PRESSURE FLOW CONTROL FOR TODAY'S HIGH PERFORMANCE GREEN BUILDINGS

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Importance of Proper Building Pressure

The control of the building or room's net pressure is essential to maintaining acceptable indoor air quality (IAQ), thermal comfort and structural integrity. Negatively pressurized spaces result in the transport of untreated outdoor air through any intentional, temporary or unintended opening and into the occupied space. This untreated outdoor air will result in:

- the transport of dirt, dust and other contaminants
- the transport of moisture in humid climates (climates where the outside dew point exceeds 60^{o} F)
- humidity control issues that result from the transport of untreated moisture
- mold growth in and near the building envelope that result from the transport of untreated moisture
- perimeter temperature control problems that result when the outdoor air temperature varies significantly from the indoor air temperature

In addition, improper space pressure flow may:

- damage the building envelope
- create door open/close issues and increase owner liability (American with Disabilities Act – ADA)
- increase energy costs when excessive pressure results in the undesired ejection of conditioned building air to the outdoor environment

Understanding Building Pressure

The term "pressure" is somewhat of a misnomer. Building pressure is observed as the result of a differential airflow created by the mechanical system across a pressure barrier. It is often referred to as the "pressurization airflow" or pressure flow. Although the pressurization airflow will result in a measurable pressure drop across interior and exterior walls, direct static pressure control of building pressure flow will not ensure proper space pressurization.

Problems with Pressure Control

Static (or differential) pressure control is widely implemented as a technique to control pressure flow. In most applications, a low cost differential pressure sensor is connected between the exterior of a building or room and an internal reference position within the pressure zone. These sensors are subject to both short and long-term drift, are affected by ambient temperature changes and have questionable accuracy at the low pressures required for proper net pressurization control. Depending on the strategy used, either a return or relief/exhaust fan or damper is modulated to maintain the differential between the reference position and building exterior. Unfortunately, the differential pressure measured will typically NOT represent the actual net building pressure because of:

- wind pressure effect on the reference tap outside of the building
- internal pressure variations that result from air flow through open doors or under closed doors
- sampling error due to the single location of the interior tap, and no valid means to average multiple sensors
- Pressure sensors drift over time, with ambient temperature change, and require periodic zeroing or recalibration

In addition, pressure control is extremely problematic in systems with multiple pressure zones or multiple air handling units serving connected zones, because of pressure interactions. One fan system will respond to changes on its zone sensor and as a result influence the operation of another fan system.

These types of situations are unable to overcome stack effect because multiple air handlers cannot act independently when using a static pressure control strategy. What is our solution?

Airflow control will result in independent pressure zone control without interaction. How?

- Control airflow rates onto and off of each floor, or in/out of each pressure zone.
- Building construction design and quality are critical.
- Pay close attention to potential airflow paths between floors and take action to minimize such paths (leaks, elevator shafts, etc.)
- Do not sum traditional VAV box flow sensors to determine the supply airflow rate. They are not designed to measure absolute values and are very inaccurate.

Stability is also affected by transient wind gusts, door open/close events (interior and exterior) and pressure sensor stability. Very small changes in pressure equal large changes in the airflow needed to create those pressures. The effect of this square root relationship can be easily seen on any typical air pressure to velocity graph.

In reality, the only time that static pressure represents net space or building pressure is when there is no wind and all of the interior doors in a pressure zone are open.

Implementing a Sound Space Pressurization Strategy

Step 1: Analyze internal pressure zone requirements

Analyze the pressure flow requirements of the building and compartmentalize the total space into multiple pressure zones, when applicable. Multiple pressure zones may be dictated by space use requirements. Examples of spaces that may require multiple pressure compartments include:

- Hospital operating rooms
- Healthcare facility spaces requiring airborne infectious disease control
- Laboratories
- Clean rooms
- Commercial Kitchens

Step 2: Consider external factors

Pressure zones may be dictated by external environmental factors, such as the pressure variations created by stack pressure on multi-story buildings. An open return air duct is essentially a large "hole" in the building, when an air handling system is used to provide air to multiple floors. Sometimes existing design issues cannot be overcome, but may only be mitigated.

Step 3: Measure and control the pressurization airflow

Pressurization airflow can only be created by a mechanical system. Wind pressure, for example, cannot pressurize a building. It can only locally pressurize surfaces of the building. The net pressurization result of a building as a whole being zero.

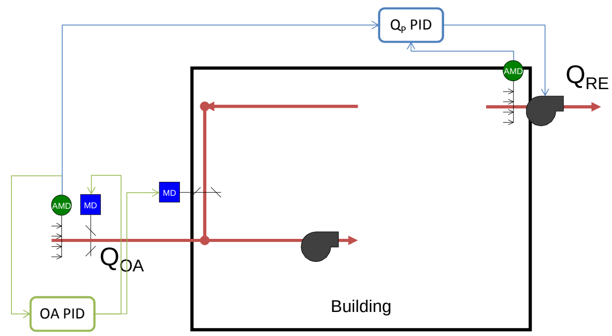
In a simple, single pressure compartment system, the compartment boundaries are the exterior walls and roof. The mechanical airflow differential of concern is the outdoor air and exhaust airflow differential. A simplified control schematic and sequence for air system operations is shown in Figure 1.

Figure 1 - SUPPLY AIR FAN SYSTEM WITH SEPARATE RELIEF/EXHAUST FAN

Minimum Outdoor Air Control: Modulate the outside air and return air dampers (in sequence) to maintain the required minimum outside airflow (Q_{OA}) during minimum outdoor air operation.

Note: The minimum outdoor air set point must be equal to or exceed the pressurization airflow plus any local exhaust airflow to maintain proper building pressure.

Pressurization Airflow Control: Modulate the relief/exhaust air fan or damper to maintain a fixed airflow differential ($Q_{OA} – Q_{RE}$) equal to the pressurization airflow plus any local exhaust airflow.



Mechanical systems that use air handlers with integral return or relief air fans often present a challenge for the proper application of an airflow measuring device in the relief air path. As a result, a different location for measurement is often required to determine the airflow differential required for pressurization flow control.

Fortunately, the challenge is easily resolved. Figure 2 demonstrates that the mathematical equivalent of Q_{OA}-Q_{RE} is Q_{SA}-Q_{RA}. This is commonly known as Fan Tracking but can involve different combinations of fans and/or dampers.

It is important to recognize that since the airflow differential between the supply and return air paths of each air handling system is essentially the pressurization airflow for the space, the control of supply and return (or relief) fans are crucial to proper net pressurization. Systems that trivialize the importance of this differential and use either variable speed fan drive slaving or low accuracy airflow measurement devices for fan tracking will have serious pressure control problems when air is being relieved at the air handler.

Below are the results of modeling space pressurization control due to the impact by ±10% of reading airflow uncertainty in a fan tracking application. After the total measurement and differential uncertainty is determined it is converted to pressure and plotted here (Figure 2). The green area is the assumed acceptable pressurization target around the red line design objective. In fact, the same model using ±5% airflow uncertainty was also unacceptable for pressurization flow control within the green area, emphasizing the importance of measurement accuracy in fan tracking applications.

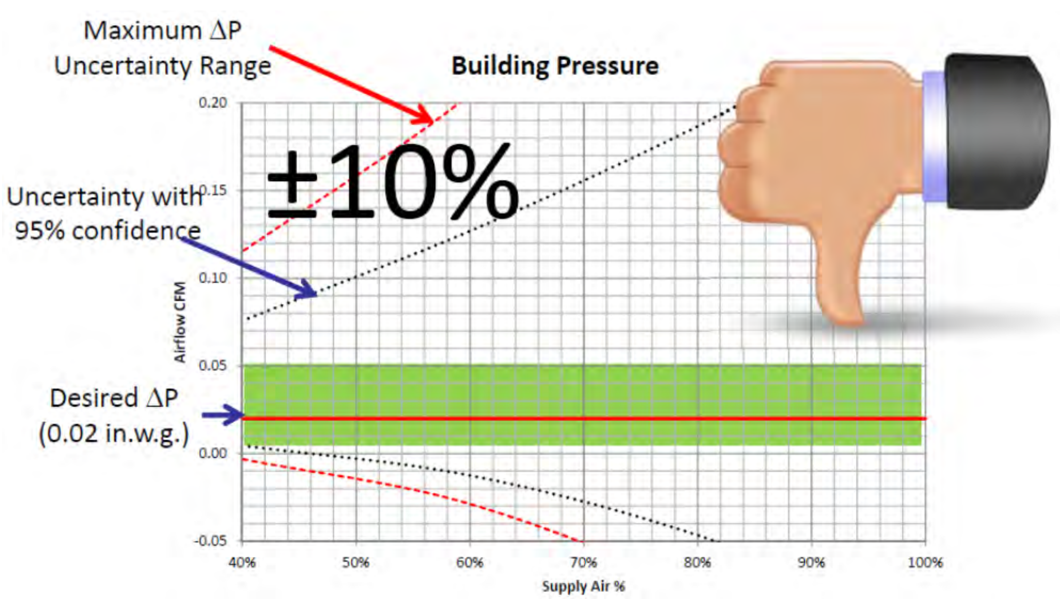


Figure 2 –AIRFLOW MEASUREMENT UNCERTAINTY COMPARED TO DIFFERENTIAL PRESSURE TARGET

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The preferred building pressure control strategy for supply/return and supply/relief air handling systems is shown in figures 3 and 4.

Figure 3 - SUPPLY AIR FAN SYSTEM WITH INTEGRAL RETURN AIR FAN

Minimum Outdoor Air Control (no active relief): Modulate the return air fan speed, outside air and return air dampers (in sequence) to maintain the required minimum outdoor airflow (Q_{OA}) during minimum outdoor air operation.

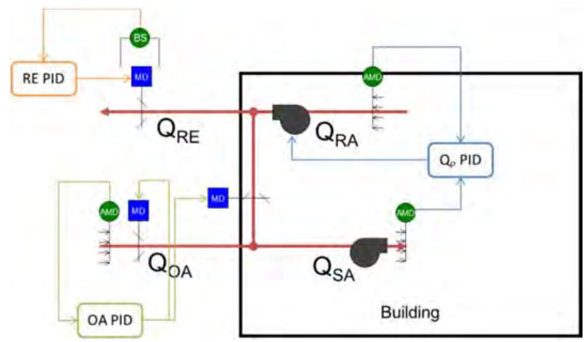
Minimum Outdoor Air Control (with active relief or integral relief air fan and no return fan): Modulate the outdoor air and return air dampers (in sequence) to maintain the required minimum outdoor airflow (Q_{OA}) during minimum outdoor air operation.

Note: The minimum outdoor air set point must be equal to or exceed the pressurization airflow plus any local exhaust airflow to maintain proper building pressure.

Pressurization Airflow Control (with active relief): Open the relief air damper. Modulate the return air fan to maintain a fixed airflow differential ($Q_{SA} – Q_{RA}$) equal to the pressurization airflow plus any local exhaust airflow.

[option #1: relief air damper control] Fully open the relief air damper when a bleed airflow sensor installed across the relief air damper indicates a positive pressure.

[option #2: relief air damper control] Modulate the relief air damper when a bleed airflow or static pressure sensor installed across the relief air damper to maintain a set point pressure of 0.1 in.w.g.



In more complex systems where a single air handling system serves multiple pressure zones, controlling the supply and return (or exhaust) differential into each pressure zone will result in compartmentalized pressurization without unwanted interaction.

Determining the Pressurization Airflow Required

Typically, the objective of building or space pressurization is to maintain a slight positive pressurization airflow (directionally, inside to outside the space). A rule of thumb is to provide between 0.03 and 0.05 CFM of pressurization airflow per square foot of floor area, for a typical commercial building. In reality, the pressurization air is more a function of the space envelope construction, door/window seals and ceiling height. However, this rule of thumb is applicable to many situations.

The pressurization airflow can also be estimated using computer models of the building envelope and openings.

Perhaps the best way to determine the pressurization airflow is in the field. Note that on multi-story buildings these techniques should be done on each floor (or vertical pressure zone) to compensate for stack effect. Two simple methods are possible, but are not the focus of this paper.

Airflow Measurement Performance: A Prerequisite for Proper Pressure Control

Determining the amount of pressurization airflow requires an accurate measurement of a relatively small airflow differential. As a result, airflow measurement accuracy is critical and in most cases must be equal or better than 3% of reading. Airflow measurement devices with lesser accuracies cannot assure proper net building pressurization and air balance professionals can rarely adjust these devices to achieve accuracies better than 5 to 10% of reading in the field. In addition, percent of reading accuracy is required over the entire operating airflow range to ensure pressurization on VAV systems or any system with a modulating airside economizer. As with any sound control strategy, long term instrument performance with negligible drift is also a prerequisite for success.

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The proper selection, application and installation of airflow measuring devices is critical for proper building pressure control.

Conclusions

Building pressure control is essential to IAQ, thermal comfort, structural integrity and the energy footprint of a building. Building pressure is achieved by maintaining net pressurization airflow. Static pressure control techniques may appear to achieve desired pressure objectives but in reality can result in false readings because of wind pressure, internal pressure variations and sensor drift.

Buildings should be compartmentalized into unique pressurization zones based on space use and external pressure variations, such as stack effect. High performance airflow measurement devices should be used to maintain the space pressurization airflow. Potential primary and alternate measurement locations are dependent on specific HVAC system designs and cannot be generalized.