Air Monitor

Unlocking Cost Savings

Improved Airflow Control in Industrial Combustion with a Fully Metered System

PRECISE, RELIABLE, TRUSTED
SOLUTIONS
IN AIRFLOW MEASUREMENT

EXECUTIVE SUMMARY

Accurate mass-based air monitoring and improved control of airflow in industrial combustion systems can save fuel costs and reduce maintenance downtime.

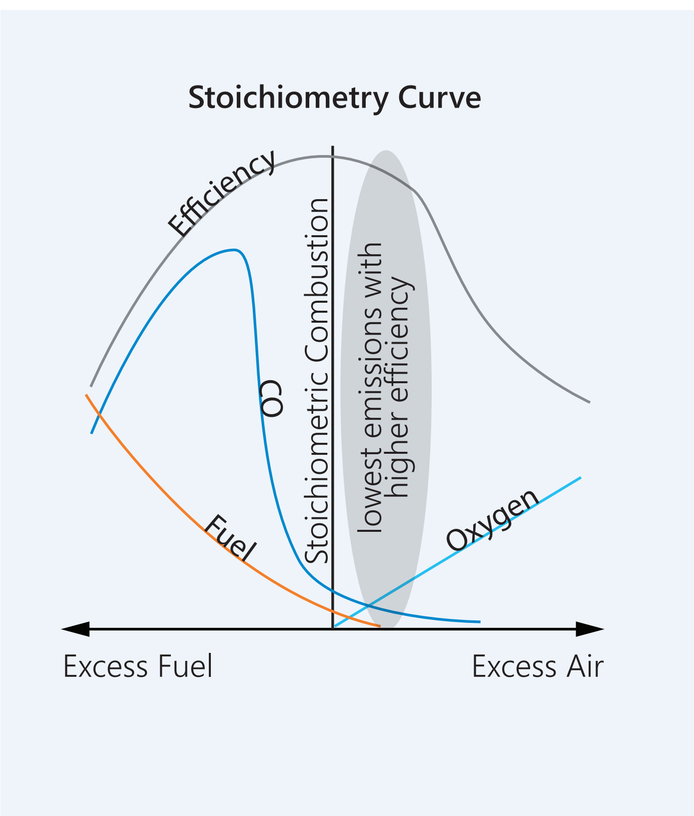
The efficiency of combustion systems - such as steam boilers, thermal oxidizers, fired heaters, waste-heat boilers, solids dryers, furnaces, incinerators and kilns - can be maximized by tightening the control over the air-to-fuel ratio in the burners. Increased effectiveness in monitoring and controlling airflow in industrial combustion systems helps allow that tighter control.

Accurate airflow monitoring and control addresses several challenges simultaneously: tighter adherence to the most efficient operating air/fuel ratio (lower fuel costs); NOx emissions that fall within regulatory specifications; improved safety during boiler purge and throughout the operating range; and lower maintenance costs (with less downtime). This white paper provides information on the available methods for controlling airflow in industrial combustion systems — including parallel positioning (PP), PP with O_2 trim and fully metered airflow control systems — as well as the advantages and limitations of each approach. Finally, this paper will show that a fully metered system offers the best solution for efficiency improvements and emissions reduction.

COMBUSTION SYSTEM CHALLENGES

In theory, a perfectly efficient combustion system would involve a stoichiometric combination of fuel and oxygen, but in practice, real-world industrial combustion systems need to operate with a slight excess of oxygen to ensure complete combustion and avoid potential safety issues associated with fuel-rich conditions. The objective for operators is to minimize excess air without creating a fuel-rich environment.

While a small level of excess oxygen is desirable to avoid fuel-rich conditions, a larger excess of oxygen degrades the combustion efficiency in several ways. First, by requiring the system to heat a larger volume of gas and decreasing the ability for the system to transfer heat from the flame to the steam (in the case of a boiler) or process fluid. Second, although oxygen at elevated levels is beneficial, too much oxygen will force the fan to operate at elevated speeds, which wastes energy over time and increase emissions.



A common margin of excess oxygen is about 2-4% as a target to maximize efficiency and minimize formation of NOx, while still ensuring complete combustion of fuel. However, effectively and accurately monitoring airflow to maintain this small excess margin in industrial combustion systems is more complicated than monitoring the flow of fuel gas.

The challenges associated with running combustion systems with a tightly controlled margin of excess air are amplified when using ultra-low-NOx burners. This type of burner is becoming more common as NOx emissions limits continue to tighten. Many low-NOx burner manufacturers require accurate airflow measurement as a prerequisite for proper burner operation and NOx reduction. While NOx-generation limits vary by state and region, the overall trend is toward requiring ever-smaller NOx concentrations for regulatory compliance.

The pressure to shift to ultralow-NOx burners to comply with emissions limits means an even greater need for tight control on air-fuel ratio and more accuracy in monitoring airflow in combustion. The gains in burner performance from tighter control of airflow have a significant effect on NOx emissions and can help achieve a balance between burner efficiency and NOx emissions. In addition, tighter airflow control can help avoid the negative effects of poor air-to-fuel ratios on the burner components of ultra-low-NOx burners. Burner components can break down at faster rates when air-fuel ratios are out of balance and suboptimal.

Controlling airflow in an industrial combustion system is generally accomplished with one of three methods: parallel positioning (PP); PP with O_2 trim; and fully metered systems. In a parallel positioning system, the objective is to link the position of the air valve or damper with a position of the gas valve in an effort to maintain an acceptable air-to-fuel ratio that is based on a process setpoint (such as a required steam pressure in a boiler system).

Parallel positioning systems are relatively straightforward technically and are generally the least expensive option for controlling airflow. With this type of system, the damper/valve controls are physically linked, so it is not possible to provide individual air and fuel control. They may work reasonably well initially, but will drift away from the desired fuel-air ratio over time as valve seals and damper linkages wear. Additionally, this type of system will not respond to fluctuations to process temperature, duct static pressure, and barometric pressure changes, which alter air density and affect air-fuel ratio.

A second option for airflow control is known as **parallel positioning with O_2 trim**. In this scheme, O_2 trim systems are applied to help minimize excess air in the combustion system, and thereby increase efficiency. To accomplish this, O_2 trim systems continuously monitor the amount of oxygen in the exhaust gas and provide feedback to an automatic positioner for the air damper. The objective is to "trim" the airflow in order to drive excess oxygen lower (closer to 2-4% excess O_2). PP with O_2 trim is most common type of control that is applied to combustion systems across a number of industries.

The third control option for airflow is a **fully metered control system**. In this scheme, flowmeters are added for fuel and airflow measurement to provide instant feedback for maintaining air-to-fuel ratio at its most efficient point. In a fully metered system, accurate mass-based airflow measurement is crucial. The rationale behind fully metered systems is to address multiple issues simultaneously: promote efficient fuel use, control emissions, extend burner lifetime (especially with ultralow-NOx burners), and expand the efficient operating range. Fully metered systems typically have O_2 trim, too. This provides the ultimate in control and final operation.

To install a fully metered system, plants need multi-point sensing arrays like self-averaging pitot-tube arrays for mass

Parallel Positioning (PP)

Pros:

- Relatively simple to implement
- Slightly less expensive than fully metered system

Cons:

- Dependent on how well fuel valve and air damper curves match
- Only works for a narrow range of operation
- Undesirable results with large turndown
- With time mechanical wear changes the performance
- Gives volumetric ratio, not mass if air & fuel conditions change
- No feedback, open loop system

Parallel Positioning (PP) with O_2 Trim

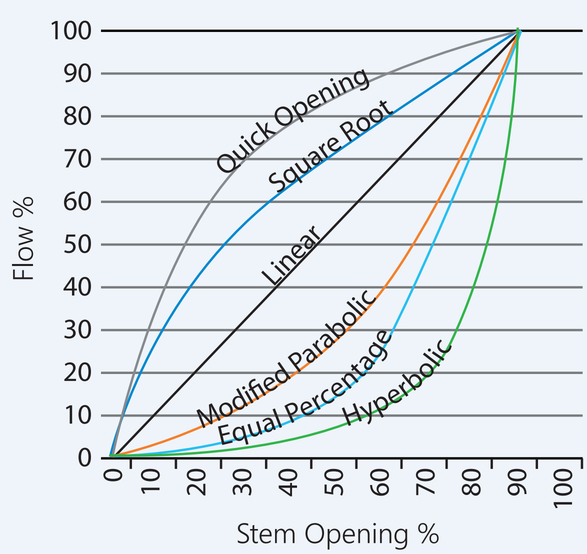
Pros:

- Relatively simple to implement
- Slightly less expensive than fully metered system
- Provides some some level of feedback in the system

Cons:

- This method has all the same cons of PP except this method introduces O_2 trim feedback and correction.
    - Feedback response time is poor
    - If there is a load change before system reaches full correction, this method fails to deliver desired results

Control Valve Flow Characteristics



flow measurement, as well as a resistance temperature detector (RTD) or thermocouple. Also, an analyzer for O_2 is needed along with valves and transmitters for the gas flow measurement.

The fully metered system is only as good as the measurement technologies used as inputs for the control system. Typically, the airflow is either measured at the fan inlet or downstream of an air preheater. In both scenarios, the available straight run is extremely limited, velocities are very low, and particulate is often in the area that can coat or plug the primary flow element. To handle the limited availability of straight run, flow conditioners followed by multipoint Pitot averaging arrays are used to accurately sense the stratified velocity profile. A low-range multivariable transmitter is used to amplify the differential pressure and compensate for changes in atmospheric pressure, static pressure and process temperature, providing a 4–20-mA output with a linear relationship to mass flow to the fully metered control system. In cases where particulate is present, an automatic purge system is integrated into the flow measurement system, ensuring that the measurement is never lost due to the sensing ports plugging. During this purge cycle, the signals are held at their last values.

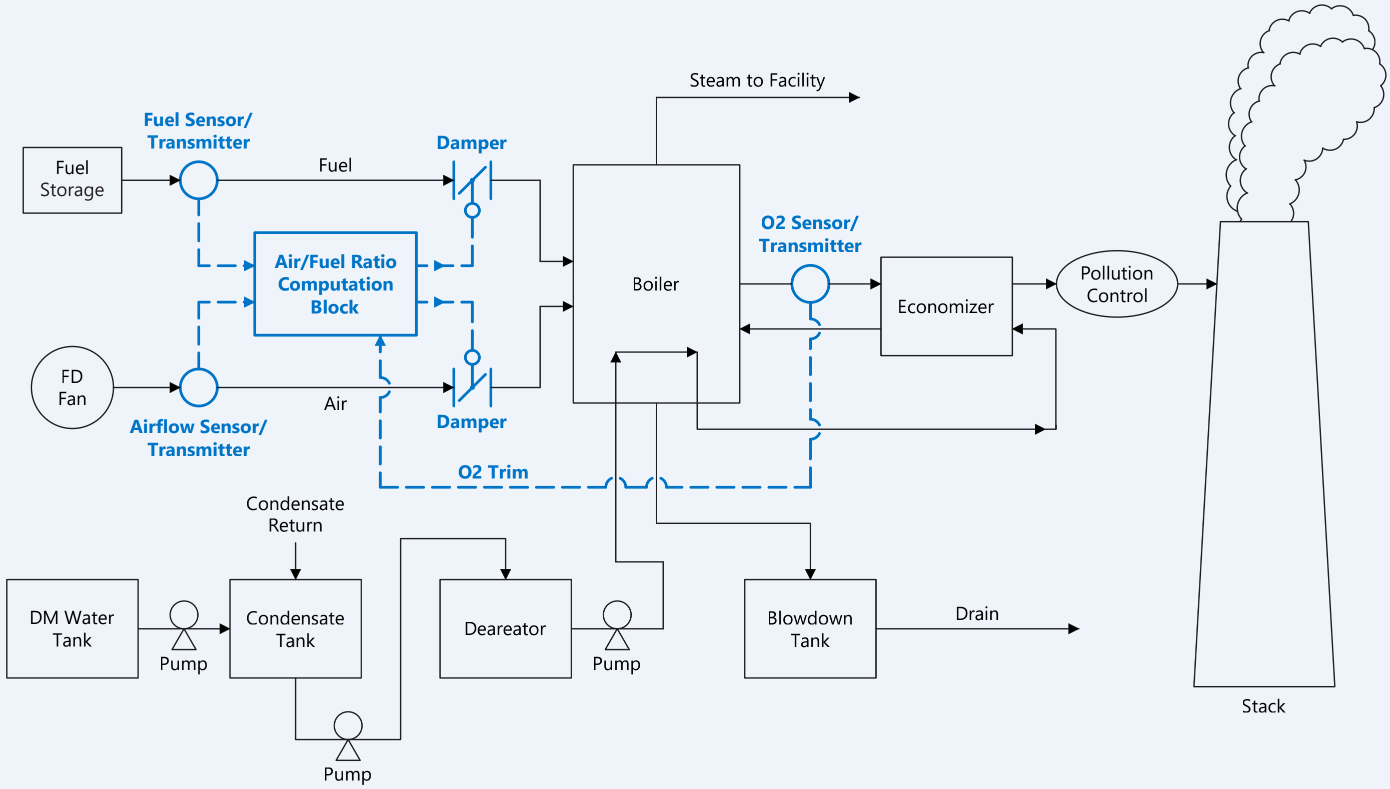
Fully Metered System

Pros:

- Fuel and airflow are measured and controlled independently
- Accurate stoichiometry results independent of process parameter changes
- Low NOx guarantee
- Fast feedback and tighter control - even with load changes
- Reduction in boiler trips with accurate and reliable combustion airflow measurement
- Longterm savings and benefits outweigh cost

Cons:

- Slightly more initial cost



FULLY METERED SYSTEM

ADVANTAGES & LIMITATIONS

Each control scheme carries advantages and limitations. Parallel positioning systems provide some degree of control for stable loads and consistent burner function, and offer the lowest capital cost of the three options. However, PP is not effective for variable loads, or rapid swings, and is the least able to maintain optimal efficiency.

PP with O_2 trim provides decent ability to adjust airflow and is relatively inexpensive. This type of system should only be used for base-loaded units, since the dampers are linked. For proper operation over a wide load range, separate air and fuel control are needed. Another significant limitation is its slow response time. The adjustment to airflow lags behind the measurement because the measurement occurs after combustion, and the O_2 analyzer instruments do not respond instantly. Also, the accuracy of lower-cost O_2 analyzers can decline over time. PP with O_2 trim is best applied to boilers at steady-state operation, while real-world boilers run at constantly varying steam loads. The degree of actual control enabled with a PP/O_2 trim system is not very large. It would go against best practices to allow the cascade control to have too much influence over the airflow. The PP/O_2 trim system is not the best choice for boilers with broad load ranges. The are best over only a limited air and fuel flow range and then only if the linkages are set properly.

Fully metered airflow control systems offer a host of advantages not observed with the other two control strategies. Fully metered systems have the best ability to optimize the efficiency of burners, and can address multiple challenges at once, including efficiency, maintenance, safety and emissions. They allow tighter control of air-fuel ratio throughout the full operating range of the boiler, and ensure that emissions are within specifications. Fully metered systems allow a much higher degree of control for operations over tuning the system, so operators can closely match the optimal air-fuel ratio even throughout process temperature swings, barometric pressure, and static pressure changes. The greater degree of control means there are fewer boiler trips, so less downtime across full operating ranges of the combustion burner when fuel-air ratio gets out of balance. Fully metered systems can easily adapt to fuel type or composition changes such as switching between natural gas and fuel oil or changing natural gas suppliers.

Flow Elements' Requirements for a Fully Metered System

- Multi-point averaging system for most accurate measurement
- Ensure an adequate number of sensing points based on the duct size and installed duct conditions - refer to 40 CFR 60 Appendix A recommendations
- Review manufacturer's minimum straight run requirements and select appropriate product to align to available straight run for the project
- Resistent to plugging due to particulates in airflow stream to maintain performance - some vendors offer automatic purge systems
- Long-term reliability in harsh conditions

Transmitter Requirements for a Fully Metered System

- Multivariable transmitter
- Continuous compensation for temperature and pressure changes in duct for accurate mass flow measurement
- Long-term transmitter calibration stability
  - Zero drifts affect accuracy at very low velocities - some vendors offer automatic zeroing functionality
- Ultra-low range (Upper Range Limit [URL] of 1-inch W.C. or lower (0.1", 0.25", 0.5" W.C.) transducer capability

The benefits of a fully metered system manifest to a greater extent in facilities that use ultra-low-NOx burners. The tighter control over air-fuel ratio extends the life of burner elements in ultra-low-NOx burners because this type of burner can be destroyed relatively easily if the fuel-air ratio is inaccurate and suboptimal. Ultralow-NOx burners, such as Alzeta burners, need more excess air because their objective is to burn all fuel perfectly at lower temperatures (2,000 versus 3,000 degrees F) to reduce the generation of thermal NOx.

The impact of improved combustion control with a fully metered system on maintenance is also great. Because poor air-fuel ratio can contribute to failures of burner internals, as well as soot buildup, there is a connection to unplanned shutdowns. Better airflow control enabled by fully metered systems results in fewer chronic maintenance issues, such as burner replacements.

For large-sized boilers, good air monitoring allows the possibility of using predictive emissions control system (PEMS) versus continuous (CEMS) to report emissions to air districts or EPA. PEMS can save money — such a system is one-third the cost of a CEMS. But in order to use a PEMS, plant operators need high levels of confidence in the control system for airflow to the combustion units to ensure the airflow measurement is accurate. Fully metered systems are mostly self-tuning.

The benefits of a fully metered system come with costs and added complexity, however the benefits far outweigh the costs. The cost of a fully metered system varies, but is slightly more than that of a PP with O_2 trim.

TYPICAL CONTROL LIMITS - BOILERS

The appropriate range within which to manage excess oxygen depends on the fuel type and the method of monitoring and controlling flue gas oxygen content. The following table provides some general information of the typical control limits for steam boilers.

The data represented in this table indicates the expected operating range for boilers. The numerical values in the table represent the amount of oxygen (O_2) in the flue gas as it exits the combustion zone. This is the actual field measurement for most boilers and it is the common control parameter. The oxygen concentrations noted in the table are "wet basis" measurements and "dry basis" measurement). The rule [§63.11223(b)(5)]) allows measurements on either a dry or wet basis as long as it is the same before and after the adjustments are made.

The two designations in the table are automatic control and positioning control. Positioning control is generally not equipped with continuous flue gas oxygen measurement. The more efficient control is automatic control.

Automatic control (or continuous automatic control) continually monitors oxygen content and combustion air flow is trimmed to maintain required oxygen limits, sometimes referred to as oxygen trim control.

Additionally, it should be noted that flue gas oxygen content targets may be influenced by environmental controls; such as, nitrogen oxides (NO x) control. When a boiler is equipped with NO x control the minimum oxygen concentrations are sometimes lower than if the boiler was equipped with a standard burner without NO x control.

Did You know?

Emissions regulations and safety standards impact plant and process efficiency goals.

The purpose is to establish requirements for the monitoring, record keeping, and reporting of sulfur dioxide (SO2), nitrogen oxides (NOX), and carbon dioxide (CO2) emissions.

Protection of the Environment:

- EPA 40 CFR Part 60: Standards of Performance for New Stationary Sources
- EPA 40 CFR Part 63: National Emission Standards for Hazardous Air Pollutants (NESHAP) for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters (Boiler MACT Rule)

Safety Standards:

- American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code
- Certification by National Board of Boilers and Pressure Vessel Inspectors

TYPICAL FLUE GAS OXYGEN CONTENT CONTROL PARAMETERS

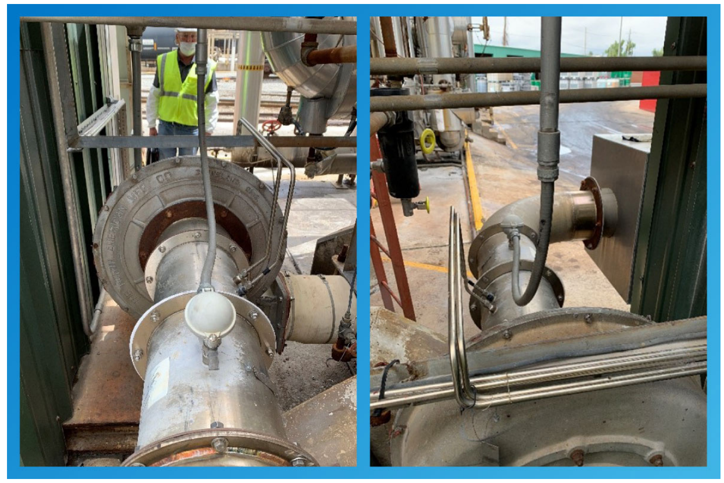
FUEL	Automatic Control - Flue Gas O_2 Content				Positioning Control - Flue Gas O_2 Content			
	Minimum		Maximum		Minimum		Maximum	
	Wet Gas Sample [&]	Dry Gas Sample [&]	Wet Gas Sample [&]	Dry Gas Sample [&]	Wet Gas Sample [&]	Dry Gas Sample [&]	Wet Gas Sample [&]	Dry Gas Sample [&]
Nat. Gas	1.5	1.8	3.0	3.6	3.0	3.6	7.0	8.0
No. 2 Fuel Oil	2.0	2.2	3.0	3.3	3.0	3.3	7.0	7.6
No. 6 Fuel Oil	2.5	2.8	3.5	3.8	3.5	3.8	8.0	8.5
Pulverized Coal	2.5	2.7	4.0	4.3	4.0	4.3	7.0	7.4
Stoker Coal	3.5	3.7	5.0	5.3	5.0	5.3	8.0	8.4
Stoker Bio-mass - Wet	4.0	5.2	8.0	9.7	5.0	6.4	8.0	9.7
Stoker Bio-mass - Dry	4.0	4.4	8.0	8.6	5.0	5.5	8.0	8.6

Source: EPA Boiler Tune-up Guide, National Emission Standards for Hazardous Air Pollutants for Area Sources: Industrial, Commercial, and Institutional Boilers. 40 CFR Part 63 Subpart JJJJJJ

EXPECTED OPERATING RANGE

CONCLUSION

The challenge of realizing fuel savings while getting the ideal air-to-fuel ratio is felt by plant managers everywhere. The three common methods for combating that challenge have been discussed in this paper. In conclusion, a fully metered system offers the best solution for efficiency improvements and emissions reduction.



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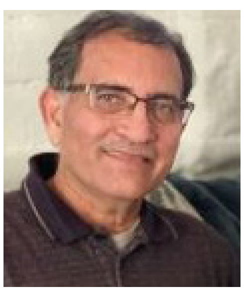
John Thompson

John entered the instrumentation industry after studying Aerospace Engineering at North Carolina State University. He draws on his extensive experience in application engineering to provide expert advice and solutions for challenging flow measurements in difficult industrial applications.



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A veteran of the instrumentation industry, Paresh has been serving clients for over 40 years. His considerable knowledge of airflow applications and the products that suit clients needs provide valuable insight into uncovering solutions to the unique challenges found in commercial and industrial applications.

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With a foundation in mechanical engineering, Blair applies his skilled experience in the instrumentation, process, and control industries to provide his astute understanding of process efficiency challenges.

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