The purpose of this paper is to describe the typical concepts of combustion and how in certain applications monitoring and applying proper air/gas ratios can be used to achieve operational efficiencies.

INTRODUCTION

There are numerous concerns related to the increasing costs in the thermal processing industry today. With the globalization of manufacturing creating a hyper competitive environment and increasing cost on all manufacturing processes where energy and labor are involved, every aspect related to efficiency is being reviewed. As energy costs increase the pressure of being more efficient is even more important.

Environmental friendly and efficient use of capital equipment is a key component to addressing the rising costs. Providing a more efficient operation, resource costs decline while output increases. Efficient and environmentally sound operations can be accomplished by taking advantage of technology.

Energy savings related to equipment remains a critical component. Many companies are looking at new technology to continuously improve on operating efficiencies in every aspect of an operation. Controls and technology related to temperature and gas consumption are practices that companies are utilizing delivering very short ROI with current energy costs and environmental concerns. Systems and procedures today can be implemented to ensure that the most environmental friendly and efficient ratio of air to gas are used to combust gaseous fuels and measuring the by-products of the exhaust.

THE TECHNOLOGY

Combustion is the exothermic chemical reaction (a reaction in which heat is given off) of hydrogen and carbon atoms contained in fuels with oxygen. In this reaction, the carbon is oxidized to form carbon dioxide (CO_2) or if insufficient oxygen is available, carbon monoxide (CO). Hydrogen is oxidized to produce water vapor (H_2O). In industrial furnace applications where temperatures of 1000 to 2000 degrees F are used and gas is the source of heat, Natural Gas (CH_4) and air are mixed together. If there is an excess of oxygen present, non-reacted O_2 will be in the products of combustion. Excess O_2 makes heating inefficient, thus requiring more gas for the same results. In addition, excess air also allows for pollutants such as Nitrous Oxide (NO) and Nitrogen Dioxide NO_2. Together NO and NO_2 make up what is typically referred to as NOx.

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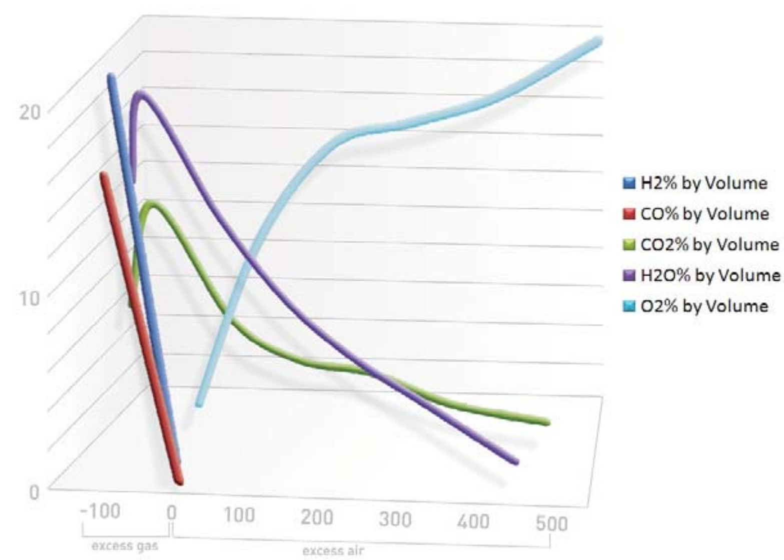
If the process is supplied with too little oxygen, then partially combusted fuel will become part of the exhaust reducing the combustion efficiency and increasing hydrocarbon emissions that lead to smog. The chart below displays the product of combustion when supplying excess gas or excess air.



According to the Department of Energy, most high temperature direct-fired furnaces, radiant tubes and boilers operate with about 10 to 20% excess combustion air at high fire to prevent the formation of dangerous CO and "soot" deposits. It is estimated that precise control of air to fuel ratio will yield 5 to 25% savings in heat generation.

Perfect Combustion (STOICHIOMETRIC) = exact ratio where air and fuel react and all the carbon and hydrogen atoms are combined with all the oxygen atoms.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Common Combustion Practice = 10 to 20% excess combustion air at high fire.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + 2O_2$$

The air gas ratio can be determined by analyzing the flue gas for the excess O_2 present. With this information, the mixture for combustion can be altered to produce the cleanest and most efficient ratio for the process.

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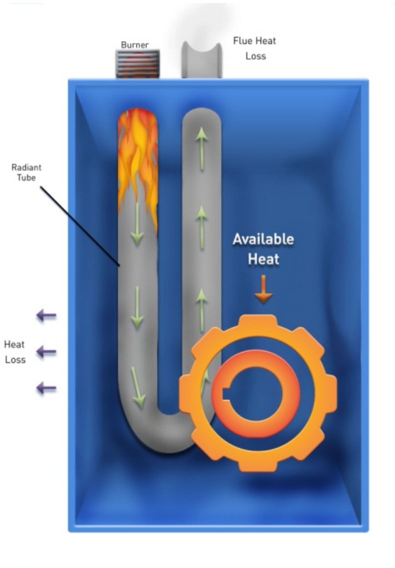
COMBUSTION EFFICIENCY - BENEFITS

% Fuel Savings

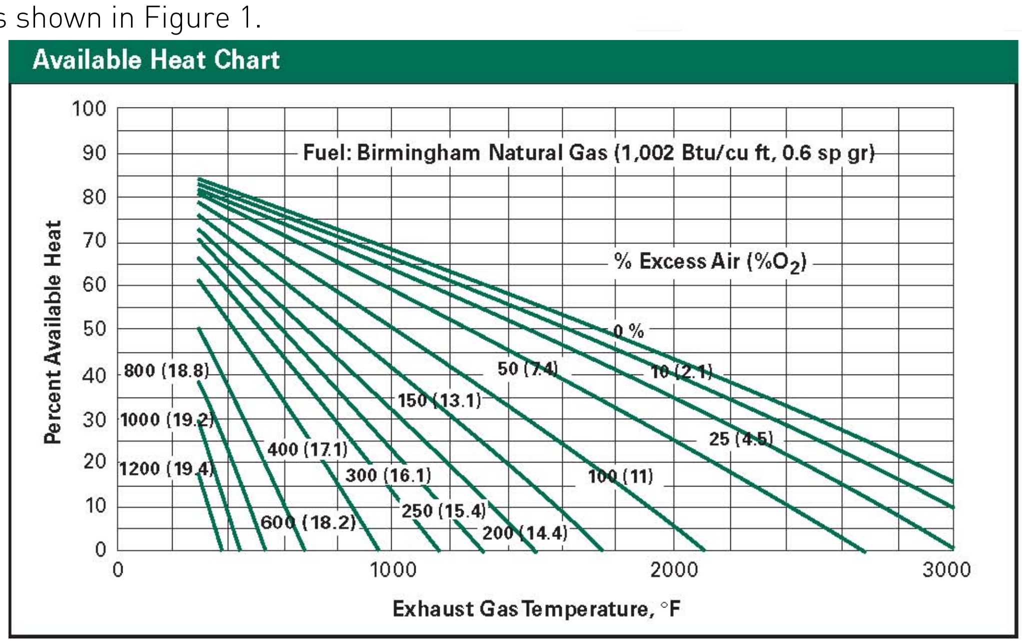


Efficient combustion will yield more available heat. Available heat is the proportion of total heat input to a furnace that is used to heat the parts. The remainder of the heat is lost in the walls, openings and in the exhaust.

An available heat chart is an excellent basis to determine potential savings in a combustion process. To determine the potential savings, you will need the following information:

- Exhaust gas temperature as it exits the furnace, tube, etc.
- % excess air or oxygen in the flue gas (actual)
- % excess air or oxygen in the flue gas (target)

The available heat chart is shown in Figure 1.



Using the chart, determine the percent available heat under actual and target conditions. The intersection of the measured exhaust gas temperature and % excess air (%O_2) curves provides these values.

The potential fuel savings would be calculated as follows:

% Fuel Saving = 100 x ((%AH Target - %AH Actual) / %AH Target)

Increased Load Capacity

Another by-product of creating a more efficient mixture for combustion is the ability to increase the through-put for a furnace. The calculation for the increase requires information about the current excess O_2 and the desired O_2 in the exhaust. A more efficient flame allows for more heat being available to the load leading to a shorter amount of time for the load to get to temperature.

Our studies have shown that a decrease in excess exhaust O_2 from 5% to 2% can reduce the time to get to heat by 31%. Our sample data shows that a consistent load size, starting and ending temperature had a heat up rate of 9°F per minute with 2% excess O_2 versus 7°F per minute at 5% O_2.

To further explore what this means, we can make some assumptions and calculate the potential benefits related to additional load capacity.

If we were to estimate 15 minute savings on heat up time for a 4 hour load we could estimate an increase in the number of loads for a furnace.

Scenario:

A furnace operates 300 days of the year at 24 hours a day and a typical load takes 4 hours. Under current conditions you could estimate 1,875 loads across those 300 days. Using the data of 8.82°F per minute we can save 15 minutes per load based on a beginning furnace temperature of 1135°F and a target temperature of 1600°F. That leaves the possibility of running an additional 117 loads in those 300 days.

The increase in the number of loads is dependent on the length of the cycle, time to heat and start and end temperatures.

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REFERENCES

1. Mr. Richard Bennet, Process Heating magazine, September 1997.

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