GB Single Jet Round Flame Low Emissions Burners

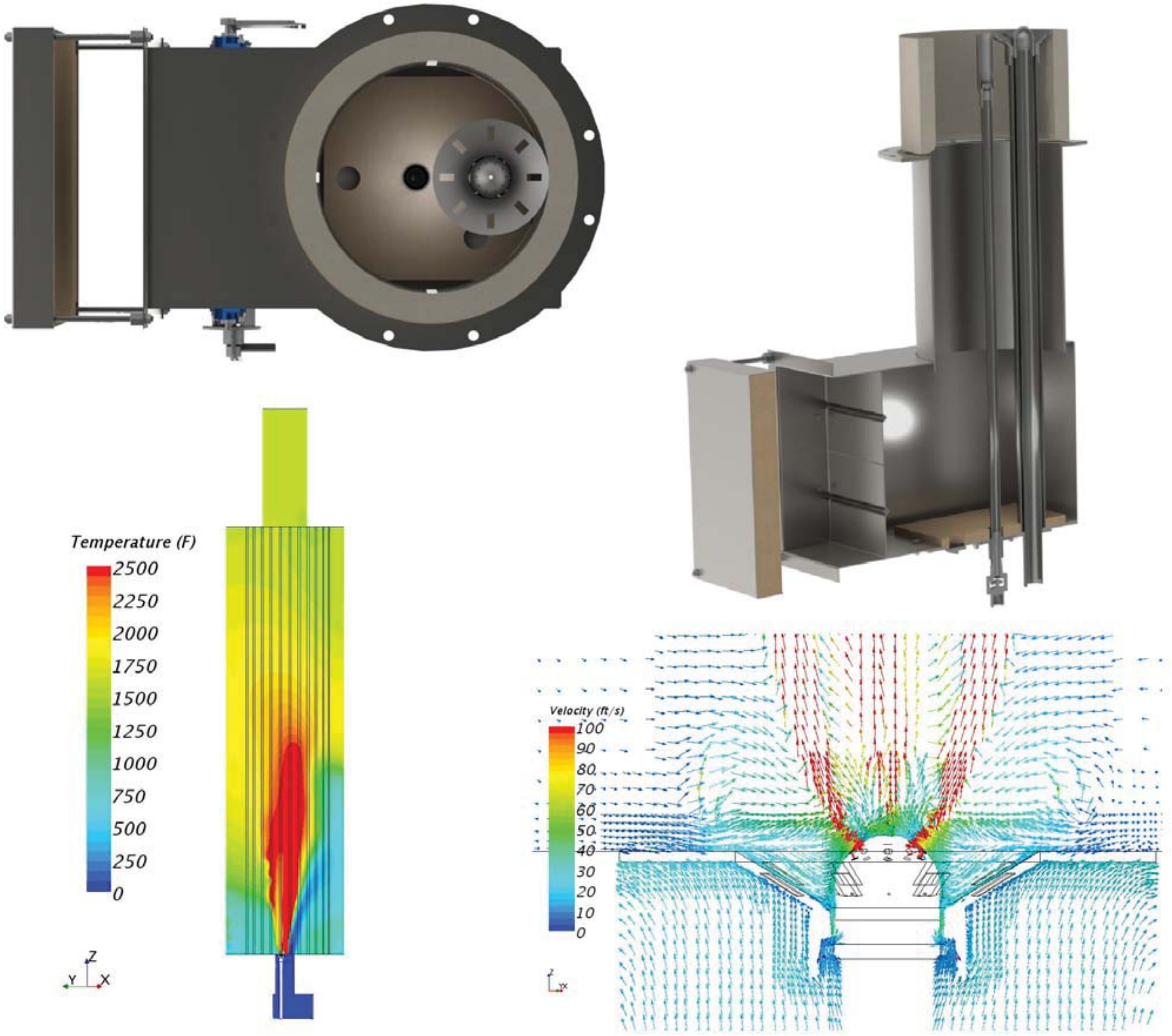


Figure 1: The GB Single Jet Burner is based upon existing conventional burner design, with the incorporation of staged fuel, staged air and internal flue gas recirculation. This design allows low emissions to be achieved in difficult applications which have limited mounting space, high heat densities, and close burner to burner spacing. Zeeco has taken a conventional single tip with a cone design burner and enhanced the concept using the same, tip, cone and tile, to achieve Low NOx emissions.

GB Burner – *Great Choice for New Applications & Retrofits*:

The Zeeco GB Round Flame burner is a simple way to meet less than 100 mg/Nm3 (49 ppmv) for many applications while still achieving high turndown, great flame characteristics, low maintenance and low probability of flame interaction. The GB design uses a single tip and cone to operate just as a conventional burners have been used since the 1960's. The advantages of the single tip and cone design include:

- ***Stable Flame*** – The single tip and cone design is a very simple concept which provides high stability. The tip drilling includes ignition ports which are used to ignite the burner, firing ports which are used to create the primary *(lean)* combustion zone, and the *center staged fuel port* which creates the secondary *(rich)* combustion zone. Since ignition ports are very close to the firing ports and the firing ports are close to the staged port, the ignition gas can travel only a very short distance less than 30 mm compared to 380 mm for many staged fuel burner design designs. Since the ignition gas only travels a short distance to create stability, the burner is much more stable than the conventional staged fuel burner.
- ***Compact Design*** – Since the burner only has a tip and cone, the burner design is very compact which allows it to be ideal for new application and retrofit applications which have limited mounting requirements.
- ***Low Probability of Flame Interaction*** – Since the burner is very small and only has one tip and that tip is located in the burner throat, the gas fired from one burner is farther away from the adjacent burner if compared to a conventional staged fuel burner with gas tips on the periphery of the burner tile. Since the design is compact and the gas fired from burner to burner is farther apart, the probability of flame interaction is much less than a conventional staged fuel burner design. This significantly reduces the possibility of a "Flame Cloud" in the heater which can contribute to elevated NOx emissions.
- ***Low Maintenance*** – Since there is only one tip and one cone, there are very few items to have maintenance issues with on this burner. The same basic tip and cone design has been used by Zeeco since the early 1980's. The tip and cone design is one of the most used configurations and is preferred by most operations groups since it does not require much maintenance. In addition, if maintenance is required, then such work can be performed quickly since only tip has to be removed and cleaned.
- ***Accurate Combustion Air Control*** – Controlling combustion air to each burner is key to good operation. Therefore we utilize a dual blade, opposed motion damper system to control the combustion air. The damper blades are mounted on 304SS shafts so rusting is not an issue in the movement of the damper blades. The damper shafts are then mounted on bearings for easy movement. To insure that the burner dampers move accurately, we use gears to link the two (2) damper shafts together.

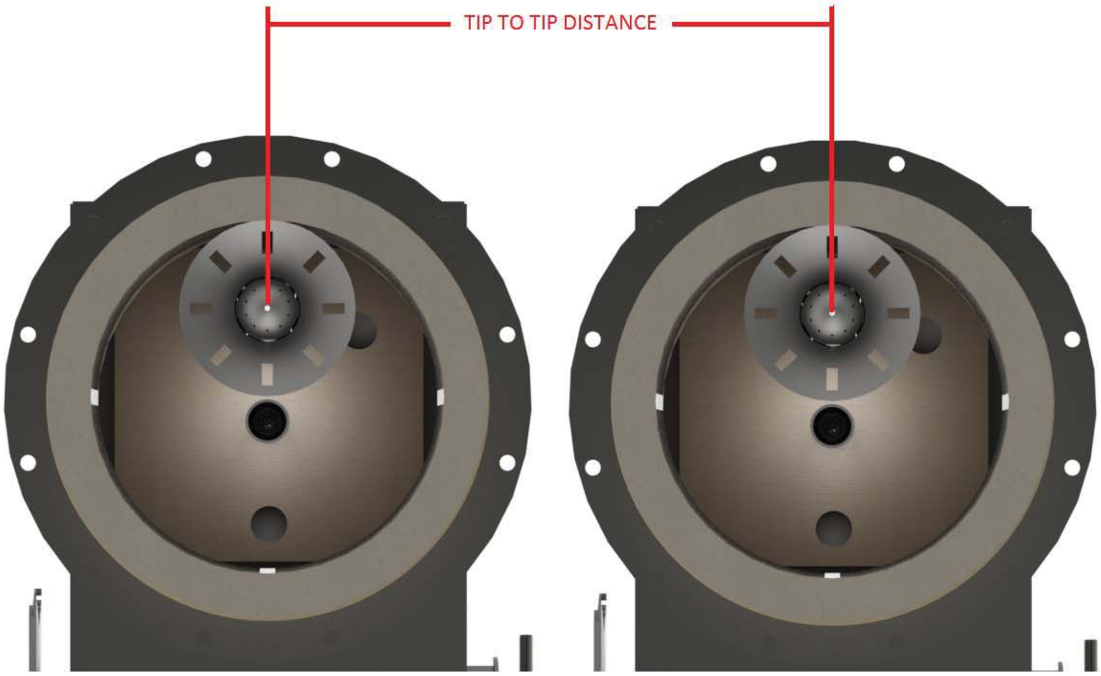


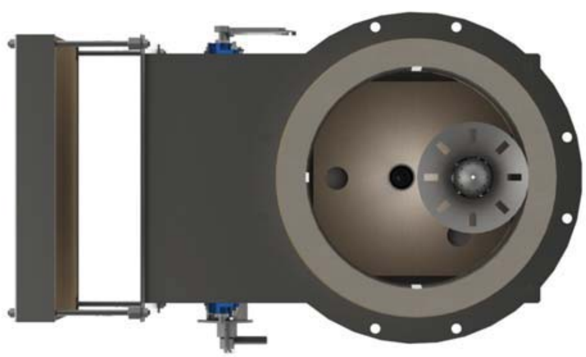
Figure 2: Reduced Probability of Burner to Burner Flame Interaction – Since there is only one tip and one cone per burner, the distance from tip to tip is greater than the tip to tip distance of a conventional staged fuel burner or ultra-low NOx burner with tips located on the periphery of the burner tile. Since the tip to tip distance is farther apart, there is less probability of flame interaction.

Features of Burner Design:

- Round Flame, Gas Only Burner Design
- NOx Reduction Method: Internal Flue Gas Recirculation, Staged Fuel, & Staged Air
- Combustion Air Induction: Natural, Forced, Induced & Balanced Draft, or Turbine Exhaust
- Mounting Options: Up-fired, Side-fired and Down-fired
- Compact Design makes this burner a great choice for retrofit applications
- Compact flame shape
- Reasonable cost and great value
- Configurations available: plenum mounted or individual wind-box

Burner Performance Information:

- Low NOx Emissions:.................................... Uses Staged Air, Staged Fuel & Internal Flue Gas Recirculation
- Predicted NOx Range (Natural Draft):........................... 40 mg/Nm3 (20 ppmv) to 100 mg/Nm3 (49 ppmv)
- Heat Release Range:... Natural Draft: 1 to 20 MM Btu/hr [0.293 to 5.860 MW]
- Heat Release Range: .... Forced Draft: 1 to 75 MM Btu/hr [0.293 to 21.98 MW]
- Turndown: .... 10:1 or greater for most cases
- Design Excess Air Range: .... 10% to 25% for most cases
- Combustion Air Pressure Drop {Natural Draft}: .... 0.2” to 1” (5 to 25 mm) H2O
- Combustion Air Pressure Drop {Forced Draft}: .... 0.5” to 10” (12.7 to 254 mm) H2O



GB Non-Symmetrical Single Jet Burner Low NOx Burner:

The *GB burner* design utilizes a non-symmetrical design in order to utilize internal fuel gas recirculation and staged air to achieve NOx emissions reduction in one simple burner design with only one (1) *fuel gas tip* and or one (1) *fuel gas riser.* The NOx reduction methods used reduce the flame temperature, resulting in reduced NOx emissions. The pollutant emission that has received much attention over the past several decades are NOx emissions. Because NOx emissions are a contributor to acid rain and smog in the lower atmosphere and to ozone depletion in the upper atmosphere, its reduction is of significant environmental importance. Regulatory agencies in many countries are enacting stricter NOx emission regulations.

Definition of NOx reduction methods:

The burner design is unique in that it incorporates Staged Fuel, Staged Air and Internal Flue Gas Recirculation to lower the flame temperature resulting in reduced NOx emissions. Below are brief definitions of *Staged Air and Fuel Designs* and *Internal Fuel Gas Recirculation (IFGR)*:

Staged Air Designs - When the combustion air is separated into two or more flows to create separate zones of lean and rich combustion, the burner is considered to be a "staged air" burner.

Staged Fuel Designs – When the fuel gas is separated into two or more flows to create separate zones of lean and rich combustion, the burner is considered to be a "staged fuel" burner.

Internal Fuel Gas Recirculation (IFGR) – When part of the fuel gas passes through and mixes with the inert products of combustion to form a new fuel gas which burns at a lower peak flame temperature.

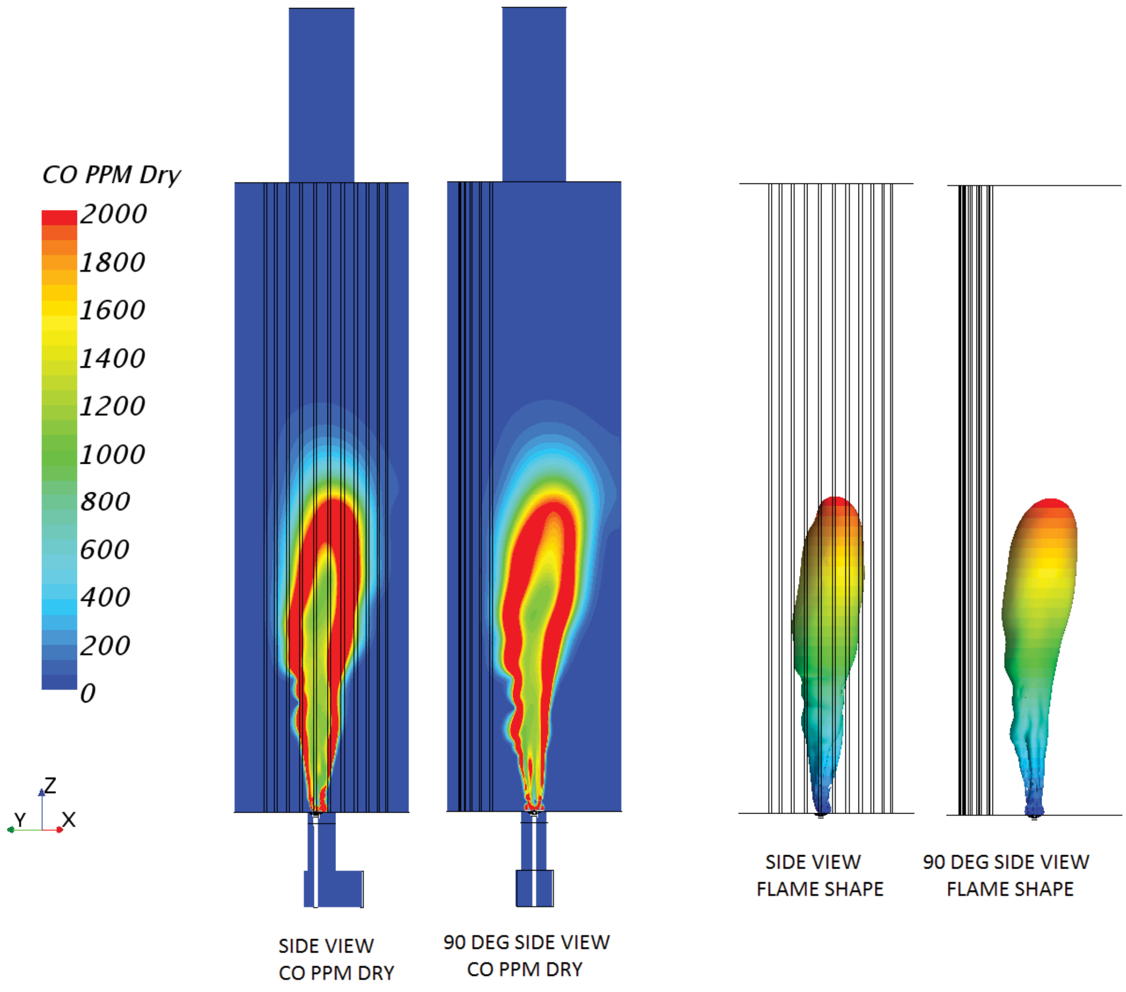


Figure 3: From the above illustration, one can see that even though the cone and gas tip are placed next to the tile, the flame stays over the top of the burner tile throat in much the same way as a typical burner with the cone & tip in the center of the tile. This is due to the fact that the volume of combustion air is the primary driver of flame shape. As the combustion air outlet is still centered with respect to the burner, the volume of air causes the flame to be centered on the burner centerline. Thus the NOx emissions are lowered, and the flame shape is the same as conventional burners of the past.

Brief description of invention:

The main feature that enables this burner design which achieves NOx emissions reduction is that the *Burner Gas Tip (1.7)* & *Burner Stabilization Cone (1.8)* are positioned next to, or close to the *Burner Tile (1.6)* assembly **(Please refer to Figure 4)**. In order to describe how the new design lowers NOx emissions, we will first describe how the burner works. A burner is used to control the amount of oxygen which is mixed with fuel in a combustion zone at a high enough temperature to start and maintain a combustion reaction and provide heat or duty. Typically (but not exclusively) oxygen is provided to the burner in air since air is comprised of around 21% (by volume) oxygen, 78% nitrogen and 1% argon. The air flows into the *combustion air inlet (1.2)*, through the *combustion air damper (1.3),* through the *wind-box (1.4),* and then through the *burner throat opening (1.5).* The fuel gas is introduced into the burner through the *Burner Gas Tip (1.7)*. As the fuel gas exits the *Burner Gas Tip (1.7)*, provided that the local temperature is high enough to start combustion, the reaction between the oxygen and fuel starts and burning begins on the *Burner Stabilization Cone (1.8)*.

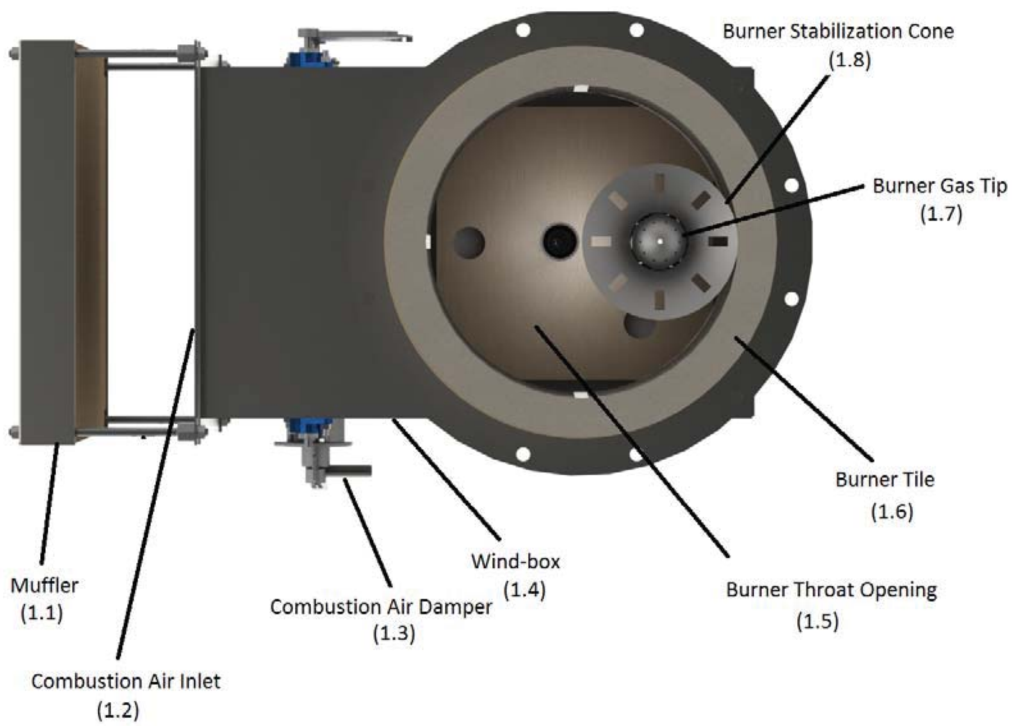


Figure 4: The above illustration shows the basic features of the Non-Symmetrical Single Jet Low NOx Design

Brief of description of how staged fuel is incorporated in burner design:

Please refer to below illustration: The *gas tip* includes *Firing Ports* which eject gas into the combustion air stream which enters the burner through the throat of the burner. When this gas mixes with the combustion air and begins to burn forming a lean combustion zone, products of combustion are generated. Located in the center of the tip is another port which fires gas directly upwards. The gas from the staged center port passes through and mixes with the products of combustion forming a fuel rich zone. When the fuel gas is separated into two or more flows to create separate zones of lean and rich combustion, the burner is considered to be a "**Staged Fuel**" burner. The GB Single Jet Burner is an excellent example of how staging fuel can contribute to enhanced NOx emissions reduction.

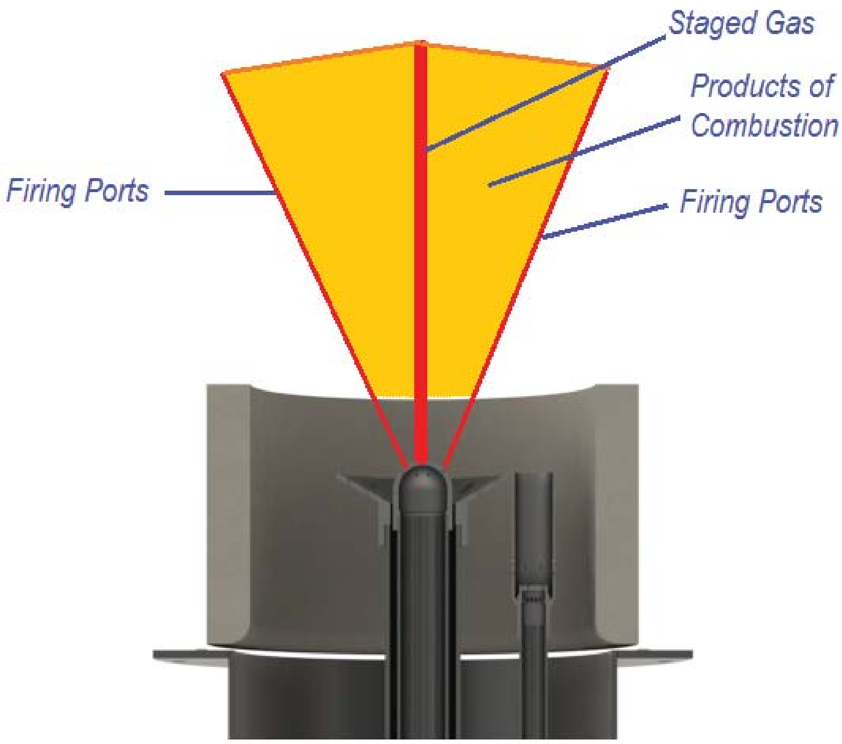


Figure 5: Staged Fuel Gas: This illustration shows how the GB burner stages fuel gas. Since the firing gas comes into contact with combustion air first, a primary lean combustion zone is created generating products of combustion. The center gas port then creates a secondary fuel rich combustion zone in which the staged gas is mixed with the products of combustion. When the fuel gas is separated into two or more flows to create separate zones of lean and rich combustion, the burner is considered to be a "staged fuel" burner.

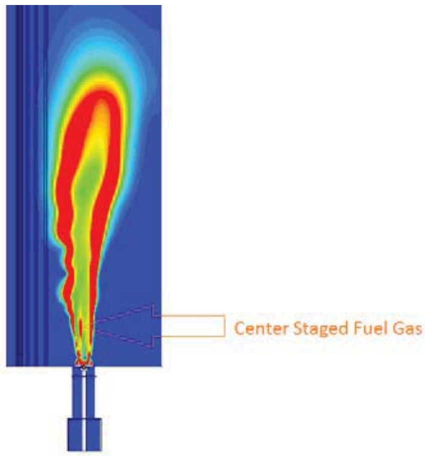


Figure 6: The above illustration shows the center staged gas in a CFD model. The center staged fuel gas burns in the center fuel rich zone or secondary combustion zone. The GB Single Jet Burner is an excellent example of how staging fuel can contribute to reduced NOx emissions.

Brief of description of how staged air is incorporated in burner design:

Please refer to Figure 7: Since the *gas tip (2.5)* & *the stabilization cone (2.6)* are located next to or close to the *burner tile (2.7),* part of the gas ejected from the *gas tip (2.5)* is next to the *combustion air stream (2.13)* and part of the fuel gas is ejected next to the products of combustion (2.4). The *combustion air stream (2.13)* is available to mix with only part of *fuel gas (2.14)* resulting in a *lean combustion zone (2.2).* Since there is more combustion air available than fuel gas, the peak flame temperature in *the lean combustion zone (2.2)* is reduced, resulting in lower thermal NOx emissions. The remaining gas is then burned in a *fuel rich zone (2.1)* located where the *burner stabilization cone (2.6)* is located next to the *burner tile (2.7)*. ***Staged Air*** is achieved since *lean (2.2)* and *rich (2.1)* combustion zones are created by the burner design.

Brief of description of how IFGR is incorporated in burner design:

Please refer to Figure 7: In addition, part of the fuel gas is ejected next to the *products of combustion (2.4).* Therefore, the *fuel gas (2.14)* in this region mixes with the *products of combustion (2.4)* resulting in fuel conditioning which allows the flame temperature of the fuel mixture to be reduced and the thermal NO_x emissions to be lowered. ***Internal Fuel Gas Recirculation (IFGR)*** is achieved when part of the *fuel gas (2.14)* passes through and mixes with the inert *products of combustion (2.4)* to form a new fuel gas which burns at a lower peak flame temperature. The amount of IFGR mixing is enhanced significantly by the momentum of the *combustion air (2.13)* in the upwards direction causing the internal products of combustion to be “pulled” into the fuel gas ejected from the *burner gas tip (2.5).*

Illustration of zones of combustion:

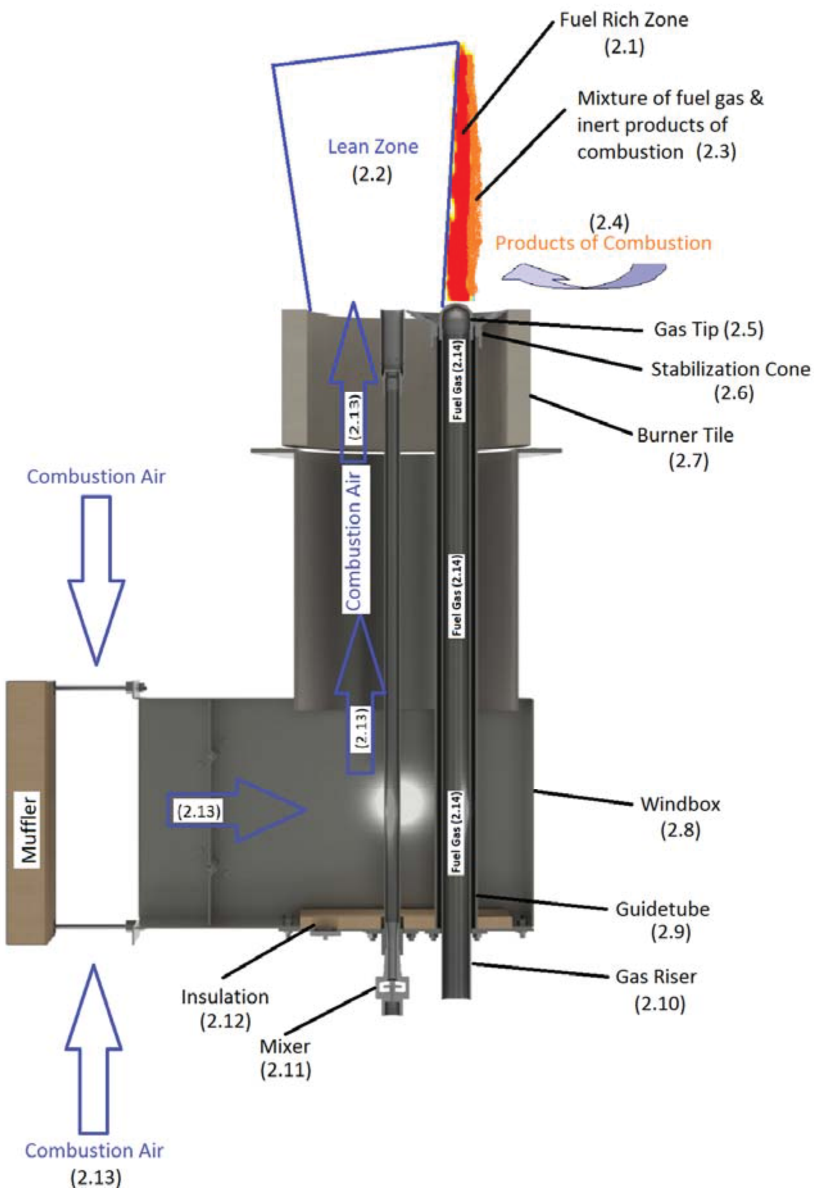


Figure 7: The GB Burner Design incorporates a Non-Symmetrical placement of the gas tip (2.5) and stabilization cone (2.6) where they are located next to, or close to the burner tile (2.7). The special placement of the gas tip (2.5) / stabilization cone (2.6) creates lean (2.2) and rich (2.1) zones of combustion resulting in what is called "staged air" NOx Reduction. In addition, since part of the fuel gas (2.14) passes through and mixes with the inert products of combustion (2.4) to form a new fuel gas mixture which burns at a lower peak flame temperature resulting in what is called "internal flue gas recirculation (IFGR)"NOx reduction. Due to the specialized drilling layout on the fuel gas tip, the ignition and firing ports create a primary combustion zone that stages the gas from the center port of the fuel gas tip. Hence, "staged fuel" NOx Reduction is utilized.

Summary of NOx Reduction Method:

The burner design is an "Internal Flue Gas Recirculation (IFGR)" burner that mixes the fuel gas together with the inert products of combustion to produce low emissions with little or no "External Flue Gas Recirculation (EFGR)". To further reduce the emissions, "staged air" & "staged gas" is added to the base design to further lower the flame temperature and the thermal NOx emissions.

The burner was designed with the specific purpose of utilizing "Internal Flue Gas Recirculation" or "IFGR" to reduce thermal NOx emissions without sacrificing burner performance with respect to flame length, turndown, and stability with part of the fuel gas. In addition, when the combustion air is separated into two or more flows to create separate zones of lean *(Figure 7, item 2.2)* and rich *(Figure 7, item 2.1)* combustion, the burner is considered to be a "staged air" burner. This design incorporates both methods of NOx emissions reduction with only one (1) *gas tip (Figure 7, item 2.5)* and or one (1) *gas riser (Figure 7, item 2.10).* Also, due to the specialized drilling layout on the fuel gas tip, the ignition and firing ports create a primary combustion zone that stages the gas from the center port of the fuel gas tip. Hence, "staged fuel" NOx Reduction is utilized.

In order to understand how the design works, we must examine how thermal NO_x emissions are formed.

Thermal NOx Emissions:

For gaseous fuels with no fuel bound nitrogen, thermal NOx is the primary mechanism of NOx production. Thermal NOx is produced when the flame temperature reaches a high enough level to "break" the covalent N2 bond apart and the "free" nitrogen atoms bond with oxygen to form NOx.

Methane & Air with Excess Air

2CH4 + 4(XA)O2 + 15(XR)N2 ---> 2CO2 + 4H2O + (XA)15N2 + (XR)O2

Combustion air is roughly comprised of 21% O2 and 79% N2. Combustion occurs when the O2 reacts and is combined with the fuel (typically hydrocarbon). However, the temperature of combustion is not normally great enough to break all of the N2 bonds, so most of the nitrogen in the air stream passes through the combustion process and remains as diatomic nitrogen (N2) in the combustion products. Some of the N2 does reach high enough temperatures in the high intensity regions of the flame to break apart and form "free" nitrogen. Once the covalent nitrogen bond is broken, the "free" nitrogen is available to bond with other atoms. The free nitrogen, or nitrogen radicals, will react with any other atoms or molecules suitable for reaction. Of the prospects in the products of combustion, free nitrogen will most likely react with other free nitrogen to form N2. However, if another free nitrogen atom is not available, the free nitrogen and oxygen atoms will react to form NOx. As the flame temperature increases, the stability of the N2 covalent bond decreases allowing the formation of more and more free nitrogen and subsequently increased thermal NOx. Burner designers can reduce NOx emissions by reducing the peak flame temperature which in turn reduces the formation of free nitrogen available to form NOx.

The varied requirements of refining and petrochemical processes require the use of numerous types and configurations of burners. The method utilized to lower NOx emissions can differ from application to application. However, thermal NOx reduction is generally achieved by delaying the rate of combustion. Since the combustion process is a reaction between oxygen and a fuel, the objective of delayed combustion is to reduce the rate at which the fuel and oxygen mix together and burn. The faster the oxygen and the fuel gas mix together, the faster the rate of combustion and the higher the peak flame temperature.

The illustration below plots Peak Flame Temperature vs. Thermal NOx. As you can see, NOx emissions increase as the adiabatic flame temperature increases. Slowing the combustion reaction allows the flame temperature to be reduced, and as the flame temperature is reduced, so are the thermal NOx emissions.

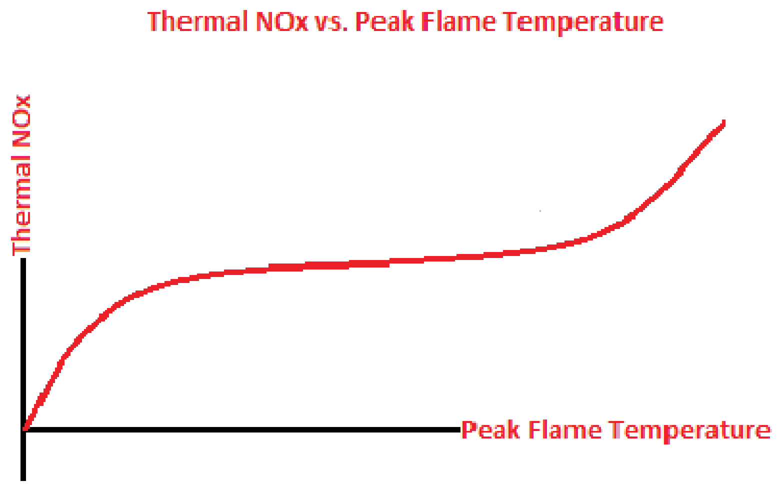


Figure 5: As the Peak Flame Temperature increases, so does the Thermal NOx production. Some fuels produce a higher peak flame temperature than other fuels. For example, burning hydrogen produces a higher peak flame temperature than when methane at the same conditions. Therefore, most Thermal NOx reduction methods focus on ways to reduce the peak flame temperature while burning a fuel while still producing the same net heat release.

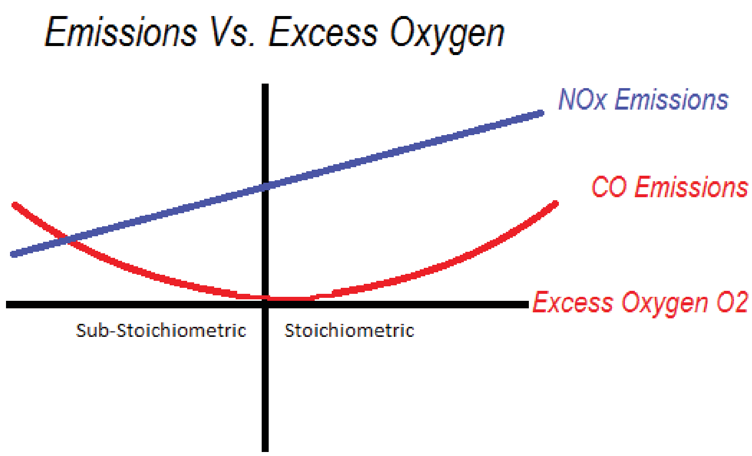
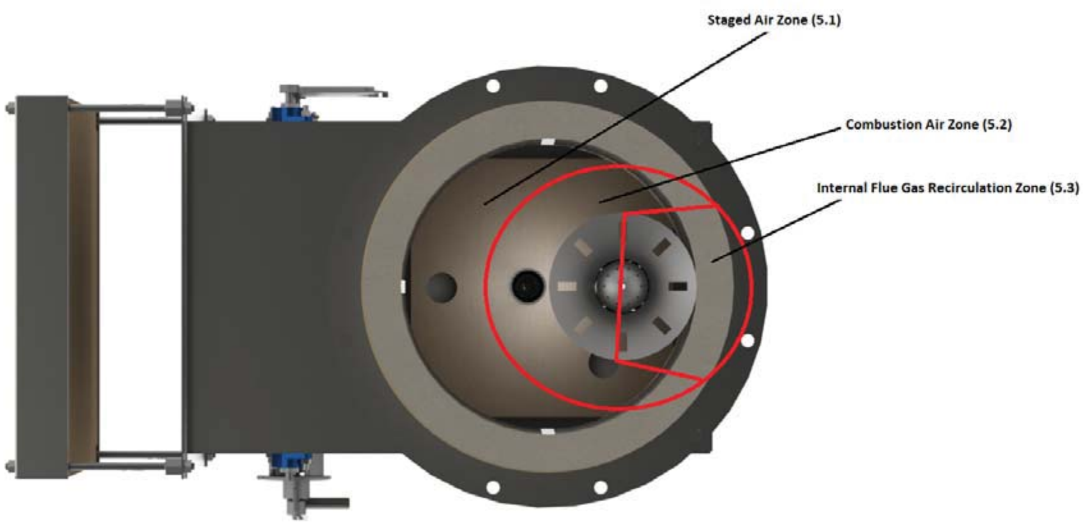


Figure 6: Thermal NOx production also increases as the amount of oxygen is increased since more free oxygen is available to bond with free nitrogen when the temperature is elevated high enough to break N2 and O2 apart during the combustion process.



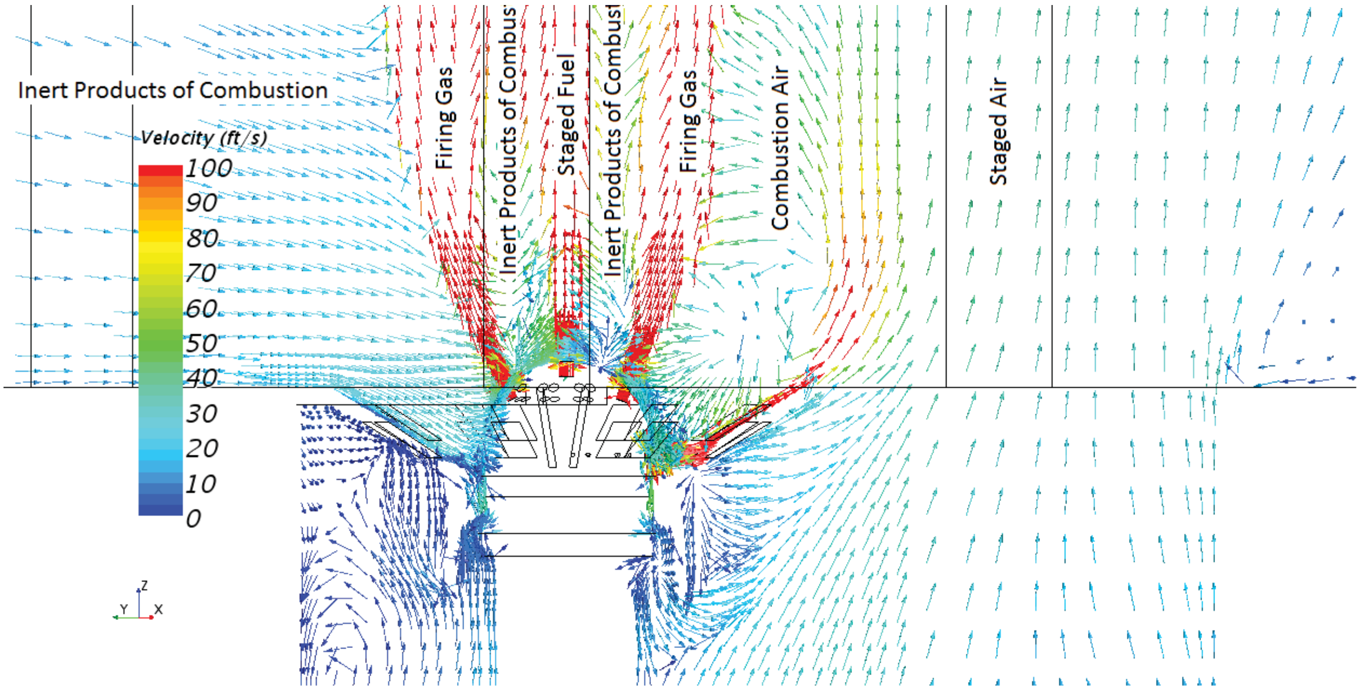


Figure 7: The above illustration is of a GB Single Jet burner with the cone shifted to the left next to the burner tile. The above CFD Analysis shows that the flue gas on the left side of the illustration is induced into the primary combustion zone. When the inert flue gas is mixed with the gas in the primary combustion zone, NOx is reduced by internal flue gas recirculation. Since all of the air is introduced on the right side of the above CFD, the fuel gas in the center of the cone is burned with sub-stoichiometric air resulting in staged air NOx reduction. In addition, since there is a gas port in the center of the burner, there are two distinct zones of gas staging, which result in staged fuel NOx reduction. Therefore, the above illustration shows that the burner utilizes internal flue gas recirculation, staged air, and staged fuel NOx reduction.

CERTIFICATIONS APPLY TO ZEECO HEADQUARTERS ONLY.

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Zeeco Corporate Headquarters
22151 East 91st Street
Broken Arrow, Oklahoma 74014 USA
Phone: +1.918.258.8551
Fax: +1.918.251.5519
E-mail: sales@zeeco.com

www.zeeco.com