ZEECO BURNER DIVISION

Low NOx Duct Burners
DB Series

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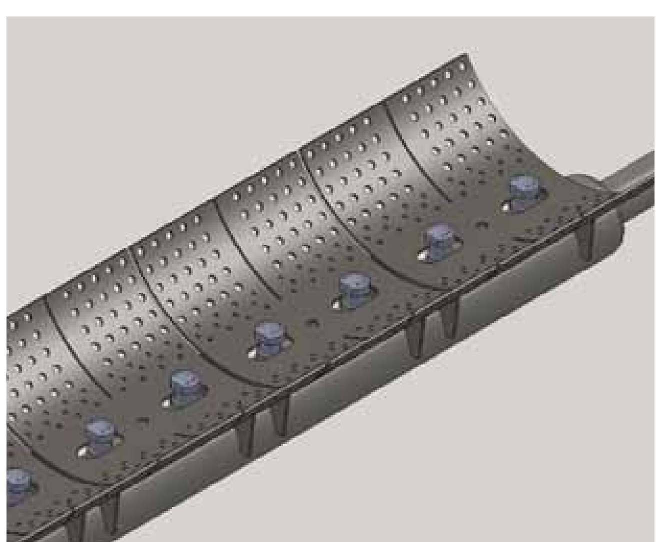
INTRODUCTION:

The DB series addresses many of the problems normally associated with duct burner type applications. Zeeco uses a "zone analysis type approach" to determine the duct burner inlet conditions in different sections of grid layout. Then by adjusting the amount of open area in the duct burner wing section in the particular zones, the emissions and flame heat pattern can be better predicted and controlled. A summary of the DB advantages are listed as follows:

1. *Reduces the effects of uneven TEG/ airflow.*
2. *Produces less NOx emissons.*
3. *Produces less CO emissions.*
4. *Produces less UHC emissions.*
5. *Produces less Particulate emissions.*
6. *Provides a more even heat distribution.*

The Zeeco Series DB Duct Burner is designed to be compatible with all turbine configurations and heat recovery systems. These reliable burners are available for gas only, oil only, or combination gas and oil firing. Gas burners consist of one or more linear runner type assemblies. Burner runners can be mounted either vertically or horizontally. Oil is fired transversely in a self-contained system. All fuel firing assemblies are mounted inside an insulated ductwork section.

This paper will describe in more detail the DB series design philosophy and advantages.



DESIGN FEATURES

Flame Length

Zeeco duct burners produce an evenly distributed flame pattern. The DB series burners can be designed for a wide range of fuels and heat release duties per linear foot of length. However, for most applications the flame lengths are in the 4 to 6 feet range depending upon the conditions.

Gas Firing

Gas assemblies are constructed with specially designed gas tips and flame holders to provide uniform heat release cross the duct and minimize emissions of NOx, CO, and Unburned Hydrocarbons. All materials of construction are high alloy metal for long life and superior performance.

Turndown

The Zeeco Series DB duct burner will achieve standard turndown ratios greater than 10:1 for gas. Higher turndowns can be achieved in certain applications.

Ignition

Zeeco duct burners are designed for ignition with the Zeeco AR/GS forced draft pilot. In addition, a Flame Front Generator (FFG) or a Zeeco S.E.T. high-energy electric igniter can also be used for ignition. Systems can be designed with either one pilot runner to light all runners or with individual pilots on each runner.

Maintenance

Zeeco duct burners are designed for minimal maintenance. Gas runners and oil guns can be easily removed from the ducting for cleaning or repair.

Fuels

Zeeco duct burners operate on a wide range of fuels including: natural gas, unsaturated hydrocarbons, plant gas, hydrogen, low Btu gases, propane, butane, pentane and LPG mixtures.

Construction

Zeeco duct burners are built for durability, reliability and low maintenance. Each burner is constructed of materials which resist warpage and fuel coking when exposed to direct flames and radiation.

DUCT BURNER CONTROL SYSTEMS

Zeeco can provide a duct burner management system to meet any safety and operational requirements necessary.

All control systems are designed to interface with existing plant computer control systems. Systems are either relay or PLC based and can be designed to meet IRI, NFPA-85, FM, CSA or other special requirements.

CFD FLOW ANALYSIS

CFD Analysis can be used for many different reasons for duct burner applications:

1. *Flow Distribution of TEG or Air before duct burner runners*
2. *Temperature distribution after duct burner runners.*

In addition, a more in depth use of CFD modeling is the "zone analysis type approach" that is used to first determine the inlet conditions to the duct burner in each section of a grid layout of the duct. The flow into each section of the grid is determined by modeling. Based upon the results of the modeling in each section of the grid, the open area in the duct burner wing design can be adjusted for the flow conditions for the particular zone of the grid.

The benefits of the zone analysis type approach are as follows:

1. *Lower thermal NOx production*
2. *Lower CO production*
3. *Lower UHC production*
4. *Lower VOC production*
5. *Lower Particulate production*
6. *Better exit temperature profile*

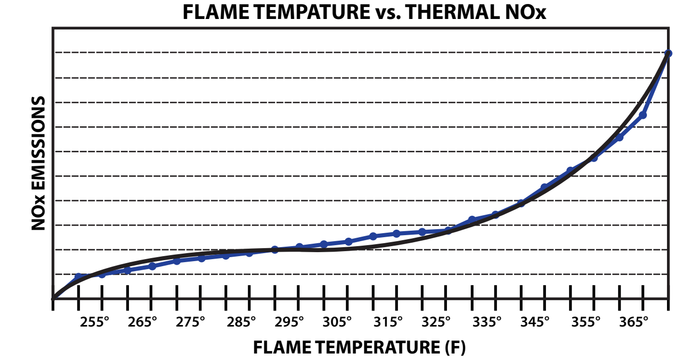
NOx EMISSIONS

Thermal NOx

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

$$2CH_4 + 4(XA)O_2 + 15(XR)N_2 \longrightarrow 2CO_2 + 4H_2O + (XA)15N_2 + (XR)O_2$$



Combustion air is 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 normally not 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 table above plots Adiabatic 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.

ZONE ANALYSIS

Zeeco uses a "zone analysis type approach" to determine the duct burner inlet conditions in different sections of grid layout. Then by adjusting the amount of open area in the duct burner wing section in the particular zones, the emissions and flame heat pattern can be better predicted and controlled. A summary of the DB advantages are listed as follows:

1. *Reduces the effects of uneven TEG/ airflow.*
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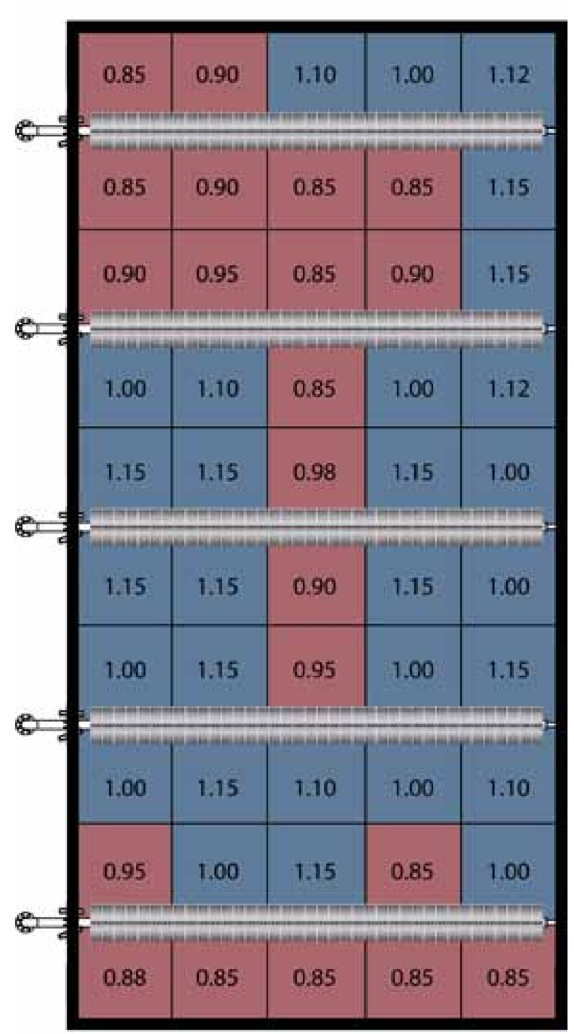
5. *Produces less Particulate emissions.*
6. *Provides a more even heat distribution.*

The "zone analysis type approach" is used to first determine the inlet conditions to the duct burner in each section of a grid layout of the duct. The flow into each section of the grid is determined by CFD modeling. Based upon the results of the modeling in each section of the grid, the open area in the duct burner wing design can be adjusted for the flow conditions for the particular zone of the grid.

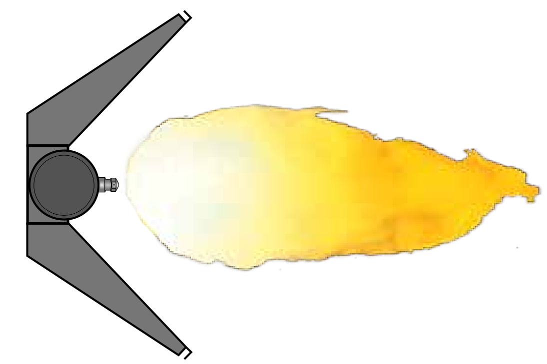
Zone analysis is very important to the successful design of a duct burner system since variances in the flow in different sections of the duct can cause changes in flame length and emissions.

Since NOx production can increase significantly with increased temperature and CO, Particulate, VOC & UHC can increase even more significantly with decreased temperature, it is very important for emissions to have the temperature exiting each of the zones within a range so the emissions can be controlled. Emissions can be controlled by adjusting the amount of open area in the duct burner wing section in the particular zones based upon the flow in each section to create more uniform emissions and flame characteristics.



Above is an example of flow distribution zones in a duct burner section with plus or minus 15% flow. If the duct was provided with uniform distribution all of the sections would be listed as 1.00. Sections which are listed as 0.85 have 15% less flow than the average and sections with 1.15 have 15% more than the average. The areas shown in red have less than average flow and the areas shown in blue have average flow or greater. In general, the red sections will produce greater NOx emissions and longer flames. The blue sections will produce shorter lames and increased CO, UHC, VOC and particulate emissions. Since our wings are manufactured in house, we can change the amount of open area in problem sections and drillings to tailor the duct system for each application.

TEG THAT DOES NOT TAKE PLACE IN COMBUSTION PROCESS



Since only the flow approximately 1 foot (305 mm) on each side of the wing takes part in the combustion process, it is very important to look at each job with a Zone Analysis type approach.

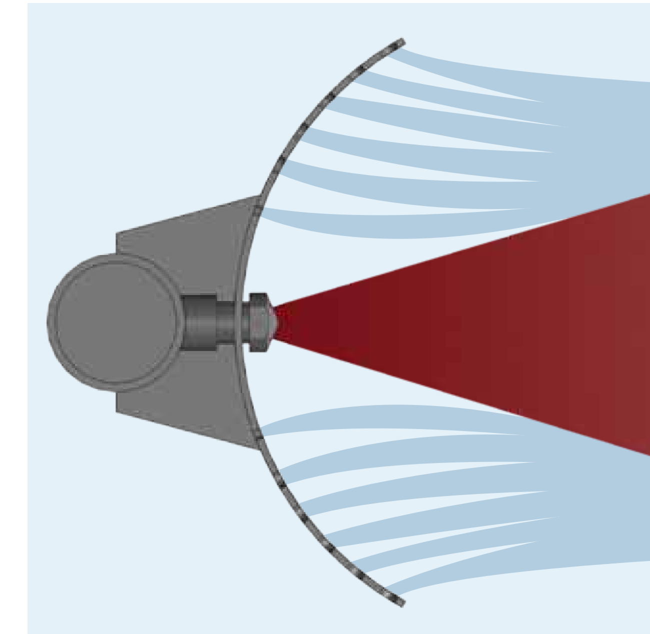
A) For applications with low excess oxygen in the TEG stream, the width of the wing can increase and the open area in the wing increased to increase the peak flame temperature.

B) For applications with high excess oxygen, the width of the wing can be decreased and the open area of the wing reduced to decrease the peak flame temperature.

DB LOW NOx EMISSIONS

Stringent environmental regulations have prompted the development of low emission duct burners for use in turbine exhaust systems. Zeeco, Inc. has addressed this critical environmental issue by redesigning their duct burner element to greatly reduce the NOx, CO and Unburned Hydrocarbons that may be produced. The DB-LN Low Emissions duct burners uses the basic "Free-Jet" mixing concept to combine the inert products of combustion with the fuel gas before combustion occurs to form new fuel composition that produces less thermal NOx emissions. The DB-LN design meets NOx emissions of 0.06 #/MM Btu (LHV) and 0.04# CO emissions for most typical applications.

The DB-LN Duct Burner design is specially designed for each application to allow for the correct flow of TEG/combustion air flow into the primary combustion zone to achieve both low CO and low NOx emissions.



The gas (shown in red) is ejected into the wing area of the duct burner and mixes with the TEG / combustion air flow via "free-jet" mixing method to produce very low emissions. The amount of TEG / combustion air flow into the primary combustion zone is controlled on each job by the amount of open area in the wing.

For applications with very low oxygen content in the TEG steam, more TEG / air mixture is allowed into the duct burner wing to ensure proper mixing for low NOx and especially low CO. For applications with higher oxygen content in the TEG stream, less of the TEG / air mixture is allowed into the duct burner wing section in order to achieve low CO and especially low NOx emissions.

Carbon Monoxide (CO)

Carbon monoxide is the result of incomplete combustion. Almost every combustion process produces trace amounts of CO. To minimize the production of CO, most combustion processes take place with more air than is required for stoichiometric combustion and the temperature of combustion should be above the minimum temperature of combustion of a specific fuel. In general, the higher the temperature, the production of CO is increasingly reduced if burned with sufficient combustion air. Because carbon monoxide is a toxic gas, it is strictly regulated.

Carbon Dioxide (CO2)

Carbon dioxide is a colorless, odorless gas that is produced by natural sources and as a product of combustion. Increasing CO2 concentrations in the atmosphere are believed to contribute to the greenhouse warming effect.

Particulate matter as defined here is a product of incomplete combustion. Particulate matter is most often produced when firing heavy fuel oils or when liquids are present in a fuel gas stream. The US Environmental Protection Agency defines particulate matter as follows:

EPA 40 CFR Part 51.100 Definitions:
(oo) *Particulate matter* means any airborne finely divided solid or liquid material with an aerodynamic diameter smaller than 100 micrometers.

(pp) *Particulate matter emissions* means all finely divided solid or liquid material, other than uncombined water, emitted to the ambient air as measured by applicable reference methods or an equivalent or alternative method, specified in this chapter, or by a test method specified in an approved State implementation plan.

(qq) *PM*10 means particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers as measured by a reference method based on appendix J of part 50 of this chapter and designated in accordance with part 53 of this chapter or by an equivalent method designated in accordance with part 53 of this chapter.

(rr) *PM*10 emissions means finely divided solid or liquid material, with an aerodynamic diameter less than or equal to a nominal 10 micrometers emitted to the ambient air as measured by an applicable reference method, or an equivalent or alternative method, specified in this chapter or by a test method specified in an approved State implementation plan.

(ss) *Total suspended* particulate means particulate matter as measured by the method described in appendix B of part 50 of this chapter.

To minimize the production of Particulates, most combustion processes take place with more air than is required for stoichiometric combustion and the temperature of combustion should be above the minimum temperature of combustion of a specific fuel. In general, the higher the temperature, the production of Particulates is increasingly reduced if burned with sufficient combustion air.

Unburned Hydrocarbons (UHCs) and Volatile Organic Compounds (VOCs)

Unburned hydrocarbons and volatile organic compounds include a variety of low molecular weight hydrocarbons produced as a result of incomplete combustion. Their release contributes to smog and ozone depletion.

To minimize the production of UHC & VOC, most combustion processes take place with more air than is required for stoichiometric combustion and the temperature of combustion should be above the minimum temperature of combustion of a specific fuel. In general, the higher the temperature, the production of UHC & VOC is increasingly reduced if burned with sufficient combustion air.

Sulfur Oxides (SOx)

Sulfur oxides are a family of gases that can react with NOx and other chemicals in the air to form acid rain. Oxides of sulfur are produced during the combustion process when fuel sources containing sulfur compounds are burned. Because SOx formation is dependent on the amount of sulfur in the fuel and the equilibrium conditions inside the furnace, it is not a function of the burner design. As a result, SOx levels are not guaranteed by the burner manufacturer.

SUMMARY

Zeeco equipment is designed to provide the best performance for the best value for your applications. To learn more about Zeeco products and services, you may contact the following locations:

Head Quarters:
Zeeco, Inc.
22151 East 91st Street
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www.zeeco.com

Additional Offices:
Zeeco – Houston, Texas
Zeeco – Korea
Zeeco – Europe

Zeeco Test facility located at Broken Arrow Oklahoma.

Duct Burner Test Rig at Zeeco. The simulated TEG is cooled by a running the TEG through a boiler to control the TEG inlet temperature to the duct runner at the correct temperature.