Oxy-Flameless Combustion for Refinery Process Heaters

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ABSTRACT

The next generation of flameless heater technology for refinery processes will be oxy-flameless heaters. Great Southern Flameless (GSF) is currently developing a flameless heater design that will utilize oxy-combustion technology in order to further reduce both carbon dioxide (CO_2) and Nitrous Oxides (NO_x) green-house gas emissions.

Now that CO_2 has been classified as a greenhouse gas, future regulations may be implemented that will require CO_2 to be monitored and emission limits set by the EPA. Since CO_2 is a natural product of the hydrocarbon combustion reaction, it will be necessary to implement carbon capture technology. Therefore, heater efficiency will become a very important part of refining operations in order to reduce the amount of CO_2 produced.

Oxy-combustion is not at all a new concept however it will be new to the direct fired process heater industry. Combining oxy-combustion with flameless technology will revolutionize the process heater industry and will be well suited for the upcoming carbon capture requirements that may be mandated in the future.

Flameless combustion significantly improves radiant heat transfer to a double fired radiant coil. The flux is equalized, and localized high peak radiant flux rates are eliminated. By combining oxy-combustion with flameless combustion, the advantages of flameless combustion are maintained and then combined with the advantages of oxy-combustion.

A Great Southern Flameless Heater[1] is ideally suited for combustion with air or oxygen. If the requirements for CO_2 capture are put into place, a simple retrofit of the flameless heater will ensure compliance with both CO_2 and NO_x regulations. The oxy-flameless heater is simple, safe, reliable and economical.

GSF will demonstrate how GSF's current flameless heater design can be installed today and then easily modified to an oxy-flameless design with minimal field construction work at a later date as carbon capture regulations are rolled out.

INTRODUCTION

Oxy-flameless combustion heaters are the most efficient way to transfer heat to a refinery process. Additionally, both CO_2 and NO_x emissions from an oxy-flameless heater produce the lowest achievable rate of emissions. Currently the operating cost of utilizing 100% oxygen for combustion in a refinery operation is prohibitive and therefore refiners are not incorporating such a technology since there is no incentive at this time for reducing CO_2 and NO_x emissions to such low levels. With the final goal being 100% oxy-flameless combustion, GSF is also exploring oxy-enhanced flameless combustion technology.

For the time being, oxygen enhanced flameless firing can also be utilized to meet extremely low NO_x emission requirements. By using GSF's flameless heater technology and also incorporating oxygen injection to reduce the amount of combustion air required, NO_x emissions of approximately 3-4 ppm can be realized. Even lower NO_x emissions are possible by turning off the pre-mix pilot and firing natural gas in place of refinery fuel gas.

In the future, the oxy-enhanced flameless heater can be easily retrofit if/when needed to operate in 100% oxy-flameless mode for reaching the absolute minimum CO_2 and NO_x emissions.

GREAT SOUTHERN'S OXY-FLAMELESS TECHNOLOGY - CONCEPTUAL DEVELOPMENT

The Great Southern Flameless Heater technology which has now been commercially proven for refinery and petrochemical applications[2] is perfectly suited for oxy-flameless combustion. The current flameless heater design can be readily and economically converted to oxy-flameless technology if or when the regulations take effect.

Beginning with the standard flameless heater design, the only modifications that would be required to convert the current flameless heater to oxy-flameless technology (Fig.1) are:

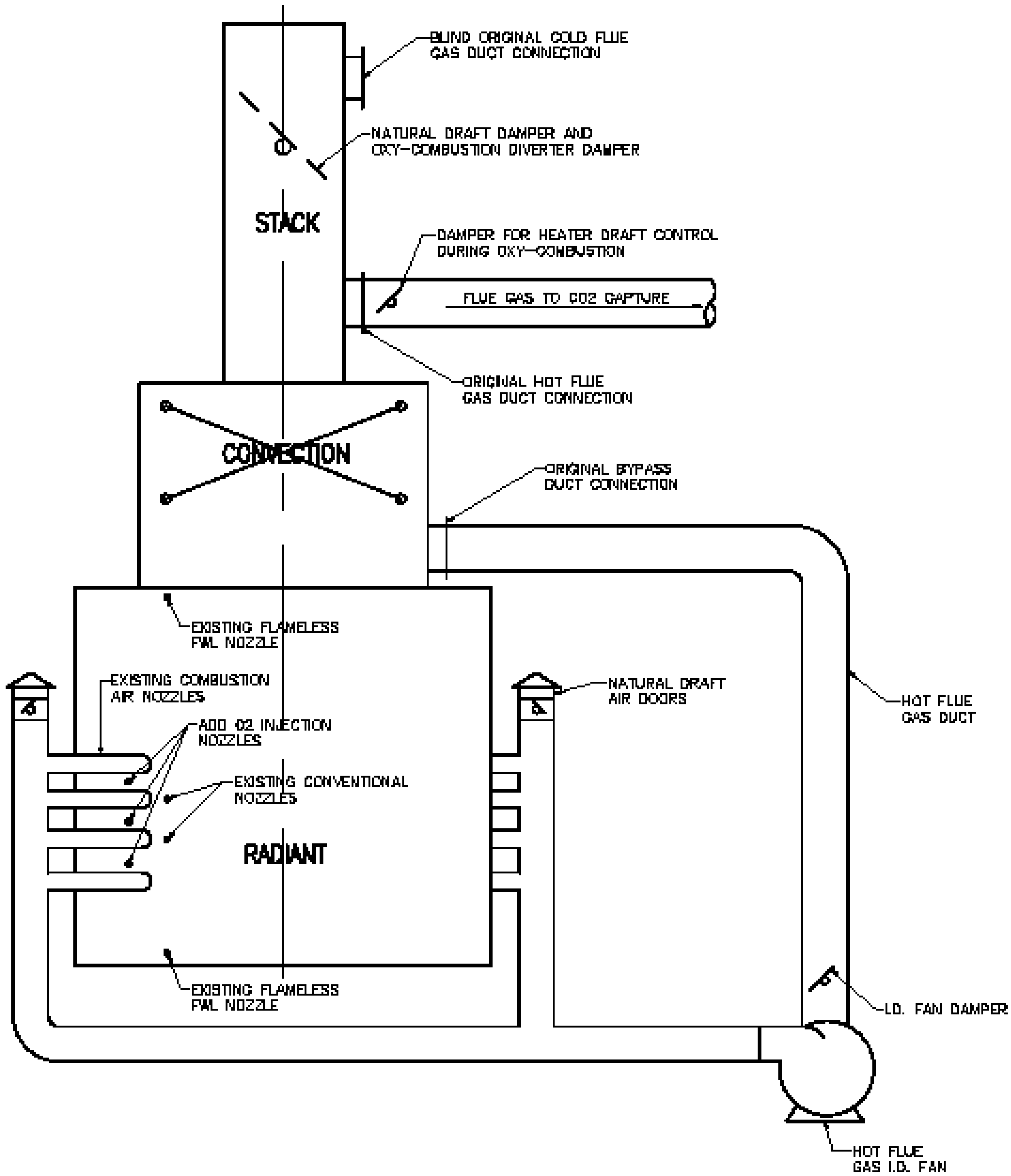
1) Addition of (3) oxygen injection nozzles between the existing combustion air nozzles on each FNG.
2) Utilize the hot flue gas duct connection in the stack to connect to the hot flue gas transfer duct. This would transfer the flue gas to the CO_2 recovery system: refrigeration, separation and ultimately carbon capture and sequestration.
3) Removal of the air preheater and fans and modification of the air-preheat system ductwork. Replace with a hot induced draft (ID) fan to recirculate hot flue gas back into the heater through the combustion air nozzles.

These items are the only modifications required to convert the current flameless heater design into an oxy-flameless heater.

Start-up would be on natural draft, conventional firing, and gradually bringing on the oxygen injection. Once the heater is up to rate with excess O_2 around 3% and temperature permissives met, the heater can be transitioned into staged firing and then on to flameless firing in the same manner as the typical flameless heater operation.

Hot flue gas is recirculated from the stack back through the existing combustion air nozzles. This provides for both of the flameless temperature permissive requirements and maintains the circulating flue gas volume needed for flameless firing operation. Oxygen is injected through nozzles located between the existing combustion air nozzles. The oxygen jets entrain furnace gases and then diffuse with the fuel gas from the flameless nozzles.

Figure 1. Oxy-Flameless Heater



Flameless combustion is still very advantageous even with oxy-combustion. Obviously, NO_x is not a concern with oxy-combustion as the primary source of nitrogen has been eliminated from the combustion process.

However, the other significant advantages of flameless combustion still apply. They are as follows:

1) Uniform heat flux to a double fired coil.
2) Large holes in the gas tips, reduces plugging.
3) Elimination of flame impingement on process coil.
4) Elimination of hot gas impingement on process coil.
5) Cooler tube metal temperatures.
6) Longer tube life.
7) Extended run lengths.

PREDICTED PERFORMANCE

Without the nitrogen in combustion air contributing to NO_x formation, the expected NO_x would be 0-1ppm, NO_x being generated only by the pilots.

Additionally, without having to heat the volume of nitrogen from the combustion air, the heater efficiency is increased when compared to air combustion (reduction in stack losses).

Table 1. Oxy-Flameless Heater Predicted Performance

	Traditional Heater	Flameless Heater	Oxy-Flameless Heater
Excess O_2, %	3	3	3
NO_x, ppmvd	31	4-8	0-1

OXYGEN ENHANCED FLAMELESS COMBUSTION

As an intermediate step between standard flameless combustion and 100% oxy-flameless combustion, oxygen enhanced flameless combustion can be utilized to achieve NO_x levels of 3-4ppm in order to meet a required NOx guarantee of 5ppm. By designing the heater system to operate with up to 50% oxygen injection, the user can “dial in” the required NO_x based on the operating condition while minimizing the amount of oxygen consumption. In addition, efficiency is increased and therefore firing rate is decreased for the same amount of heat absorption to the process. Table 2 presents comparison data for NO_x in ppmvd and lb/MMBtu higher heating value (HHV) for both standard flameless combustion and 50% oxygen enhanced flameless combustion for equivalent process heat absorption.

Table 2. Oxy-Enhanced Flameless Heater Predicted Performance

	Flameless Heater	50% Oxy-Enhanced Flameless Heater	100% Oxy-Flameless Heater
Excess O2, %	3	3	3
NOx, ppmvd	4-8	3	0-1
Nox, lb/MMBtu (HHV)	0.0106	0.0021	0.0000

The operating cost for oxy-enhanced combustion can be minimized by simply adjusting the amount of injected O_2 to achieve the required NO_x level. Because oxygen injection will improve the heater efficiency, we must also consider the energy savings from reduced fuel gas firing. Table 3 shows an estimated net cost for 93% pure oxygen injection system based on the cost of oxygen less the fuel savings along with NO_x on a lb/MMBtu (HHV) basis.

Table 3. Oxy-Enhanced Flameless Heater Operating Cost

Design Basis:	3% O_2 (dry) in flue gas; 300°F Stack Temp.								
Mass % Combustion Air	O2 Injection, lb/hr	Fired Duty, MMBtu/hr (LHV)	Reduction of Heat Release, MMBtu/hr (LHV)	Efficiency (LHV), %	Fuel Savings, $*	Cost of O2 Inj, $ **	Net cost of O_2 Inj, $ per fired duty (LHV)	NOx, ppmvd	NOx, lb/MMBtu (HHV)
100	0.00	1	0	90.9	$0.000	$0.00	$0.00	8	0.0106
90	21.12	0.995	0.005	91.4	$0.022	$0.74	$0.72	7	0.0084
80	38.90	0.990	0.010	91.8	$0.039	$1.36	$1.32	6	0.0064
70	56.72	0.986	0.014	92.2	$0.056	$1.99	$1.93	5	0.0048
60	74.21	0.981	0.019	92.7	$0.078	$2.60	$2.52	4	0.0033
50	91.62	0.976	0.024	93.1	$0.095	$3.21	$3.11	3	0.0021
$4.00	* basis for fuel gas, $ per MMBtu/hr (LHV) fired duty								
$70/ton	** basis for 93% O2								

SUMMARY

Plan ahead for CO_2 capture without any additional cost at this time, and with minimal modification costs in the future. A Great Southern Flameless heater is ideally suited for combustion with air or oxygen. If the requirements for CO_2 capture are put into place, a simple retrofit of the flameless heater will ensure compliance with both CO_2 and NO_x regulations. As an interim step, Great Southern Flameless' oxy-enhanced flameless heater is a viable option for meeting near term NO_x requirements. The oxy-enhanced or 100% oxy-flameless heater is simple, safe, reliable, and economical.

REFERENCES

1. Gibson, W.C., U.S.Patent 8,128,399, 2012

2. Gibson, William C.; Zimola, Marianne, *The World's First Flameless Crude Heater,* AWMA 2014, June 224-27, 2014. www.GreatSouthernGroup.com