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Eco-Friendly Regenerative Burners: Global Effects & Significance

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Abstract: It's time to confront the reality of our changing environment-our earth. The earth's global temperature is on a rise and this due to our human race. Global emissions break down into sectors like agriculture, industry, energy, land use, forestry and transportation. Various studies have been able to rank top greenhouse emitting countries around the globe which includes Saudi Arabia, Republic of Korea, United States, Canada, China and Australia.The industrial sector accounts for about 21% of the global greenhouse gas emissions. In this paper, we will discuss about the regenerative burner heating system which employs High Temperature Air Combustion technology (HiTAC) in High Temperature Burners (HTB) and High cycle Regenerative System (HRS) using the highly efficient honeycomb regenerator. When the temperature of preheated air is over 650°C and that of the furnace 1250°C, we can significantly reduce nitrogen oxides emission (NOx) up to 4 times. We will also analyze various heat transfer processes, fuel saving, commutation cycle using a numerical model. A detailed study of the advantages of using this system, $N0_X$ and CO_2 emitted, thermal efficiency, product quality and output of the system are also done. The difference this new system has done to the global environment is quite notable.

Index Terms—Global warming, High Temperature Air Combustion (HiTAC), High Temperature Burners (HTB), High cycle Regenerative System (HRS), greenhouse gas, NO_x emission reduction, highly preheated air combustion technology.

1. INTRODUCTION

As we all know, global warming is an on-going heating of our earth that was observed from the pre-industrial period till date. These activities result in rise of greenhouse gases trapping heat. Heat increases environmental temperature. An international agreement was taken up by several developed countries on 9th of May, 1992 named UNFCCC. It was effective from 21st March, 1994. The UNFCCC intention was to balance greenhouse gas concentrations in the air which will resist the alarming anthropogenic interference with the environment. Even though, the treaty was signed the global emissions of all countries were still on a rise. At a later stage, the Kyoto Protocol came into effect on 16th February, 2005 and it was developed to meet the objective of the UNFCCC by developed countries having different capabilities to fight climate change. This protocol is applicable for various greenhouses gases like Sulphur Hexafluoride (SF_6), Carbon

Dioxide (CO_2), Per fluorocarbons (PFCs), Methane (CH_4), Nitrous oxide (N_2O), Hydro fluorocarbons (HFCs).non linear loads like power computer, induction heater and arc furnace will indirectly contribute the increase the greenhouse gas emission [1] The emission from industries as discussed earlier account for about 21% of the total greenhouse gas emission as represented in Fig. 1. If we use the non conventional resource like solar electric panel the amount of green house gases production can be control.[2] .modern vehicle control technologies also control the toxic gas emission[3]. There has always been a steady rise in the global temperature rise right back from 1936 till date. Since then, we have noticed 1° C rise in temperature. This is evident from Fig. 2. One device that is common to most industries is a heating furnace. We have developed an eco-friendly sustainable regenerative burner heating mechanism. The recovery of heat absorbed from furnace is done by regenerative burners and it is done by heat exchange between the combustion air stored and flue gases present in each regenerator. Now, let's go deeper into each one of the topic.

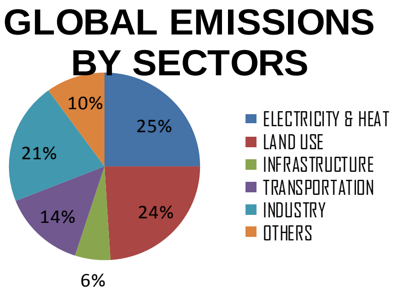

Fig. 1 Global greenhouse gas emissions by various sectors with percentage

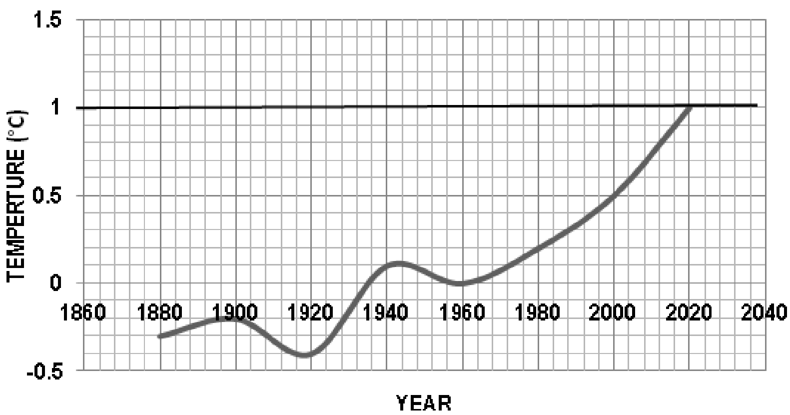

Fig. 2 Global temperature from 1880 to 2020

HIGH TEMPERATURE REGENERATIVE BURNER

Our eco-friendly regenerative heating system is done by an exchange process [4]. Heat transfer happens between flue gases and combustion air. This is illustrated in Fig. 3. When a ceramic honeycomb regenerator is used instead of a ball regenerator, we can bring the preheated air temperature close to temperature of furnace gas. Utilizing this technology has resulted in an extremely efficient Recovery of heat. A honeycomb regenerator is an example of the ideal heat exchanger. Geometrically compared, it has a very large surface area within a honeycomb -

structure. Fig. 4 shows burner capacity measured in MW in a honeycomb regenerator and a ball regenerator which was compared with its weight. Comparatively, it is light weight and also seems exceptional about pressure drops.

A burner with the highly preheated air combustion technology significantly suppresses emission of NO_x that are produced when nitrogen is oxidized in the air. [5] Its generation is based on a few factors like the concentration of oxygen (O_2) and temperature. Two different ways to attain reduced levels of NO_x are either by decreasing the maximum flame temperature or avoiding higher and excessive amounts of oxygen. Fig. 5 is an example of how this can be implemented.

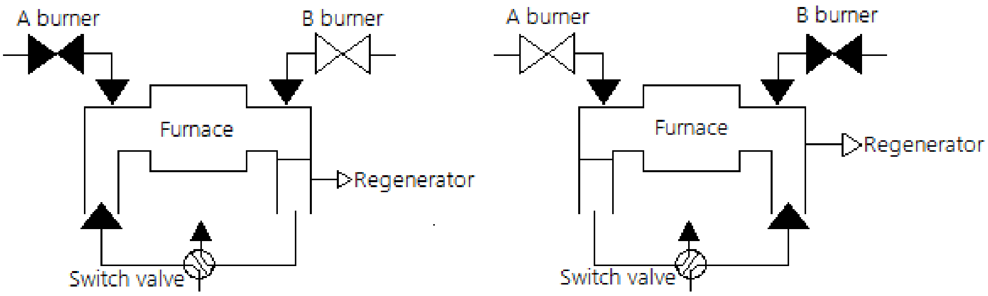

Fig. 3 Regenerative Heating System

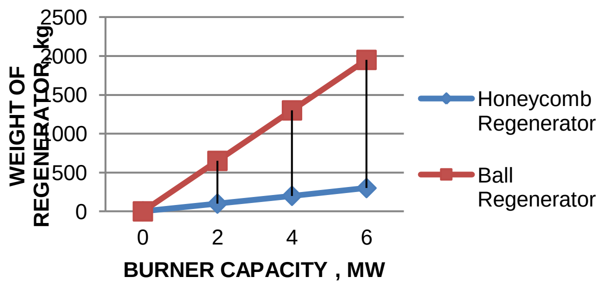

Fig. 4 Burner Capacity Vs Weight of Regenerator

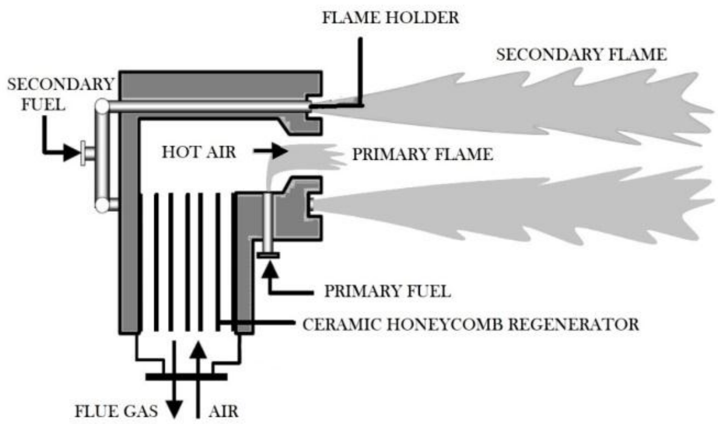

Fig. 5 Highly Preheated Air Combustion Technologies

NO_x FORMATION MECHANISM

NO_x is a most relevant gas for air pollution which is mainly nitrogen dioxide and nitric oxide. Both them being greenhouse gases cause acid rain and smog. Importantly, our main tropospheric

ozone which protects us from UV rays is also affected by these gases. During combustion, three major mechanisms are involved in the nitrogen oxide formation[6] and they are:

A. *Thermal NO_x*

Zel'dovich mechanism explains the formation of NO_x, when nitrogen undergoes oxidation.

The reaction mechanisms are as follows:

$$Dinitrogen\ (N_2) + O \overset{k_1}{\leftrightarrow} Nitric\ Oxide\ (NO) + N \quad (1)$$

$$N + Dioxygen\ (O_2) \overset{k_2}{\leftrightarrow} NO + O \quad (2)$$

where k_1 and k_2 are reaction rate constants. The global reaction is

$$N_2 + O_2 \overset{k}{\leftrightarrow} \mathrm{NO} \quad (3)$$

At fuel rich condition, there is lack of oxygen and new reaction mechanism is involved,

$$N + OH \overset{k_3}{\leftrightarrow} \mathrm{NO} + \mathrm{H} \quad (4)$$

The rate of nitrogen concentration is given by,

$$\frac{d[NO]}{dt} = k_{1f}\,[N_2][O] + k_{2f}\,[N][O_2] + k_{3f}\,[N][OH] - k_{1b}[NO][N] - k_{2b}[NO][O] - k_{3b}[NO][H] \quad (5)$$

B. *Prompt NO_x*

Prompt NO_x formation occurs when nitrous oxide reacts to form nitrogen oxide. This is attributed to N_2 reaction with radicals like C, CH, and CH_2 present in fuel rich conditions. In fuels containing nitrogen, prompt NO_x formation is very small.

C. *Fuel Bound NO_x*

In nitrogen-bearing fuels, during combustion nitrogen is released as free radical and forms N_2 or NO. Roughly about 20% nitrogen in fuels are evolved and released as NO_x[7].

Amidst the above mechanism, thermal NO_x is the most likely to happen in combustion process. Now, this phenomenon is controlled by using our high technology air combustion technology by reason of low resident time, lower concentration of oxygen and average temperature inside chamber. When preheated air is used, an increased efficiency is observed and drastic reduction in NO_x formation. Exhaust flue gases are guided to fresh reactants in chamber, high temperature is thus eliminated.

Consequently, thermal NO_x mechanism ejecting them declined. NO_x formation reduced to 70% when compared to traditional burners.

ADVANTAGES

All advantages are notable due to the main characteristics of HiTAC and HRS. Burners comprising of honeycomb regenerator beds result in the increased efficiency. A decline in NO_x emission due to absence of temperature peaks is also notable. Advantages observed by various users differ. In reheating furnaces where we use open flame technology, we notice a decrease in unit fuel consumption, reduction in loss, improved quality of products; flat heat flux distribution, flat temperature distribution, increased efficiency, low noise, improved productivity, reduced NO_x emission and temperature uniformity were noteworthy. [8]

Advantages were grouped in four major areas and they are:

1. Increased efficiency and decrease in fuel consumption
2. Better quality products
3. Reduction in atmosphere polluting gases
4. Increased life time of machinery

HEAT TRANSFER PROCESS

Gas temperature is distributed uniformly and is homogeneous at t_f and is a very high value to avoid loss of heat through the walls and slab. Heating potential is the energy required for slab heating.. The enthalpy difference of furnace gas temperature, t_f and adiabatic temperature condition is always equal to the heating potential. [4]

Let us consider the furnace gas enthalpy at t_f as H_f. Let H_o be the enthalpy of fuel gas, H_a preheated combustion air enthalpy. Suppose, V_c and V_a as rate of fuel flow for a normal cool air mechanism and preheated air system respectively. The relation between rates of fuel flow at constant total energy input is

$$(H_o - H_f)V_c = (H_o + H_a - H_f)V_a \qquad (6)$$

As $H_o > H_f$,

$(H_o - H_f)$ is heating potential when no preheating system is used.

$(H_o + H_a - H_f)$ is heating potential when preheating system is used.

$(V_c - V_a)$ is the fuel saving.

Now, we will rearrange the equation to get

$$\frac{V_a}{V_c} = \frac{(H_o - H_f)}{(H_o + H_a - H_f)} \qquad (7)$$

From this it is evident that the fuel saving is larger than normally used air. [3]

Now, let us consider two different cases in Fig. 6 and study them. Case 1 is when we don't use preheated air at 300 K and case 2 is when we use highly preheated air at 1570 K. The furnace gas temperature is 1620 K and the heating rate is 1.2 kW for both.

Case 1: Fuel gas at room temperature is delivered at 1 m^3/h (3.24 kW). The ignition temperature of air is 300 K delivered at 2.66 m^3/h (.02 kW). Total input energy is 3.26 kW. 1.2 kW was absorbed in furnace. The rest 2.06 kW was carried by the flue gas at temperature 1620 K.

Case 2: Fuel gas at room temperature is delivered at .47 m^3/h (1.52 kW). The ignition temperature of air is 300 K delivered at 1.24 m^3/h (.01 kW) to the additional regenerator and receives .64 kW. After being passed through regenerator air temperature is 1570 K. Total input energy to furnace is 2.17 kW. 1.2 kW was absorbed in furnace. The rest 0.97 kW was carried by the flue gas at temperature 1620 K. 80% of this gas is introduced into the regenerator. There it loses 0.64 kW and is exhausted to mix with the left 20% at temperature 780 K. Here, energy lost is 0.33 kW. Fuel consumption is less than 50% than the first one.

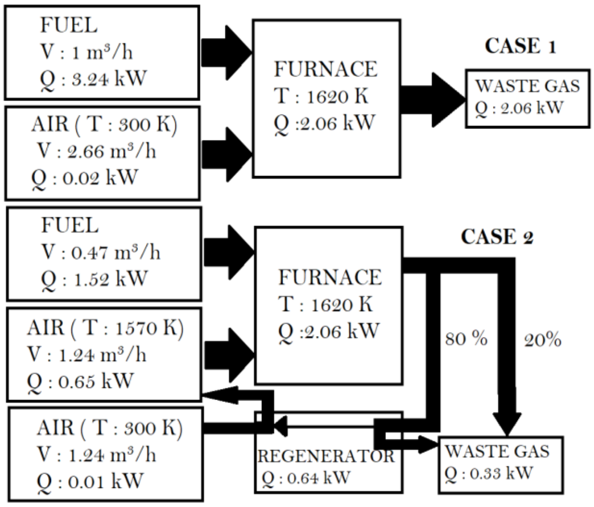

Fig. 6 Case Study for energy calculation

FUEL SAVING & EFFICIENCY

Pollution is not the only factor to be considered. Energy cost also contribute in the production costs in every company product.

The possibility of fuel consumption reduction was explained with the HiTAC technology. The two areas to be considered for fuel consumption reduction are:

1. High efficiency of regenerative heat exchanger
2. Features of HiTAC combustion technology

As the first area, High Regenerative System depends on the HiTAC technology. HRS is used and the energy flux is interchanged between heating charge and flue gases. Two burners work simultaneously. When one is in the firing mode, other is in the regenerative mode. When Burner A works as burner, Burner B draws in the exhaust gas from combustion chamber. They switch functions after a predefined time. The best thermal efficiency is attained when there is a 30 s switching time.

The utilization of a honeycomb regenerator bed over ball regenerator has gained considerable significance. Honeycomb is made up of ceramics. It is highly resistant to very high temperature of exhaust gases. The heat exchanger provides a chance for the combustion air to preheat up to the temperature of flue gases that were sucked during the regenerative mode. A honeycomb is the regenerative medium.

An ideal honeycomb comprises of 100 cells per square inch. These act as an added advantage to the burner. Features of regenerative honeycomb heat exchangers are:

1. High surface area; up to 8 times bigger than ball type regenerator.
2. High heat transfer rate per volume; rate up to 5 times more than the ball regenerator.
3. Low unit weight
4. Switching time is optimum as it is very short and extends for 30 s – highest efficiency is obtained. As switching time decreases, least fluctuation
5. Low pressure drop

These regenerators are highly efficient and results in fuel saving. As in a typical furnace, flue gas temperature ranges between 900 °C and 1100 °C. The preheated air temperature is between 300 °C to 450 °C. Thus, fuel saving happens between 20% to 40%. [9]

The second area is based on features of HiTAC technology. The even temperature distribution is one of the main features of the HiTAC technology. Reduced NO_x concentration and greater lifetime of the equipment are worth mentioning. Refractory lining is stable for a very long time. Due to all these characteristics, the average furnace temperature could be decreased or the capacity increased. Unit energy cost is finally low.

2. FUTURE PROSPECTS

Industrial burner manufacturers have always observed that the eco-friendly regenerative burners are preferred over other burners in the industry. Most of the customers come from various sectors like petroleum, oil and gas, ceramics, iron, steel and automobile industries. There was significant reduction in NO_x emitted and many tests were conducted to prove the same.

Future prospects include extending these features to all other combustion facilities. It includes pulverized coal-fired boilers, high temperature chemical furnaces, and waste burning furnaces. Problem with these burners are that we can't directly apply preheated air technology to them.

We can't constraint its uses to the above industries. We can find replacement for hot air with hot fluid which is utilized in the honeycomb regenerator and provides a better heat efficiency. If this is combined to a chemical reaction, it finds more application.

3. CONCLUSION

Uses of these burners have gone up in the recent years. For each and every different application we have been able to develop different burners with optimum designs. High temperature burners have become significant and indispensable part of industries.

4. REFERENCES

[1] P. Jenopaul, Prakash, R.D. and Raglend, J. 'Design and simulation of phase locked loop controller based three phase unified power quality conditioner for nonlinear and voltage sensitive loads', International Journals of Applied Engineering Research, Vol. 1, No. 2, pp.234–243(2010)

[2] P. Jenopaul, R. Sagayaraj, K. Saravanan, Subiramoniyan S., Tony George. M. Sreedevi. (2021). An Efficient Power Management of Rooftop Grid Connected Solar Photovoltaic System Using Micro FACTS Devices. *Annals of the Romanian Society for Cell Biology*, 2718

[3] Akhil Jose Sreedeepkrishnan, Dileep K Vehicular Adaptive Cruise Control Using Laguerre Functions Model Predictive Control International Journal of Engineering and Technology (IJET)Volume10IssueNo 6 Pages1719 -1730 2018

[4] Shinichiro Fukushima, Yutaka Suzukawa, Toshikazu Akiyama, Yuzo Kato, Akio Fujibayashi, Takeshi Tada Eco- friendly regenerative burner heating system technology application and its future prospects (R) 2002

[5] Dariusz Szewczyk, Jun Sudoh, Artur Swiderski, Bjorn Forsberg Over decade of the industrial experiences in high temperature air combustion applied with HRS regenerative burners, 6th HiTAC, October 17-19, 2005

[6] Yutaka Suzukawa, Syunichi Sugiyama, Isao Mori Heat

transfer improvement and NO_x reduction in an industrial furnace by regenerative combustion system , IEEE, 1996

[7] Zhaokang XU High temperature air combustion energy-saving technologies and environmental characteristics analysis TransTech Publications 2012

[8] T. Dobski, R. Slefarski, R. Jankowski Combustion gases in highly preheated air technology 2007

[9] Seyed Ehsan Hosseini, Mazlan Abdul Wahid, Abuelnuor Abdeen Ali High temperature air combustion International Review of Mechanical Engineering (I.R.E.M.E) Vol.6 July, 2012