Control Methodology

In this Section:

- *Laboratory Clean Room Pressure Relationship Control Methods*
- *Fume Hood Face Velocity Control Methods*

Laboratory Clean Room Pressure Relationship Control Methods

Airflow Tracking

A typical application of an airflow tracking system is a simple laboratory with one supply air device, one general exhaust air device, and one fume hood. Since airflow tracking requires measurement of all air supplied to the space and all air exhausted from the space, a flow measuring device is required for each piece of ventilation equipment. Each unit has an actuating element for airflow regulation and there is a controller determining the required position of each element.

The fume hood controls to its own specific requirements. The supply air is modulated to the highest volume need,of the minimum air change rate, the required make-up air rate, or the required cooling load offset. The general exhaust air is modulated to maintain the required ΔCFM setpoint.

The measurement technology for airflow tracking could be any of the listed methods. However, since the space pressurization relationship is dependent upon accurate readings, the method of choice is the one which represents the best possible flow accuracy through a full operating range.

Airflow tracking schemes do not have the ability to detect or compensate for changes to the space pressure envelope. These kinds of changes occur when doors are left open, penetrations are made through the barrier without being sealed or, in the case of an open lab, there are changes to the pressurization levels in the surrounding zones.

Maintenance requirements for this configuration are mainly related to cleaning of the flow elements (if the chosen elements require it) and calibration of the flow transducers. In larger, more complex labs than those in the example, maintenance becomes a large factor as the number of transducers and flow elements increases.

Initial costs for the example lab are approximately the same as they are for other pressurization methods. However, these costs can increase rapidly compared to those for other methods when more complex labs are required.

Control of makeup air requirements in this application is more complex than in others as the supply can be selected from three possible setpoints. The desired supply airflow rate is determined by the greatest need. The primary element is the flow rate for the desired minimum air change rate. If the makeup air requirements of the fume hood exceed the minimum air change rate then the ΔCFM calculations determine the new desired supply flow setpoint. Finally, if the cooling load requires a greater volume of air than either the minimum air change rate or the makeup air change rate then the required cooling volume determines the supply flow setpoint.

The most critical consideration for this type of control is to ensure that the desired ΔCFM setpoint maintains a high enough differential airflow to avoid possible errors in flow readings that might defeat or lower the actual ΔCFM to the point where space containment is compromised.

Space Static Pressure

The typical application of a space static pressure system would again be a simple laboratory with one supply air device, one general exhaust air device, and one fume hood. Since static pressure is determined by a single reading, measurement of supply air to the space is the only airflow measurement required. This requirement is solely to ensure the desired minimum air change rate. Each unit has an actuating element for airflow regulation and there is a controller determining the required position of each element.

The fume hood controls to its own specific requirements. The supply air is modulated to the highest volume need, of the minimum air change rate, the volume required to satisfy the cooling load, or the volume required to maintain space static pressure at its setpoint during makeup air control. The general exhaust air is modulated to maintain the space static pressure at its setpoint whenever the supply is at its minimum air change rate and the fume hood is at its minimum volume or when the supply is in cooling load offset control and the fume hood is drawing less air than required to maintain space static pressure at its setpoint.

The measurement technology for space static pressure control employs the described static pressure sensing method and an airflow measuring method to determine supply volume. Since measured supply airflow is only used to ensure the minimum requirement of air, some of the more moderately accurate methods can be applied.

Space static pressure schemes have the ability to detect and/or compensate for changes to the space pressure envelope. These kinds of changes occur when doors are left open, penetrations are made through the barrier without being sealed, or there is a significant change in the pressure in any surrounding space.

Maintenance requirements of this configuration are mainly related to cleaning the flow elements (if the chosen elements require it) and calibration of the flow and pressure transducers.

Initial costs for the example lab are approximately the same as for other pressurization methods. These costs increase only on the basis of the number of supplies to be monitored and controlled in the more complex labs.

Control of makeup air requirements in this application is similar to the complexity of the airflow tracking scheme until the lab becomes more complex. At that time, the space static pressure method becomes less complex. The desired supply airflow rate is determined by the greatest need. The primary element is the flow rate for the desired minimum air change rate. If the makeup air requirements of the fume hood exceed the minimum air change rate then the space static pressure will determine the new desired supply flow setpoint. Finally, if the cooling load requires a greater volume of air than either the minimum air change rate or the makeup air change rate, the required cooling volume determines the supply flow setpoint.

The most critical consideration for this kind of control is the tendency of this system to go into total upset every time a door is opened. The upset is due to the immediate loss of a measurable reading and the resulting loss of control stability and possible starvation of the fume hood.

Through-the-Wall Infiltration Velocity

A typical application of a through-the-wall infiltration velocity system is again a simple laboratory with one supply air device, one general exhaust air device, and one fume hood. Since pressurization is determined by a single reading of infiltration velocity, measurement of supply air to the space is the only airflow measurement required, solely to ensure the desired minimum air change rate. Each unit has an actuating element for airflow regulation and there is a controller determining the required position of each element.

The fume hood controls to its own specific requirements. The supply air is modulated to the highest volume need, either the minimum air change rate, the volume required to satisfy the cooling load, or the volume required to maintain infiltration velocity at its setpoint during makeup air control. The general exhaust air is modulated to maintain the infiltration velocity at its setpoint whenever the supply is at its minimum air change rate and the fume hood is at its minimum volume or when the supply is in cooling load offset control and the fume hood is drawing less air than required to maintain the infiltration velocity at its setpoint.

The measurement technology for infiltration velocity control employs the described through-the-wall sensing method and an airflow measuring method to determine supply volume. Since measured supply airflow is only used to ensure the minimum air, some of the more moderately accurate methods can be applied.

Through-the-wall schemes have the ability to detect and/or compensate for changes to the space pressure envelope. These changes occur when doors are left open, penetrations are made through the barrier without being sealed, or there is a significant change in the pressure level of any surrounding space.

Maintenance requirements of this configuration are mainly related to cleaning the flow elements (if the chosen elements require it) and calibration of the flow and velocity transducers.

Initial costs for the example lab are generally less than for other pressurization methods due to the low cost of a single-point thermal anemometer. These costs increase only on the basis of the number of supplies to be monitored and controlled in more complex labs.

Control of makeup air requirements in this application is similar to the complexity of the airflow tracking scheme until the lab becomes more complex. At that time the through-the-wall method becomes less complex. The desired supply airflow rate is determined by the greatest need. The primary element is the flow rate for the desired minimum air change rate. If the makeup air requirements of the fume hood exceed the minimum air change rate then the through-the-wall sensor determines the new desired supply flow setpoint. Finally, if the cooling load requires a greater volume of air than either the minimum air change rate or the makeup air change rate then the required cooling volume determines the supply flow setpoint.

The most critical consideration for this type of control is the ability of thermal anemometers to read equal flow in either direction as the same value. Additionally, placement of this device is very critical as the low velocity level being measured can be easily overcome by air currents on either side of the boundary wall.

Total Pressure Differential Across the Boundary Wall

The usual application of a total pressure differential system is again a simple laboratory with one supply air device, one general exhaust air device, and one fume hood. Since pressurization is determined by a single reading of total pressure differential, measurement of the supply air to the space is the only airflow measurement required. This is solely to ensure the desired minimum air change rate. Each unit has an actuating element for airflow regulation and there is a controller determining the required position of each element.

The fume hood controls to its own specific requirements. The supply air is modulated solely and directly to maintain the total pressure differential at its setpoint. The general exhaust air is modulated to maintain the greater of the two requirements of either minimum air change rate or cooling load offset. As the general exhaust modulates open to meet the minimum air change rate or cooling load offset, the total pressure differential will, by nature of the increase in exhaust flow, begin to drop. As it drops below setpoint the supply air damper modulates open to bring the total pressure differential back to setpoint, thus increasing the amount of conditioned or fresh air to the space.

The measurement technology for total pressure control employs the described method sensing total pressure differential and an airflow measuring method to determine supply volume. Since measured supply airflow is only used to ensure the minimum air flow some of the more moderately accurate methods can be applied.

Total pressure differential schemes have the ability to detect and/or compensate for changes to the space pressure envelope. These changes occur when doors are left open, penetrations are made through the barrier without being sealed, or there is a significant change in the pressure of any surrounding space.

Maintenance requirements of this configuration are mainly related to cleaning the flow elements (if the chosen elements require it) and calibrating the flow and velocity transducers.

Initial costs for the example lab are typically the same as those for airflow tracking methods. These costs increase only on the basis of number of supplies to be monitored and controlled in more complex labs while airflow tracking schemes increase proportionally with every ventilation device.

Control of makeup air requirements in this application is much less complex compared to those of the pressurization schemes. The supply air is regulated directly by the total pressure differential, allowing for fast response to changes caused by fume hood use.

The best feature of this type of control is the ability to provide smooth stable pressure readings regardless of current pressure envelope status. The very low total pressure required for containment is measured and maintained even in the presence of a door that has been left open. Since the measurement is total pressure, the system is less prone to be upset by air currents inside and outside the space than all of the previously described methods.

Fume Hood Face Velocity Control Methods

Through-the-Wall Velocity Measurement

This application consists of a single thermal anemometer mounted in an orifice which penetrates the sidewall of the fume hood interior shell. The penetration provides an air path from the exterior of the hood. The signal from the thermal anemometer is used as the feedback input variable in a closed loop controller (read input, compare to setpoint, calculate error, adjust flow control device to correct error) whose output positions an airflow regulating device in the fume hood exhaust duct.

The theory behind this method of measurement is that the fume hood interior is operating at a negative pressure in relation to the surrounding space and air always flows from the exterior of the hood, through the orifice, and into the hood. In addition, the thermal anemometer senses the speed of the air flowing through the orifice. With correct placement of the orifice this airspeed is equal to the speed of the air entering the face opening of the hood.

This methodology is very dependent upon the correct placement of the orifice in the hood sidewall as there is a restricted amount of available area to provide a pressure relationship corresponding to that of the fume hood face opening. This relationship can also be easily upset by placing larger apparatus near the sidewall of the hood interior. In practice this method presents an accurate means of measuring average face velocity in an empty hood, but it loses its accuracy whenever the hood contains a lot of laboratory apparatus or equipment.

Response times associated with this system are in the 3 to 5 second range at best— and those are only achieved with a fast actuating device. The slow response of this system seems to be related to the time response of a thermal anemometer and the processing speed of the controller.

Maintenance of this system is relatively simple because the thermal anemometer is the only sensor and it can be easily cleaned with a cotton swab and distilled water.

Initial costs for this system are usually low due because of the inexpensive nature of the velocity sensor and the quality of the controls applied.

In practice this method of measurement provides for a velocity reading which, under the right conditions, is indicative of the average face velocity. This method also responds to the effect of external changes in sash area, such as someone working at the hood, and to competing air velocities caused by operators walking past the fume hood or by air currents within the space itself. However, this method is not the most desirable due to the changes in velocity readings caused by apparatus within the hood, the unequal time response function of increased vs. decreased flow and the possibility of measuring flow in the wrong direction.

Most applications of this measurement methodology use the output from the thermal anemometer as the prime control variable in a closed loop control system, which *is* the most desirable implementation. However, due to its time response characteristics this application *does not* lend itself to the type of control response times required to maintain adequate containment during sash upset (extreme sash movement).

Sash Position Derived
(Closed Loop Measured Exhaust Flow Volume)

This application consists of a resistive or electronic means of measuring the open area of the hood face based on current position of its sash(es), as described earlier in Sash Position Sensing Methods, and a means of measuring or deriving the current hood exhaust flow rate in cubic feet per minute (CFM), as described earlier in Flow Regulating Devices. The face velocity, in FPM, is then calculated by dividing the current flow rate, in CFM, by the current sash open area in square feet. The resulting velocity value is then used as a representation of average face velocity. This method effectively relies on a *calculated prime control variable* instead of a measured one. The effective control variable setpoint is an exhaust volume setpoint calculated by multiplying the current sash area by the desired face velocity setpoint. The desired exhaust flow set is then controlled to this setpoint by a controller modulating the exhaust control device.

While this method provides a means of fast response to sash changes since it directly measures the sash area, it cannot compensate for changes in sash area caused by operators working at the hood or changes in face velocity affected by competing air currents. Also, multiple or combination sashes require expensive or complex configurations of sash sensors in order to accurately determine sash area.

It is critical to consider the effects on this technology caused by operators using the hood. In the case of a 4 foot fume hood the typical inside width of the sash is about 38 inches. A large person standing in front effectively cuts the sash width in half, resulting in twice the desired face velocity. At these high face velocities a vortex develops on either side of the operator's body creating an area where contaminants can be trapped and possibly introduced to the operator's breathing area.

Additionally, when people walk at a normal speed of three 3 to 5 feet per second they create air currents behind their bodies at speeds up to 300 FPM. If these currents are not sensed, which a sash position based system cannot do, they can draw air and airborne contaminants out of the hood into the environment.

This system can provide the required response time of about 1 second for 90% recovery due to the fast response of sash sensing elements and the use of feed forward control boosts from sash position. However, it is undesirable because of its lack of ability to compensate for external changes in sash area or for competing air velocities.

Maintenance requirements for this system are a bit more complex due to the mechanical complexity of sash sensing devices. But with that aside, the only remaining considerations are the normal cleaning and calibration of the flow element and transducer for the hood exhaust airflow.

Initial costs for this system are somewhat higher due to the need for flow sensing. The cost can also climb rapidly if the hood sash is a combination style. Initial cost can also vary with the manufacturer because some varieties of the system are based on commercial grade components and controllers. However, lower quality systems tend not to respond anywhere near the 1 second recovery rate for 90% of setpoint.

Sash Position Derived
(Open Loop Calibrated Linear Air Valve)

This application is basically the same as the previous one with the exception that a linear air valve is used for control and flow feedback. All methods of control and calculation are the same except the system does not measure actual airflow, it reads a position from the linear air valve and considers this the current CFM rate. This system uses straight proportional analog control from sash position to exhaust flow rate.

Measurement technology is based on the sash position sensing methods and the linear airflow valve flow regulating method.

This system has the same drawbacks as the closed loop/sash system as they pertain to accuracy of the average face velocity. There is one further disadvantage in that it does not measure actual airflow so it is dependent on a differential pressure switch to show there is less than adequate airflow.

System response time for this configuration is excellent, typically less than 1 second for 90% recovery to setpoint. Its poor ability to sense accurate face velocity and the fact that it does not measure face velocity make its speed of response seem inadequate.

The maintenance requirements of this system are related to the more complex sash sensing combinations and the possible fouling of the cone and shaft assembly that makes up its heart.

Initial cost of this system is often much higher than almost all the others because of the expense of the linear air valve, the analog controller, and the more complex sash sensing systems.

Airfoil Pitot Face Velocity Control

A common application of this system is a single bench style hood with any sash configuration and a bypass airfoil mounted at the work surface. An airfoil pitot is mounted under the bypass airfoil and connected to a face velocity transducer. A high speed digital controller uses the face velocity signal as its primary control variable and provides a modulating signal to a precision butterfly damper with an electronic high speed actuator.

The measurement technology is solely based on the airfoil pitot measurement method. This type of measurement has definite advantages over the previous methods in that it can compensate for both external competing airflows and external effects on sash area. Both are directly sensed by this technology. Also, since the measurement is taken directly in the plane of the fume hood face, it represents the most accurate means of sensing face velocity on the market. The transducer has a response time of 100 milliseconds and it can produce changes in signal output 10 times per second—resulting in fast recovery time when coupled with a high speed controller.

This velocity reading is an average of the flow across the width of the hood within the plane of the fume hood face. Since a relationship exists between the speed of the air flowing under the airfoil and the speed of the air going through the fume hood face good average face velocity readings are possible within ±5% of the actual measured average velocity. These readings are confirmed with an NIST-traceable instrument. Since the transducer is based on a high volume design the characteristic noise of low range pressure transducers is eliminated, resulting in smoother readings.

In practice this sensing method is combined with a high speed networkable digital controller providing loop response time of 50 milliseconds and a high speed electronic actuator with a stroke time of 12 inches per second (a typical unloaded stroke time of 250 milliseconds for a 90° travel damper arm). The resulting control response provides 90% recovery to setpoint in less than 1 second for extreme sash movement.

Maintenance is limited to periodic calibration checks of the face velocity transmitter zero and the actuator zero, and to span calibration.

Initial costs are lower than systems of comparable accuracy and performance, but not as competitive as the lower grade systems.

Space Pressure Primary Face Velocity Control

A common application of this system is a single walk-in style hood with any sash configuration. A set of multiple space pressure sensors is mounted in the hood lintel and a hood pressure probe (a multi-port averaging element) is installed inside the front of the hood above the top of the sash when it's at its minimum position. These elements are connected to a face velocity transducer. A high speed digital controller uses the face velocity signal as its primary control variable and provides a modulating signal to a precision butterfly damper with electronic high speed actuator.

The measurement technology is solely based on the space pressure primary method. This type of measurement has definite advantages over the sidewall- and sash-based methods in its ability to compensate for both external competing airflows and external effects on sash area. Both are directly sensed by this measurement technology. Also, since the measurement is taken directly in the plane of the fume hood face it represents the most accurate means of sensing face velocity on the market. Since the transducer has a response time of 100 milliseconds it can produce changes in signal output 10 times per second, resulting in fast recovery time when coupled with a high speed controller in the same manner as the airfoil pitot method.

This velocity reading is an average of the flow across the width of the hood in the plane of the fume hood face. Since a relationship exists between the total pressure differential across the fume hood opening and the speed of the air going through the fume hood face good average face velocity readings are measured to within ±5% of the actual measured average velocity. These readings are confirmed with an NIST-traceable instrument. Since the transducer is based on a high volume design the characteristic noise of low range pressure transducers is eliminated, resulting in smoother readings.

In practice this sensing method is combined with a high speed networkable digital controller providing loop response time of 50 milliseconds to a high speed electronic actuator with a stroke time of 12 inches per second (a typical unloaded stroke time of 250 milliseconds for a 90° travel damper arm). The resulting control response provides 90% recovery to setpoint in less than 1 second for extreme sash movement.

Maintenance is limited to periodic calibration checks of the face velocity transmitter zero and the actuator zero and span calibration.

Initial costs are lower than systems of comparable accuracy and performance, but not as competitive as the lower grade systems.