Technical Publication

What You Don't Know About Air / Gas Flow Measurement Can Be Very Expensive

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The measurement of air and gases in chemical plants is essential in many functional applications, including safety, process control, product quality, production efficiency, environmental compliance and cost. When the measurement of air or gases is inaccurate or inconsistent, the result can be serious accidents, emergency shutdowns, unplanned maintenance, production slow-downs or cost over-runs.

There are six to eight viable air/gas flow measurement technologies on the market today, but only about half of them are suitable for the heavy duty metering applications found in the most challenging chemical plant processes. Each of them has its own strengths and weaknesses, depending on exactly what needs to be measured, the required accuracy, where it needs to be measured, etc.

The truism "knowledge is power" definitely applies when it comes to choosing an air/gas flow meter for measurement tasks in chemical plants. The same flow sensing technology that you choose for one application in your plant is quite possibly the wrong choice in a different application that can even be in close proximity.

The cost of choosing the wrong flow meter in terms of extra maintenance, repairs and spares in large chemical plants *(Figure 1)* can add up quickly to tens of thousands of dollars alone. If safety events or poor product quality or a production slow-down or environmental compliance issues occur, then the cost of failing to recognize the subtle differences in air/gas flow measurement technologies can be punitive.

Figure 1: Chemical plant

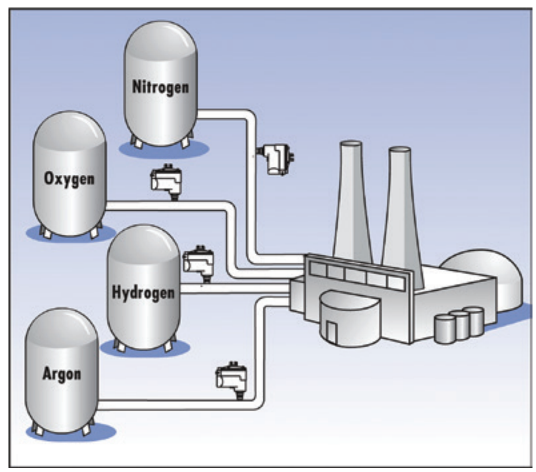

Figure 2: Typical plant gas distribution

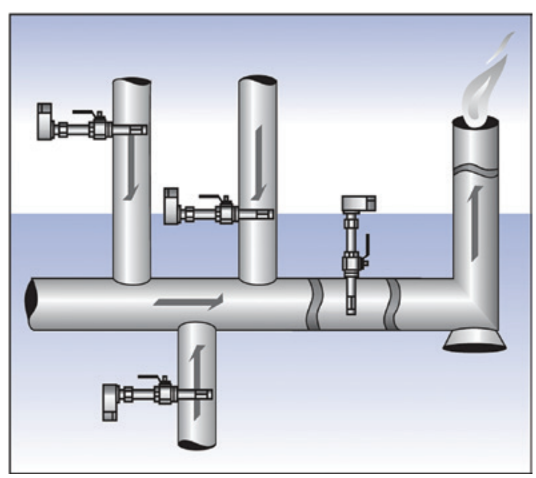

Figure 3: Flaring system

Common Measurement Applications

Flow meters are used to measure air/gas flow rate and totalized flow. Due to the hazardous operating environment of chemical plants, air/gas flow meters generally require HazEx approvals and often must be SIL compliant as part of a Safety Instrumented System (SIS) in many applications. Four of the most common and the most demanding air/gas flow measurement applications in chemical plants are:

Gas Distribution Metering

Many chemical processes require large varying volumes of specific gases, such as nitrogen, argon and oxygen for inert ion or purging or blanketing; hydrogen is required as a catalyst and other specific gases are used as well *(Figure 2)*. The accurate measurement of these gases is necessary for process control, gas inventory control and cost management.

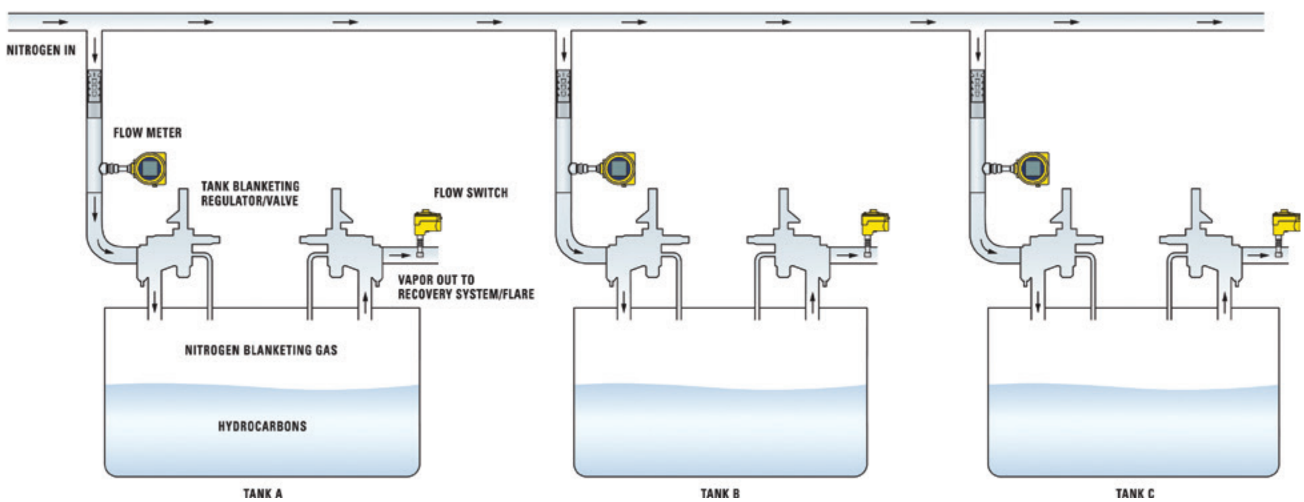

Figure 4: Flaring system

Flaring Systems

In petrochemical production, refining and storage, flare gas systems are used to burn off and dispose of waste, excess or off-gases and as a safety system *(Figure 3*). The accurate, responsive and reliable measurement of flare gas is essential in order to assure proper operation of the flare gas system, which protects people and equipment from hazardous combustible gas to maintain a safe working environment and to avoid environmental contamination.

Tank Blanketing

Nitrogen blanketing is used in the chemical and petroleum refining industries to reduce the hazards associated with flammable liquids, which supports plant safety and can help increase productivity. Blanketing or padding is a process of applying inert nitrogen gas to the vapor space of a tank or vessel *(Figure 4)*, which minimizes the possibility of an explosion or fire by reducing the oxygen content or the concentration of flammable and/or explosive vapors.

Stack Gas Monitoring

Measuring the output of chemical plant waste gases through large stacks with scrubber systems for environmental compliance requires multiple air/gas flow sensors, which are placed in strategic locations *(Figure 5)*. Stack continuous emission monitoring systems (CEMS) must meet U.S. Environmental Protection Agency (EPA) 10 CFR 40; 40 CFR 98; EU Directives 2003/87/EC and 2007/589/EC; US MMR 30 CFR Part 250, Subpart K, Section 250 and others.

Air/Gas Measurement Challenges

Accurate, dependable gas flow measurement applications present challenges to chemical industry plant, process and

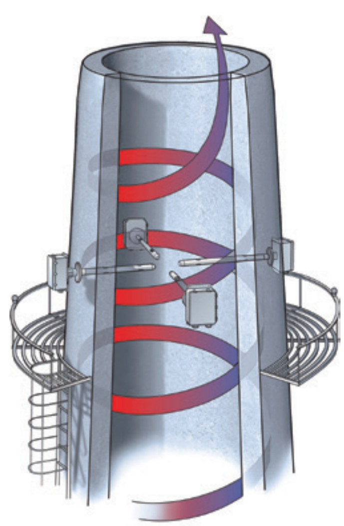

Figure 5: Stack gas monitoring system

instrument engineers. The following issues require careful attention when choosing a flow meter sensing technology:

Low and High Flows
Sensitivity to low flow conditions is required to identify and measure leaking valves and the normal low flow associated in day to day operations. The capability to measure very high flows is needed during system upset conditions requiring a meter that needs to measure flow accurately over an extremely wide turndown range.

Meter Calibration
This application requires the calibration of flow meters specifically for hydrocarbon composition gases and matching to actual process conditions is essential.

Large Line Sizes
As pipe sizes increase, the number of effective and suitable flow meter sensing technologies decreases.

Available Straight-Run
All velocity based flow meter technologies have pipe straight-run requirements upstream and downstream from the meter in order to achieve accurate flow measurement. These straight-run requirements may not be available in crowded production sites and process plants.

Limited Access
Access and re-access to piping for installation, maintenance or servicing is frequently difficult. For example, spool-piece flow meters can require prolonged process shut-downs and extensive on-site labor costs to install and continuously maintain the system as opposed to insertion style meters that can be easily inserted into or retracted out of the process through a ball valve.

Agency Approvals
When installing meters in hazardous (Ex) locations, the entire flow metering instrument should carry agency approval credentials for installation in environments with potential hazardous gases; enclosure only ratings are inadequate.

Major Gas Measurement Technologies

There are two basic types of flow meters: liquid and air/gas. Liquid is primarily measured in terms of volumetric flow, while air/gas is a mass flow measurement because of the unique properties of gases (versus liquids). While some volumetric technologies can measure air/gas flow rates, there can be problems with totalized flow. Generally, the best choice is mass flow sensing technology when measuring air/gases—especially in critical applications.

Coriolis
The principle of operation for Coriolis flow meters relies on a vibrating tube were the flow of a fluid causes changes in frequency, phase shift or amplitude, which is proportional to the mass flow rate. Coriolis meters are highly accurate and frequently used in custody transfer applications, but they are on the expensive side and require labor intensive in-line applications.

Differential Pressure
DP meter sensors come in several designs, including orifice plates, pitot tubes and Venturis. The typical DP meter designs requires the fluid to move through or past two points of reference, creating a differential pressure rate that is equivalent to the rate of flow using the Bernoulli equation with some modifications. If the air/gas or fluid is dirty, there can be orifice clogging issues that require frequent maintenance in order to maintain accuracy.

Ultrasonic
Flow meters designed with ultrasonic flow sensing technology rely on ultrasound and the Doppler Effect to measure volumetric flow rate. In ultrasonic flow meters, a transducer emits a beam of ultrasound to a receiving transducer. The transmitted frequency of the beam is altered linearly by particles or bubbles in the fluid stream. The shift in frequencies between the transmitter and receiver can be used to generate a signal proportional to the flow rate.

Optical
Flow meters designed with optical sensing rely on laser technology and photo detectors. This technology requires the presence particles in the gas stream. These particles scatter the light beam and the time it takes for these particles to travel from one laser beam to the other

laser beam can be used to calculate the gas velocity and volumetric flow rate. These meters have good accuracy and wide turndown, but are traditionally expensive.

Thermal Dispersion

Flow meters with thermal dispersion sensors provide direct mass flow measurement. Two thermowell protected platinum RTD temperature sensors are placed in the process stream. One RTD is heated while the other senses the actual process temperature. The temperature difference between these sensors generates a voltage output, which is proportional to the media cooling affect and can be used to measure the gas mass flow rate without the need for additional pressure or temperature transmitters.

Flow Meter Calibration

In measuring flow accurately, second only to selecting the proper flow sensor is the method of calibration. There are two methods used in calibrating air/gas flow meters: (1) the Direct Method, where the meter is calibrated to a specific pure process gas and/or to the actual components of a mixed gas in use and (2) the Air Equivalency Method, where the meter is calibrated using air and then the calibration is adjusted with a pre-defined correction factor.

It is important to ask your supplier about the method of flow meter calibration. You should know if manufacturers contract out and with whom, or if they operate their own calibration laboratory with direct method calibration test stands and equipment traceable to NIST and ISO/IEC 17025 *(Figure 6)*.

Installation Considerations

When choosing an air/gas flow meter technology, one of the most important criteria to consider is the location and the manufacturer's installation requirements. Most flow meter technologies require a stable fluid flow profile upstream and downstream from the point of meter installation; a specific number of pipe diameters in each direction. Flow sensors are potentially sensitive to swirling air/gas conditions in the pipe, or pressure drops (turndowns) or flow surges.

In many cases, irregular flow issues can be solved with flow conditioners. There are various types of flow conditioners that can be inserted strategically in the pipe to "straighten" the flow before it reaches the flow sensor. They consist of tabs or honeycombs or vanes or other designs, which all straighten the flow. Some straighteners, such as the tab type, actually speed up the rate flow by creating regular vortices to avoid any loss of air/gas throughput (pressure drop).

There are two ways to install a flow meter: (1) in-line or (2) insertion *(Figure 7)*. In-line flow meters must be installed horizontally inside a section of the pipe. Insertion flow meters are top mounted through a tap point.

Some flow meters can only be installed using one method. Venturi meters, for example, must be installed in-line (inside the pipe). In comparison, thermal meters, some DP meters (orifice plates) and others can be installed in either in-line or insertion configurations.

Lastly when considering installation requirements, some flow meter technologies rely on direct mass flow sensors. Other flow meters infer mass flow and require pressure and/or temperature sensors to be installed nearby along with transmitters, which can add to their cost and installation complexity.

Figure 6: FCI's world-class flow calibration laboratory

Figure 7: FCI ST100 Series In-line and insertion flow meters

Maintenance Requirements

All flow meters require maintenance. Some meters, however, require more maintenance. The type of air/gas fluid to be measured can have a major impact. Pure process gases in a benign plant environment are generally going to have less impact on a flow meter than dirty waste gases.

Some meter designs require less cleaning or are easier to clean than others. For example, top mount insertion style meters with packing glands can be quickly pulled out of the pipe without shutting down the process and cleaned in place with compressed air and then returned to service.

Conclusions

There are many factors to consider when choosing a flow meter for application within a chemical plant. A good check list of considerations would include:

- Accuracy
- Repeatability
- Flow sensor technology
- Calibration type
- Installation requirements
- Maintenance
- Cost

In considering the cost of a flow meter, there are three crucial factors to think about: (1) the purchase price of the meter, (2) the installed cost and (3) the lifecycle cost. Stopping your analysis at the purchase price is misleading when it comes to reviewing the true cost of instrumentation — especially flow meters.

We've discussed the two types of flow meter installation. Insertion configuration flow meters are simpler to install, which is going to result generally in a lower installed cost versus a flow meter that is less expensive to purchase though it requires an in-line installation.

The last factor to consider is the lifecycle cost. How long does the manufacturer expect the flow meter to remain in service? Is its life span 5, 10, or 20 years? Over that lifetime what kind of maintenance will be required? Some meters have movable parts that can break and require repair. Some meters depend on small orifices that tend to narrow or clog in dirty environments, requiring cleaning. These expenses can add up over time, which increases the cost of ownership.

In conclusion, knowledge and experience with flow meters is power. The more you know about flow meter technologies, the better the decisions that you'll make. ■