# Simulation of Combustion Control by tweaking Air- Fuel Ratio

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***Abstract:***

*Combustion is the most critical process in Gas Fired Boilers. Air-Fuel Ratio is the key factor in enabling a stoichiometric (complete) combustion. In this paper we have improvised the combustion process by continuously adjusting the Air – Fuel Ratio by altering the quantity of inlet air with respective to the Oxygen Content in the Boiler Stack. The optimum Air- Fuel Ratio for Natural gas is identified as 9.53m3 Air to 1m3 Fuel. In most scenarios, a liquid and gas fuel burner achieves this desired balance by operating at 105% to 120% of the optimal theoretical air. This results in an excess oxygen level of 3%. In the combustion zone, it is difficult to measure excess air. In the stack, however, it can be easily measured using Oxygen analysers. When operating with 5%-20% excess air, it would correspond to a 1% to 3% oxygen measurement in the stack. We force the value of an Oxygen Analyser for this purpose which will adjust the Air Ratio with respect to the Oxygen content in the Stack. Simulation of this project is done using SIEMENS TIA software and resulted efficient adjustment of Air-Fuel Ratio with respect to the given Oxygen content in stack.*

***Keywords***

*Combustion Control, Ratio Control, Boiler, Oxygen Analyser, Air-Fuel Ratio*

## 1. Introduction

Combustion is a chemical process in which an oxidant reacts rapidly with a fuel, liberating stored energy as thermal energy, usually in the form of high-temperature gases. In the majority of applications, the oxidant used for combustion is oxygen (O2) in air. Combustion processes have been, are and will be for the near future the prime generator of energy in our civilization. For the sake of the environment and the sustainability of civilization these processes must be well managed. Conventional fuels are comprised of various hydrocarbons, meaning that they consist mainly of carbon (C) and hydrogen (H). Combustion of hydrocarbons produce mainly carbon dioxide (CO2) and water (H2O). For combustion to start, the ignition temperature of the fuel must be reached. Also, the proportions of the fuel and air must be in the proper range for combustion to begin. For example, natural gas does not burn in air concentrations less than 5 % or greater than 15 %. Components before reaction are called reactants and components after combustion are called products. In large scale applications like boilers combustion efficiency plays a vital role in enabling economical operations, safety and eco-friendliness.

## 2. Stoichiometric Combustion

The ideal combustion process during which a fuel is burned completely is called stoichiometric combustion. After stoichiometric combustion all carbon, sulfur, and hydrogen is oxidized and forms only H2O, CO2 and SO2. Stoichiometric air, sometimes also referred to as theoretical air, is the exact amount of air needed for complete combustion. In practice stoichiometric combustion is seldom realized because of imperfect mixing and finite reaction rates. Combustion processes therefore operate with some excess air.

## 3. Excess Air

The term excess air refers to the amount of air in the combustion process that exceeds the theoretical or stoichiometric amount. In practice it is impossible to maintain effective combustion using the exact stoichiometric amount of air. This is due to several reasons, for example the fact that burners are unable to mix air and fuel completely. Each type or design of burner and furnace has a specific optimum level of excess air which often is highly dependent on the type of fuel used. Controlling the amount of excess air is one of the most effective methods for improving boiler efficiency. If the amount of excess air is not correctly controlled however, the result can be severely reduced energy efficiency. The amount of excess air is in fact such an important aspect of boiler efficiency that a generally accepted rule of thumb is that reducing excess oxygen by 1 % results in a 1 % reduction in fuel use.

International Journal of Research
Available at https://journals.pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 08
July 2019

## 4. Air – Fuel Ratio

To improve the percentage of excess air given for combustion it is required to maintain a higher than normal Air percentage in Air – Fuel Ratio. The optimum Air- Fuel Ratio for Natural gas is identified as 9.53m3 Air to 1m3 Fuel. Therefore we target to increase the percentage of Oxygen up by 5.2% using the equation 1.

New Air Ratio = 9.53 + (0.5 X Error %) – (1)

## 5. Auto tweaking of Air-Fuel Ratio

To maintain Air excess by 5.2% short fall of oxygen in the combustion process is identifies by the equation 2.

Error % (from AIC) = (SP of O2- PV from Oz Analyzer) / SP X 100% – (2)

And this error is substituted in the equation 1 to feed the new Air-Fuel Ratio to the controller.

## 6. Simulation

Simulation of the project is done in SIEMENS TIA software with option for the operator to enter desired oxygen content in the stack.

## 7. Results

**7.1 Case -1: Less O2% in stack than the Set point**
Set Point of Oxygen in Stack is given 3%. When the Percentage of Oxygen in Stack is less than the Set point percentage of oxygen quantity of Air to combustion is increased in order to provide excess air for combustion as shown in Figure 1. When a less

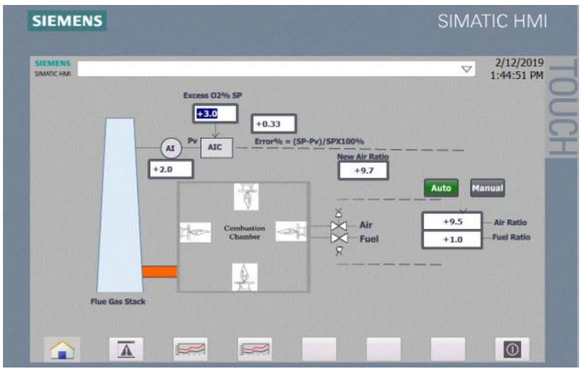


Figure 1. Increase in Air Ratio when percentage of O2 in stack is less than the set point

oxygen percentage is observed in the stack it is indicative that the combustion process is incomplete and much of the fuel is escaping unburnt into the atmosphere due to lack of oxygen in the boiler furnace. In order to provide sufficient Oxygen in the Boiler Furnace Air percentage in Air Fuel Ratio is increased.

**7.2 Case -2: More O2% in stack than the Set point**
At the given set point of Oxygen if the percentage of oxygen in stack is greater than the Set point indicates an inefficient combustion in Boiler. Excess of oxygen results in flaming out in boiler furnace and can be a dangerous condition. Flame out results in accumulation of fuel and air in boiler furnace and lead to explosions when a small spark of sufficient heat is generated. Therefore, controller reduces oxygen percentage in Air-Fuel Ratio as shown in Figure 2.

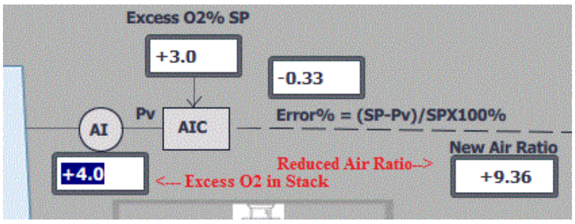


Figure 2. Increase in Air Ratio when percentage of O2 in stack is less than the set point

**7.3 Case -3: O2% in stack is equal the Set point**
At the given set point of Oxygen if the Process Variable is equal to the Set Point then it indicates that there is uniform combustion through out in the boiler furnace and Air-Fuel ratio is maintained constant as shown in Figure 3. For every 1m3 of Natural gas 9.53m3 of air is given for combustion. Any change in oxygen content in stack will adjust the air quantity by the controller automatically.

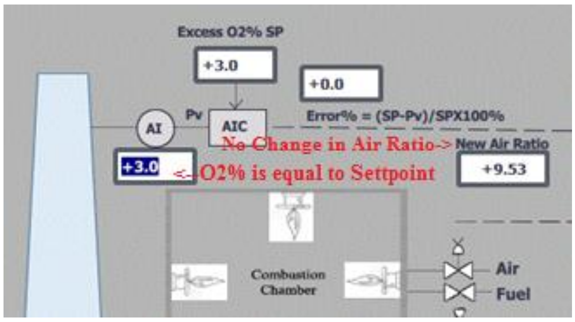


Figure 3. Constant Air Ratio when percentage of O2 in stack is equal to the set point

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