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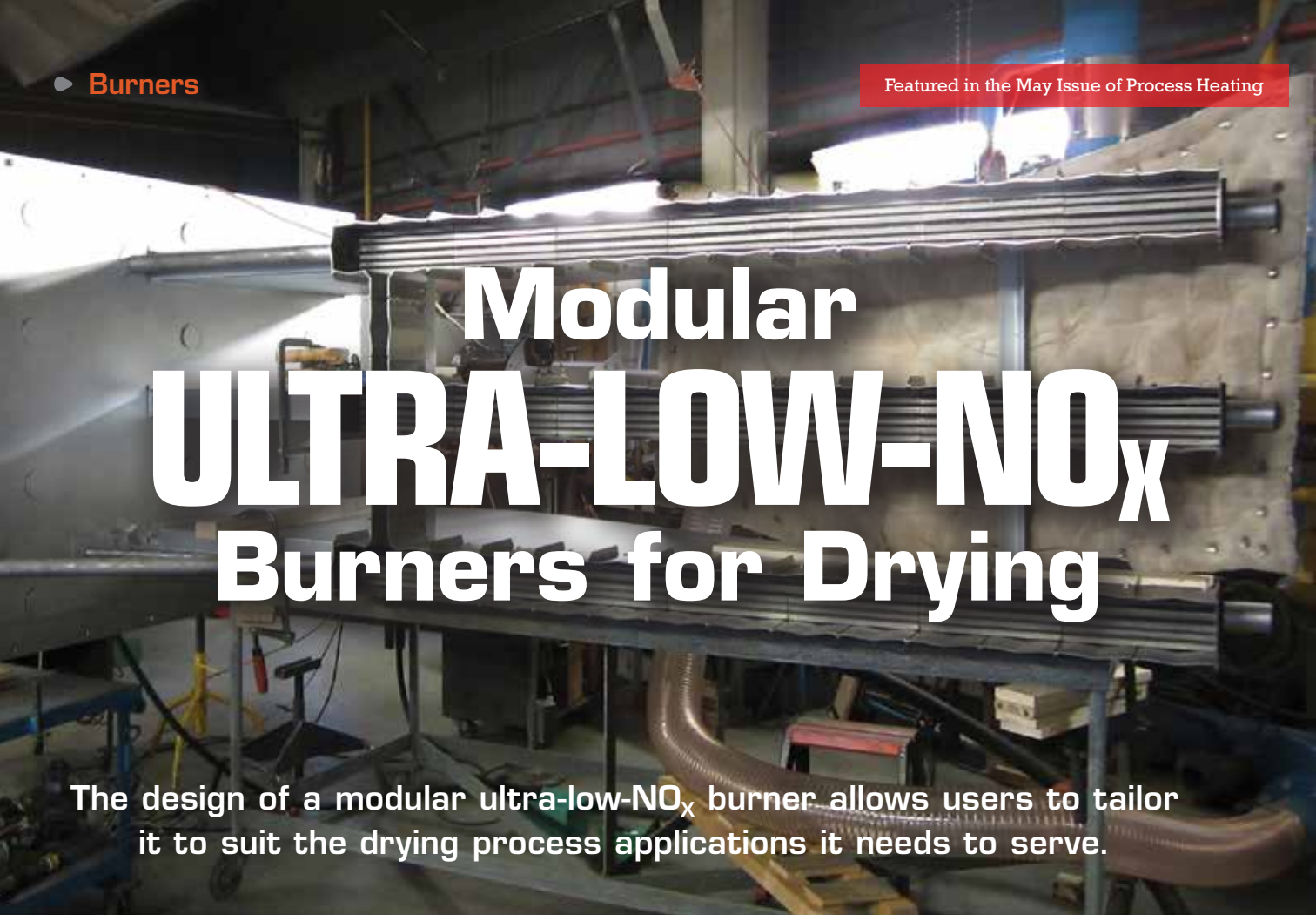


Modular ULTRA-LOW-NO_X Burners for Drying

The design of a modular ultra-low-NO_X burner allows users to tailor it to suit the drying process applications it needs to serve.

By Jessica Irons, Eclipse

As emissions standards around the world become stricter, companies continue to search for methods of reducing the NO_X and carbon monoxide (CO) emissions from their processes. At the same time, manufacturers in the process industries must focus on continually improving efficiency and reducing overall fuel usage. Much like in the automotive industry – where manufacturers are required to improve vehicle fuel efficiency – manufacturers in the process industries are given specific emissions requirements for their thermal processes. They must meet them or risk heavy penalties.

Reducing emissions in process heating applications can be difficult because making heat requires fuel, oxygen (O_2) and an ignition source. Many industrial heating applications use natural gas, which is a hydrocarbon such as CH_4. The basic ingredients – oxygen and fuel – follow a simple combustion reaction:

$$O_2 + C_XH_Y \xrightarrow{Ignition} CO_2 + H_2O + Heat$$

If this equation were to result in complete and perfect combustion, then the three emissions ingredients would be carbon dioxide, water and heat. These products of combustion are considered quite clean by industry standards.

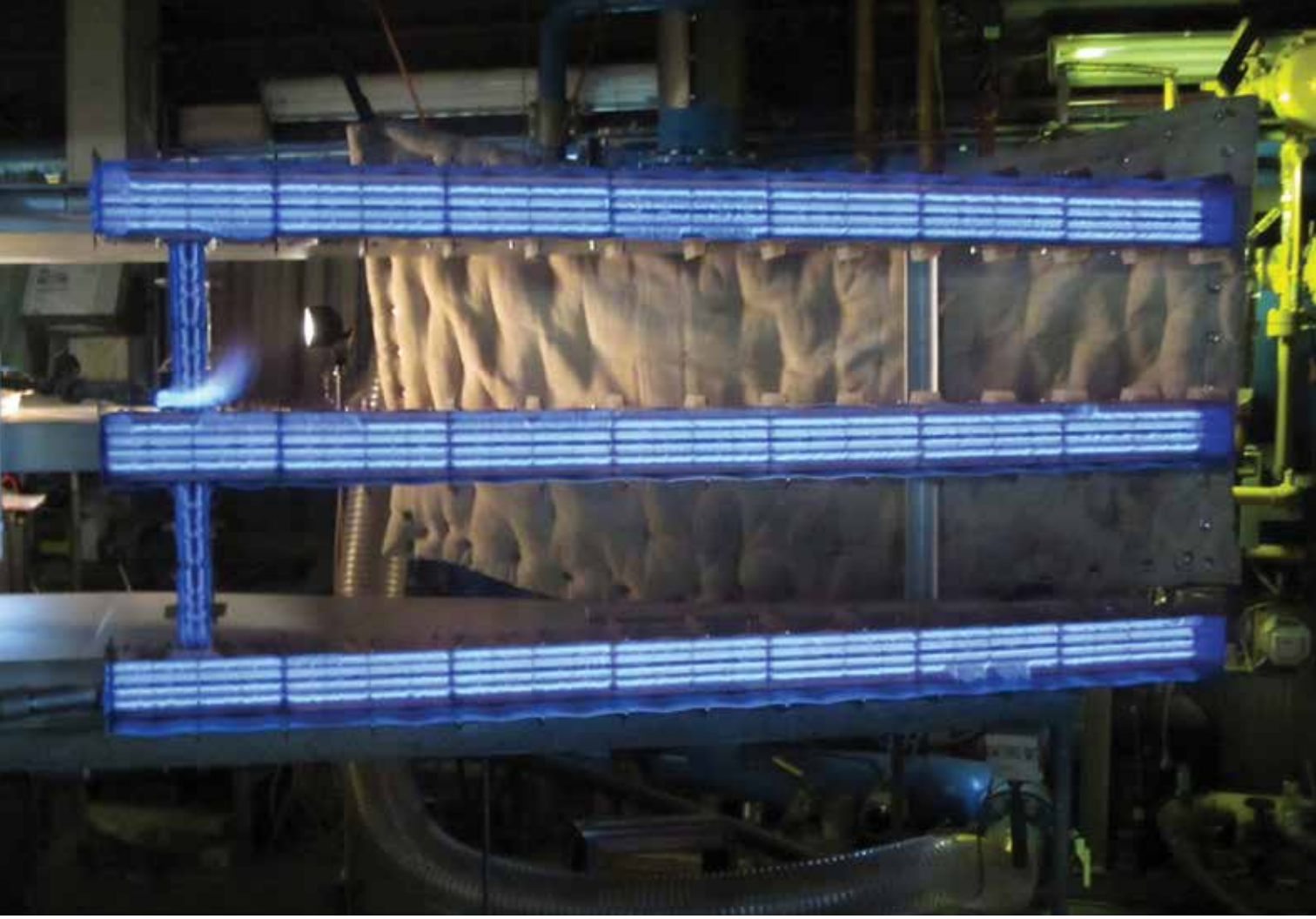
The dynamics of combustion are so complex, however, that perfect combustion is nearly impossible. Additionally, most processes get their oxygen from air, which also contains nitrogen. This complicates the combustion reaction as follows:

$$O_2 + N_2 + C_XH_Y \xrightarrow{Ignition} CO_2 + H_2O + N_2 + Heat$$

Still, if nitrogen did not react with any of the other elements and perfect combustion were possible, this also would be a fairly clean combustion reaction.

In reality, because the complexity of combustion never really allows for perfect combustion – and because the nitrogen does react with the other elements – emissions such as NO_X and CO have the potential to be created.

Emissions standards typically are stated in a way such that, when process exhaust gas is measured, levels of NO_X and CO may not be above a certain parts-per-million (ppm) threshold. In many low-emissions requirements, NO_X is required to be below 80 ppm, and CO is required to be below 200 ppm at 3 percent O_2. With ultra-low emissions standards being developed in places such as Southern California, Houston, the Northeast, Canada and Europe, the requirements can mandate NO_X levels as low as 20 ppm and CO levels as low as 100 ppm at 3 percent O_2.



Ultra-Low-NO_X Burner Developed

In order to explain how ultra-low-emissions burners can possibly achieve such low NO_X emissions, 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.
- Prompt NO_X.

Thermal NO_X is caused by the heat from the combustion reaction and 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 they cannot be changed significantly.

Thus, in order to reduce NO_X, one must focus on reducing thermal NO_X. This can be done by reducing flame temperature, recirculating flue gases (both in the burner and in the flame), designing the burner to operate with staged combustion, and premixing the fuel and air in combination with excess air. The better the fuel and the air mix, the better the reaction – and the better chance you have at complete combustion.

You might be wondering, "How do companies who are under these heavy emissions restrictions adjust their processes in order to meet them?" That is where low-NO_X and ultra-low-NO_X burners come in.

One such burner is a line-style, air-heating burner that typically is mounted inside a duct or into the side of a duct. It is designed for applications where a maximum linear heat distribution is required. It can be used in either direct or indirect drying applications such as drying gypsum board, food products, paper, textiles and paint finishing.

The modular, ultra-low-NO_X burner provides features such as:

- Uniform heat distribution.
- A short flame.
- Ultra-low emissions.
- A flexible design for use in most drying applications.

It has NO_X emissions of less than 15 ppm and CO emissions less than 100 ppm (at 3 percent O_2) across the entire firing range of 540000 to 43200000 BTU/hr (158 to 12672 kW).

Mixing Plate. The low-NO_X burner uses the technology of premixing in combination with excess air to achieve

Above: A three-row, modular ultra-low-NO_X burner is shown both firing and off. The modular design allows the heating system to be designed to provide the air heating profile needed for the thermal process.

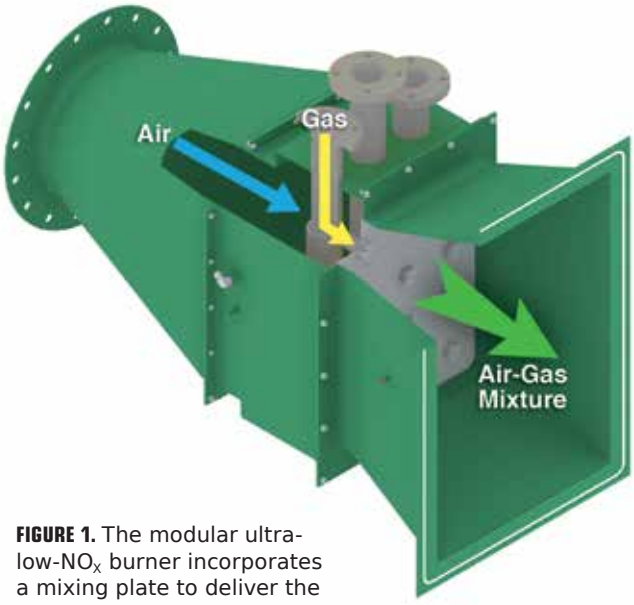


FIGURE 1. The modular ultra-low-NO_X burner incorporates a mixing plate to deliver the desired air and gas mixing pattern.

FIGURE 2. An ultra-low-NO_X burner with three modules and one row was designed for an air-heating application.

FIGURE 3. An ultra-low-NO_X burner with seven modules and two rows was designed for a drying application.

a reduction in NO_X. In order to ensure a well-mixed fuel-air flow, the burner uses an integrated mixing plate design (figure 1).

The mixing plate is designed with small slits cut at different angles to allow the air and gas to mix effectively using a swirl motion. Swirling is a common feature in many burners and is a proven method to lower NO_X. The modular low-NO_X burner's mixing plate design allows the air and fuel to mix effectively and uniformly, leading to uniform flame characteristics. The mixture has consistent quality; therefore, the burner can achieve high-quality combustion and low-NO_X emissions across the entire firing range of the burner.

Ultra-Low Emissions. In addition to the mixing plate helping with reducing emissions, the design and construction of the burner module help reduce emissions.

While testing the low-NO_X burner technology in the development stage, the temperature of the burner modules was constantly monitored by the manufacturer. Even at worst-case conditions, the temperatures did not reach anywhere near dangerous levels. This is because the construction of the burner modules allows them to act as flame arresters. The high mass of the modules makes them difficult to heat up.

As previously discussed, one of the causes of NO_X is high temperatures. Thus, by the nature of the ultra-low-NO_X burner module design, the burner produces lower NO_X due to the lower temperature of the modules.

The burner also uses excess air to cool the flame, which again lowers NO_X. When using excess air, there is a danger that the flame can be cooled too much and CO emissions can occur. During tests, it was found that the modular ultra-low-NO_X emission levels can be achieved at an optimum gas/air ratio of 40 percent to 50 percent excess air.

With all the above emissions-lowering features, the burner has NO_X emissions of less than 15 ppm and carbon monoxide emissions less than 100 ppm (at 3 percent O_2) across the entire firing range.

Burner Has Design Flexibility

To be suited for use in a range of process heating systems, one modular ultra-low NO_X burner is offered with a varying number of rows and row lengths (figure 2 and 3). The same input can be achieved by using fewer, longer rows or more, shorter rows. For instance, the modular ultra-low-NO_X burner is available in a straight design with one row of modules, or a T design with up to four rows of modules. The number of modules and rows depends on the

application and input required. Figure 4 shows the module used to propagate the flame from one row to another.

Theoretically, the burner can be built in any combination of lengths, module inputs and rows to spread the heat evenly over the entire process. Additionally, the modular ultra-low-NO_X burner can be mounted horizontally or vertically, which expands the applications in which it can be used.

In addition to choosing the number of inputs, length and number of rows per module, the user can choose the air and gas piping orientation, how far the burner extends into the duct, and whether to insulate the mounting plate. While these choices are highly dependent on the application, having the ability to customize the ultra-low-NO_X burner's features help ensure design flexibility and customization.

If needed, a modular low-NO_X burner can be installed inside a duct section with all the necessary piping, instrumentation and controls (figure 5). In those applications, the user simply splices it into a duct and hooks up the air and gas supply. The burner is ready to operate.

Short Flame Length. One feature of the modular ultra-low-NO_X burner is a short flame length (figure 5). One advantage of a short flame length is that it increases the number of applications in which the burner can be used. Often, this means the ultra-low-NO_X burner can be used in applications where there are space constraints. The short flame length also enables equipment to be smaller without damaging adjacent equipment such as a blower.

For one ultra-low-NO_X burner, the flame length is 10 to 15" (250 to 380 mm) from the ends of the flame shields. This is up to three to four times shorter than other low-NO_X burners.

Modular Burner Configuration. Some ultra-low-NO_X burners have a modular build. One such burner – offered in both straight and T layouts – is designed and manufactured in 1' (300 mm) long modules (figure 6) with heat outputs from 90000 to 2700000 BTU/hr (26 to 791 kW) per module. The modular ultra-low-NO_X burner can be configured into whatever size unit is needed. For instance, a single 1' section with one row is possible as is nine 1' modules for each of four rows. The same input can be achieved by several different combinations of lengths, rows and inputs per module. The modules all have the same width, and, because of the smart design and construction, the modules can be exchanged if necessary. That means a module can be changed or retrofit without replacing the whole burner.

The flexible ultra-low-NO_X burner design allows for precise heat control and uniformity, making it possible to spread the burner input over the whole length. This creates an optimal heat flux distribution for many applications. Also, it is possible to place the ultra-low-NO_X burner close to the process without utilizing any

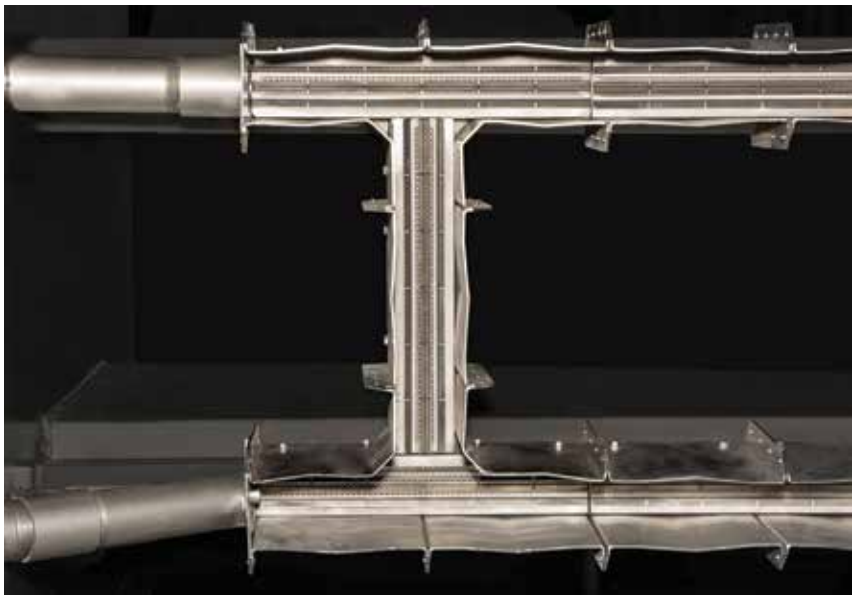


FIGURE 4. The propagation module on the ultra-low-NO_X burner disseminates the flame across all of the burner's modules and rows.

FIGURE 5. An ultra-low-NO_X burner is installed inside a duct with all required piping and instrumentation included.

FIGURE 6. The short flame length of the modular ultra-low-NO_X burner allows it to be used in applications with space constraints.

FIGURE 7. Designed in 1' long modules, one ultra-low-NO_X burner allows for precise heat control and uniformity, making it possible to spread the input of the burner over the whole length of the dryer.

complex methods to distribute the heat evenly over the process.

Safety. One of the main goals with any industrial burner is to ensure that anyone using the industrial burner – or any industrial combustion equipment – is safe while doing so. With the modular ultra-low-NO_X burner (and all other premix burners), safety is an important issue because of the possibility of flash-back into the mixing duct.

One burner manufacturer mitigates some of this risk by the design and construction of its modular ultra-low-NO_X burner modules. As previously noted, the ultra-low-NO_X burner modules act as a flame arrester, and the high mass of the modules makes them difficult to heat up. Additionally, the elements within the modules have a specific channel size and length incorporated into the design that prevents flash-back.

Heat Recovery

One common way for engineers and manufacturers to save energy and fuel in their applications is to add heat recovery into their processes. The modular ultra-low-NO_X burner can help with this by recovering heat from the exhaust and using it to preheat combustion air for the burner. This means less energy is needed to heat the process; thus, the processor can reduce fuel expenditures.

Because the ultra-low-NO_X burner modules act as flame arresters and cannot reach dangerous temperature levels, it is possible to provide the burner with preheated combustion air. Several successful projects have used preheated combustion air at temperatures up to 390°F (200°C) to improve the energy efficiency of the process.

It is important to note, however, that increasing the temperature of the combustion air can result in increased NO_X levels. Burner users must be careful when using preheated combustion air. In some cases, using preheated combustion air can save a lot of energy, and the NO_X increase is not a big concern. In other cases, any increase in NO_X is unacceptable, and using preheated combustion air would not be recommended.

Applications for the Ultra-Low-NO_X Burner

The modular ultra-low-NO_X burner was originally developed for direct-fired fiber and gypsum-board dryer applications. More recently, the modular ultra-low-NO_X burner has found use in the food industry with food-drying applications such as powdered milk and whey protein powder. In these food-drying applications, the firing must be indirect because of stringent guidelines preventing products of combustion from contacting food products. The modular ultra-low-NO_X burner installed in an air heater provides indirectly heated process air to meet these strict food product guidelines. It also produces low levels of NO_X and CO emissions that meet global emissions requirements.

The modular ultra-low-NO_X burner has proven to be an excellent burner for air-heating applications; therefore, it is used in many of those installations. The modular ultra-low-NO_X burner works especially well in applications where large or small process air-volumes must be heated up to a certain temperature and uniform heat distribution is important. The modular ultra-low-NO_X burner also could be used on drum dryer applications or in incinerators. When combined with a heat recovery heat exchanger, the possibilities are expansive.

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