PRESSURE CONTROL FOR TODAY'S HIGH PERFORMANCE GREEN BUILDINGS

EBTRON, Inc. December, 2012 updated March, 2020

Importance of Proper Building Pressure

The control of building pressure is essential to maintain acceptable indoor air quality (IAQ), thermal comfort and structural integrity. Negatively pressurized buildings result in the transport of untreated outdoor air into the building. 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 building pressure may:

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

Understanding Building Pressure

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

Problems with Static Pressure Control

Static pressure control has been widely implemented as a technique to control building pressure. In most applications, a low cost differential pressure sensor is connected between the exterior of a building 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 and have questionable accuracy at the low pressures required for proper building pressurization. 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

In addition, static pressure control is extremely problematic in systems with multiple pressure zones or air handling units because of pressure interaction. One fan system will influence the operation of another fan system.

Stability is also affected by transient wind gusts, door open/close events (interior and exterior) and pressure sensor stability.

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

Implementing a Sound Building Pressurization Strategy

Step 1: Analyze internal building pressure zone requirements

Analyze the pressure requirements of the building and compartmentalize the building 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 and other medical facility spaces requiring airborne infectious disease control
- Clean rooms
- Laboratories
- Kitchens

Step 2: Consider external factors

Pressure zones may be dictated by external environmental factors outside of the building, 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.

Step 3: Measure and control the pressurization airflow

The 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 as a building as a whole being zero.

In a simple single pressure compartment building system, the pressure compartment boundaries are the exterior walls and roof. The mechanical airflow differential of concern is the outside air and exhaust airflow differential.

The relationship between differential airflow (not building static pressure) and IAQ is clearly stated by ASHRAE Standard 62.1-2019, with approved addenda.

> **5.11 Building Exfiltration.** Ventilation system(s) for a building shall be designed to ensure that the total building outdoor air intake equals or exceeds the total building exhaust under all load and dynamic reset conditions. .....
>
> **Informative Note:** Although individual zones within a building may be neutral or negative with respect to outdoors or to other zones, net positive mechanical intake airflow for the building as a whole reduces infiltration of untreated outdoor air.

Building mechanical systems that use supply fan air handling units with a separate relief or exhaust fan in each pressure zone can often control building pressure effectively by maintaining the airflow differential between the outside air intake and relief/exhaust fan.

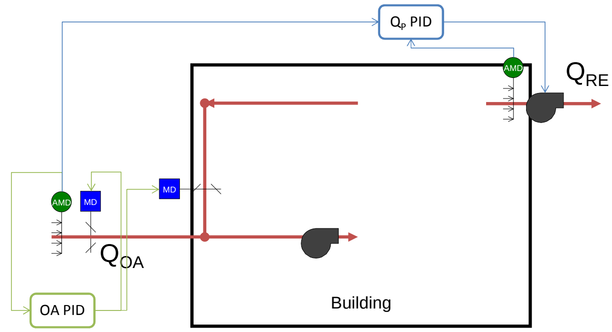
A simplified control schematic and sequence of operations is shown in figure 1.

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

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

Note: The minimum outside air setpoint 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.



Building 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.

Fortunately, the challenge is easily resolved. Figure 2 demonstrates that the mathematical equivalent of Q_{OA}-Q_{RE} is Q_{SA}-Q_{RA}.

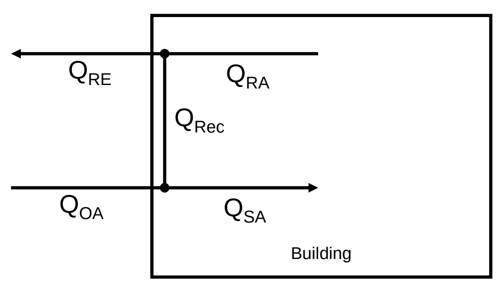
Figure 2 – MATHEMATICAL EQUIVALENT OF Q_{OA}-Q_{RE}

$Q_{Rec} + Q_{OA} = Q_{SA}$ (equation 1)

$Q_{Rec} + Q_{RE} = Q_{RA}$ (equation 2)

subtract equation 2 from 1

$Q_{OA} - Q_{RE} = Q_{SA} - Q_{RA}$



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 building, the control of supply and return (or relief) fans are crucial to proper building 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.

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

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

Note: The minimum outside air setpoint 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 setpoint pressure of 0.1 in.w.g.

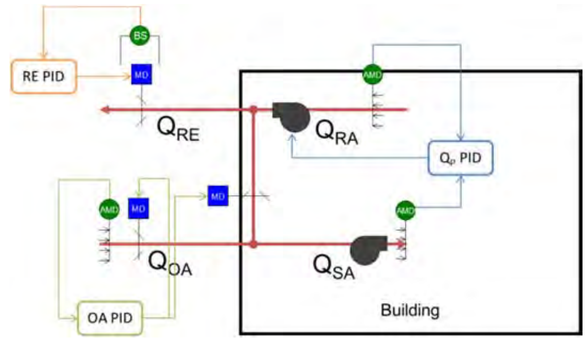
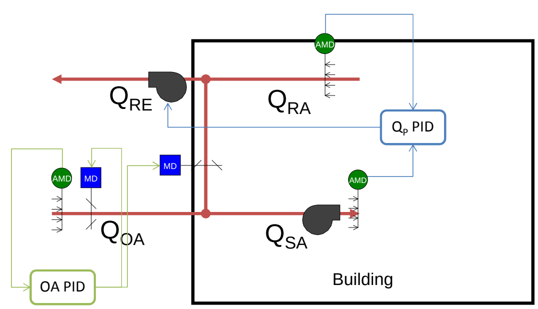


Figure 4 - SUPPLY AIR FAN SYSTEM WITH INTEGRAL RELIEF AIR FAN

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

Note: The minimum outside air setpoint 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 air fan to maintain a fixed airflow differential ($Q_{SA} – Q_{RA}$) equal to the pressurization airflow plus any local exhaust airflow.



In more complex building 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 pressurization is to maintain slight positive pressurization airflow. A rule of thumb is to provide between 0.03 and 0.05 CFM of pressurization airflow per square foot of floor area. In reality, the pressurization air is more a function of the building envelope construction, door/window seals and ceiling height. However, this rule of thumb is applicable to many buildings.

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. There are two methods currently being developed by Ebtron. Note that on multi-story buildings these techniques should be done on each floor to compensate for stack effect.

<u>Method 1:</u> Use installed airflow measuring devices to slightly over-pressurize the building. This technique is similar to that employed in envelope leakage studies. A larger than desired pressure (but less than that which would damage the envelope or roof) is created with the mechanical system and the pressure between a reference position inside of the building and an external reference is measured with all interior doors in the pressure zone open. This can be done with a good quality portable pressure sensor. A larger pressure is selected to minimize wind effect. The pressurization airflow is then extrapolated from the test data for the net pressure desired in the absence of wind and with all interior doors open (i.e. the pressurization flow required for the net pressure desired with no wind and no airflow pressure losses under closed doors).

<u>Method 2:</u> Use portable pressure sensors on all exterior surfaces of the building to obtain the average exterior pressure that result from wind velocity being converted to static pressure. Open all interior doors to eliminate pressure drop from flow paths under closed doors. Use the average pressure to set the airflow differential desired.

Airflow Measurement Performance: A Prerequisite for Proper Pressure Control

Determining the 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.

The bottom line is 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 a 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 building pressurization airflow. Measurement locations are dependent on HVAC system design.