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# Approbation of the algorithm for combustion optimization of a multicomponent fuel with air

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**Abstract.** The article describes the laboratory setup designed to study the combustion of multicomponent fuels, in particular methane-hydrogen fuel, with air. The setup simulates a boiler with a heat exchanger. The results of experimental simulation of the initial combustion regime optimization of propane-butane fuel according to the existing algorithm are developed.

## Introduction

The main fuel in the Russian Federation used in the power generation is natural gas. Due to fossil fuel reserves decrease and global energy consumption increase there is an increasing interest in using alternative fuels such as biogas, syngas and industrial hydrocarbon wastes.

In the Russian Federation there is a problem of effective utilization of petrochemical wastes. High research interest is in finding ways to utilize wastes containing methane and hydrogen. One of the ways to effective utilization these wastes is combustion in boilers. However, these wastes have a variable composition, which varies in time and depend on the processes at the petrochemical plant. The change in waste composition leads to a change of the combustion thermophysical characteristics: heat release rate, temperature and burning rate, composition of the combustion products, etc. Change in thermophysical characteristics lead to the boiler operational instability: blowout, flashback, combustion instability, fuel autoignition, etc.

There are the following methods for optimizing combustion process in boilers:

1. A method for automatically optimizing the combustion process in a boiler [1] based on controlling the air flow rate in order to eliminate carbon monoxide and maintain an optimum concentration of oxygen in the combustion products. The disadvantages of this method are the need to use gas analyzer and preset the optimum amount of oxygen in the flue gases, which is practically impossible in the case of using variable-composition fuels.

2. The method of burning process optimization [2] by measuring the temperature parameters in a flame. Disadvantages of the method are the need to use devices for contactless determination of the flame temperature and highest temperature flame point determining inaccuracy.

3. A method for automatically optimizing the combustion process by calculating the thermal efficiency of the boiler [3], which is determined from the measured values of the heat flow rate from the combustion chamber and the heat flow rate introduced by the fuel into the chamber. The disadvantage of the method is its high inertia, due to the large number of operations.

Common disadvantages of these methods: high inertia, the necessity to install additional equipment, inability to quickly respond to random changes in fuel characteristics.



The authors previously developed a method [4-7] for automatic optimization of combustion process of the variable-composition fuel in boilers. The method maintains the required heat carrier temperature in the boiler with complete combustion of fuel and minimum specific fuel consumption, based only on a change in the outlet heat carrier temperature. Preliminary, according to the developed method, the initial optimal combustion regime is achieved. Based on the change in the heat carrier temperature, the fuel and air flow rates are adjusted to eliminate the fuel underburning and air excess.

For experimental confirmation of method effectiveness, a laboratory setup simulating a boiler was developed. At the initial stage, in the absence of a source of methane and hydrogen, it is planned to conduct studies on the available propane-butane fuel in order to assess the capabilities of the laboratory setup and develop an experimental technique. Also in the experiment, the algorithm for optimizing the initial combustion regime was tested.

### Description of the laboratory setup

The experiments were carried out on a laboratory setup simulating a boiler (Fig. 1). The main parts of the setup are the combustion chamber 12, gas mixer 9, flame holder 10, inspection window 11, chimney 22 and heat exchanger 13. The heat carrier (water) circulates into the heat exchanger by the pump 18. From the tank 19, water at room temperature is fed into the heat exchanger. After heating, water is fed into the tank 20.

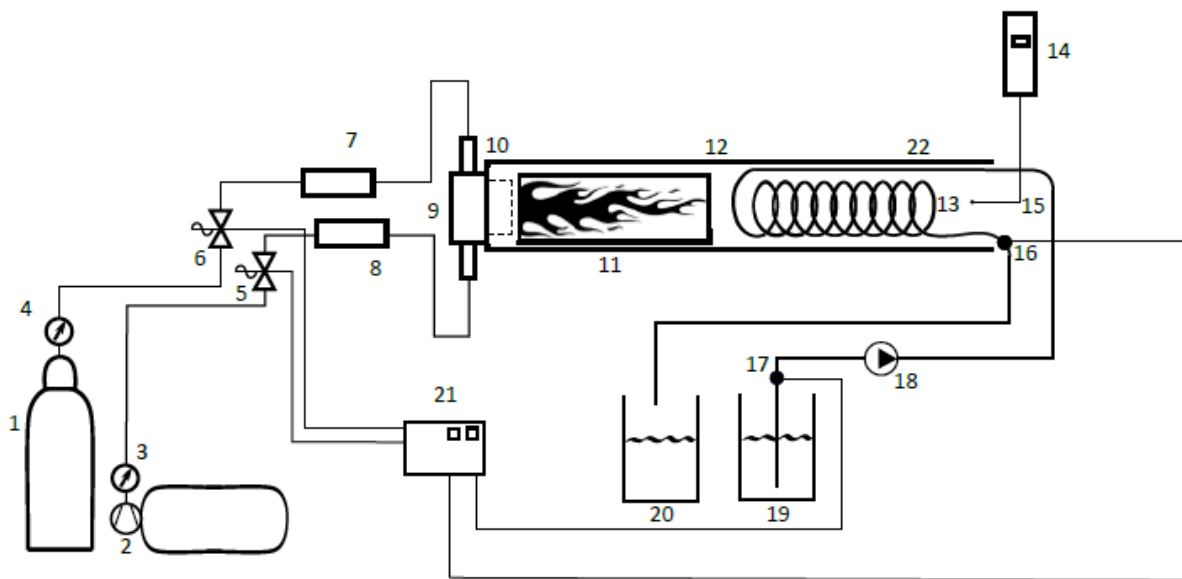


Fig. 1. Laboratory setup scheme: 1 – propane-butane tank; 2 – air compressor; 3,4 – manometer; 5,6 – gas valves; 7,8 – flow meters; 9 – gas mixer; 10 – flame holder; 11 – inspection window; 12 – combustion chamber; 13 – heat exchanger; 14 – exhaust gas analyzer; 15 – analyzer probe; 16,17 – thermocouples; 18 – water pump; 19,20 – water tanks; 21 – controller (Arduino); 22 – chimney.

### Experimental procedure

The experiment was carried out according to the algorithm [8-10], based on finding the optimal fuel-air ratio by recording the change in the heat carrier temperature at the output (fig. 1) and consisted of two parts.

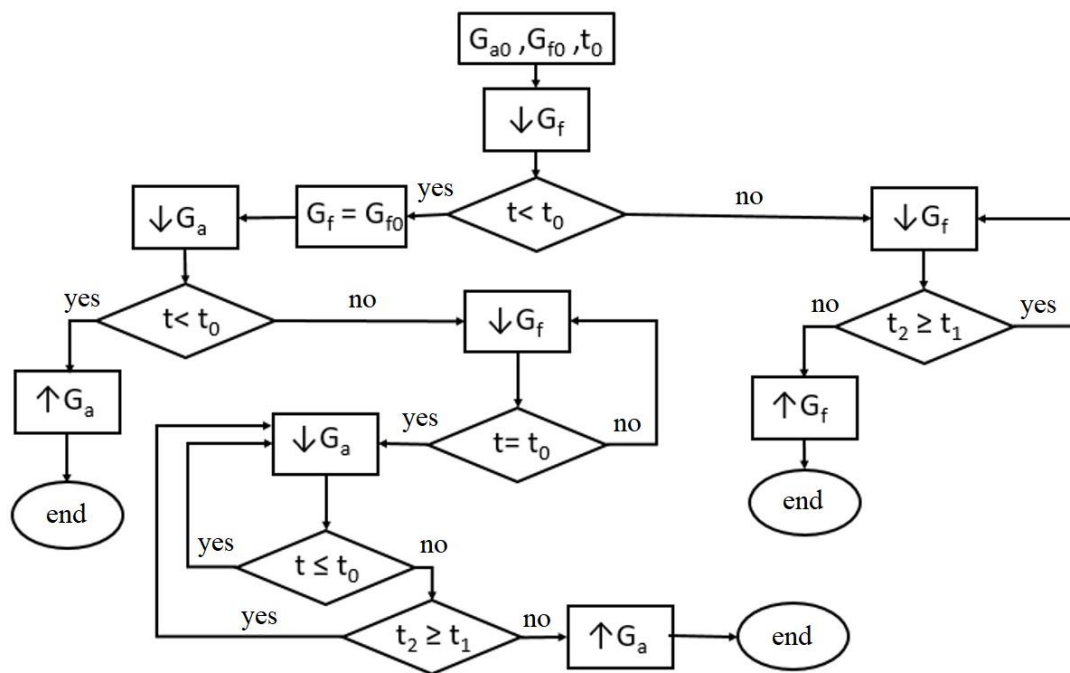


Fig. 2. Block diagram of the optimization algorithm, based on the nature of the change in the heat carrier temperature at the outlet

In the first part of the experiment, a fuel-air mixture is feeding to the laboratory setup with excess of air. The optimal combustion regime is determined by reducing the air flow rate  $G_a$  at constant fuel flow rate until the temperature of the water begins to decrease. Thus, the optimum combustion regime is achieved at the maximum temperature extremum.

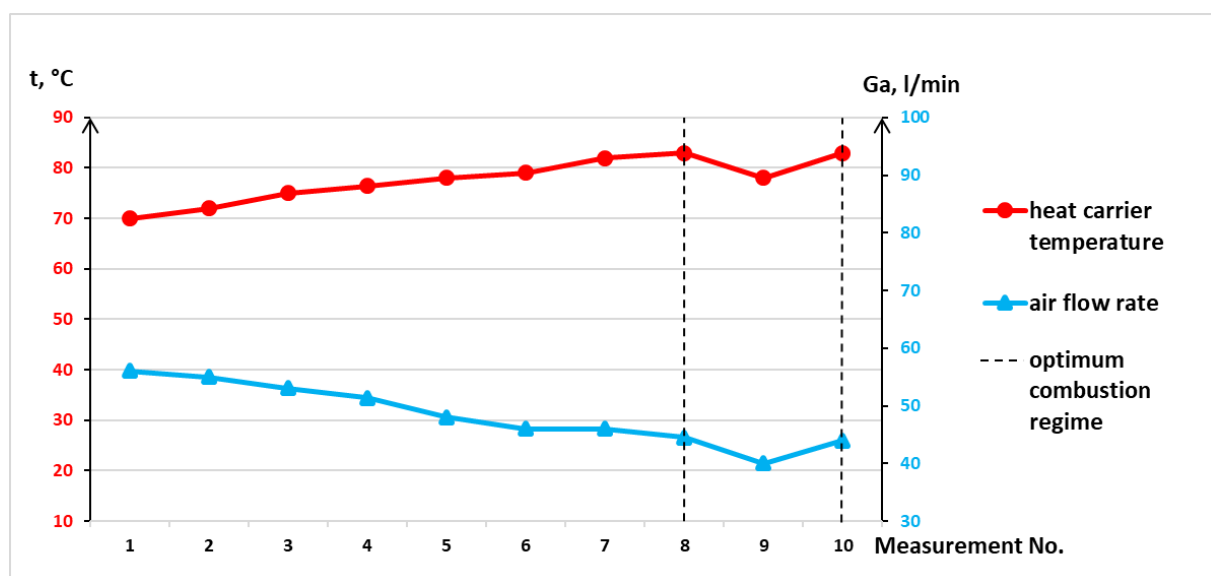


Fig. 3. Achieving the optimum combustion regime in case of excess of air

In the second part, the fuel-air mixture is feeding with an excess of fuel. To determine the optimal combustion regime, according to the algorithm, it is necessary to start reducing fuel flow rate  $G_f$  at

constant air flow rate until the water temperature decreases. After decreasing the water temperature, it is necessary to return the previous fuel flow rate to achieve optimum combustion regime.

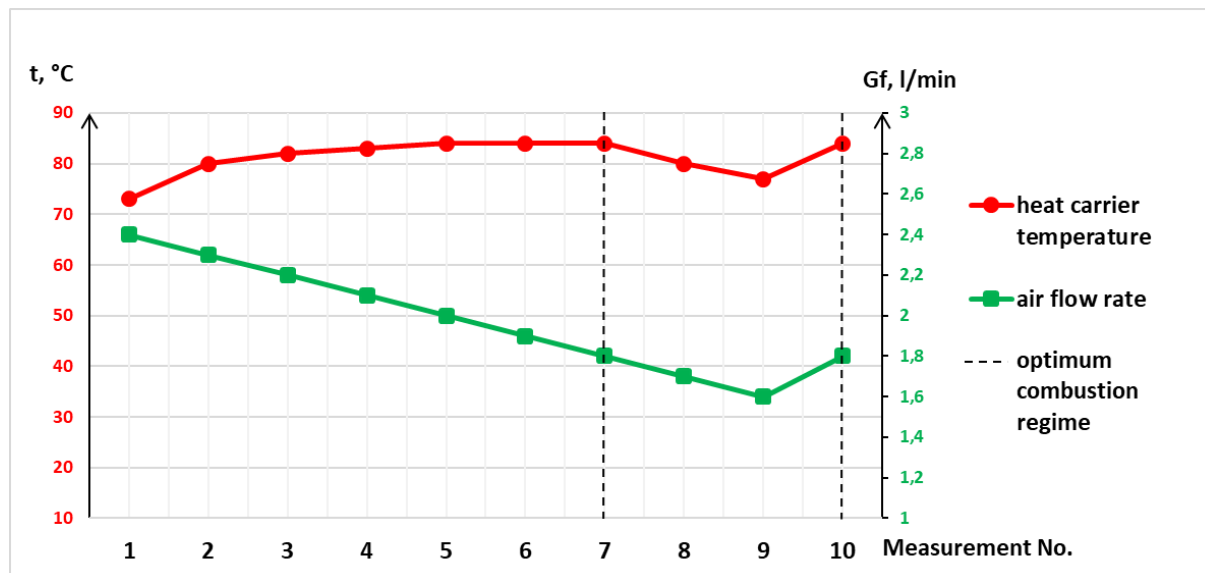


Fig. 4. Achieving the optimum combustion regime in case of excess of fuel

## Conclusion

A laboratory setup simulating a boiler was created. The setup will allow studying the combustion process of variable-composition fuel in a stable mode.

The results of the experiment confirmed the previously developed algorithm for optimizing the combustion process in boilers, based on an analysis of the change in the heat carrier outlet temperature, in the case of a non-optimal initial fuel-air ratio.

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