A typical control approach for an industrial fired heater uses global measurements to keep the system efficient and within safe operating limits. Differences in combustion stoichiometry between individual burners, however, can cause global measurements to produce an incomplete picture of the combustion taking place within the heater.

While global measurement and controls have been employed for decades, the implementation of new control philosophies can enable significant improvements in fired heater performance. These solutions — created by combining combustion expertise, new measurement technologies and advanced data analytics — provide better insight into key areas of combustion health, resulting in safer operation.

In a fired heater, the transition from the radiant section to the convection section — often referred to as the bridgewall — is a common place for measurement of excess O₂, combustible gas concentration, flue-gas temperature and draft (negative pressure within the firebox). Additionally, some furnace stacks are equipped with continuous emissions monitoring systems (CEMS) to measure excess O₂, NOₓ and CO emissions for regulatory reporting purposes.

Global O₂ measurements are a cost-effective way to ensure there is enough combustion air within the firebox to achieve safe, complete fuel combustion. Minimizing excess air improves fuel efficiency by reducing the energy consumed to heat the additional air. Operating the heater without enough air to complete combustion, however, can result in unsafe conditions and should be avoided. (Common terms for this latter operating condition are heater bogging, sub-stoichiometric combustion and fuel-rich combustion, amongst others.)

As already mentioned, industry typically utilizes the bridgewall instead of the stack as the primary O₂ measurement location for combustion control. This mitigates the risk of errors in the excess O₂ measurement.
Process heating furnaces operate under negative pressure. As a result, “tramp,” or ambient, air can enter the heater through tube penetrations and sight ports if not sealed properly. Tramp air from the convection section will skew stack O₂ measurements to an artificially high value relative to the bridgwall section measurement.

Even though most global flue-gas measurements are taken at bridgwall level within the radiant box, there are still some instances where operational challenges prevent them from accurately representing the stoichiometry of each individual burner within the firebox. Some often-observed operational challenges include:

- Tramp-air ingress in the radiant section.
- Unequal air-register settings per burner.
- Gas tip plugging.

These challenges can compound as the fired heater designs become more complex. Heater features that can affect the ability to get accurate readings at the bridgwall include:

- Multiple burner-firing zones.
- Different burner types, sizes and technologies
- Adverse combustion flue-gas patterns.
- Instrumentation drift
- Mechanical burner failures.

Tramp air in the radiant section commonly is entrained through viewing doors and radiant-tube penetrations. When air leakage enters the system, the measured excess O₂ will increase, which could result in a response by operations to reduce excess O₂. This trimming of global excess O₂ can inadvertently result in sub-stoichiometric burner operation. Because the amount of tramp air is proportional to the heater draft, heaters that operate with significant negative pressure are at increased risk for air leakage and sub-stoichiometric burner operation.

In natural-draft and forced-draft heaters, excess O₂ is most commonly tuned with stack damper or fan adjustments. Typically,
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the burner air register is manipulated when the stack damper or fan are outside their controllable range. Additional reasons for burner air-register adjustment include:

- Attempts to resolve undesirable flame shape.
- Localized high tube-metal temperatures measurement.
- Observations of flame impingement.

Yet, because these issues are generally addressed in an isolated manner, the uniformity of burner air-register settings tends to decay with time.

While the combustion system is at normal operating conditions with relatively hot flue-gas environments, sub-stoichiometric operation of one or more burners may not be easily detectable. Generally, burner stability and burner-flame anchoring are much more sensitive to burner-stoichiometry variations at low furnace temperatures. As a result, the safety concerns associated with varying burner-stoichiometric ratios are more likely to occur when the heater firing rate is reduced to turndown operating conditions or when performing cold startup operation.

To complicate matters, the distribution of fuel may vary from burner to burner. This is frequently observed when tip plugging or fouling takes place. Even if all burner air registers are at the same setting, the maldistribution of fuel can result in considerable differences in individual burner combustion stoichiometry. Because the bridgiewall excess \( O_2 \) measurement is an average of the stoichiometry of all burners in operation, the extremes of individual burner stoichiometry are simply unknown. Given the potentially severe consequences of sub-stoichiometric combustion, great caution should be exercised to ensure each individual burner stoichiometric ratio is acceptable and safe.

With such challenges affecting the ability to accurately measure excess \( O_2 \), the need for solutions to address the challenges associated with global measurement and control become apparent. The ability to provide the operator with operating data for each individual burner and optimize heater operation without sacrificing safety has contributed to the development of control technologies that combine novel measurement techniques and advanced data analytics.

These burner-level insights also can be leveraged to improve the emissions per-

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**FIGURE 2.** Within the new burner design, two independent combustion zones are dynamically adjusted using proprietary control philosophies (left). This approach enables single-digit NO\(_x\) and near-zero CO emissions throughout the operating range of the heater. The modern burner is shown firing refinery fuel gas at 8 MM BTU/hr (right).
formance of combustion systems. Modern burner technology employing the control technologies demonstrate how the advanced control philosophies can enable a level of emissions performance that was not previously possible from a burner-only solution utilizing the typical global control approach.

The key to improved emissions performance is the utilization of two independent combustion zones (figure 1) that are dynamically adjusted using the novel control philosophies. This approach enables single-digit NO$_x$ and near-zero CO emissions throughout the entire operating range of the heater, regardless of process demand, flue-gas temperature, fuel composition and combustion air temperature.

One modern burner has a mixed-air combustion zone that utilizes a proprietary, lean-premix arrangement to reduce NO$_x$ emissions (figure 2). The burner also achieves shorter flames compared to traditional ultra-low NO$_x$ burners. A cool-mix combustion zone utilizes proprietary remote fuel-staging techniques that permits global excess O$_2$ trim while enabling single-digit NO$_x$ emission performance levels. Additionally, the decoupled nature of the cool-mix zone of combustion allows customized heat flux profiles, which can help increase process throughput.

The low NO$_x$ emissions are achieved by a reduction of localized flame temperature driven by the application of significantly high excess air within the mixed-air combustion zone. With a global control philosophy, typical operational swings such as changing fuel compositions would cause the NO$_x$ from the mixed-air combustion zone to vary significantly. By contrast, the burner technology directly controls the fuel and combustion air to each burner, and to the discrete combustion zones within each burner.

While control philosophies that leverage global measurements are widely accepted in the process heating industry, the continual desire for improved safety, reduced emissions and optimized process performance drive the development of transformative solutions for fired heater measurement and controls. New control strategies, equipped with burner-level insights, are certainly a way to satisfy the industry’s growing demand for improved combustion performance.

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