*Journal of Mechanical Engineering Research and Developments*
*ISSN: 1024-1752*
*CODEN: JERDFO*
*Vol. 43, No. 4, pp. 367-371*
*Published Year 2020*

# Thermal Behavior of Up to Down Vertical Flame Using Iraqi (LPG) As Fuel

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ABSTRACT: As the Iraqi natural gas is one of the main combustion fuels used throughout Iraq for the Electrical power generation by the thermal system, and in order to improve the combustion process and thermal behavior of the flame inside of boilers, a mathematical simulation for a cylindrical combustion chamber with an internal diameter of (510 mm) were performed. Thermal distribution was performed for 5 flame models where the Iraqi liquefied petroleum gas (LPG) fuel is injected through the nozzle with variable diameters (5-26 mm). The current study shows the effect of the thermal distribution inside the combustion chamber on the exhaust gases temperature when the fuel ejected up to down inside the vertical combustion chamber. The flame length affected by the variations in the nozzle diameter where the flame length is directly related with the nozzle diameter.

KEYWORDS: LPG, Thermal behavior, Combustion chamber, Flame, Nozzle diameter.

## INTRODUCTION

Boilers are very widely used in industrial processes by converting the internal energy of the fuel to thermal energy for steam and electric power generation. Due to escalating cost of fuel, boilers must be operated as near to optimum conditions as possible. Therefore, efforts can be made to improve efficiency of the boilers by modification of the flame length. The heat produced from burning process in the combustion chamber of the boiler is a function of several variables. One of those variables is the hot gases temperature resulted from chemical reaction. In fact, the boilers work to transfer the heat from the combustion products to the working material which is often water. There are two terms used frequently with this process the first one is upper calorific value which represents the heat got from oxidization process of fuel when the combustion products cooled to the temperature of reacted materials.

The second term is the lower calorific value which refers to the heat got from chemical reaction without cooling of the results to initial temperature before reaction. The heat got from the first terms is more than that in the second one, so that; the combustion product cooling will increase heat transfer, which will lead to improve boiler efficiency. The recognizing for the temperature of the flame is very important to understand the conversion of energy and efficiency of combustion [1,2]. The variation and size of the flame depends on several factors such as type of fuel, furnace load, air and fuel supplies, and settings of burner [3,4]. Based on the flame pictures, the flame characteristic parameters, including temperature are quantitatively specified and represent the basic characteristics of the flames under start-up and normal operating [5]. In this research, it could be understood the relationship between flame length and temperature of the products leaving the combustion chamber which gives an idea about the heat get from the combustion process.

Controlling of flame length clearly shown in [6]. One of the main factors effect on temperature of gases leaving combustion space is the flame length. As the flame is long, that mean the temperature of the exhausted products will be higher than in case of short flame because the maximum temperature of the flame happened at the contact foil between fuel and oxidizer (air in this case). This zone in case of the long flame is near to exhausting opens, so that; relatively short time duration for heat transfer from flame to the combustion chamber walls which lead to decrease the boiler efficiency [7]. Computational simulation was performed to understand the combustion and thermal-flow behaviors inside the boiler [8]. The cold flow inside the boiler was simulated to investigate the effect of the boiler height on the temperature distribution [9]. The aim of this research is to focus on the improvements of boiler efficiency by studying the thermal behavior of the variable length flame where the temperature of the products leaving the combustion chamber effected.

MODELLING

This work depends on the results that get from mathematical simulation of combustion in vertical boiler where the fuel ejected up to down using a computer program in which Iraqi Liquefied petroleum gas (LPG) used as fuel [10].

Combustion chamber geometry

The proposed combustion chamber is a cylinder with an internal diameter of (510 mm) and conical entrance. The study is conducted using certificated special Russian program known as plamya (пламя) [11]. The burner installed at the beginning of the conical entrance. It have two channels, the first channels is (140 mm) inner diameter through which the primary air flows into the combustion chamber (10% of the total volumetric flow of air) to prevent flame flying to ensure the continuity of the combustion process [12]. The second channel of the burner is an annular with adjustable directional gates, where the secondary air enter the combustion chamber with an annular motion. Figure 1 explains the dimensions of the combustion chamber and burner.

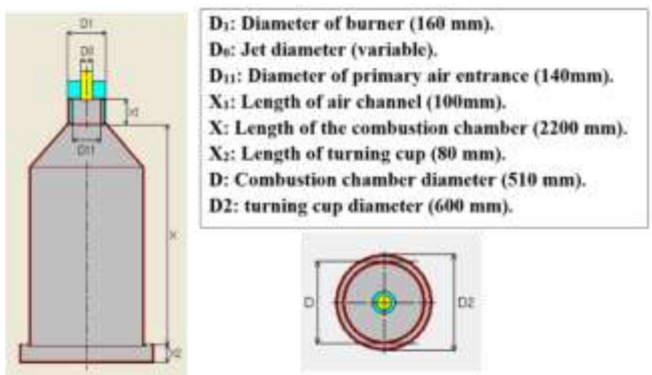


**Figure 1.** Combustion chamber and burner dimensions.

The Iraqi (LPG) is ejected through the nozzle (5-26 mm in diameter) which is installed in the burner center. The injected (LPG) velocity is variable from (340 m/s to 12.6 m/s) depending on the nozzle diameter.

Description of the grid generation

The combustion chamber divided into rounded, radial and longitudinal grids in order to obtain precise results with least possible time for computing.

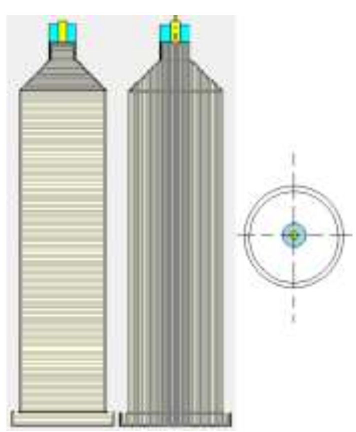

**Figure 2.** Longitudinal, radial and rounded grids.

The longitudinal divisions are 57 elements while the cross-section divisions are 176. The circumference divisions are 4 divisions. The elements are not equal in size in order to reduce the computing time. Figure 2 displays the grids division of the combustion chamber.

RESULTS

The following graphics Figure 3 represents some of selected cases under study because the inserting of the all situations will minimize the size of the graphics which make that not clear. Those graphics are get from the program as results of the temperature distribution inside of the combustion chamber. The first one (A) represents the shorter flame situation while the last (E) is the longest flame chamber. It can be clearly seen that the effect of the flame length on the temperature distribution and temperature of the exiting products and bigger diameter nozzle has the longer flame length, so that; the temperature of the leaving products increase as the nozzle diameter increase. In addition to that, case (A) has the highest temperature near the walls of the combustion chamber compared to other cases as shown in the color gradation in the images of the flames. Accordingly, the case (A) has the highest heat transfer among the other cases and therefore, it has the highest efficiency.

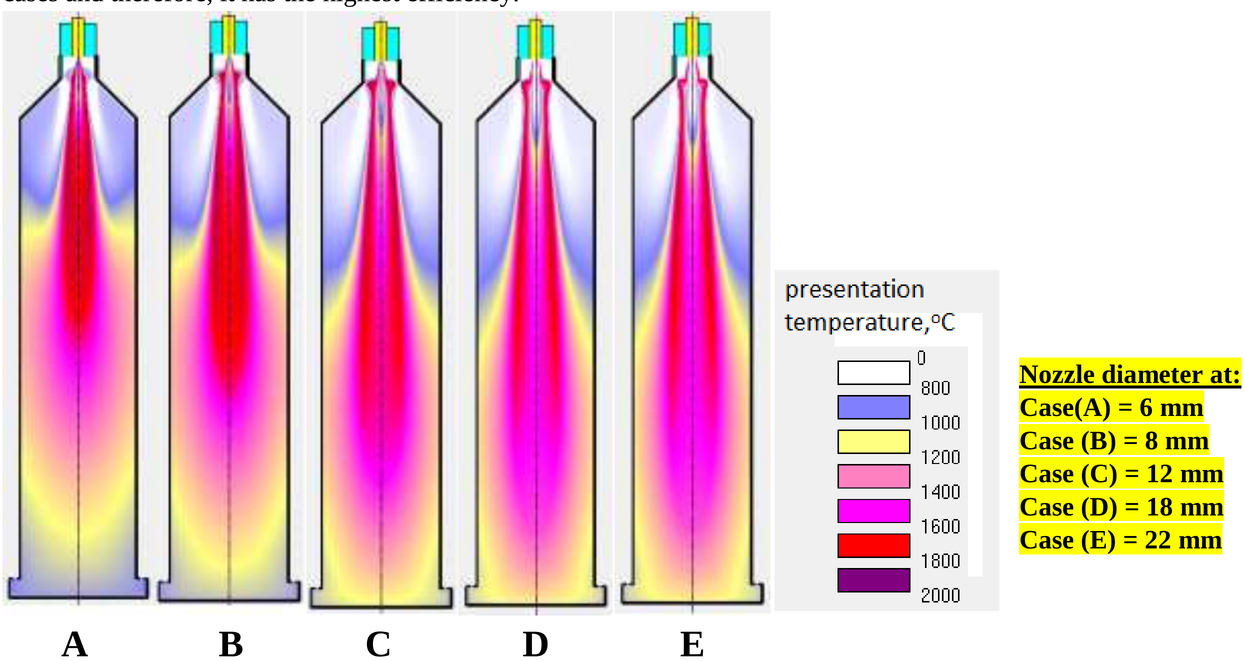


**Figure 3.** Temperature distribution inside the combustion chamber.

The improvement of heat transfer in the boiler is accompanied by cooling the flame. Therefore, the temperature of the exhaust gases gives us information about the perfection of heat transfer in the boiler. In case of efficient transfer of the heat, the temperature of the combustion products will be lower. The relationship between the temperature of the exhaust gases and the diameter of the nozzle is clearly visible in figure 4. With an increase in the nozzle diameter, the temperature of the exhaust gases for this model increase until the nozzle diameter is equal to 15 mm, and then the temperature is approximately constant. According to the results from this study, the smallest nozzle diameter is best in terms of heat transfer efficiency.

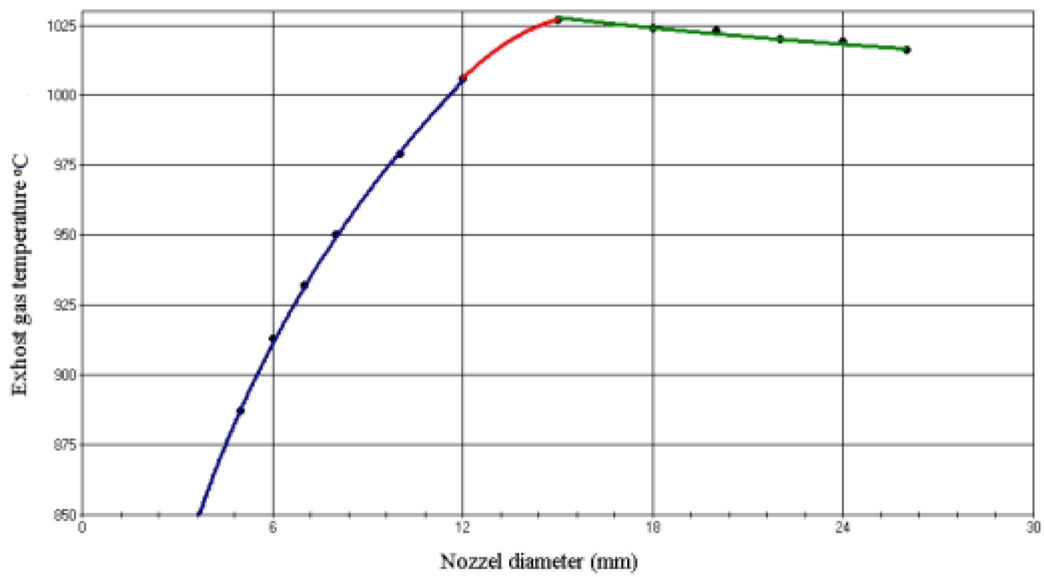


**Figure 4.** The relation between fuel nozzle diameter and temperature of gases that leaves the combustion chamber.

## CONCLUSIONS

In this study, the mathematical simulation of thermal behavior inside of a boiler using LPG as a fuel was performed using a special Russian program known as plamya (пламя). The results provide comprehensive information concerning thermal behavior inside the boiler in case of up to down vertical flame and the following inferences can be drawn:

1. The temperature distribution inside the combustion chamber in case of up to down flame depends on the flame length.
2. The performance of the boiler greatly affected by the flame length controlled by the nozzle diameter which effecting on the temperature of the exhaust gases.
3. In this study, it can be control the heat transfer and the thermal efficiency by the nozzle diameter for constant fuel flow.

## REFERENCES

[1] M. Hossain, G. Lu1, D. Sun, Y. Yan, "Three-dimensional reconstruction of flame temperature and emissivity distribution using optical tomographic and two-colour pyrometric techniques", *Measurement Science and Technology*, Vol. 24, No.7, Pp. 010-074, 2013.

[2] X. Li, D. Sun, G. Lu, J. Krabicka, Y. Yan, "Prediction of NOx emissions through flame radical imaging and neural network based soft computing", *IEEE International Conference on Imaging Systems and Techniques Proceedings*, Vol. 44, Pp. 502-505, 2012.

[3] G. Lu , Y. Yan , M. Colechin, "A digital imaging based multifunctional flame monitoring system", *IEEE Transactions on Instrumentation and Measurement*, Vol. 53, No.4, Pp. 1152-1512, 2004.

[4] J. Smart, G. Lu, Y. Yan, G. Riley, "Characterization of an oxy-coal flame through digital imaging", *Combustion and Flame*, Vol. 157, No. 6, Pp. 1132-1139, 2010.

[5] G. Cugley, M. Lu, Y. Hossain, I. Yan, Searle, "Visualization and measurement of flames in a gas-fired multi-burner boiler", *Journal of Physics: Conference Series*, Vol.1065, No.20, Pp. 202009, 2018.

[6] О. Альмохаммед, В. Кузнецов, "Numerical study of patterns of combustion gas in a vertical boiler", *Вестник Белгородского государственного технологического университета им. В.Г. Шухова*, No. 2, Pp. 163 – 167,

2013.

[7] A. Hamodat, B. Ahmad, A. Al-Saffar, "Free diffusion flame height", *The Third Scientific Conference of Technical Education*, 1992.

[8] R. Saripalli, T. Wang, B. Day, "Simulation of combustion and thermal flow in an industrial boiler", *In Proceedings of 27th Industrial Energy Technology Conference*, New Orleans, Louisiana, 2005.

[9] F. Vidian, W. Permadi, "CFD simulation cold flow inside boiler: the effect of boiler height on temperature distribution", *International Research Journal of Engineering and Technology (IRJET),* Vol.6, No.3, Pp. 29-32, 2019.

[10] A. Abdulla, O. Almohammed, "Computational analysis of flame behavior ejected from up to down inside a vertical combustion chamber of a boiler using Iraqi natural gas as a fuel", *International Journal of Advanced Research (IJAR),* Vol 5, Pp. 1926 – 1931, 2017.

[11] В. Кузнецов, О. Альмохаммед, "Vertical combustion of natural gas", *Промышленная энергетика,* No.11, Pp. 16-19, 2013.

[12] F.A. Williams, "Combustion theory", 2nd ed. California: Benjamin/ Cummings, 1985.