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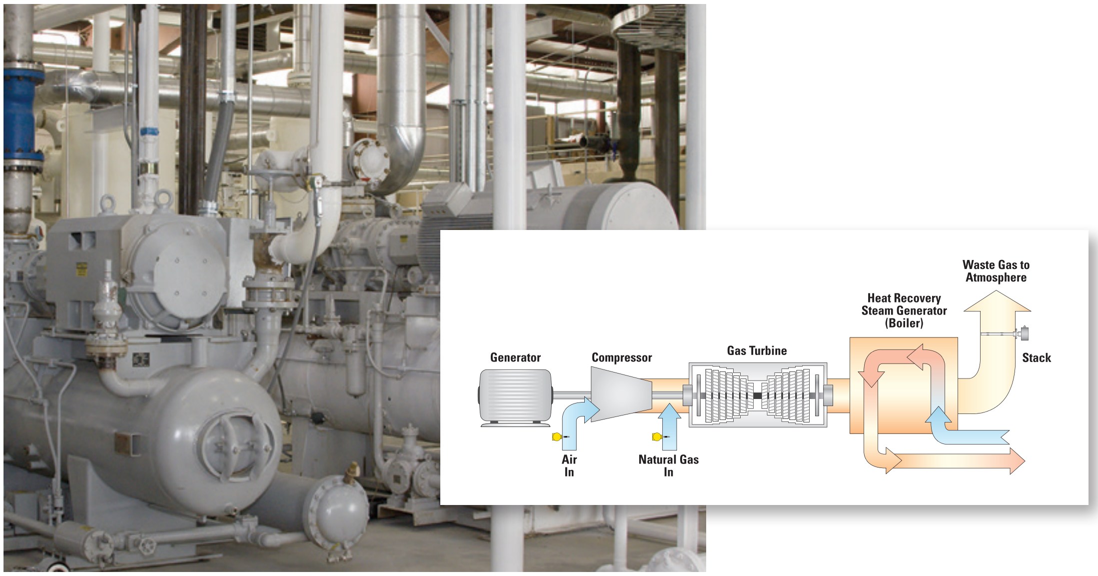

Air/Gas Flow Measurement for Turbomachinery: What You Don't Know Can Be Frustrating

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The accurate, repeatable flow measurement of air and gases is critical to the safe, efficient and cost-effective operation of turbomachinery and related equipment in the electric power generation, oil/gas production/refining and other industries. Choosing the wrong air/gas flow meter sensing technology can have significant consequences.

There are at least nine common industrial flow measurement technologies available today, all having their strengths and weaknesses depending on the specific application, operating environment, maintenance, cost and other factors. Understanding these flow sensing technologies prevents mistakes that can be costly or even dangerous depending on the application. The costs associated with installing the wrong flow meter in terms of extra maintenance, repairs and spares in larger operations can add up quickly.

Common Measurement Applications

Flow meters often measure both the fluid flow rate and totalized flow. Given the operating environment of electric power plants and oil/gas refineries, air/gas flow meters generally require hazardous area approvals and often must be IEC 61508/61511 (SIL) compliant as part of a Safety Instrumented System (SIS). The most common turbomachinery air/gas flow measurement applications involve turbines and compressors.

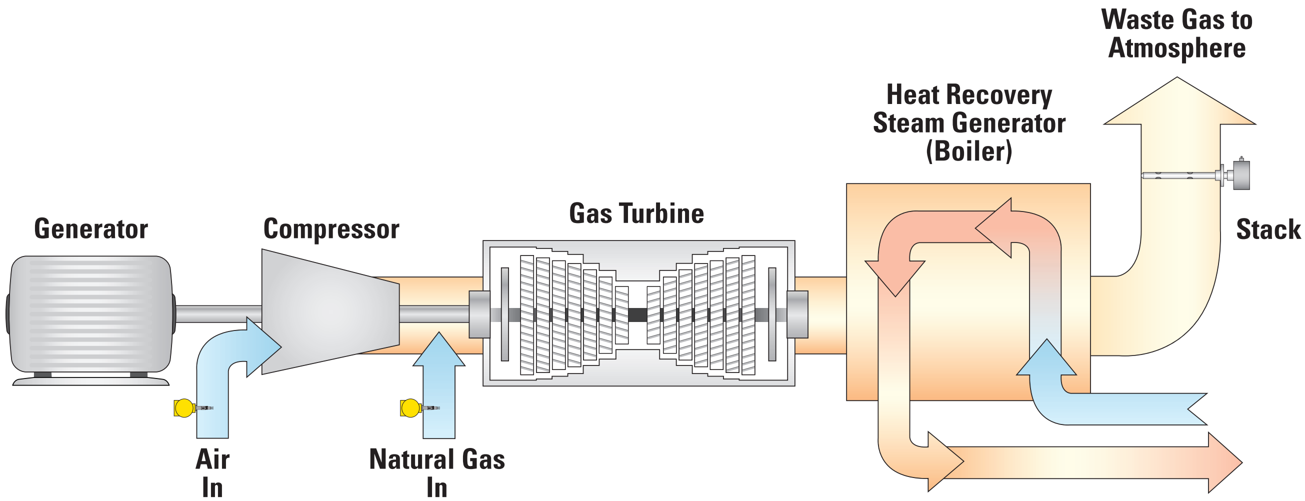
Turbines

Accurate and consistent air/gas flow measurement over a wide turn-down range is important in electric power steam driven turbine systems, including combined cycle gas turbines (CCGT), combined heat and power (CHP) and co-generation systems utilizing waste gases. Repeatable measurement of the air-to-gas fuel mixture supports efficient boiler operations to generate steam as needed. Monitoring of mass flow rate of hydrogen in cooling systems allows early detection of leaks in order to minimize environmental impact. The ability to operate over a wide turn-down range is important to support variable power demand that goes up and down throughout the day, requiring the turbines to cycle their output *(Figure 1)*.

Compressors

There are thousands of miles of natural gas pipelines serving the world utilizing compressor stations located mid-stream to keep the gas flowing to its end destination. The operation of these compressor stations requires accurate natural gas flow measurement from the pipeline to fuel the compressor station. Monitoring the health of dry gas seals, which serve as a back-up leakage system to prevent the gas from accidentally leaking into the atmosphere, can also reduce operational costs *(Figure 1)*.

Figure 1: Typical turbine and compressor application



Air/Gas Measurement Challenges

Accurate, repeatable gas flow measurement in turbomachinery applications can present challenges to plant, process and instrument engineers. The following issues require attention when evaluating and selecting a flow meter sensing technology.

Low and High Flows
Sensitivity to low flow conditions is required to identify and measure gas leaks that deviate from the normal low flow condition in day-to-day operations. Process upset conditions may cause very high flows, requiring a meter capable of measuring flow accurately over an extremely wide turndown range.

Meter Calibration
Many gas turbine and compressor applications require flow meter calibrations specific to unique hydrocarbon composition gases. Matching the flow meter's calibration to actual process conditions with actual gas mixtures is essential. In some applications, gas mixture variations periodically occur and require multiple calibration groups that can be called upon for improved repeatability.

Large Line Sizes
As pipe sizes increase, the number of effective and suitable flow meter technologies decreases. Not all flow sensing technologies are capable of accurate measurement in large air/gas lines supporting large turbomachinery equipment and processes. Single point measurements will introduce greater inaccuracies as line sizes increase.

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, especially when larger lines are involved.

Limited Access
Access to piping for installation, maintenance or servicing is frequently difficult. For example, spool-piece (in-line) 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 single isolation ball valve.

Agency Approvals
When installing meters in hazardous locations, the entire flow metering instrument should carry agency approvals that demonstrate suitability for installation in environments with potentially explosive gases; enclosure only ratings are inadequate. Acceptable approvals can vary globally and may further limit your options.

Major Gas Measurement Technologies

The fluid being measured typically drives the preference for volumetric versus mass flow measurement. Liquids are primarily measured in terms of "volumetric" flow, while a "mass" flow measurement is often preferred for air/gas because of the unique properties and compressibility of gases. While some volumetric technologies can measure air/gas flow rates, there can be limitations with measuring totalized flow. Generally, the best choice is a mass flow technology when measuring air/gases—especially in critical applications.

Coriolis
The principle of operation for Coriolis flow meters relies on a vibrating tube where 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 can be expensive, especially in larger line sizes, and often require costly bypass piping systems to accommodate field maintenance.

Differential Pressure (DP)
DP transmitters are often paired with primary flow elements such as orifice plates, averaging pitot tubes and Venturi's. The typical DP meter design 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 fluid is dirty, orifice, impulse tubing and manifold blockage can occur that requires frequent maintenance in order to maintain accuracy. Turndown

capability can be limited if a single transmitter is used for the measurement.

Ultrasonic

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 of 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 required by volumetric technologies.

Flow Meter Calibration

To ensure accuracy, the method of calibration is the second most important consideration. 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. Flow meter accuracy is greatly improved when calibrations utilize actual gas mixtures and process conditions that best represent field conditions. Air equivalencies can be given consideration when there is sufficient data to support its use or it is unsafe to use the actual process media.

Installation Considerations

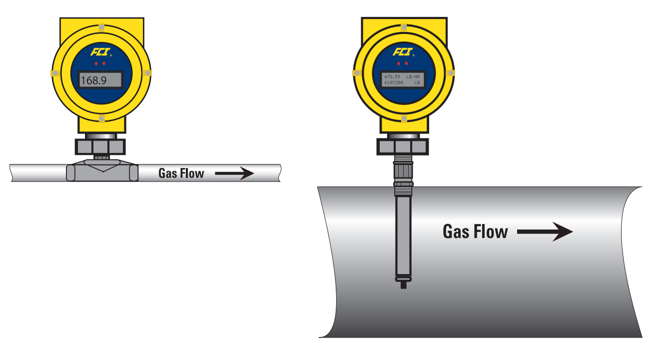
When choosing a technology, another key area of concern is the intended meter location and the manufacturer's installation requirements. Most flow meter technologies require a stable flow velocity profile upstream and downstream from the point of meter installation; a specific number of pipe diameters in each direction. Flow sensors are potentially sensitive to swirling conditions and velocity profile distortions created by obstructions before and after the metering point.

Irregular flow profiles can be addressed 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, perforations, tube bundles, vanes or other designs, which all straighten the flow to some extent. Some straighteners, such as the tab type, actually speed up the rate of flow by creating vortices, also minimizing head loss (pressure drop).

There are two ways to install a flow meter: (1) in-line (spool) or (2) insertion *(Figure 2)*. Spool type flow meters are installed as a section of the process piping. Insertion flow meters are mounted through a tap point to the pipe section.

Some flow meters can only be installed using one method. Coriolis meters, for example, must be installed in-line (part of the piping). In comparison, thermal meters, some DP meters (orifice plates/averaging pitot tubes) and others can be installed in either in-line or insertion configurations.

Figure 3: In-line and insertion meter installations



Lastly when considering installation requirements, few technologies rely on direct mass flow sensors. Most flow technologies require pressure and/or temperature sensors to be installed nearby along with the transmitters, or use of multivariable transmitters, which can add cost and complexity to the installation when mass flow readings are required.

Maintenance Requirements

All flow meter technologies require periodic maintenance. Some can require more maintenance than others. The type of air/gas to be measured also 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, insertion style meters with packing glands can be extracted and isolated without shutting down the process and cleaned in place with compressed air and then returned to service. In-line style flow meters require costly and elaborate bypass systems in order to remove them for maintenance without shutting down the process.

Before choosing any flow sensing or metering technology be sure to calculate the cost of installation and the cost of maintenance to arrive at a total life cycle cost. While not previously mentioned, service life can vary significantly with the different flow sensing technologies.

Conclusions

There are many factors to consider when choosing a flow meter for application within the Process industries. A good check list of considerations would include: sensor technology versus application requirements, accuracy, repeatability, calibration, installation requirements, maintenance, service life and lifecycle cost.

When considering the cost of a flow meter, there are three crucial factors to think about: (1) the initial purchase price, (2) the installed cost and (3) the lifecycle cost. Limiting your analysis to the purchase price is misleading when it comes to understanding the true cost of ownership — especially with flow meters.

We've discussed the two types of flow meter installation. Insertion flow meters are simpler to install, which is going to result generally in a lower installed cost versus a spool type flow meter that may be less expensive to purchase though it requires 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, increasing the cost of ownership.

In conclusion, the more you know about the various flow meter technologies the more likely you are to make the best choice for your application, eliminating future frustrations and concerns. The more you learn about flow meter technologies, the more thorough and effective your selection process will become. ■