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Room Pressurization Control Methods

Volumetric Airflow Tracking vs. Differential Pressure Sensing

Proper room pressurization is critical for preventing unwanted air transfer. In chemical and biological research facilities chemical fumes and airborne biological agents must be prevented from migrating out of laboratory rooms to non-laboratory areas. Air must be prevented from flowing into spaces that require a high degree of cleanliness and purity, such as food and drug processing operations. The absence of airborne particulate is especially critical for microelectronics and optical manufacturing. Proper room pressurization is vital for protecting the medical staff and patients from exposure to harmful and sometimes deadly airborne pathogens in treatment facilities. This report discusses the advantages and disadvantages of the two most commonly accepted methods of room pressurization control—Volumetric Airflow Tracking and Differential Pressure Sensing.

Pressurization and Directional Airflow

The potential direction of air transfer is always from an area of higher static pressure (termed the positively pressurized area) to an area of lower static pressure (referred to as a negatively pressurized area). The difference between the static pressure of two rooms or spaces is commonly referred to as the differential pressure.

Leakage Area

Although the positive or negative pressurization relationship between spaces establishes the potential for air transfer or airflow, there must be an opening between the spaces for airflow to actually occur. Typically, such openings are the combination of unintentional construction related gaps created by the transverse of mechanical components (pipes, electrical conduit, ventilation ducts, etc.) and the necessary clearance openings around doors. All of these openings are cumulatively referred to as a room's leakage area.

If there is absolutely no leakage area (a room is totally and perfectly sealed off) then no airflow takes place, even though a differential pressure exists between the room and its adjacent space. However, except for extreme situations (such as a Biological Level 4 Laboratory), there is little reason to try to attain a perfect seal or barrier between most pressurized spaces. Personnel typically need to freely enter and leave, and materials often need to be transported into and out of such spaces. Thus, a perfect seal or barrier is not a practical solution for the prevention of unwanted air transfer. This is the fundamental reason for maintaining a differential pressure relationship; it is the most practical way to prevent unwanted air transfer. The required differential pressure relationship is created and maintained by a properly designed and controlled ventilation system.

Volumetric Airflow Tracking Control

Perhaps the most commonly applied means to maintain a room at a negative or positive static pressure with relation to an adjacent space is by volumetric airflow tracking, often referred to as airflow tracking. Airflow tracking maintains the desired differential pressure relationship between rooms or spaces by maintaining a specific difference (termed the Airflow Tracking Offset) between the air supplied to and the total amount of air exhausted from a room or space.

To maintain a room at a negative static pressure with respect to another room or space, the airflow tracking offset ensures that the total amount of air exhausted from the room always exceeds the amount of air supplied to the room. This creates a slight vacuum effect in the room causing air from adjacent areas to flow into the room through the room’s leakage area.

For positively pressurized rooms, the airflow tracking offset ensures that the total amount of air exhausted from the room is always less than the amount of air supplied to the room. This creates an excess amount of air in the room causing room air to flow outward to the adjacent areas. Figure 1 illustrates the airflow relationship of a negatively pressurized room where the total room exhaust airflow exceeds the total room supply airflow by the airflow tracking offset.

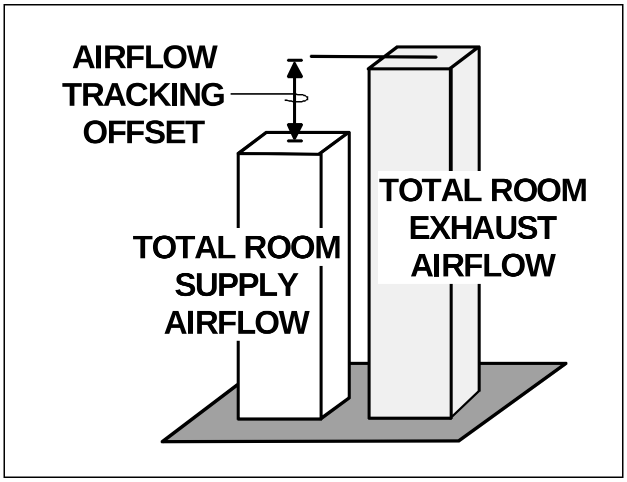

Figure 1. Negatively Pressurized Room Airflow Relationship.

Goal of Volumetric Airflow Tracking

Airflow tracking does not ensure that a specific room differential pressure value will be attained. However, it does ensure that the desired negative or positive pressure relationship will be attained along with the desired directional airflow (into or out of the room). Since the goal of room pressurization is mainly to ensure proper directional airflow, volumetric airflow tracking is a very reliable way of achieving this goal.

Volumetric Airflow Tracking For Laboratory Rooms

Figure 3 shows a LABORATORY ROOM with a TOTAL ROOM EXHAUST AIRFLOW that is higher level than the ROOM SUPPLY AIRFLOW. (The relative quantity of the airflows is indicated by the difference in size of the airflow arrows.) The resulting *deficiency* in the ROOM SUPPLY AIR created by the larger TOTAL ROOM EXHAUST AIR creates the negative pressure relationship between the laboratory room and the two adjacent corridors. The laboratory room static pressure is therefore negative with respect to both corridors and transfer air will always tend to flow into the laboratory room, which is the desired result.

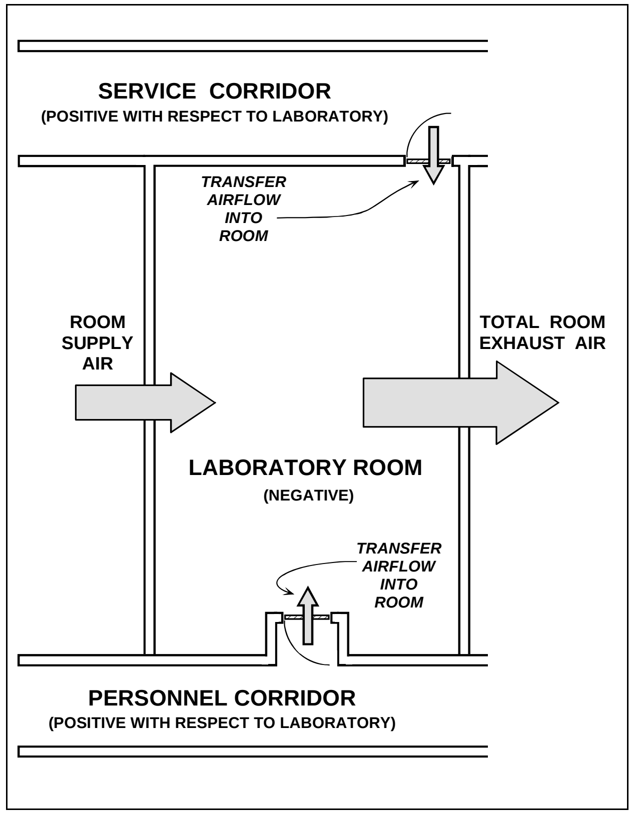

Figure 2. Laboratory Room at a Negative Pressure.

The specific relationship between Room Differential Pressure, Room Leakage Area, and the Differential Airflow (transfer airflow) is expressed by the following two equations that apply to Inch-Pound and SI (metric) units respectively:

(IP) **$Q = 2610\ A\ (dP)^{1/2}$**

Q is the differential airflow in CFM

A is the total room leakage area Square Feet

dP is the differential pressure Inches of H_20

(SI) **$Q = 840\ A\ (dP)^{1/2}$**

Q is the differential airflow in Liters per Second

A is the total room leakage area in Square Meters

dP is the differential pressure in Pascals

Room Pressurization Factors

Figure 3 contains a graph the shows the relationship between DIFFERENTIAL PRESSURE, ROOM LEAKAGE AREA, and ROOM DIFFERENTIAL AIRFLOW. The family of curves on the graph represent room leakage area (in square feet). ROOM DIFFERENTIAL AIRFLOW (the difference

between the total room supply airflow and total room exhaust) is shown in CFM along the bottom of the graph. And, the resulting DIFFERENTIAL PRESSURE between the room and an adjacent area is shown in INCHES OF WATER along the left hand vertical axis.
To determine the differential airflow required to attain a specific room differential pressure, follow the DIFFERENTIAL PRESSURE value (on the left vertical axis) to where its horizontal line intersects the appropriate ROOM LEAKAGE AREA CURVE. Then, from the point of intersection, proceed downward to obtain the required ROOM DIFFERENTIAL AIRFLOW CFM.

As seen from Figure 3, a room's differential pressurization value with respect to an adjacent area is totally dependent upon the room's differential airflow and the room's leakage area. For instance, the graph shows that to attain a differential pressure (dP) of 0.008 Inches of Water for a room with a 0.75 square feet leakage area, the difference between the room supply air and the total room exhaust needs to be 175 cfm. Therefore, to maintain a specific room differential pressure value, the room's differential airflow must be controlled and maintained at the proper value. Note that neither room size nor its dimensions directly enter into the room pressurization relationship.

Leakage Area Considerations

With relatively good quality construction, modest sized rooms such as a two person laboratory with two hinged doors will typically have a total room leakage area of between 0.5 and 1.0 square feet. Maintaining a pressure differential with significantly more leakage area than about 1.5 square feet requires a relatively high differential airflow. Experience indicates that a negative 0.010 Inch W.C. room differential pressure (typical utilized for chemical laboratory rooms) would be difficult to maintain with a leakage area greater than about 2.0 square feet due to the excessively high differential airflow required.

It is also very important to consider the effect that an open door will have on room pressurization. Opening a single width door having dimensions of about 3 feet by 7 feet will increase a room's leakage area by approximately 20 square feet or more. The resulting room leakage area curve (20.0 square feet.) would essentially lie at the bottom of the graph and correspond to a near zero differential pressure for the room. Therefore, while a door is open no appreciable room differential pressure can be sustained. However, the normal opening and closing of doors does not really compromise the goal of room pressurization—to prevent unwanted air transfer. Proper directional airflow (inward for a negative room and outward for a positive room) will still exist through the open door and other leakage areas as long as the room's airflow tracking offset is maintained.

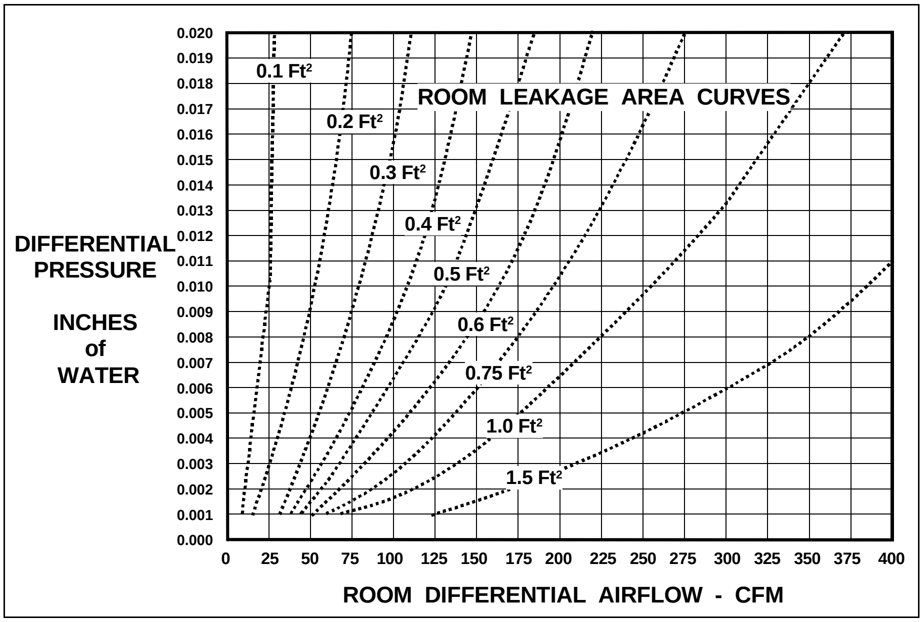

Figure 3. **Room Differential Airflow vs. Differential Pressure for Various Room Leakage Areas.**

Maintaining Room Pressurization with Volumetric Airflow Tracking

Airflow tracking can maintain the desired room pressurization polarity (positive or negative) for both constant air volume (CAV) as well as variable air volume (VAV) ventilation systems. Figure 4 shows an airflow tracking control configuration for a VAV chemical laboratory room ventilation system.

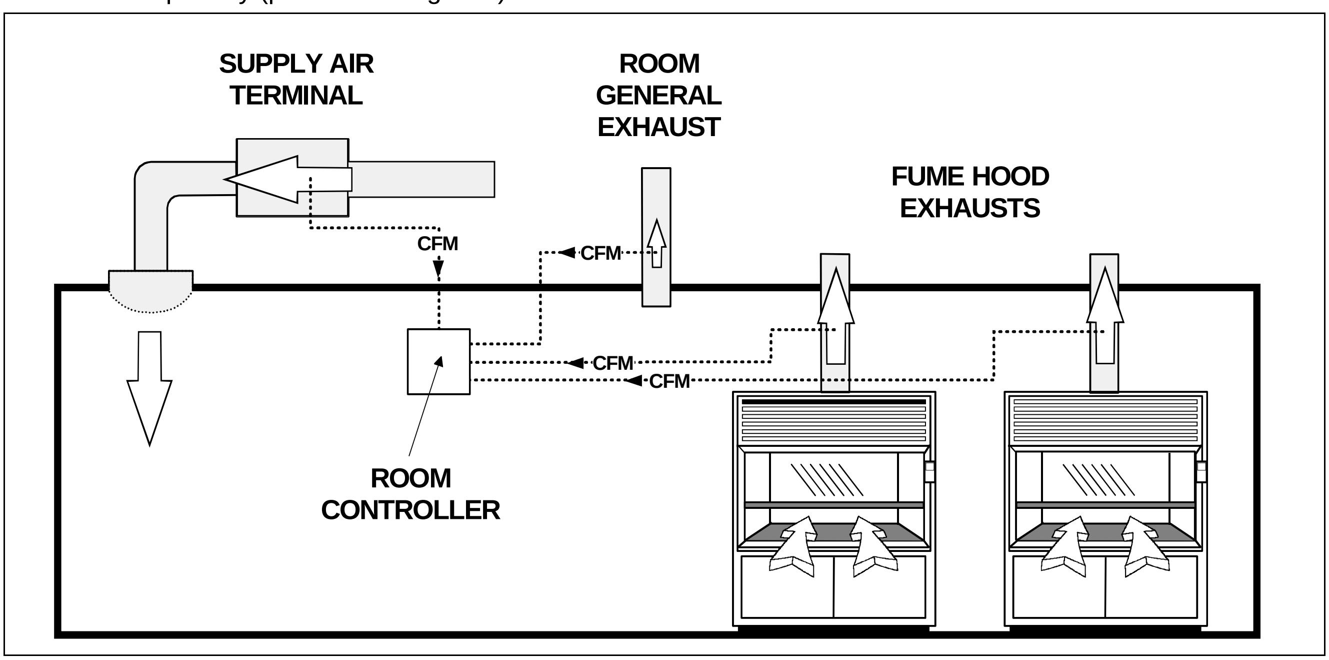

Figure 4. Airflow Tracking Control Arrangement for a VAV Laboratory Room.

Volumetric airflow tracking is based upon measuring and controlling room airflows. Figure 4 shows the essential components of a volumetric airflow tracking control configuration for a VAV chemical laboratory room. The exhaust of each VAV fume hood is modulated as necessary by individual fume hood controllers (not shown) to maintain the required fume hood face velocity. In addition, the ROOM CONTROLLER also continuously monitors the specific exhaust airflow of each fume hood. To maintain sufficient room exhaust when all fume hood sashes are closed, the room may also need a ROOM GENERAL EXHAUST. The ROOM CONTROLLER then controls both the ROOM GENERAL EXHAUST and the SUPPLY AIR TERMINAL to always provide the proper amount of room exhaust and supply make-up airflow. Whenever the room's total airflow changes (such as when fume hood sashes are repositioned), the ROOM CONTROLLER adjusts the room supply airflow and the room general exhaust to maintain proper room airflow along with the room's airflow tracking offset.

Volumetric Airflow Tracking Considerations

As Figure 3 illustrates, the airflow tracking offset necessary to maintain a specific room differential pressure is dependent upon the room's total leakage area. However, it is not usually possible to know where a particular room’s leakage area will be prior to construction. Therefore, a designer may initially specify a room airflow tracking offset based upon the designer's experience. Later, the airflow tracking offset may be modified during the test and balancing phase of the project to attain a specific level of room differential pressure.

In practice, it is seldom necessary to achieve a specific differential pressure value for laboratory rooms since the purpose of room pressurization is to create and ensure proper directional airflow for the room. It should also be noted that a given airflow tracking offset will not ensure that a specific differential pressure value will be maintained over an extended period such as the life of a building. As buildings age and modifications are made, room leakage area usually changes somewhat and results in some minor variation from the initial room differential pressure value. Although eventual variations in room pressurization are likely, it must be emphasized again that the primary goal of room differential pressurization is preventing undesirable air transfer that would still be attained.

Differential Pressure Sensing Control

Differential pressure sensing control is based upon the input from a room differential pressure sensor. This sensor is typically located in the wall that separates the room from the adjacent space. Figure 5 shows the essential components of a differential pressure sensing control configuration for a chemical laboratory room.

The ROOM CONTROLLER monitors the room differential pressure by means of the ROOM DIFFERENTIAL PRESSURE SENSOR. The ROOM CONTROLLER controls the SUPPLY AIR TERMINAL airflow and the GENERAL EXHAUST to maintain the required room differential pressure setpoint. If the room differential pressure is less than the setpoint, the ROOM CONTROLLER reduces supply airflow to increase the room differential airflow and consequently increase the room negative pressure. If the room differential pressure is greater than the setpoint, the ROOM CONTROLLER increases supply airflow to decrease the room differential airflow and thus, decrease the negative pressure.

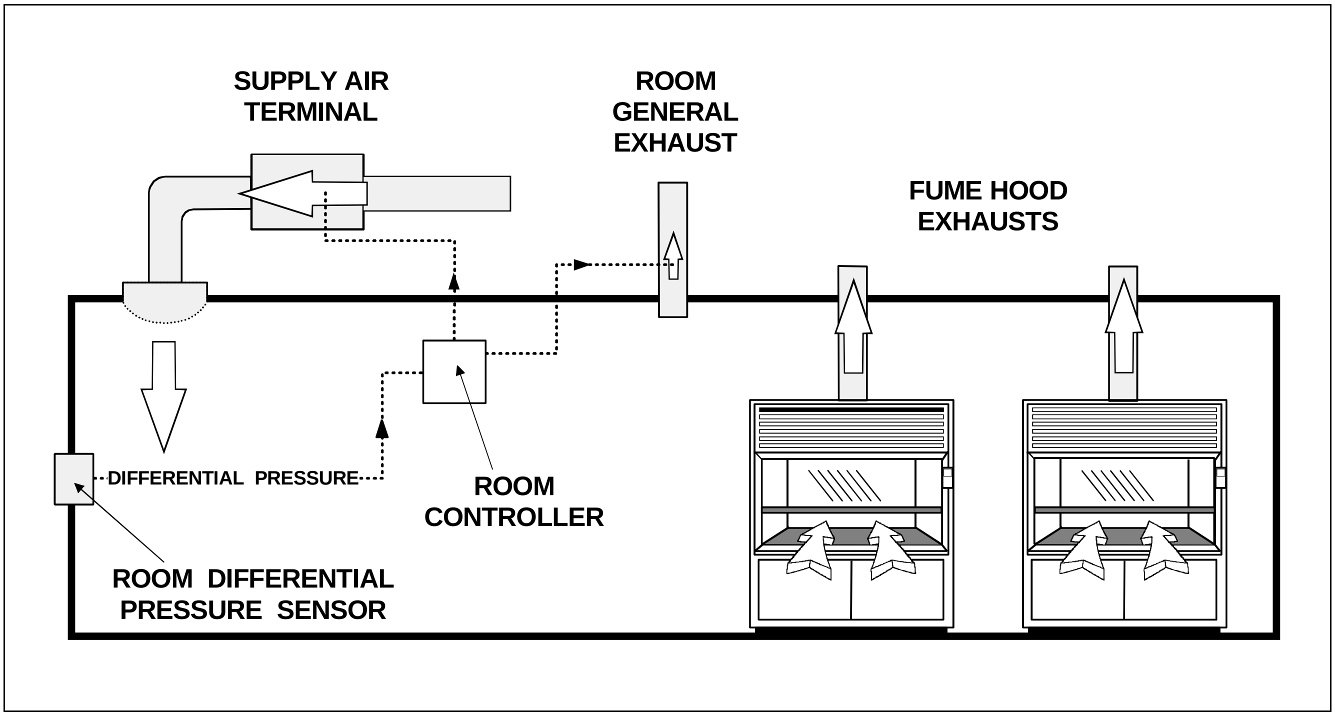

Figure 5. Differential Pressure Sensing Control Arrangement for a Laboratory Room.

Differential Pressure Sensing Considerations

Although differential pressure sensing control responds directly to room differential pressure, it can be adversely affected by numerous factors during normal room usage.

Door Opening Effects

When open, a standard single width door can increase the room leakage area by about 20 square feet causing the resulting room leakage area curve to lie along the bottom of the graph (see Figure 3). Even if the ROOM CONTROLLER decreases the supply airflow to zero, it will be unable to attain sufficient room differential airflow to maintain the differential pressure setpoint with a door open. Having no supply airflow can adversely affect the room's ambient temperature and humidity especially if the door remains open for an extended period. To minimize the effect of door openings, a differential pressure sensing control arrangement must always ensure that there will be a minimum supply airflow. As an alternative, a door switch can be used to signal the ROOM CONTROLLER to maintain the last supply airflow value whenever a door is open. However, the door switches and associated wiring involves additional cost.

Adjacent Area Makeup Air

Recall that with volumetric airflow tracking the room differential airflow (also referred to as the airflow tracking offset) is fixed. The total of all room airflow tracking offsets is the total quantity of air that will flow from the adjacent area (typically a corridor) into the laboratory rooms. Because the ventilation system designer knows the amount of corridor makeup airflow required, a provision for this in the ventilation system design can be made readily.

However, with differential pressure sensing control the amount of airflow into each laboratory room from the corridor is a variable. Thus, corridor makeup air requirements cannot be readily established especially when there are many laboratory rooms. This complicates the designer's task and often requires additional ventilation system components and controls to ensure that proper corridor makeup air will be provided.

VAV Fume Hood Effects

Differential pressure sensing control is not recommended whenever the room airflow can undergo rapid changes as in laboratory rooms with VAV fume hoods. VAV fume hood exhaust must be dynamically controlled to maintain a constant fume hood face velocity for all sash positions. When a user moves a fume hood sash, the fume hood controller must rapidly increase or decrease the hood exhaust to maintain the required face velocity. Therefore, every VAV fume hood control action affects the room differential airflow and consequently the room differential pressure.

To obtain a reliable room differential pressure value from a room differential pressure sensor, the ROOM CONTROLLER must sample and integrate the sensor output for a period of time—perhaps ten or more seconds. This is necessary to factor out signal noise caused by personnel movement, local air currents and even the effects of wind on the building. When a VAV fume hood sash is opened, this delay in obtaining a new stable room static pressure value can delay increasing the supply makeup air necessary to balance off the increased fume hood exhaust airflow. This can delay the restoration of the fume hood face velocity to the level necessary to ensure fume containment.

In contrast, airflow measurements in ducts as utilized by volumetric airflow tracking, provides the ROOM CONTROLLER with actual airflow values much more rapidly since duct airflow signals are more robust and subject to much less signal noise. Figure 6 depicts the output signals from a room differential pressure sensor versus a ducted airflow measurement signal upon an increase in fume hood exhaust. Because of the appreciable signal noise, it typically takes the ROOM CONTROLLER ten seconds or more to obtain a new reliable differential pressure value and begin the necessary makeup airflow control action. In contrast, ducted fume hood exhaust airflow measurements enables makeup airflow control action to begin within one or two seconds.

Cascaded Pressure Control

Although airflow tracking is the preferred method for maintaining laboratory room pressurization and ensuring fast fume hood response, there may be valid reasons to ensure that a specific room differential pressure level is maintained. When this is necessary, cascaded pressure control can be applied to retain the superior speed and stability of airflow tracking and also ensure that the desired differential pressure value is maintained.

Cascaded pressure control combines the control functionality of both volumetric airflow tracking and differential pressure sensing. The control configuration is essentially the same as in Figure 4 but with the addition of the ROOM DIFFERENTIAL PRESSURE SENSOR shown in Figure 5. The control scenario basically uses airflow tracking as the regular online means to ensure fast and stable control response. The ROOM CONTROLLER also monitors the ROOM DIFFERENTIAL PRESSURE SENSOR, and when necessary adjusts the airflow tracking offset to maintain the room differential pressure at the level desired.

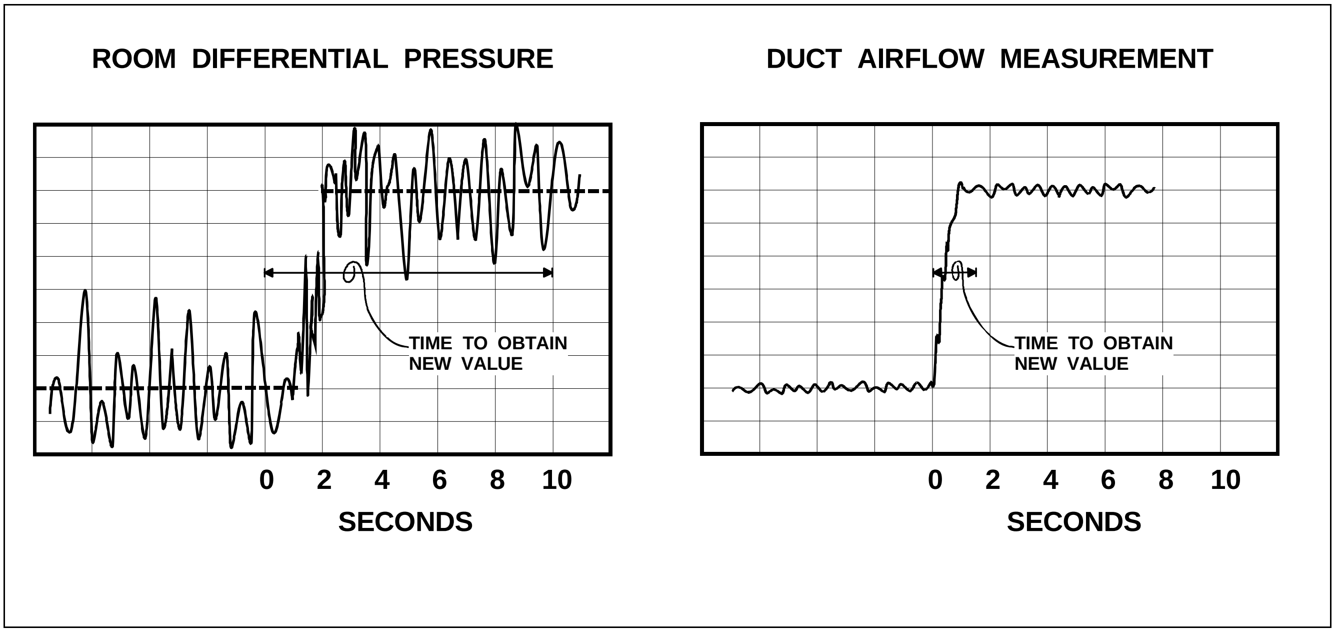

Figure 6. Comparison of Time Needed to Obtain New Values After Room Airflow Change.

As a result of this arrangement, the airflow tracking offset value does not remain *fixed* as in regular airflow tracking, but is periodically reset if needed. A cascaded control arrangement will compensate for differential pressure variations that might occur over the long term. Since a differential pressure sensor is part of a cascaded control arrangement, it also enables local indication as well as remote monitoring of a room's differential pressure level.

Although cascaded pressure control might seem to be the best of both worlds, it also poses some drawbacks:

- It is more costly than regular airflow tracking since it also requires installation of the room differential pressure sensor and inclusion of a more complex room control algorithm.
- It requires the ventilation system designer to also address some of the vexing problems associated with differential pressure sensing control such as the effects of open doors and ensuring that the proper amount of corridor make air will be provided.
- It involves a more complex startup and balancing process.
- Equally satisfactory results can usually be obtained with regular volumetric airflow tracking and having someone occasionally check the differential pressure values of various rooms.

Conclusion

This report has presented a detailed factual discussion on room pressurization control by both volumetric airflow tracking and differential pressure sensing. Due to its slower response, differential pressure sensing control is best limited to applications where room airflows remain very stable as in constant air volume ventilation systems.

The vast majority of experienced ventilation system designers find volumetric airflow tracking to be more satisfactory for room pressurization control. In particular, airflow tracking is well suited to and is perhaps the only reliable approach for controlling room pressurization in VAV laboratory ventilation systems and whenever fast and stable pressurization control is crucial.

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