AFRC 2014 Industrial Combustion Symposium
Sept. 7-10, 2014
Houston, TX

FLAMELESS COMBUSTION SAFETY

Authors:
William C. Gibson – President
Marianne Zimola – Sr. Process Engineer-Advanced Technologies
Great Southern Flameless, LLC
2700 N. Hemlock Ct., Suite 100
Broken Arrow, OK 74012
bill.gibson@greatsoutherngroup.com
marianne.zimola@greatsoutherngroup.com

ABSTRACT

It is necessary to provide the refining industry with documentation and information on the inherent safety of the Great Southern flameless heater technology.

High Temperature Air Combustion (HTAC) and Flameless Combustion are not at all new concepts but they are both new to the direct fired process heater industry. With safety being a key focus of all refineries and chemical process plants, it is necessary to understand the basics of flameless combustion and how a simple control system will ensure safe and reliable operation of the flameless heater.

GSF's technical paper and presentation will focus in detail on how the flameless process heater works, how to set up a simple monitoring and control system and why it is the safest combustion technology available for delivering heat input to the process with extremely high efficiency and low NOx.

TECHNICAL PAPER

INTRODUCTION

Flameless combustion is the safest combustion technology available because the combustion reaction cannot just extinguish itself or de-stabilize like sometimes may happen with conventional and ultra-low NO_x burners. All that is required to sustain flameless combustion is high temperature air preheat and fuel, thus a simple yet reliable monitoring and control system is needed to monitor temperatures and the firing mode (conventional, staged fuel or flameless).

Most heater incidents occur during start-up or shut down so it is imperative to not over-instrument the heater with shut-downs that will cause nuisance trips requiring operators to frequently re-start the heater. The safety and control system must be simple, reliable and also provide a high rate of heater availability.

The SIL definition of “reliability” is “The probability that an item will perform a required function, under stated conditions, for a stated period of time”.

The SIL definition of “availability” is “The proportion of time for which the equipment is able to perform its function”.

REVIEW OF FLAMELESS HEATER COMPONENTS

The reader is requested to review and reference the Great Southern Flameless, AFRC 2013 technical paper *“The World’s First Flameless Crude Heater”* for the discussion that follows.

The flameless heater system is comprised of the following: a radiant section enclosing a double fired process coil, a patented dimple pattern formed in the hard castable refractory lining of the heater walls, flameless nozzle groups (FNG’s) which include (4) air nozzles, (2) conventional firing fuel injection nozzles with pilot and (2) flameless firing fuel injection nozzles. The heater also has a convection section, air preheater and fans (see Fig. 1 - Elevation View). The heater is designed to run primarily in forced draft, flameless mode but can also run in conventional firing mode under natural draft at full design capacity. This is very typical of any balanced draft conventional heater. The only atypical component is the three way valve at each FNG for fuel delivery to the FNG conventional firing fuel injection nozzles and flameless firing fuel injection nozzles plus a convection section by-pass duct with automated dampers. Both the three way valves and the convection section diverter and by-pass dampers are automated through the control system therefore no special operator training is required.

The FNG’s fire tangentially around the castable heater walls radiating heat to the double fired process coil (see Fig. 2 – Plan View). Start-up of the heater is done on natural draft, conventional firing mode. The air preheater and fans can be brought on line after temperatures and flow rates are increased. Once all temperature permissives have been met, the operator simply pushes a button and the three-way valves transition to staged firing mode where half the fuel is directed through the conventional gas nozzles and the other half is directed through the flameless nozzles. After the heater has stabilized for a short period in the staged firing mode and temperature permissives are maintained, the operator can push a button and the three-way valve will transition into flameless firing mode.

As long as high temperature combustion air and fuel gas flow are maintained, the heater will fire continuously in the flameless mode with NO_x emissions of 4-6 ppmvd without an SCR.

CONTROL SYSTEM

Because flameless combustion technology is new to the refining and petrochemical industry, the term “flameless” tends to make some people uneasy because it is so different from traditional conventional burners.

Flameless combustion is complete combustion but without a visible flame. The relatively high temperature of a conventional flame causes carbon cracking in the flame burst. This carbon cracking appears to the human eye as a visible flame. Complete combustion at temperatures that do not produce carbon cracking will result in flameless combustion.

The flue gas that is circulating adjacent to the heater wall inerts the combustion air and the fuel gas. Flameless combustion is achieved when the inerted combustion air and inerted fuel gas diffuse into each other above the auto ignition temperature. The patented dimple pattern of the radiant wall castable refractory assures that the combustion process remains adjacent and attached to the radiant wall. Any possibility of flame impingement or hot gas impingement on the radiant tubes is eliminated.

The fact is, that flameless combustion is the safest technology available for transferring heat to the process fluid of fired heaters.

As stated in NFPA 86, 8.10.1, for furnace/boiler temperatures over 1400^{o}F, no flame monitoring is required due to conditions well above auto-ignition temperatures. As long as fuel and sufficient air are mixed and local temperatures are above the auto-ignition temperature, the oxidation reaction will occur. In addition, the GSF flameless heater stabilizes the combustion reaction along the heater’s internal castable refractory wall (face temperature also above auto ignition) so there is no burner tile or flame holder that a flame must rely on for stabilization.

A small local panel or HMI at the heater is all that is required for operators to control the flameless heater firing mode. GST has coined the term “Operator Interface 556” for this panel since the GST recommended control system and operator interface panel are compliant with API RP556. Start-up of the flameless heater is no different than any other balanced draft refinery process heater.

Over instrumentation can cause adverse results due to nuisance trips. A nuisance trip occurs when faulty instrumentation or faulty instrument signals close main fuel block valves and/or close pilot gas block valves and shut down a heater that was in a safe operating mode. Nuisance trips not only present a safety issue, they also reduce the heater's availability for processing products. Simple instrumentation and controls that monitor combustion air temperature and recirculating flue gas temperature inside the heater ensures that auto-ignition temperature requirements are met and maintained whenever the heater is firing in the staged or flameless mode. As long as these temperatures are maintained at or above the set-point, the combustion cannot be extinguished or destabilized. If the circulating flue gas in the heater or the combustion air temperatures should drop below the set point due to loss of a fan for example, the control system would simply switch back to the conventional firing mode and natural draft operation. With this flexibility, the end user can still operate the heater and produce product while a fan or any other external piece of equipment is being serviced.

The main flame safeguard monitoring system consists of high temperature thermocouples in the radiant section. A set of thermocouples at three elevations located just downstream of each FNG monitors inside furnace temperature directly in the oxidation zone. The temperature signals are relayed to the BMS and the temperature rate of change is monitored. If the temperatures decrease by a certain number of degrees over a specified period of time at all three elevations, the control system will transition the three-way valves back to conventional firing mode. If a loss of temperature is detected while in the conventional mode, the control system will trip the main fuel gas valve to the off position. The GST system uses redundant thermocouples at each elevation. They have proven to be 100% available over the past 18 months.

In addition to these downstream thermocouples, another set of thermocouples just upstream of the FNG's are monitoring the temperature of local flue gases in circulation. This temperature and the temperature of the combustion air are used to calculate the "blend temperature". If blend temperature falls below a specified set-point, the control system will transition the three-way valves from staged or flameless firing mode back to conventional firing.

The combustion air temperature is also monitored and must remain above the specified set point in order to stay in the staged or flameless firing mode. Should the combustion air temperature fall below the set point, the three way valves are automatically actuated back to the conventional firing position.

These three flame monitoring safeguards provide redundant layers of protection for safety and they have proven extremely robust over the past 18 months that the heater has been operational.

Monitoring of the FD and ID fans is tied into the control system to provide another layer of protection. Fan monitoring is typical for any balanced draft air preheat system. If either fan fails, the control system transitions the heater into the natural draft, conventional firing mode. The heater can run in conventional, natural draft mode indefinitely while a fan is being serviced or replaced.

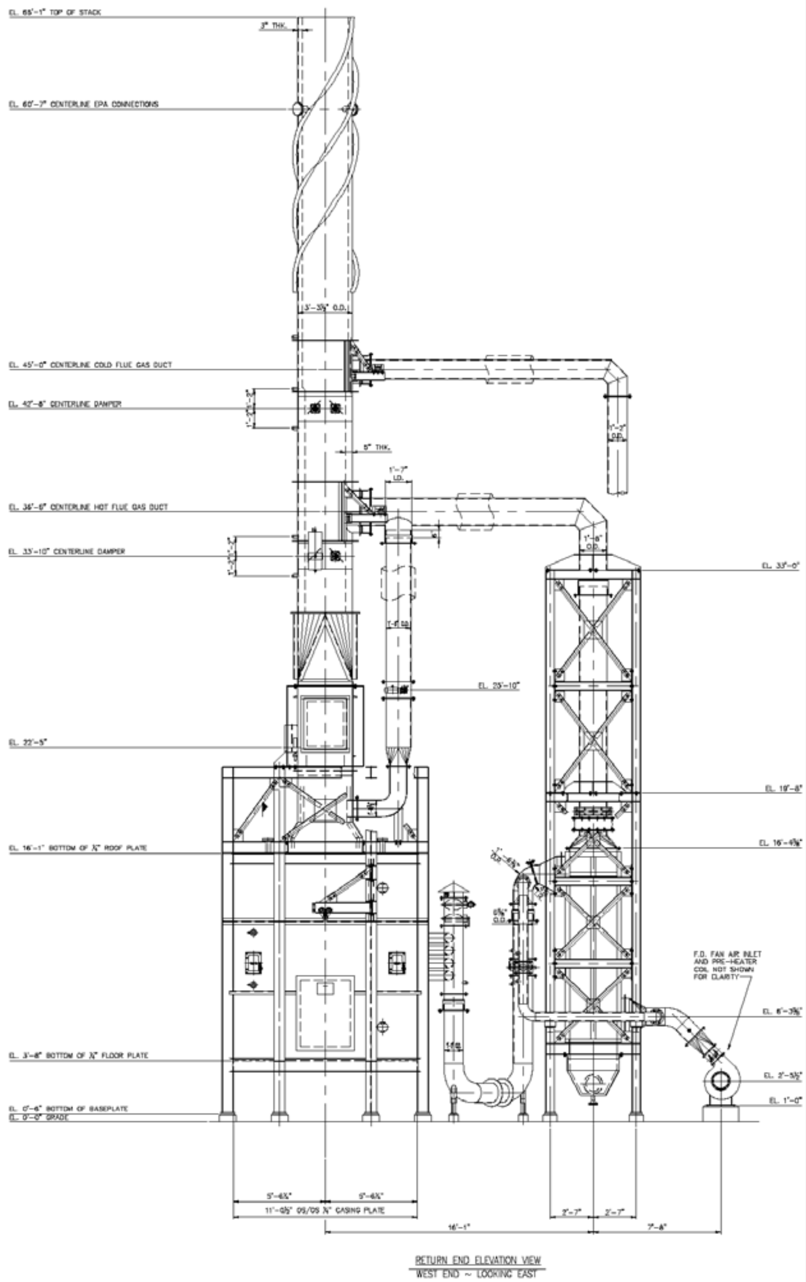
To prevent frequent transitioning back and forth from flameless to conventional firing, the flameless heater control system has an additional feature to maintain flameless combustion. For example, if process flow rate is reduced, this in turn causes reduced combustion air temperature. When the combustion air temperature from the air preheater begins to drop it could potentially drop below the required temperature set point for flameless operation. If this starts to occur, the convection section diverter and by-pass dampers actuate automatically to force a portion of the high temperature flue gas directly from the radiant section to the air preheater (by-passing the convection section) in order to maintain the combustion air temperature as required. This allows flameless firing to be maintained over a wide range of heater operation.

SUMMARY

The first flameless crude heater in Coffeyville KS has now been operational for 18 months as of this presentation. The heater has run in flameless mode continuously for 127 days (as of this writing) with NO_x emissions of 4-6 ppmvd and without nuisance trips.

Not only has flameless technology now been proven robust, reliable, available and environmentally superior, it has also proven to be the safest fired heater technology available for refinery process.

GREAT SOUTHERN



U.S. PATENT No. 8128399
ADDITIONAL PATENTS PENDING

Fig. 1 Elevation View

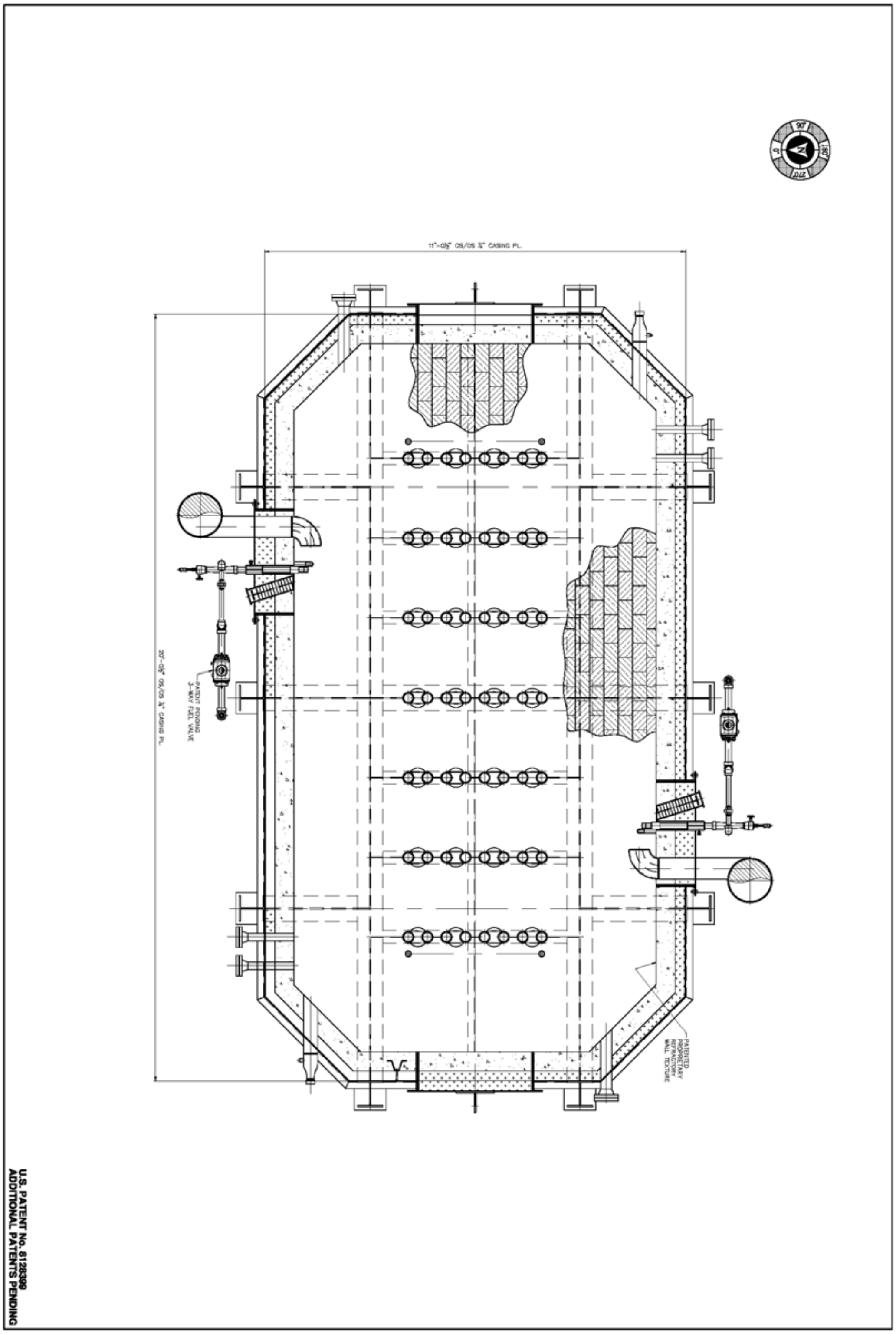


Fig. 2 Plan View – Radiant Section