Process Burners 101

Erwin Platvoet
Charles Baukal, P.E.
John Zink Hamworthy Combustion

Process burners may be classified based on flame shape, emissions, fuel type, and other characteristics. Here's what you need to know to work effectively with a burner manufacturer when selecting a burner for your application.

Process burners *(1)* operate in heaters and furnaces in the refining, petrochemical, and chemical process industries (CPI). While each of these industries has specific requirements, most process burners have a heat release of 1–15 MMBtu/h (0.3–4.4 MW), a firebox pressure at the burner of –0.25 to –0.75 in. H_2O (–0.62 to 1.87 mbar), and an excess air ratio of 10–25%. Although most process burners have common operating characteristics, they can be classified in a variety of different ways:

- motive force — forced draft, natural draft, self-aspirated
- NOx emission control — conventional, low-NOx, ultra-low-NOx
- flame shape — round, flat
- placement in the firebox — freestanding (floor), against the wall (floor), in the side wall, in the roof
- fuel type — gas, oil, combination
- NOx reduction method — fuel staging, air staging
- fuel/air mixing — diffusion, premixing.

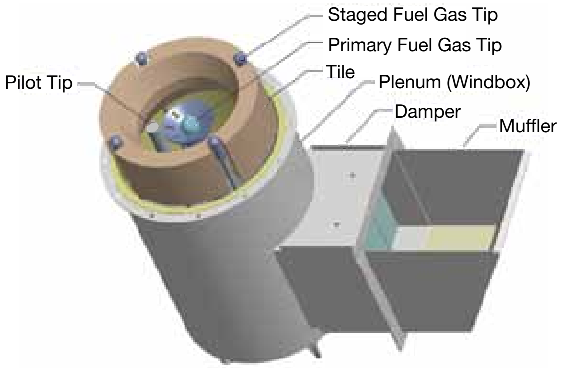
Most process burners have a similar design (Figure 1). In a natural-draft burner, air enters through a muffler, which dampens the noise from the burner. Next, the air control adjusts the amount of air flowing through the burner. The air control is typically a set of louvers or damper blades that can be rotated to partially or completely close the entrance into the plenum. The plenum, or windbox, distributes air to the burner throat and dampens the noise from the firebox. The burner tile is a refractory piece that shapes and stabilizes the flame. One or more burner tips are used to inject the fuel into the air stream. They are connected to the fuel risers, which, in turn, are connected to the fuel manifold. A small pilot burner provides an ignition source for the main burner.

Round and rectangular flames

Burners can be classified by their flame shape. The two most common flame shapes are round and rectangular (*i.e.,* flat).

Round flames. Freestanding burners typically have round flames and are placed in the middle of the firebox with radiant tubes mounted on the firebox walls (Figure 2). This firebox configuration is cost-effective because the amount of tube surface area per unit of firebox volume is high. However, the tubes are heated only from one side. Therefore, this firebox design is restricted to applications where the tubes' circumferential heat-flux distribution is not critical. Round flames are also appropriate in applications where horizontal flames are required or where burners are firing in the downward direction.

Article continues on next page

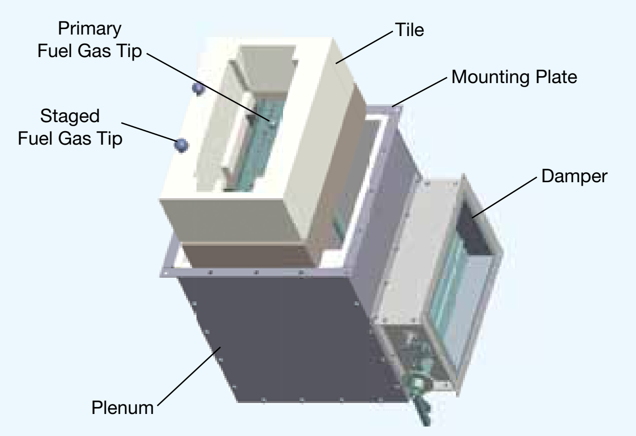


▲ **Figure 1.** Air enters a process burner through the muffler and is distributed into the burner throat via the plenum. Fuel gas tips inject fuel into the air stream. A pilot burner ignites the main burner.

Rectangular flames. Wall-fired burners (Figure 3) typically produce a flat or rectangular flame (Figure 4). These burners heat the firebox refractory wall, which radiates heat toward the tubes located in the center of the firebox. This type of firebox arrangement is more costly to build because the amount of tube surface area per unit of firebox volume is low. However, it does permit much better control of heat flux in the tubes, and is therefore the preferred solution in applications where the flux and temperature profile, both longitudinal and circumferential, are critical, such as coker heaters and steam cracking furnaces. Fluegas alone is a poor radiative emitter because it emits and radiates only at certain wavelengths. A solid wall does not have this restriction and is therefore capable of more-efficient radiant heat transfer.

Flat-flame wall-fired burners rely on the firebox wall to create a certain heating pattern that is compatible with the process. This relatively simple concept produces good flame patterns and low NOx emissions by optimally distributing (staging) the fuel into the air stream and against the wall. This burner is well suited for applications with low heat release per burner, such as delayed coker heaters.

◀ **Figure 2.** Individual freestanding burners located in the middle of the firebox provide radiant heat for the tubes lining the firebox walls.



▲ **Figure 3.** Wall-fired burners produce flat flames that heat the refractory wall of a firebox. This provides more-efficient radiant heat transfer for the tubes in the center of the firebox.

Freestanding flat-flame burners are also typically used in applications with horizontal tubes and low heat release per burner, such as vacuum and coker heaters. Flat flames are preferred in these process heaters because they provide better radiant coverage of the tubes than round burners. This results in a more uniform heating profile and lower fouling rates.

In some firebox designs, a combination of round and flat flames is used. In such cases, the flat-flame burners fire against the wall and the round-flame burners are arranged between rows of tubes.

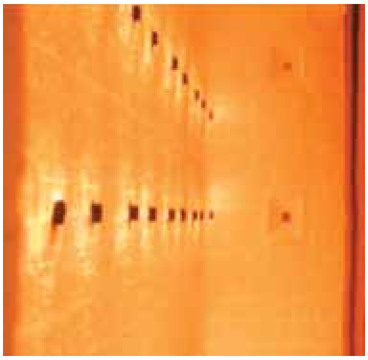
Burner emissions control

Burners may be classified based on their nitrogen oxides (NOx) emissions as: conventional, low-NOx, ultra-low-NOx, and next-generation ultra-low-NOx *(2)*. Unfortunately, there are no industry standards for the definition of each of these terms, and their use is at the burner manufacturer's discretion. The manner in which burner designs reduce emissions has a significant impact on flame shape and behavior.

Conventional burners are designed with no other criteria than flame shape and stability in mind. Until the mid-1980s, when emission limits became very important, this was the dominant burner style. Emissions of NOx, carbon monoxide (CO), unburned hydrocarbons, and particulate matter are not considered in the design of this burner. Fuel and air are mixed as rapidly as possible to create a compact flame, allowing furnace engineers to design very compact fireboxes with high heat densities.

Low-NOx burners delay combustion by staging the air or fuel in multiple zones. In this way, the initial fuel-air mixture is deliberately made very rich or very lean, which slows the combustion process and reduces the peak flame temperatures

◀ **Figure 4.** This flat flame is produced by a wall-fired burner.



▲ **Figure 5.** In this configuration of a radiant-wall burner array, dozens of burners are mounted on the wall of the firebox.

and thermal NOx production. In staged-air burners, the primary air (approximately 40% of the total air) is mixed with the total quantity of fuel, producing a fuel-rich flame. This primary-zone flame is both relatively cool and deficient in oxygen — conditions that inhibit NOx formation. Secondary air is introduced downstream of the primary-flame zone so combustion is completed in an environment that is sufficiently cool to limit thermal NOx production.

A similar effect is accomplished in staged-fuel burners by separating the fuel into two stages while all of the air is introduced into the flame at once.

In ultra-low-NOx and next-generation ultra-low-NOx burners, more advanced techniques such as internal fluegas recirculation and lean premixing of the air and fuel are used to reduce NOx emissions to very low levels. These techniques and their impact on firebox design are outside the scope of this article.

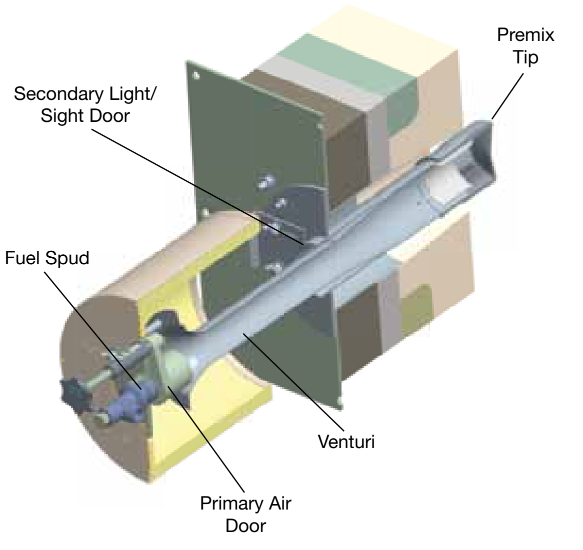
Radiant-wall burners

The term radiant wall refers to the configuration of the firebox. Dozens (or even hundreds) of burners mounted on the wall of the heater provide even, radiant heat to the process tubes in the center of the firebox (Figure 5). Applications that require even heat flux to process coils, such as hydrogen reforming and hydrocarbon cracking to ethylene, have been using many small premix radiant-wall burners since the late 1950s. In a premix burner, some or all of the fuel and air are mixed inside the burner, prior to reaching the tile. A typical radiant-wall burner (Figure 6) is comprised of five parts: the venturi, the primary premix tip, the fuel orifice spud, the primary air door, and the secondary lighting and sighting port(s). Burner tile assemblies, such as tile-mounting plates (plates on which tiles are mounted), high-temperature hot face, and insulating back-up block, are also available.

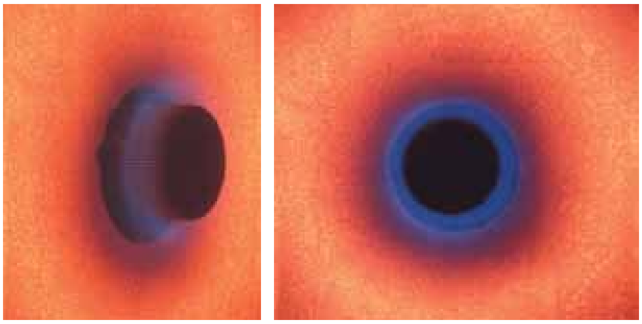
The fuel gas is metered and injected into the venturi through the fuel orifice, which is positioned at the entry to the venturi. The high-velocity fuel draws ambient air into the venturi for premixing ahead of the ignition zone. Primary airflow can be manually adjusted by opening or closing the primary-air door assembly at the entry to the venturi. If necessary, secondary air can be introduced to the annular space around the venturi and tip assembly.

Radiant-wall burners provide a flat, radially projected flame pattern (Figure 7). This burner is typically mounted horizontally, but can be mounted in any direction. The burner is mounted flush through a furnace-refractory-lined casing, with its tip projecting a short distance into the radiant chamber. The radial flame then heats the surrounding refractory and firebox wall, which then radiates to the process tubes.

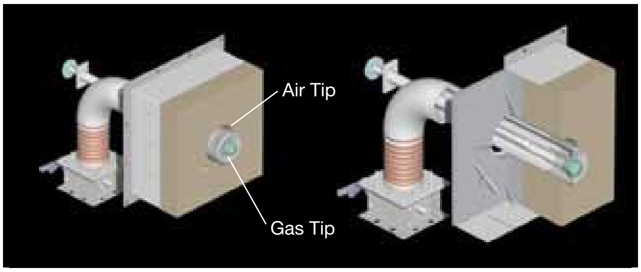
Some radiant-wall burners are designed to operate with cold or preheated combustion air under forced-draft conditions (Figure 8). The fuel and air are introduced into the furnace at separate locations. The fuel is injected into the furnace through a central gas tip. The combustion air is provided in an annular region around this tip and is injected in a radial pattern into the furnace, parallel to the furnace wall. Prior to the initiation of the combustion reaction, both the fuel and the air mix with high-temperature, inert furnace



▲ **Figure 6.** Radiant-wall burner assemblies are used for applications that require a very even heat flux to process coils.



▲ **Figure 7.** Radiant-wall burners provide a flat, radially projected flame pattern, and can be mounted in any direction.



▲ **Figure 8.** In this forced-draft radiant-wall burner, fuel is injected through a central gas tip and air is injected in a radial pattern.

gases. The fuel is finally oxidized in a quasi-flameless combustion environment (*i.e.,* the flame is less visible to the naked eye than a traditional flame because of the way the fuel and air are mixed). This type of burner has been used in steam/methane reforming furnaces and could also be applied in ethylene dichloride crackers.

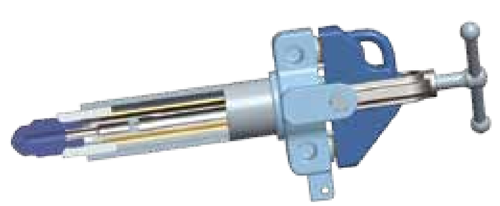
Combination burners

Many refining and petrochemical plants use liquid burner fuel, especially outside the U.S., due to its availability, ease of transport, and flexibility in storage. A liquid-fired burner's design is significantly different from that of any gas-fired burner, and it presents many more challenges during operation than a gas-fired burner. For those reasons, most burners designed for liquid firing are also equipped with gas-firing capability. Therefore, oil burners for process heaters are typically combination gas-oil burners.

A combination burner can be thought of as two or even three burners in one — the combination burner must perform using oil exclusively as the fuel, gas exclusively, and sometimes both gas and oil simultaneously. Good performance with one fuel does not imply good performance with the other fuel or the combination. The design strategies that work well for gas-only or oil-only burners can conflict in a combination burner.

Firing a liquid fuel requires atomization of the liquid. In order to efficiently combust, the liquid fuel needs to be broken up into small droplets. Smaller droplets allow fast surface vaporization, providing the required gas phase for mixing with air. To break the fuel into small droplets, an atomization system (*i.e.,* oil gun) is required. Most oil guns in industry have a concentric tube design in which oil flows through the inner tube while the atomizing medium, usually steam, flows through the annular area between the inner and outer tubes (Figure 9).

A typical combination burner contains a primary oil tile (*i.e.,* regen tile) and a secondary tile, as illustrated in Figure 10. The oil gun is located at the center of the regen tile and the gas tips are located between the regen tile and the secondary tile. While oil firing is uncommon due to its complexity and high NOx emissions, there are still many older combination burners in the U.S. that fire gas only.

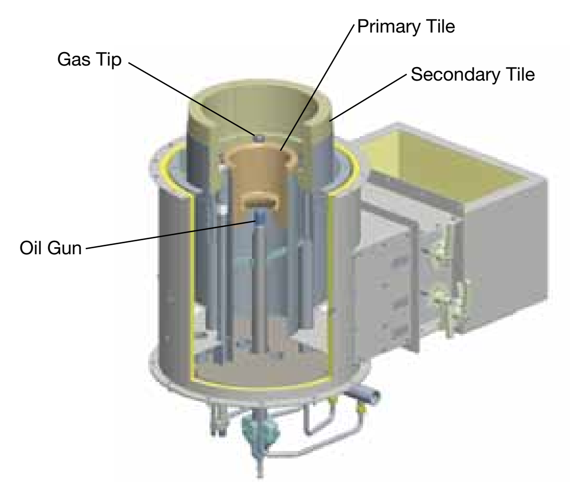


▲ **Figure 9.** This oil gun has a concentric tube design. Oil flows through the inner tube, while the atomizing medium, typically steam, flows through the annular area between the inner and outer tubes.

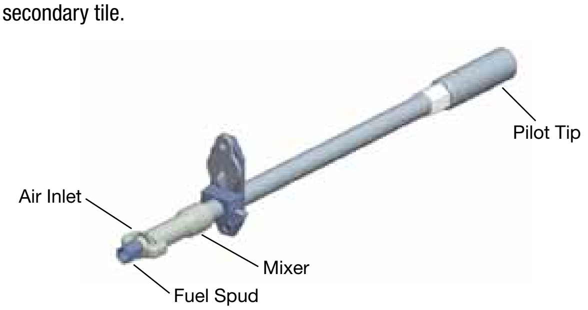
Pilot burners

Pilot burners are small, independently controlled burners that act as an ignition source for the larger process burners. Pilot burners are predominantly premixed, although there are raw-gas and liquid-hydrocarbon-fueled pilots. This article discusses gas-fired premix pilots only.

One of the earliest attempts at specifying pilots was National Fire Protection Association (NFPA) Standard 85C for pilot burners in power-generation boilers *(3)*. These pilots were initially used in coal-fired and heavy-oil-fired large-capacity-boiler burners. The most recent standards are NFPA 85, Boiler and Combustion Systems Hazards Code *(4),* and NFPA 87, Recommended Practice for Fluid Heaters *(5)*. The American Petroleum Institute (API) has issued two publications that address pilots: API Standard 560/ISO 13705, Fired Heaters for General Refinery Service *(6),* and API Recommended Practice 535, Burners for Fired Heaters in General Refinery Services *(7)*. Engineers working with pilot burners should familiarize themselves with the full content of these referenced publications, as they are generally accepted industry norms.



▲ **Figure 10.** A typical combination burner has a primary burner tile, or regen tile, and a secondary tile. The oil gun is located at the center of the regen tile and the gas tips are located between the regen tile and the secondary tile.



▲ **Figure 11.** This standard premix gas pilot for process burners is manually ignited.

A typical pilot for process heaters is shown in Figure 11. This is a manually ignited, premix gas pilot, designed for high efficiency with natural gas fuels. The pilot mixer, which premixes the air and fuel, is generally located external to the burner housing, so the combustion air for the pilot is typically ambient air. The external mixer also facilitates adjustments to the pilot air door.

Flame detection

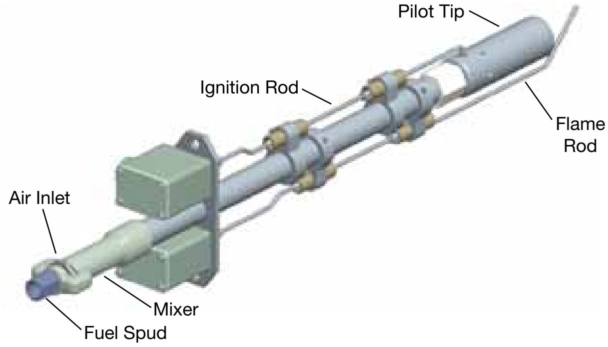
The two most common technologies for burner flame detection are flame rods and scanners.

In recent years, flame ionization rods with flame rectification circuits have become more common. When a flame rod is placed within a flame zone, the ionized particles within the flame provide a conducting pathway between the isolated and insulated flame rod assembly and the grounded pilot and main burner assemblies. The flame rectification circuit provides a low voltage to the flame rod (Figure 12). With the presence of flame, the ionized zone within the flame allows current to flow; sensing this current flow is proof of flame.

In order for the flame rod to function properly, it must be immersed in the pilot flame, the flame rod assembly must be isolated and insulated from any grounding or contact with the pilot and main burner assemblies, and the pilot body must be adequately grounded.

Optical scanning technology, typically in the ultraviolet (UV) range, is frequently used for main-burner flame detection, but can be used for pilot flame detection as well. In a UV flame scanner, optical sensors detect the UV radiation emitted during combustion.

Ignition of pilot burners and process burners can be accomplished either locally or remotely. Either a torch (*i.e.,* flame ignition) or electronic starter can provide local ignition. If ignition is accomplished via remote signal, electronic methods are typically used.



▲ **Figure 12.** In this electrically ignited pilot, to detect the presence of a flame in the burner, a flame rectification circuit applies a low voltage to the flame rod. The ionized zone of a flame allows current flow and indicates the presence of a flame.

Burner selection

Process burners are typically custom-designed for each unique application. Therefore, process burner selection must be made in conjunction with a burner manufacturer. Heater geometry, fuel type, heat input requirements, and emissions performance are important factors that must be considered prior to burner selection. In addition, replacing conventional burners with low-NOx or ultra-low-NOx burners often requires special attention, because of the increase in flame dimensions and the limited space in the heater. Computational fluid dynamic (CFD) studies can be performed to identify potential adverse fluegas flow patterns so appropriate steps to prevent flame impingement on coils can be taken during burner design and selection *(8)*. Plants and companies may select a limited number of burner designs to minimize maintenance and operator training. CEP

Literature Cited

1. **Platvoet, E., *et al.*,** "Process Burners," Chapter 1 in Baukal, C., ed., "John Zink Hamworthy Combustion Handbook," Vol. 3: Applications, CRC Press, Boca Raton, FL (2013).
2. **Baukal, C., and W. Bussman,** "NOx Emissions," Chapter 15 in Baukal, C., ed., "John Zink Hamworthy Combustion Handbook," Vol. 1: Fundamentals, CRC Press, Boca Raton, FL (2013).
3. **National Fire Protection Association,** "Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boiler-Furnaces," NFPA 85C, NFPA, Quincy, MA (1991).
4. **National Fire Protection Association,** "Boiler and Combustion Systems Hazards Code," NFPA 85, NFPA, Quincy, MA (2011).
5. **National Fire Protection Association,** "Recommended Practice for Fluid Heaters," NFPA 87, NFPA, Quincy, MA (2011).
6. **American Petroleum Institute,** "ANSI/API Standard 560 (ISO 13705:2006), Fired Heaters for General Refinery Services," 4th ed., API, Washington, DC (Aug. 2007).
7. **American Petroleum Institute,** "API Recommended Practice 535, Burners for Fired Heaters in General Refinery Service," 2nd ed., API, Washington, DC (Jan. 2006).
8. **Lorra, M. A., and S. Chen,** "CFD-Based Combustion Modeling," Chapter 13 in Baukal, C., ed., "John Zink Hamworthy Combustion Handbook," Vol. 1: Fundamentals, CRC Press, Boca Raton, FL (2013).

ERWIN PLATVOET is the Director of Process Burner Engineering at John Zink Hamworthy Combustion (Tulsa, OK) since 2009. While working for major petrochemical and engineering companies, he has gained over 22 years of experience in CFD, combustion, heat transfer, and furnace engineering. He holds an MS in chemical engineering from the Univ. of Twente in the Netherlands and is an inventor on six patents. He is a member of AIChE.

CHARLES BAUKAL, PhD, P.E., is the Director of the John Zink Institute, which is the training organization for John Zink Hamworthy Combustion (Tulsa, OK). He has been with John Zink Hamworthy since 1998. He has over 30 years of industrial combustion experience, has authored or edited 13 books on industrial combustion and over 150 other publications and presentations, is an inventor on 11 U.S. patents, and is an adjunct instructor for several universities. He holds a BS and an MS from Drexel Univ. and a PhD from the Univ. of Pennsylvania, all in mechanical engineering, and an MBA from the Univ. of Tulsa.