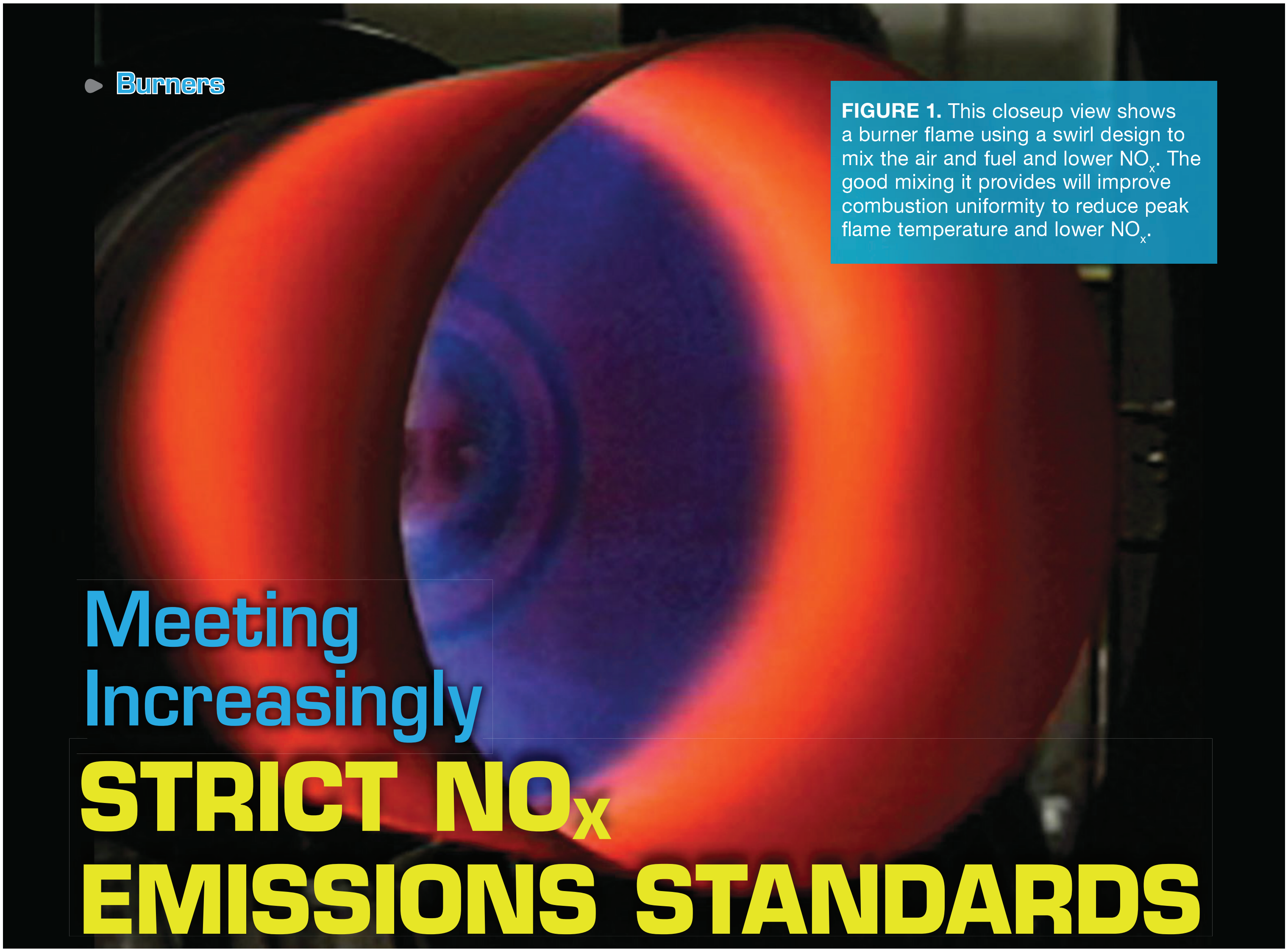

FIGURE 1. This closeup view shows a burner flame using a swirl design to mix the air and fuel and lower NO_x. The good mixing it provides will improve combustion uniformity to reduce peak flame temperature and lower NO_x.

Meeting Increasingly STRICT NO_X EMISSIONS STANDARDS

Advanced burner and control solutions ensure minimal pollutant formation without sacrificing operational reliability or efficiency.

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The global industrial sector has never placed greater demands on manufacturers. Companies in a range of industries must optimize performance and minimize waste while holding the line on emissions, regardless of the regulatory requirements in their state, region or country. With all of the changes in emissions standards, it can be difficult to sort through all of the information to find the best way to meet the standards while achieving the process and product quality demanded.

The following article describes the challenges involved in reducing NO_X emissions and offers guidance on the selection of effective burner and control technologies in process heating applications.

Emissions Critical

Because of the complexity of combustion processes and the variables that come into play, it is not possible to achieve perfect combustion of air and natural gas, which is defined as $CH_4 + 2(O_2 + 3.76\ N_2) \rightarrow CO_2 + 2\ H_2O + 7.52\ N_2$. At high temperatures, the nitrogen in the combustion air will react with the oxygen to form NO_X — a collective term for nitric oxide (NO) and nitrogen dioxide (NO_2) — and with the carbon in the fuel to form carbon monoxide (CO). These products of combustion — carbon dioxide (CO_2), NO_X and CO — are under scrutiny in combustion processes around the world.

Typically, emissions standards are stated such that when process exhaust gas is measured, levels of NO_X and CO may not be above a certain threshold, measured in parts per million (ppm). In many low emissions, low temperature applications such as in California's South Coast Air Quality Management District (SCAQMD), NO_X is required to be below 30 ppm, and CO is required to be below 200 ppm, corrected to 3 percent O_2. High temperature applications have more lenient requirements of 60 ppm NO_X or less, corrected to 3 percent O_2. A concept that has been adopted primarily in California's San Joaquin Valley is the use of Best Available Control Technologies (BACTs), which emphasize technologies such as mass-flow control (discussed below).

All over the world, emissions standards are becoming stricter. For example, in Canada, Base-Level Industrial Emission Requirements (BLIERs) have been established. In a relatively short period of time, NO_x emissions limits in some areas have decreased by 50 percent — from 30 ppm to 15 ppm.

In Germany, the requirement for emissions is included in a standard called TA-Luft. It is essentially a best-available technology concept used by the authorities when defining permits to give to manufacturing facilities for their allowable emissions. A recent set of European Directives also is requiring lower emissions over time.

In China, there has been an effort to move toward lower emissions vehicles, and industrial processes are beginning to follow suit. In 2016, cities like Beijing will see tighter emissions for boiler applications, going from less than 50 ppm NO_x down to less than 30 ppm NO_x.

India and other high growth regions also have begun the movement toward lower emissions vehicles. If these other regions are any indication, they will likely move to stricter industrial process emissions requirements in the coming years.

A Brief History of NO_x

In order to select the best equipment to lower NO_x in your process, it is important to understand a bit more about how NO_x is formed. NO_x comes from three primary sources: thermal NO_x, fuel NO_x and prompt NO_x. Thermal NO_x is caused by the heat from the combustion reaction. It is considered the most relevant when attempting to reduce NO_x. Fuel NO_x and prompt NO_x are inherent in the fuel and nitrogen reaction properties, respectively, and cannot be changed significantly.

Thus, in order to reduce NO_x, one must focus on reducing thermal NO_x, which can be done with a combination of burner design and selection strategies and air-fuel control schemes.

Burner Selection

Compared to high temperature applications, reduced NO_x numbers can be achieved in low temperature air-heating applications because the overall temperature is lower, which reduces thermal NO_x. In general, the regulations for ultra-low NO_x numbers apply to low temperature, air-heating burners. NO_x requirements are higher for high temperature burners, but like in the low temperature applications, they are always being driven lower by regulations.

One common burner design for lower NO_x and CO in single-burner applications is a swirl burner. Swirl is achieved in a variety of ways such as nozzle- or burner-body design. No matter the design, the goal is to mix the air and gas extremely well to ensure as complete combustion as possible. Additionally, good mixing will improve combustion uniformity to reduce peak flame temperature and, as such, lower NO_x (figure 1).

It is important to note that complete combustion reduces CO production by burning into CO_2 while uniform combustion reduces NO_x production by reducing peak temperatures.

For line-style burners, a common way to achieve good mixing of the air and fuel is through a premix design in combination with high excess air. In order to thoroughly premix the air and fuel, unique mixing plates are used. Much like the swirl burner, the cut-outs and holes in the mixing plates cause the air and fuel to mix thoroughly, ensuring as uniform combustion as possible (figure 2).

For applications requiring higher temperatures, one common method to reduce NO_x is through the use of flue-gas recirculation (FGR), which is illustrated with the red arrows in figure 3. Some self-recuperative burners have a uniquely designed internal combustor that draws exhaust gases back into the flame to cool it, lowering ther-

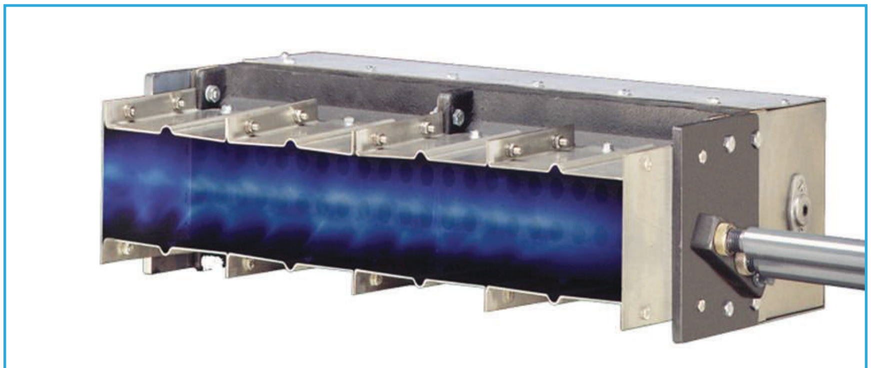

FIGURE 2. In a low NO_x line-style burner, the cut-outs and holes in the mixing plates cause the air and fuel to mix thoroughly, ensuring as uniform combustion as possible.

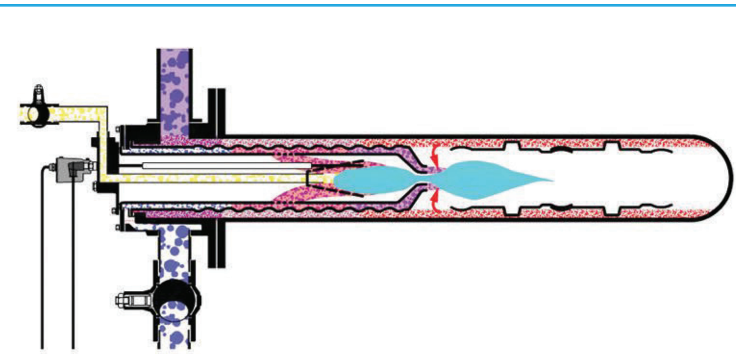

FIGURE 3. For applications requiring higher temperatures, one common method to reduce NO_x is through the use of flue-gas recirculation (FGR), as shown with the red arrows in this cutaway of a self-recuperative burner in a radiant tube.

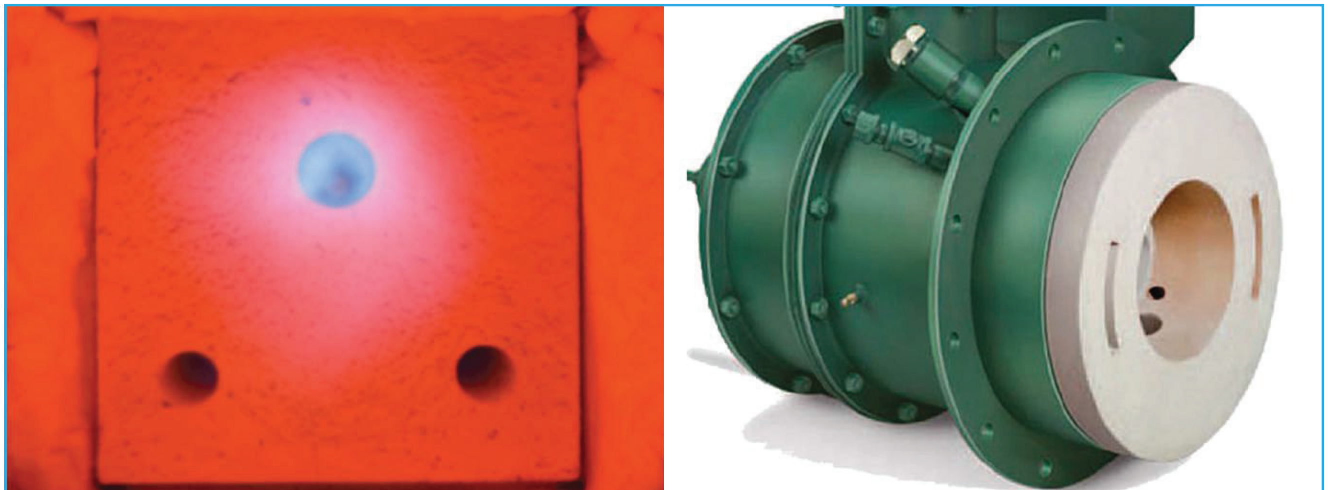

FIGURE 4. The telltale sign of a burner designed for staged combustion is an extra set of holes or slots for the secondary stream to travel through and into the combustion chamber. Here, two types of air staging are shown: holes on the left, slots on the right.

mal NO_X. It should be noted that FGR will improve NO_X but reduce overall efficiency.

Another method for reducing NO_X in high temperature applications is what is known as staged combustion. Burners designed for staged combustion typically use internal baffles or switching valves to split the combustion air or gas into primary and secondary streams. The telltale sign of a burner designed for staged combustion is an extra set of holes or slots for the secondary stream to travel through and into the combustion chamber (figure 4). The main idea in staged combustion is to introduce the primary air or gas into the fuel stream, as is typical in burner designs, but at sub-stoichiometric conditions. The secondary stream, required to complete combustion, then is introduced away from the flame, delaying combustion and lowering the peak flame temperature. This reduces the creation of NO_X. The lowest level of NO_X is achieved with this type of burner when operating at low excess air levels of 5 percent (or 1 percent O_2).

Flameless combustion also is used to reduce NO_X. The general principle is that once the combustion chamber reaches autoignition temperature (approximately 1400°F [750°C]), the combustion of the fuel gas shifts from within the burner to the space outside of the burner or chamber. This essentially spreads the combustion over a larger volume instead of concentrated at the nozzle, so the temperature is lower. The overall temperature within the chamber still is high enough to cause combustion of the fuel gas, but it is low enough (compared to visible flame combustion) to reduce NO_X levels.

Control Selection

Almost as important as burner design and selection in controlling emissions is specifying a control scheme.

For flameless combustion, you must choose a flame safety with a high temperature bypass. With the switch from flame mode to flameless, there is no longer a flame for the sensor to detect, and a standard flame safety would detect a loss of flame inside the combustor. A flame safety with a high temperature bypass will allow the burner to continue operating after switching to flameless.

Pulse firing is a technique that is used in multiburner applications to help lower NO_X by operating the burners in two positions: either high/low or on/off. This method can reduce NO_X because when the burner is at high fire, it is operating at its optimum NO_X performance. Unique controls are required because each burner has to be on (and off) for a certain amount of time, and this cycle is timed with the other burners in the system to deliver the required heat to the process.

One of the best ways to control emissions with a combustion system is to use a mass-flow control system, which combines control valves for gas and air, flowmeters for gas and air, and a burner-management system (sometimes called a "burner brain"). All five of these components "talk" to each other in order to provide precise electronic control of the air and fuel flow to the burner. The flowmeters provide feedback to the burner-management system, which then adjusts the control valves accordingly. This type of system can respond to and automatically compensate for changes in combustion or process conditions such as temperature, humidity and air density, thus maintaining the best air-fuel ratio for optimal burner performance and NO_X emissions.

Conclusion

With any combustion application, it is important to select the best burner and control combination for your application while meeting the emissions requirements in your region. Each application is unique, but the products and methods discussed in this article are safe, industry-proven techniques for improving emissions in industrial combustion processes.

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