Factors Affecting the Performance of Airflow Measurement Devices in Critical Applications

Phoenix Controls
Corporation

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As a recognized leader in airflow control for critical spaces, Phoenix Controls is often asked to comment on the use of flow measurement devices. Our equipment does not measure flow. In fact, when other system suppliers claim to be measuring flow, they are not directly measuring flow in these applications. Instead, the flow is estimated using velocity pressure, static pressure drop across a restriction, or pressure variation frequency, and translating that measurement through the use of pressure transducers. While these techniques are based on sound physical principles, the process of using these measurements to maintain highly accurate flow control is fraught with significant real-world challenges as described in this white paper.

Phoenix Controls' theories of airflow control use sound physical principles. Our equipment is designed specifically for the demands of a critical flow environment, therefore avoiding the inherent challenges to providing precise, repeatable control. We *meter* flow by pre-characterizing our valves and monitoring the flow with a feedback signal and differential static pressure sensor. Our patented Accel® II valve is a complete flow-metering device.

The bottom line, however, is not one manufacturer's philosophy versus another. Instead, it is producing the safest laboratory environment–one that will operate reliably for the 15- to 20-year life span of the primary exhaust device.

The following factors should be addressed when selecting ventilation controls for laboratories:

- Speed of response
- Accuracy
- Stability
- Maintenance
- Installation issues
- Balancing

Each of these factors is discussed in this white paper.

Speed of Response

In any critical environment, it is imperative to maintain sufficient equipment reaction time to maintain the containment of the space under control (either the fume hood or the room pressurization). Measuring flow changes and making control changes based on the proxy parameters described above have several significant time delays. Phoenix Controls' equipment uses closed-loop control to set the valve relative to a factory-characterized position versus flow relationship. The time to accomplish this action is minimal. Static pressure changes in the system are compensated virtually instantaneously through the use of a mechanical function independent of flow control. Conversely, flow-measuring systems imply a flow measurement derived from air velocity. This means that when the static pressure changes, the velocity changes and the system will constantly be measuring and readjusting–always trying to "catch up."

Accuracy

In order to maintain containment or pressurization, a critical environment control system needs to be very accurate across a broad range of flows. While flow measurement systems are typically very accurate at high flows, the error can increase to greater than 40% as the flow is decreased. This is illustrated by the simple example in Table 1, which assumes a 0.25-inch water column (WC) 1% full-scale accuracy pressure transducer for flow measurement in a 10-inch diameter duct.

In addition, measurements obtained with velocity readings below 400 fpm are not practical because the accuracy of the measurements is compromised further. This limits the effective turndown to less than 5:1 with respect to flow.

Table 1. An example of the accuracy of airflow measurement system readings

Desired Flow (CFM)	Velocity/Pressure (FPM/inches WC)	Sensor Error (inches WC)	Velocity Pressure + Error (inches WC)	Flow Reading (CFM)	Reading Error (%)
1000	1835/0.2099	0.0025	0.2124	1006	< 1%
400	734/0.0336	0.0025	0.0361	415	4%
200	367/0.0084	0.0025	0.0109	228	14%
100	183/0.0021	0.0025	0.0046	148	48%

NOTE: Velocity = Volumetric flow ÷ Area, Velocity Pressure = $(\text{Velocity} \div 4005)^2$

The Phoenix Controls approach to precise flow metering is ±5% accurate of command, regardless of flow desired. Specifically, a flow command of 1000 CFM will be provided within 50 CFM and a flow command of 50 CFM will be provided within 2.5 CFM. This accuracy is achieved by commanding the valve to precise position and allowing an independent, highly accurate static pressure compensation mechanism to maintain this flow, regardless of significant static pressure changes.

Stability

There are two factors to consider regarding stability. First, when trying to measure flow, in order to obtain a reasonably accurate flow reading, several samples must be taken over a period of time to obtain an average airflow reading. Or the transducer signal must be dampened in some way to produce a stable command signal to the flow control mechanism. Either of these attempts to stabilize an inherently fluctuating flow signal leads to inaccuracies or time delays. The airflow controller's response time must be slowed or dampened to make it stable.

Second, the process of flow measurement must compensate for changes in system static pressure, as well as changes to flow command based on changes at the fume hood or room control. While these changes are underway, the building system is typically trying to maintain system static pressure at a plenum or common manifold. The interaction between the flow measurement and control devices on the same branch of the manifold or with the system static pressure controller can lead to troublesome oscillations. These oscillations are also known as *breathing buildings*.

The Phoenix approach does not need to be slowed to maintain stability and no external control adjustments are made to compensate for static pressure changes.

Maintenance

All flow measurement systems require regular maintenance to clean the pressure sensing points and recalibration to compensate for drift in the transducers. Most manufacturers recommend annual maintenance on these systems.

Cleaning is required for two reasons. First, the pressure sensing ports are typically tiny orifices that are subject to blockage, thereby disrupting the system readings. Second, large volumes and broad varieties of contaminants may pass the sensing element. These contaminants may be dangerous to personnel and equipment, resulting in extensive safety precautions and potentially disruptive decontamination efforts.

Recalibration is necessary because the pressure transducers drift over time based on changes in their internal physical characteristics and sensitive electronic components. Many employ drift compensation methods during the interim period but verification to a known reference pressure is still typically required at least yearly.

The Phoenix control system does not require regular maintenance because simplified methods and components are used to control the flow. The position is set relative to a potentiometer that has been designed and tested for no deterioration over 20 years of life. Pressure independence is maintained through a simple spring designed well below the material's limits and tested for more than 20 years of performance with no variance.

Installation Issues

Flow measurement devices require straight duct runs upstream and downstream of the sensing element to provide a smooth, stable velocity profile to the sensing element. In most experimental situations, good engineering practices recommend 10 diameters upstream and five diameters downstream of a straight duct. While the standards vary on the number of diameters, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) advocates, "If possible, measuring points should be located *at least* 7.5 hydraulic diameters downstream and 3 hydraulic diameters upstream from a disturbance."

Although typical flow measurement suppliers for commercial and industrial applications say shorter straight runs are acceptable, recommendations of only four diameters upstream can be difficult and costly to design into a facility. Installations with less than the recommended straight lengths before a sensing element seriously compromise the accuracy of the measurement. While many systems have been designed with proper duct configurations, it is not uncommon that actual installations were not provided according to the design.

Phoenix Controls' equipment is not measuring flow. Because of the inherent nature of the venturi design and the pressure compensating mechanism, our products are inlet and exit condition insensitive. These products can be installed in the duct in any configuration upstream or downstream of the valve without any impact on the accuracy, repeatability or stability of the flow control.

Balancing

Because providing 10-14 diameters of straight duct around a measurement device is highly impractical in the field, measurement device manufacturers have reduced this recommendation to significantly lower levels (four to six diameters). Therefore, devices that measure flow must typically be field calibrated for the installation condition to which these are subjected. Coefficients specific to installation are obtained in the field and used to provide better accuracy to these measurement devices. However, these coefficients are specific to the airflow rate at which they were determined and contribute to further inaccuracies at lower or higher airflow rates. Balancing the system at building start-up becomes a significant effort. In addition, any significant changes to the system will require rebalancing to some, if not all, components in that branch of the ductwork.

Phoenix Controls' approach is to factory characterize each venturi valve. As mentioned above, the components are insensitive to field conditions. Therefore, no further fieldwork is required other than the standard verification of appropriate flow. If changes are made to the system, the Phoenix valve compensates automatically. In essence, it is a self-balancing valve. The testimony of numerous balancing agents is independent confirmation that the initial start-up of a Phoenix system is far simpler, shorter and less costly than any flow measurement system.

Summary

There are a number of reasons why it is imperative *not* to rely on calculated flow measurement values as a basis for airflow control in critical environments. These types of devices, typically provided as commodity products, are subject to significant challenges, such as required speed of response, accuracy demands, stability, physical installation, and balancing and maintenance issues.

Phoenix Controls' approach to critical airflow controls relies on a product specifically designed for this purpose. The products are provided as a systematic solution to a challenging problem. Each system starts with job application engineering, continues with 100% characterization of every valve that leaves our factory and ends with years of trouble-free performance.

Reference

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). *ASHRAE Handbook: 2005 HVAC Applications.* Atlanta, GA: ASHRAE, 2005.

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