Measuring Air Flow is Easy. Measuring Air Flow Accurately Can Be Very Difficult.

The trend to improve efficiency in today's power plant environment drives the need for effective boiler trim controls which, in turn, requires accurate air flow measurement. An air flow measurement that is not repeatable, accurate, or representative of mass flow can destabilize the airflow control loop and leave you with virtually no control over the fuel-to-air ratio.

Here are the primary causes of inaccurate air flow measurements:

- Improper selection of measurement technology
- Blockage of the flow element (due to plugged pitots or duct collapse)
- Inadequate straight runs of duct upstream and downstream of the flow measurement
- Collapse, or blockage of flow straightening devices (honeycomb, etc.)
- Change in duct size due to heat or pressure
- Density (and thus mass flow measurement) is uncompensated by temperature and static pressure

Choosing the Correct Measurement Technology

Pitot tubes are a time-tested method of measuring airflow in ducts. Pitot technology is cost-effective, easily maintained, and applicable to most duct configurations.

A significant advantage of pitot tubes over venturi, orifice plates, and airfoils is the minimal unrecovered pressure drop across the flow element. Use of pitot tubes can represent cost-savings associated with reduction in fan horsepower requirements.

Pitot tubes, like other differential pressure-based technologies, measure the velocity of air in a duct. The velocity, or speed, of the air is often confused with the mass, or amount, of air moving through a duct. The combustion process is a "mass-based" relationship. The mass of air must be stochiometrically balanced against the mass (and BTU) of fuel. In rare cases where duct pressure and air temperature change minimally, uncompensated air velocity measurement can be adequately used to infer mass air flow and in trimming the boiler.

Conventional pitot tubes are single-port measurement devices. Duct-mounted pitot tubes often have multiple ports, which average the velocity over a number of ports, providing a more representative sample of duct velocity in a single plane. Several multi-port pitots can be arranged in an array to increase the number of sample locations and improve accuracy.

In most cases, pitot tubes have one port facing into the air stream (high), and one port at 90° to the air stream (low). The differential pressure between this "high" and "low" port represents the velocity, as noted above. The port facing the air stream (impact port) is vulnerable to plugging from airborne particulate. Some manufacturers offer purge systems that periodically blow out the ports to prevent interference with pitot measurement.

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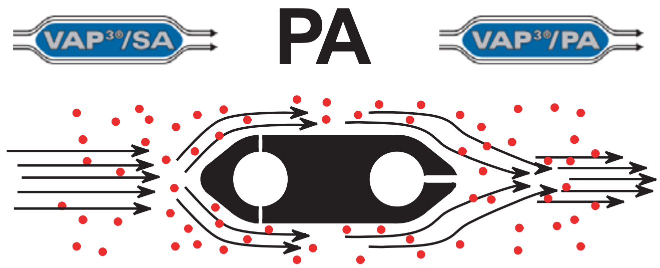
Dealing with Flow Element Blockages

Purge systems are costly, add complexity to the measurement, and are prone to plugging over time as hydration of airborne particulate occurs inside the flow element. ***A notable exception to the plugging problem is pitot technology from Eastern Instruments.***



A cross section of the VAP3®/PA Pitot Tube, demonstrating its resistance to plugging.

The VAP3®/PA pitot places its “high” port inline with airflow and thus, has no impact ports. Becuase the PA pitot from Eastern Instruments is not subject to plugging, for most applications, no purge system is required.

Air Flow Measurement with No Straight Duct Runs

Turbulent air flow can cause great difficulty in air flow measurement. According to ASTM standards, and like other differential pressure-based flow measurement techniques, pitots require sufficient upstream and downstream duct runs for accurate measurement. In most power plants, there are rarely sufficient straight runs to permit accurate measurements. The purpose of the straight runs is to allow duct flow patterns to recover to a laminar state after an obstruction or changed direction. For instance, immediately downstream of an elbow, centripetal forces pull air to the outer edges of the duct. The air profile at the cross-section immediately following the elbow is turbulent. After traveling a distance equal to several diameters, the flow again becomes laminar. In circular ducts, the flow is nearly always cyclonic, creating an even more difficult measurement environment. Differential pressure-based technologies require balanced flows free of cyclonic and turbulent conditions. To achieve these conditions, flow straighteners are often used to reduce the straight-run requirements for the measurement. These devices can be effective, but they are not without cost.

Collapse or Blockage of Traditional Flow Straightening Devices

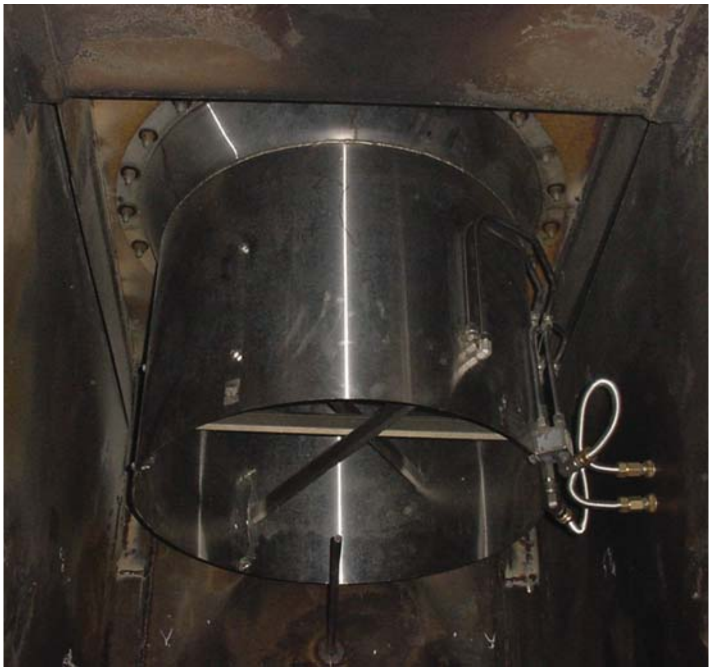
Honeycomb style flow straighteners can cause an unacceptable pressure drop upstream of the measurement. These devices are also sensitive to clogging or breaking if duct debris hits them, and are subject to long-term corrosion as well. As an alternative, custom duct inserts can be fabricated to perform a straightening function. While effective, they typically do not settle cyclonic flow and are expensive to install. If the duct dimensions change, the inserts may become ineffective.

Changes in Duct Size (Effective Area) Due to Heat or Pressure

Ducts continually expand and contract. As duct pressure increases, due to temperature increases or various other factors, the walls of a rectangular duct tend to bow slightly outward. This change in effective duct area can severely impact flow measurement because mass calculations inferred by velocity depend on a duct's constant cross-sectional area.

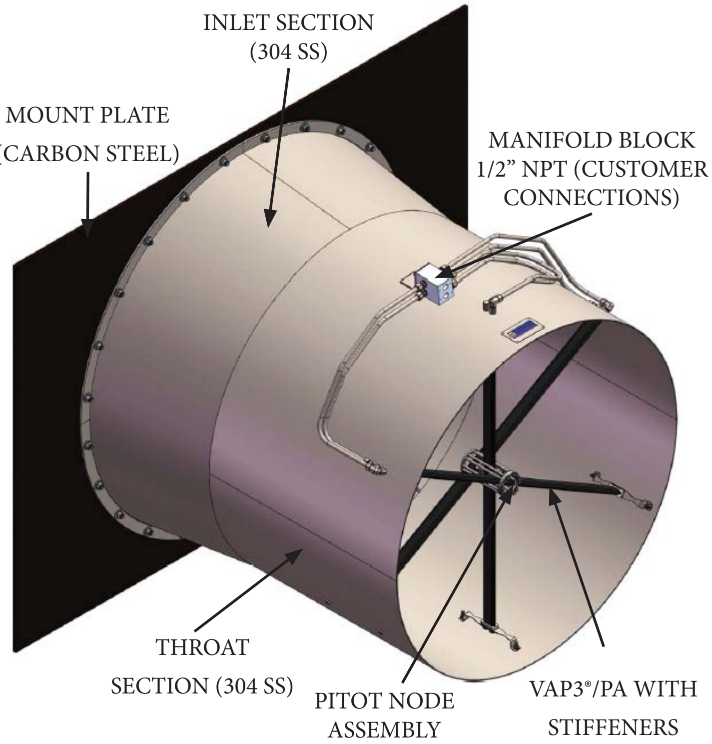
A notable exception to the primary causes of inaccurate flow mesurement - the High Beta® Flow Conditioner from Eastern Instruments.

The High Beta® Flow Conditioner, which integrates a set of flow-straightening vanes and an array of integral VAP3®/PA pitots within a spooled duct section, utilizes time-tested pitot technology and a revolutionary plug-resistant design to create a flow conditioning device that drastically minimizes the required upstream and downstream straight duct requirements, increases the structural integrity of the duct and reduces the chance of duct expansion and contraction, all of which dramatically increases the accuracy of the flow measurement.



A typical High Beta® - Installation.

A typical High Beta® - Components



The High Beta® Flow Conditioner

The High Beta® Flow Conditioner creates a rigid, non-moving cross-sectional area of duct that profiles the air while it is being measured. The High Beta Flow Conditioner's® converging duct section effectively straightens the flow profile while accelerating the air passing through its round measurement area. Becuase the High Beta® both straightens the air and profiles it prior to measurement, the High Beta® Flow Conditioner can be mounted in areas where conventional differential pressure measurement devices cannot, such as directly downstream of an elbow, damper, or other obstruction.

Air moving through elbows, dampers, etc is typically accelerated and the converging duct section within the High Beta® accelerates the air further so that some or all of the pressure loss can accually be recovered. The result is that the High Beta® improves measurement accuracy and repeatability while potentially reducing pressure loss due to erratic flow patterns, all of which translates directly into savings. Please refer to the next page for charts comparing various technologies against the VAP3® Pitot and the High Beta® Flow Conditioner.

The VAP³® Pitot and High Beta® Flow Conditioner versus Alternative Technologies

Comparative Attributes of Various Flow Straighteners

Flow Straightening Selection:	Straightening Vanes	Honeycomb Straightener	High Beta®
Comparible Attributes:			
Ability to Eliminate Swirl	Fair	Good	Great
Adequately Straightens Flow	Fair	Good	Great
Ease of Installation	Poor	Fair	Good
Integral Flow Measurement	No	No	Yes
Resistant to Breakage	Fair	Poor	Great

Comparative Attributes of Various Air Flow Conditioning and Measurement Devices

Flow Element Selection:	Venturi	Airfoil	Orifice Plate	Standard Pitot Tube	VAP³®/PA Pitot Tube	High Beta®
Comparable Attributes:						
Pressure Drop Across Element	High	High	High	Low	Low	Med
Intermittent Purge Required	No	No	No	Yes	No	No
Straight Pipe Diameters Upstream (guideline)	4-8	4-8	7-8	8-10	5-8	0.5-1
Straight Pipe Diameters Downstream (guideline)	3	3	4	4	2	1
Compensation for Duct Expansion/Contraction	No	No	Yes	No	No	Yes
Resists Impact Port Blockage/Plugging	No	No	No	No	Yes	Yes
Available for Rectangular Ducts	Yes	Yes	No	Yes	Yes	Yes
Can be Used to Calculate Mass Flow	Yes	Yes	Yes	Yes	Yes	Yes

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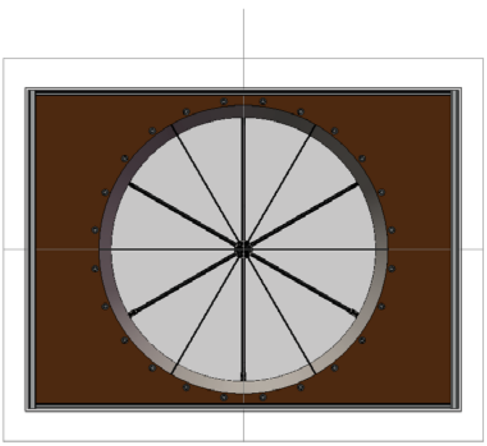
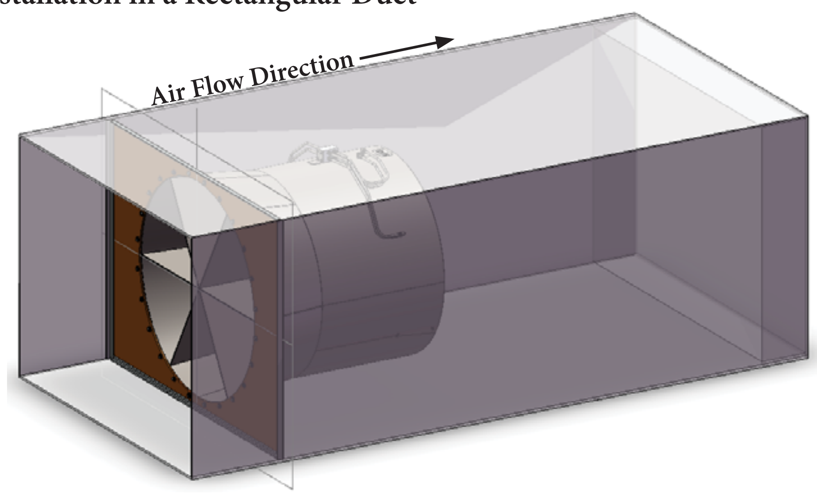
Calculating Mass Air Flow Using Differential Pressure

As with all differential pressure-based measurements, the density of the flowing air must be compensated for air temperature and duct static pressure in order to achieve a true mass flow measurement. Temperature compensation is accomplished through direct measurement of air temperature (Thermocouple or RTD), wired to a multivariable transmitter. Pressure compensation is accomplished through an internal absolute pressure measurement (Duct Static and Barametric Pressure) within the multivariable transmitter. Both VAP3® Pitots and High Beta® Flow Conditioners from Eastern Instruments, will offer an accurate and repeatable, compensated mass flow measurement when coupled with nearly any brand of Multivariable Transmitter.

Typical HBE Installation in a Rectangular Duct

Conclusion

While obtaining an air flow measurement is relatively easy; obtaining an accurate, repeatable signal can be challenging. Taking into account all of the duct and flow characteristics that need to be considered in measuring air flow accurately, it is not surprising that most boiler trim control systems need improvement. As a key element in boiler efficiency, and considering costs associated with fan power, accurate, robust, and simple air flow measurement is essential to modern boiler control. The High Beta® Flow Conditioner's combination of integrated flow straighteners, converging profiler, constant cross-sectional measurement area, and plug-resistant pitots makes the most cost-effective, accurate, repeatable air flow measurement technology in the power generation market. Most importantly, it permits combustion controls to achieve stochiometric balance, yielding quantifiable cost savings for any power plant.