategy. In some instances, it may be necessary to bring in excess outdoor air in order to maintain building pressurization. This control strategy will increase energy usage, but the air that is brought into the building will be filtered and conditioned. Untreated air infiltrating into a building can lead to moisture issues, as well as generate temperature and draft comfort complaints by the occupants. Both the positive and negative aspects of the control strategy should be evaluated prior to implementation.
- If applicable, consider reducing speed or turning off return fans to reduce negative building pressurization in the winter. (Sellers, 2004). Calculate these operational savings in addition to the heating fuel and fan savings.

6. Example Test Results

The following two pressure tests were performed on a 17 story office building, with pressure measurements taken at the lobby, 9th, and 16th floors. The first pressure test (Figure 1) identified that the building was very leaky since even with all fans at 70% speed pressurizing the building, the lobby could not reach positive pressure (thus the +0.05, +0.1, +0.2, and +0.3" w.c. pressures were not achieved.)

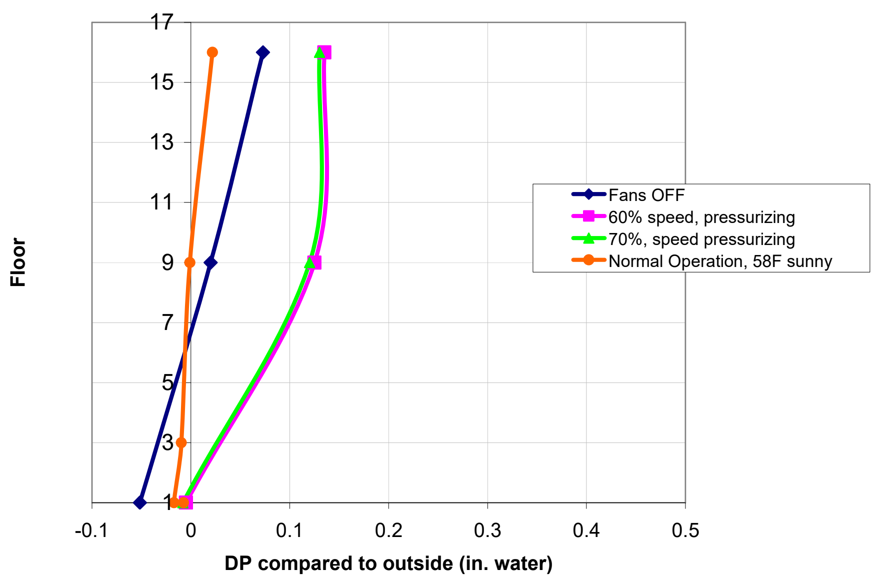

Figure 1. Building pressure test results with supply fan pressurization, relief dampers closed

A second building pressure test was performed on this facility to determine appropriate operating modes to reduce infiltration. With return fans turned off then relief dampers closed, pressure measurements were taken. The results of the test (Figure 2) show that turning off all of the return fans significantly improves building pressure.

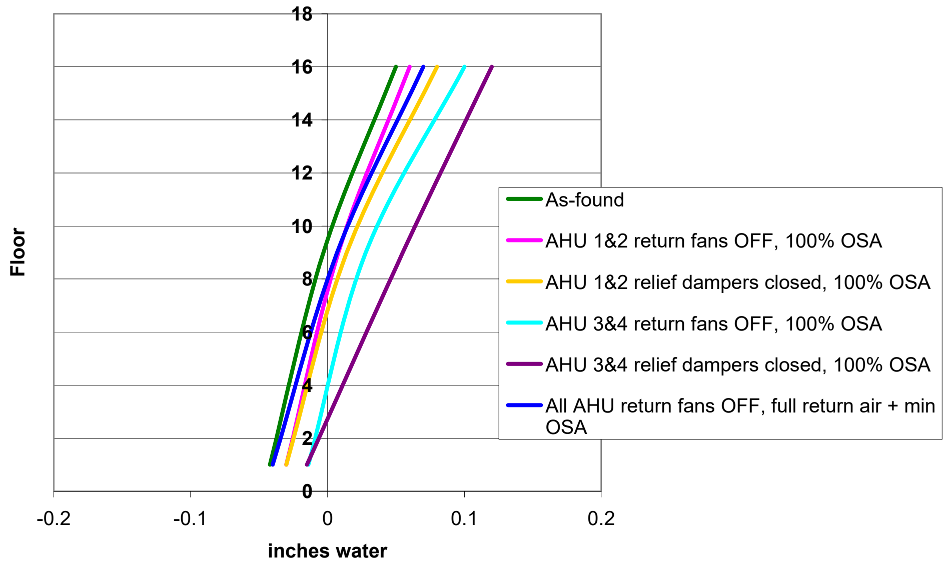

Figure 2. Building pressure test results under different operating modes

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