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Considerations For The Selection Of Air Flow Sensors

(AFM-1)

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Background

In general there are several technologies from which to choose. Each has specific performance advantages as well as cost and maintenance considerations. Some of the more popular technologies include differential pressure, thermal measurement and vortex shedding.

Differential pressure, the sensing of both total and static and reading the difference between the two pressures, is an indication of velocity of the air stream. Using the velocity the flow rate may be calculated by a remote computer program. The most popular (and least expensive) flow sensor is a Pitot based design which measures both the impact (total) pressure and the static pressure of the air stream. Variations of the Pitot tube design often enhance the static and total pressure signal to extend the range of operation. Multiple sensing ports in one tube are often used to average the flow contours across a duct profile. This is relatively inexpensive and dependable method of sensing airflow. A remote transmitter is normally used to convert the pressure signal to an analog output for remote monitoring and control.

Thermal measurement of the rate of heat conduction from a sensor is often used to measure high as well as very low flows and is independent of the density of the air. In general two rates of conduction are measured and compared- the temperature of the air stream and the temperature of the moving air stream. The current required to maintain this constant difference is indicative of the air steam velocity. The integral transmitter often will out put an analog signal linear and proportional to flow.

Vortex shedding and a doppler based sensor are sometimes used for air flow sensing.

The Application of Air Flow Sensors

Particle and dust loading

Particle movement in air has been studied extensively in the air cleaning industry. ASHRAE has also published some excellent reference material. This research suggests "small particles (those less than 200 microns size) which are disbursed in a stream of gas are generally assumed to travel along a streamlines with a mean velocity equal to the mean velocity of the gas". Particles above this size in normal HVAC velocities (up to1750 ft /min and above 200 microns or .007874" diameter, a typical dust particle) begin to either settle out of the main steam flow or are carried to the exterior of the flow by centrifugal force. The "dead" spaces in a duct system will often collect a sizeable amount of dust. Additionally most sensor holes are about .0625 "in diameter or larger so most small particles are carried through the sensors with very little deposition. These are general comments and should be confirmed for the specific application.

Supply air streams are commonly filtered to between 20 and 70 microns so particle contamination of sensors in the supply side should not be a large issue. After an extended period cleaning of dust from the "dead "spaces in supply ductwork may be needed to maintain good IAQ.

Particle and dust loading should always be considered but in some practical proportion to the amount and the size of the particles generated by the process. Ordinary people and light process (e.g., classrooms, research laboratories, pharmaceutical and electronic manufacturing spaces) can be easily dealt with a differential pressure based sensor with a series of averaging holes.

Special processes such as measuring the Products of Combustion (with soot contamination) and Pharmaceutical pill covering (lots of dust) can also be dealt with using differential pressure sensors by cleaning the sensors on a periodic basis. This can easily and inexpensively be done by purging the system with a small amount of 20# air activated with a timer on repetitive intervals. This can be done with a commercially available piece of hardware.

Dust loading should also be considered when applying the thermal sensors. Very heavy dust loading will affect the heat transfer rate of the thermal sensors. The thermal sensors do have a cylindrical surface but no cylindrical surface is completely "self cleaning".

Explosion proof or intrinsically safe applications

The mere existence of explosive vapors or dust does not automatically dictate the need for explosion proof or intrinsically safe hardware. Most insurance groups (NFPA) and motor manufactures (NEMA) have setup exposure and

hardware construction recommendations for each class or zone of exposure. An example of rational design is the use of ordinary electrical device in most research laboratories rooms. The common sense behind this decision is that most gases are used in small quantities and released in hoods with good airflow control and immediately cooled to ambient air temperatures (well below flash points of 250°F) and diluted to very low concentration levels.
However given the possibility of explosive gases or dust at the temperatures and concentrations which could be explosive a design can be based either on explosion proof or intrinsically safe construction.

One explosion proof solution is to use a differential pressure sensor that adds no electrical energy to the air steam and is inherently explosion proof. Local (standalone) control is easily possible using a pneumatic controller that again is inherently explosion proof, and is commonly available. If remote control is desired the pneumatic signal can be run to a transmitter located in a safe area.

Consideration of the potential surface temperatures of other types of sensors should be considered during design. The air steam sensor temperatures of thermal probes are normally low (100°F to 150°F depending on the manufacturer) so that the lowest flash point for vapors are not reached (250°F). The energy level stored in any circuit board must be considered. If the transmitters are installed outside of the duct in a non-hazardous area normally there is no effective exposure. If the transmitter must be located in a hazardous area, it can be enclosed in an explosion proof casing, or, any potential power consumption may be limited by using an intrinsically safe barrier (Zener Diode or Transformer isolation). We suggest contacting a barrier manufacturer for installation recommendations.

Humidity level

No sensors operate accurately in condensing air streams. Installation downstream of coils sized for latent cooling, air washer fume scrubber etc should be avoided.
A maximum 85% to 90% humidity level is a conservative design goal.

Density

Any changes in density in the flow steams should be considered. The differential pressure sensors are sensitive to density changes and any readings will have errors when the density shifts appreciably. This is a typical design issue in outside air streams. Often modifications to the building computer programs can help to compensate for these errors. The thermal flow sensors do not depend on duct pressure and therefore the velocity signal is indicative of the velocity regardless of any density changes.

Velocity contours and Min/Max Velocities

On VAV systems common maximum velocities range about 1500 to1600 ft/min. With common turn downs (load shedding or Occupied/Unoccupied strategies) the minimum velocities can often be one fourth to one sixth of the design rate or 300 to 400 ft/min.

Assuming the velocity is uniform across the entire area of the duct the differential pressure sensor will transport this small (.01") to the diaphragm of the transmitter. This is a very low number and very hard to hold repetitive set points. A more repetitive technology for low flow rates is the thermal sensor which has been tested under field conditions to about 100 ft/min. Below this velocity the convective heat forces from the small temperature stratification begins to affect the repetition of the output. We often use a rule of thumb of 700 ft/min being the minimum velocity that can de used for differential pressure flows sensors with transmitters and 150 ft/min for thermal sensors.
When sensors are located downstream (or field located) of elbows or other abrupt fittings duct velocity contours will vary from very low to very high values. Vortices with flows in a reverse direction are quite common. Unfortunately no sensor reacts well to reverse flows (if differential pressure the readings are unpredictable - if thermal it will indicate positive number of some amount). The flow field contour may drive the type of sensor selected-- the differential pressure sensor should always have air flow parallel to the sensors to achieve rated accuracy.

Materials of construction

The level of contaminants in the air handling systems will normally dictate the material selected for the flow sensor. Supply systems can use aluminum (easily extruded) or galvanized steel. Exhaust systems carrying potential corrosive fluids should have either stainless steel, plastic (CPVC) or epoxy coated flow sensors.
The temperature of the air steam will affect the material of which the sensor is made. If the air steam is above 200°F the sensor should not be plastic.