LOW NOx BURNERS

Introduction

Bloom Engineering, founded in 1934, serves the world market through its Pittsburgh headquarters, a subsidiary operating in Europe, license partners and a world-wide network of sales offices and representatives. Bloom Engineering is a combustion oriented company serving basic industry with particularly strong roots in steel and aluminum. Process Combustion Corporation, wholly owned by Bloom, serves the chemical industry and thermal oxidizer users. The Bloom family of companies specializes in problem solving and custom engineering solutions, rather than using a “catalog sales” approach.

Over forty years ago, Bloom developed the unique baffle burner concept, which is still applied to its large direct fired and many of its smaller direct fired burners. Bloom’s modern recuperative radiant tube burner has its origins in the early 1950’s.

For over a decade, Japan and Europe have faced the necessity of reducing NOx emissions. Although the Bloom baffle burner is inherently a low NOx design, modifications were made which lowered NOx even further to meet the challenges presented by the clean air requirements of Japan and Europe. With the development of regenerative burners, the low NOx baffle concept was successfully applied to these designs. To improve air quality with radiant tube burners, several changes to the basic design have been developed.

Bloom Low NOx Burners

Bloom’s low NOx products cover the spectrum from cold air to hot air, small to large, and include direct fired, radiant tube fired, conventional and regenerative burners. Among the products are:

- 1060-, 1070-, 1080-, 1440-, 1500-, 1550-, 1560-, 1570-, and 1610- Series large capacity hot and cold air fabricated low NOx direct fired baffle burners.
- 2000-, 2070-, 2100- and 2170- Series hot and cold air high thermal release (HTR) direct fired burners.
- 1360-, 1400-, and 1430- Series small capacity, low NOx baffle burners.
- 1440-, 1500- and 1550- Series small capacity hot air low NOx direct fired baffle burners with air staging.
- 1080-, 1090-, 1100- and 1150 Series low NOx direct fired regenerative baffle burners utilizing various methods of NOx suppression.
- Type “F” 2370- Series low NOx recuperative radiant tube burners which, use recirculated products of combustion to reduce NOx. Radiant tube burners using staging are also available.

What is NOx?

The two oxides of nitrogen related to combustion are nitric oxide (NO) and nitrogen dioxide (NO2). NOx refers to either one of the gases, which play a major role in the formation of smog and ozone.

NO and NO2 are considered toxic, with NO2 being one of the most toxic of commonly found atmospheric gases. NO2 contributes to the formation of acid rain and several airborne carcinogens.

Thermal NOx

NOx formed during combustion using nitrogen and oxygen in the combustion air is referred to as “thermal” NOx. Several important variables influencing thermal NOx are:

- Flame temperature
- Air preheat
- Furnace temperature
- Excess air
- Chemical environment within the flame

Flame temperature is the most important variable. The higher the flame temperature, the higher the NOx concentration. Air preheat and furnace temperature are related to flame temperature and, as a consequence, have a major influence on NOx generation.

As excess air is increased above stoichiometric, the amount of NOx produced begins increasing. The amount of NOx produced will start decreasing when excess air continues to increase because the suppressed combustion temperature begins having a major influence. For practical and economic reasons, it is generally not feasible or desirable to reduce NOx by using excess air.
Thermal NO\textsubscript{x} Control

There are a variety of methods for controlling thermal NO\textsubscript{x}. Among them are:

- Burner design
- Exhaust or Flue Gas Recirculation (EGR or FGR)
- Chemical additives (e.g. ammonia)
- Catalyst aided

Burner manufacturers utilize designs such as low NO\textsubscript{x} baffles and air staging as well as flue gas recirculation. Flue gas recirculation may be achieved by inducing products of combustion (POC) into the flame from the furnace or by using POC from the exhaust system to mix with air or fuel which reduces flame temperature. Oxygen, which controls the reaction rate, is also diluted, reducing the probability that the available oxygen will enter into the NO\textsubscript{x} generating reactions.

Air staging controls flame temperature and the chemical environment to reduce NO\textsubscript{x} formation.

The Bloom Baffle Burner Concept and NO\textsubscript{x}

Bloom’s baffle burner design (Figure 1) effectively recirculates furnace gas into the flame. It consists of a body, gas nozzle, baffle and port. Air enters the burner body directly and the gas passes through the body separated from the air with the fuel tube. The refractory baffle separates the body from the burner block (port).

Air passes through the port through a series of holes around the circumference of the baffle. Gas enters the port through a hole in the center of the baffle. Only after the air and gas enter the port area do they mix together and allow ignition to occur.

The ceramic baffle provides support to the gas tube and is a radiation shield between the flame and the internal burner parts. Baffle hole and port geometries determine flame characteristics, such as shape and luminosity. Geometry also influences the amount of furnace gases recirculating into the port, a major factor in reducing NO\textsubscript{x} levels.

The HTR Burner is inherently low NO\textsubscript{x} because large amounts of furnace gases are recirculated into the flame area. Bloom has developed a lower NO\textsubscript{x} version of the HTR with no loss of performance.

CO and the Bloom Baffle and HTR Burners

An extremely important characteristic of all Bloom baffle and HTR burners is their low carbon monoxide production. Low NO\textsubscript{x} versions of the baffle do not sacrifice low CO performance. This is the result of excellent mixing, flame stability and burning characteristics.
Air Staged Burners

In the first stage of an air staged burner, all of the fuel is mixed with a portion of the combustion air. The remaining combustion air is then added in one or more additional stages until the fuel is completely used.

Figure 1 shows a typical example of an air-staged low NOx burner. The first stage air is introduced through the inner air jets and the second stage air through the outer air jets. Fuel flows through the center.

Air Staged Radiant Tube Burners

Air staged concepts have also been applied to radiant tube burners to reduce NOx. Additionally, radiant tube burner NOx performance can be improved significantly by adding exhaust gas to the combustion air.

EGR and Radiant Tube Burners

Bloom Engineering has developed radiant tube burner designs utilizing flue gas recirculation from the exhaust to the combustion air.

The Type F burner (Figure 3) uses an eductor in the recuperator’s air discharge to draw POC from the exhaust into the combustion air. Impact on thermal efficiency is small. Tube temperature uniformity is improved.

Regenerative Burners

Regenerative burners present a particularly difficult NOx reduction problem to the designers. Regenerative burners have excellent thermal efficiency because they achieve very high preheat temperatures leading to a high potential to emit NOx.

Regeneration requires a pair of burners where one burner was previously used (Figure 4). When one burner is firing, the other burner is exhausting the furnace gases. The exhaust gases pass through the burner body and into a media case which contains refractory material. The refractory media is heated by the exhaust gases, thus recovering and storing energy from the flue products. When the media bed is fully heated, the burner currently firing is turned off and begins to exhaust the flue products. The burner with the hot media begins firing. The combustion air passes through the media bed and is heated by the hot refractory. The two burners cycle approximately every 40 to 90 seconds to alternately heat the combustion air and recover and store the heat from the furnace exhaust gases.

With products of combustion at 2300°F (1260°C), regenerative burners will produce air preheats of about 2000°F (1093°C). Generally, recuperators will produce preheats in the range of 1000°F (538°C).

Bloom’s low NOx baffle designs induce furnaces gases into the flame resulting in exceptionally low NOx levels. The technique is often referred to as internal exhaust gas recirculation (EGR). When emissions are measured in pounds of NO2 per million Btus of useful heat delivered to the process, regenerative burners often outperform cold air burners as well as recuperative burners.

Exhaust gases also can be added to the combustion air either before or after the regenerator. When they are added after the regenerator, the process is referred to as external warm EGR because the EGR is not reheated in the regenerator. Hot EGR refers to the approach where the recirculated gases are added externally and reheated in the regenerator.
Hot EGR processes have a higher thermal efficiency than warm EGR processes particularly at high furnace temperatures. Generally, internal EGR has replaced external EGR in the United States but is still considered elsewhere in the world.

It is extremely important to design regenerative burners, keeping in mind not only NO\textsubscript{x}, but also, carbon monoxide. Carbon monoxide levels should not significantly exceed those of their conventional counterpart. It is possible to achieve less than 50 parts per million CO while simultaneously achieving the desired NO\textsubscript{x} performance.

An aspect of regenerative burners which often goes unnoticed is CO\textsubscript{2} emissions, which are also reduced. CO\textsubscript{2} is reduced because less fuel is required to accomplish the process requirements because of the very high thermal efficiency. In many instances, the regenerative burner is clearly the most environmentally responsible choice. It reduces fuel use. It frequently improves NO\textsubscript{x} emissions even below cold air burners. It reduces total carbon monoxide and carbon dioxide emissions to the atmosphere.

**Summary**

Bloom’s low NO\textsubscript{x} product line spans the input range commonly used in industrial applications. It includes direct fired and radiant tube fired burners which can be designed for cold air or hot air produced by recuperators or with regenerators.

The heart of the direct fired burners is the well proven baffle concept. With regenerative applications, efficiencies and emissions levels which reduce NO\textsubscript{x}, CO and CO\textsubscript{2} below the levels expected even from modern cold air burners are achieved.

In radiant tube designs, Bloom uses unique engineering approaches to provide exhaust gas recirculation to the burner with only insignificant or very small losses in thermal efficiency. The relative NO\textsubscript{x} performance of Bloom’s various burners is illustrated in Figures 5 and 6.

For more information or assistance with application evaluation, contact Bloom Engineers at 5460 Horning Road, Pittsburgh, PA 15236. Telephone: 412-653-3500, Fax: 412-653-2253.