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Using modern technology to analyze the process of heat-and mass transfer in the combustion chamber

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Here we present the results of 3D computer modeling of combustion coal-dust in the combustion chamber of the boiler BKZ-75. Calculations performed by the numerical model for the conditions adopted by the organization of the actual process on Shahtynskaya Thermal Power Plant. Carried out in this paper, the research allowed identifying the main patterns of distribution of heat exchange performance in the entire volume of the combustion chamber of the researched boiler and at the exit from it. The authors carried out numerical experiments of 3D computer modeling for describing complex processes of heat and mass transfer. Proposed the numerical methods of solving a system of equations describing heat and mass transfer, and a program package has been developed for solving combustion problems. New computer modeling results of turbulent heat-and mass transfer process received during burning coal-dust fuel in the combustion chamber of the BKZ-75 boiler. The developed technologies will make it possible to exclude inefficient and costly methods of conducting research in the field of fuel-burning energy industry. Numerical modeling including thermodynamic, kinetic and three-dimensional computer modeling of burning low-grade Kazakhstan coal will optimize the process of ignition, combustion and stabilization of coal combustion, and also develop technical solutions for the modernization of existing power plants and for the design of new power boilers.

Key words: combustion chamber, thermal characteristics, numerical modeling, temperature, coal, energy of chemical reactions.
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1 Introduction

Kazakhstan ranks first in the world in terms of specific greenhouse gas emissions per unit of gross external product (GEP) (3.38 kilograms per dollar). This is stated in the strategic plan of the Ministry of Environment of the Republic to 2011-2015 years. The greatest contribution to carbon dioxide emissions makes energy and of energy – coal. At the same time, calculations show that the share of coal in the generation of emissions will increase. It is expected that by 2020 this indicator will be 66% of the total gross emissions from fuel combustion [1-4].

In addition, the rise in prices for primary energy sources such as oil and natural gas, forced to look for alternative, clean coal technologies, which in the foreseeable future will remain the main source of primary energy reserves are in Kazakhstan is very significant [5-7].

With the development of new power units, as well as the transition to alternative and clean coal technologies that use pulverized coal, combustion research processes in order to improve them is extremely difficult [8-11]. To increase reliability and improve the quality of the design more urgent development of methods for calculating the integrated flue devices based on the aerodynamics of the combustion chamber, ignition, heat transfer mechanisms and burn pulverized coal torch [12].

Currently, the only way in the implementation of a comprehensive study of the processes of burning pulverized coal in the furnace boiler industrial facilities (TPP, TPP, and others.) Are the numerical methods and computer experiment using the methods of three-dimensional modeling and the attraction of modern computer equipment computer equipment and software packages [13-14]. Only when using a computer 3D – modeling accounted for the largest number of events and factors influencing the flow of real processes. In addition, this research technique provides high accuracy in predicting the behavior of these factors in the calculations [15-16].

2 Object of research

In this paper, with use of methods of three-dimensional modeling, computing experiments on research of heat exchange characteristics of the combustion chamber BKZ-75 Shakhtinskaya CHP. The authors have developed and applied geometry, physical and mathematical models of heat-and mass transfer and chemical pulverized in inhomogeneous turbulent flows in the combustion process of pulverized coal in the combustion chamber of the power boiler.

When developing the above models the entry and boundary conditions reflecting the real physical and technological processes happening in the combustion chamber of the BKZ-75 boiler of the Shakhtinskaya CHP were used.

Figure 1 shows the geometry of the investigated power boiler furnace:

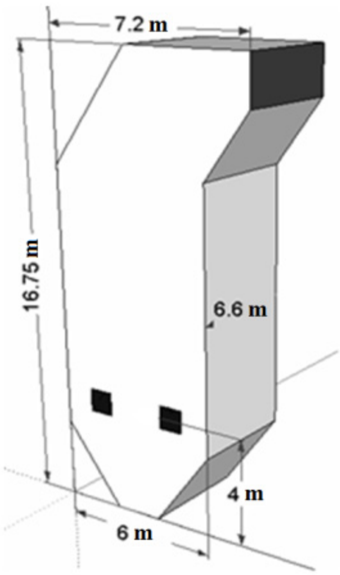


Figure 1 – General view of the combustion chamber

Analyzed in this paper boiler unit block design investigated in this work on the brown and black coal, peat, culm and lean coals, it is a single drum, natural circulation and is made of a U-shaped pattern. The combustion chamber of the boiler BKZ-75 Shakhtinskaya CHP completely shielded pipe diameter of 60 mm and a wall thickness of 3 mm. Pipes of front, rear and bottom of the screen to form a ash hopper [17-18].

For the combustion of pulverized coal combustion chamber of the boiler is equipped with four of the investigated coal-dust burner arranged two on each side wall (figure 2).

For such a design has a direct injection of dust and pulverizing individual system consisting of two hammer mills. Each burner provided with coal from the two mills.

The BKZ-75 Shakhtinskaya CHP burned Karaganda raw coal brand KR-200, 35.1% ash content, volatile 22%, 10.6% moisture content and calorific value of 18,550 kJ / kg. Coal fineness R_{90} = 20% [19].

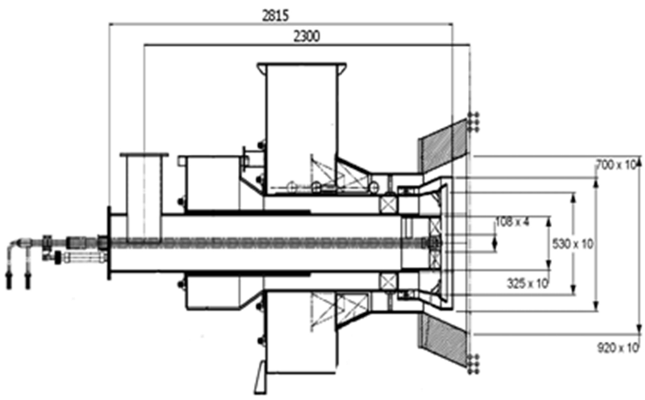
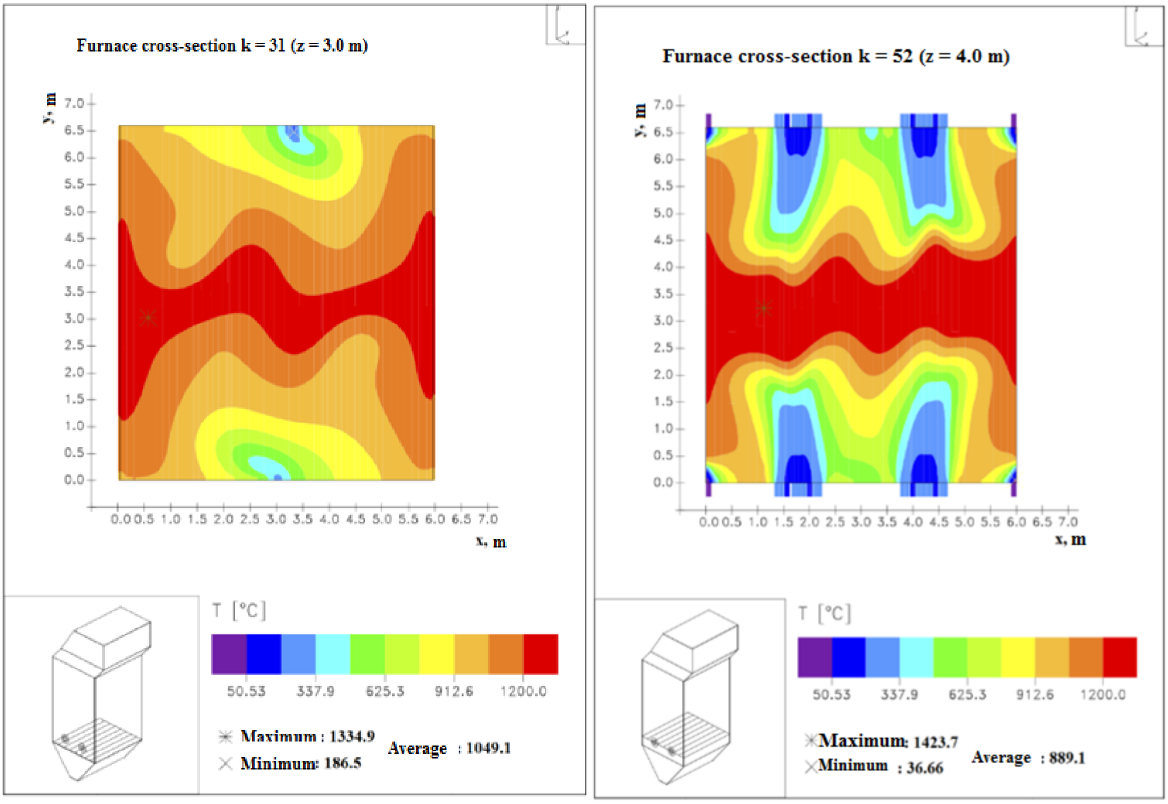


Figure 2 – Coal-dust burner

Used in steam boiler BKZ-75, Karaganda coal of the KR-200 has the following composition: C=43.21%; H_2=3.6%; O_2=5.24%; S_2=1.04%; N_2=1.21%; W^p =10.6%; A^c =35.1% [20].

3 Results of computational experiments

The study thermal characteristics is an important step in the modeling process heat-and mass transfer from the combustion of pulverized coal which allows to determine the temperature of the field throughout the volume of the combustion chamber and his outlet [21].



a) b)

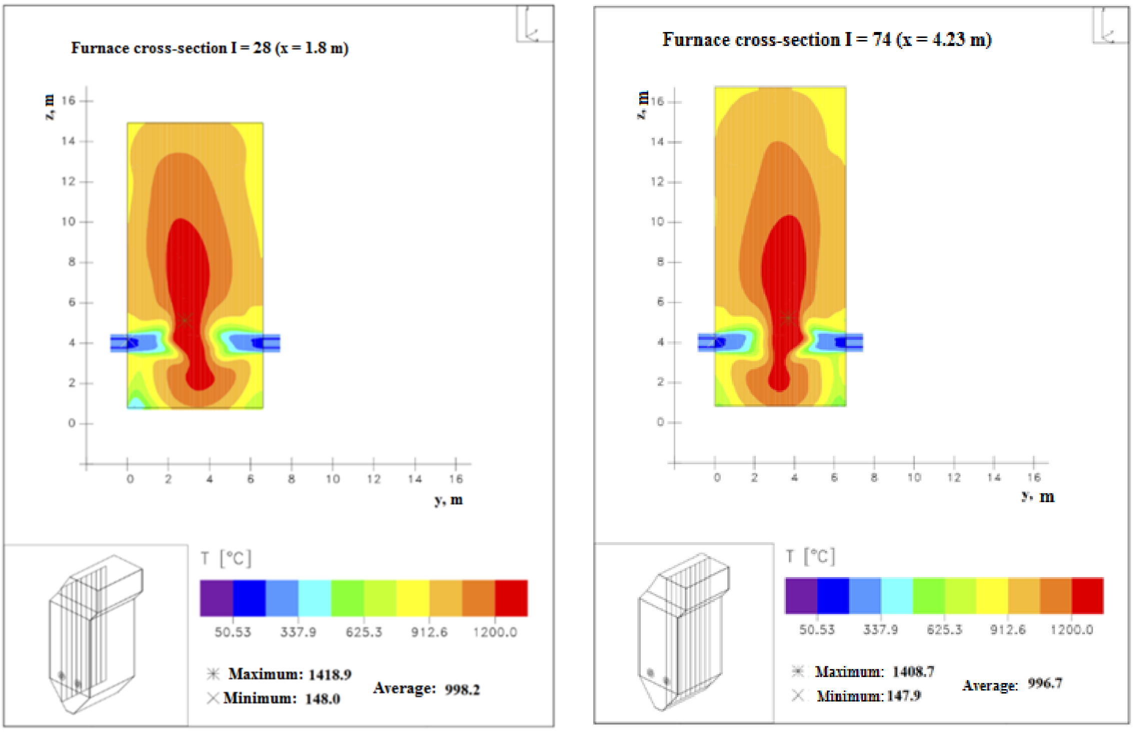
Figure 3 – The temperature distribution in the cross-section: a) ash hopper; b) the installation of burners

Figures 3-6 shows the temperature profiles that characterize the thermal behavior of pulverized coal flow in the combustion chamber. It can be seen that temperature values reach their maximum values in the region close to the location of the burners, as here, by the vortex character of the flow is observed maximum convective transfer.

In places where there is turbulent flow, the temperature is much higher than in the remaining region (Figure 4-5).This proves the fact that the aerodynamic characteristic has a significant impact on the character of the temperature field in the combustion chamber of the boiler [22].

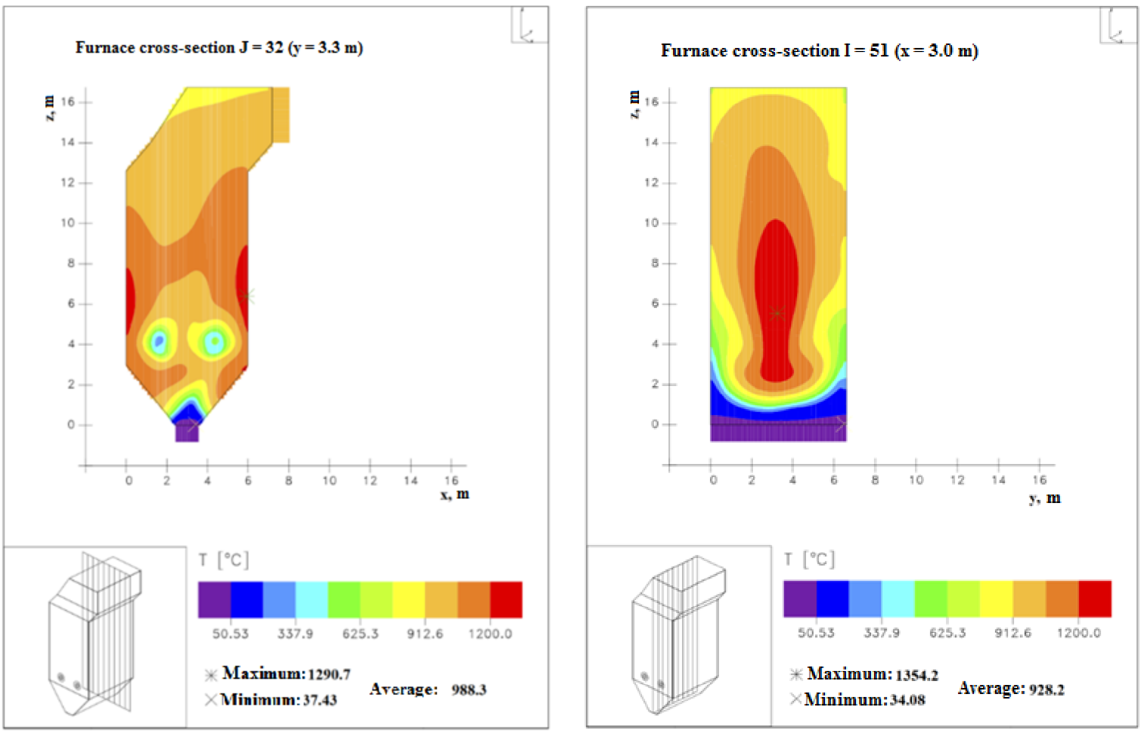
Figure 4 show that the temperature field has a symmetrical profile with respect to the axis of the combustion chamber. It can be seen that the turbulent transport of substance (aero mix) causes the spread of coal-dust flame throughout the volume of the combustion chamber – from the ash hopper to the turning part of chamber of the boiler.

Each chemical reaction occurring in the combustion chamber, accompanied by the release or absorption of a certain amount of energy [23]. Distribution of chemical energy released by the combustion of pulverized coal into the combustion chamber, presented in various cross-sections of the combustion chamber (figures 7-11).



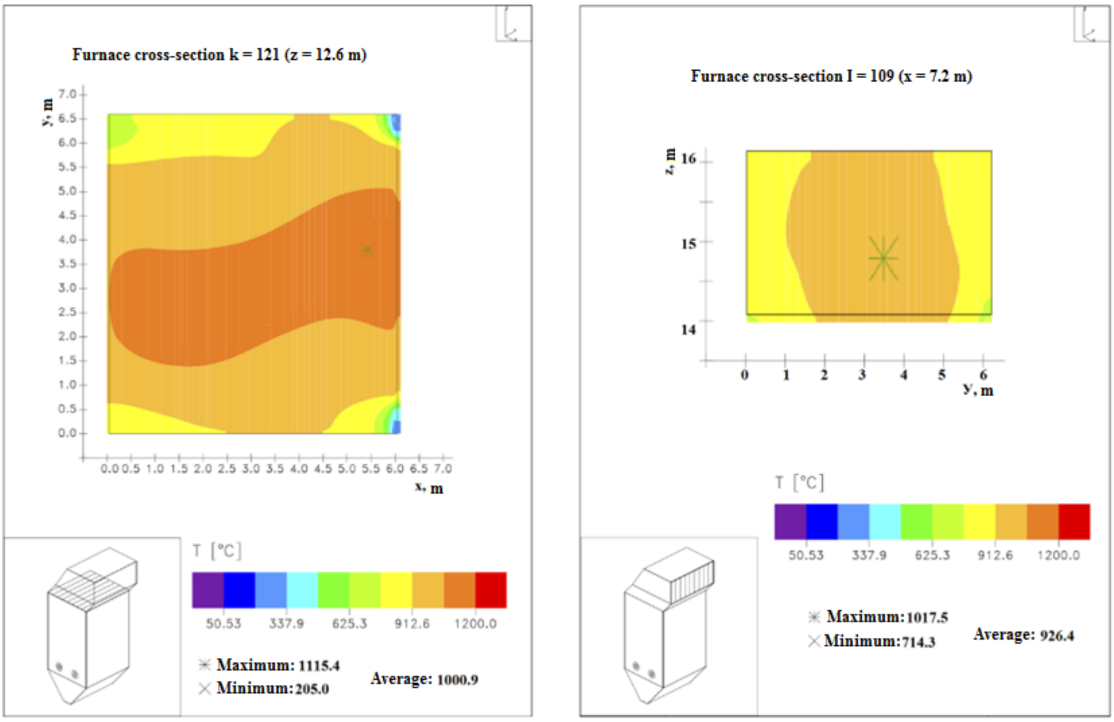
a) b)

Figure 4 – The temperature field in the longitudinal sections of the burners:
a) a first pair; b) a second pair



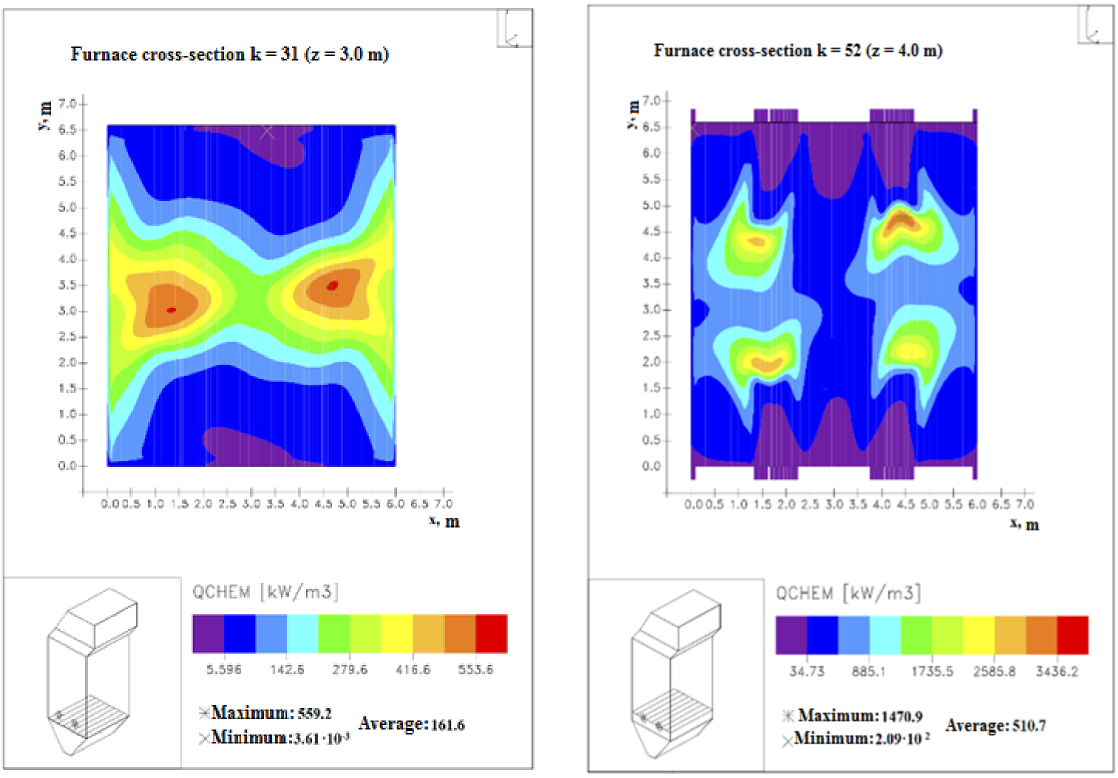
a) b)

Figure 5 – The temperature distribution in the central cross-section
of the combustion chamber: a) a front wall; b) a sidewall



a) b)

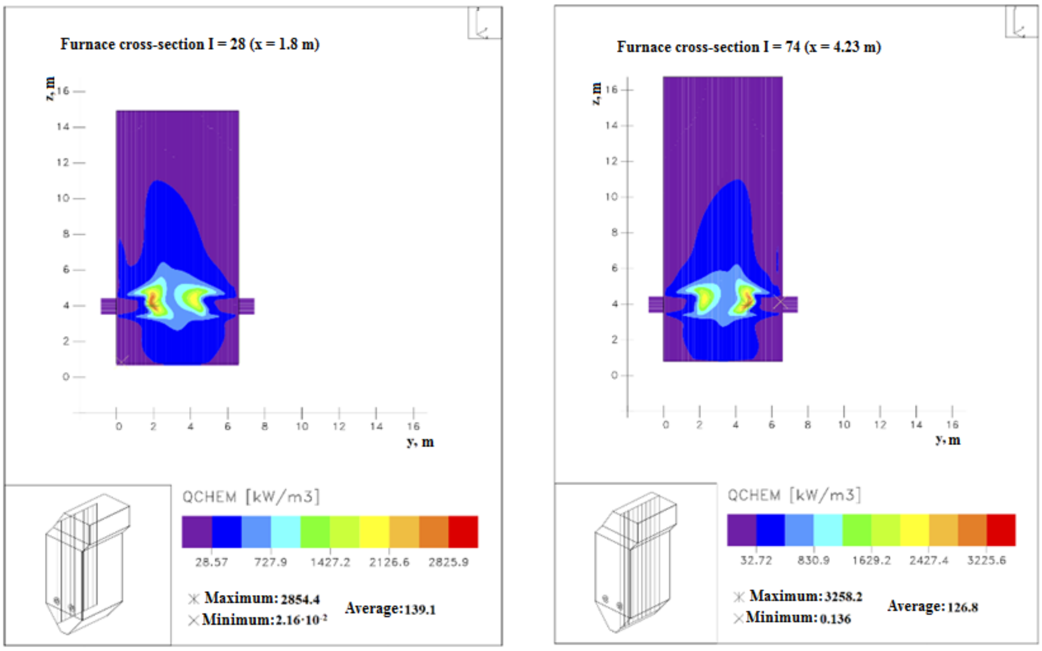
Figure 6 – The temperature distribution in cross sections:
a) the turning part of chamber of the boiler; b) at the outlet of the combustion chamber



a) b)

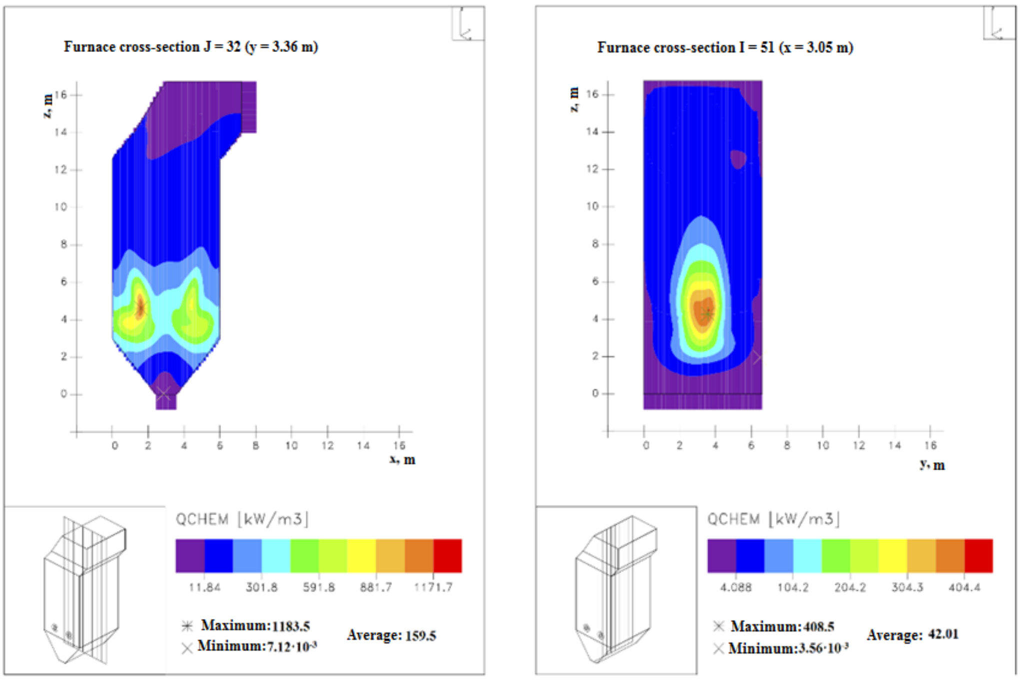
Figure 7 – The distribution of the energy released by chemical reactions in the sections of:
a) ash hopper; b) burners.

From the analysis of figures 7-9, 11 that the chemical reactions with the greatest release of heat occur in the supply of fuel and oxidant, i.e. near the installation of burners. It is in this area observed of a fuel and oxygen in the air reaches its maximum level.



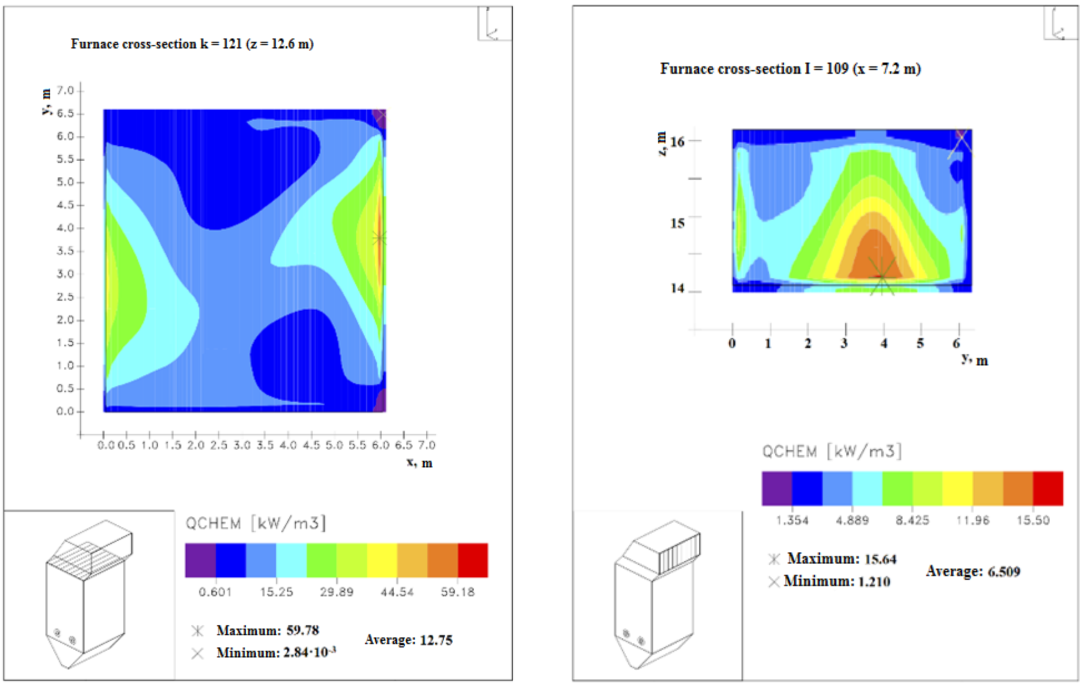
a) b)

Figure 8 – The energy distribution of chemical reactions of burning in the longitudinal section of the combustion chamber near the burner: a) a first pair; b) a second pair



a) b)

Figure 9 – The energy distribution of chemical reactions in the central longitudinal sections of the combustion chamber: a) a front wall; b) a sidewall



a) b)

Figure 10 – The energy distribution of chemical reactions in the cross-sections:
a) the turning part of chamber of the boiler; b) at the outlet of the combustion chamber

Analysis of the figures 10 and 11 shows that as we move pulverized coal flow to the exit, the intensity of chemical reactions course weakens, and the output energy of chemical reactions is only 15.64 kW / m^3, compared with 3470 kW / m^3 in the zone burners. This reflects the real picture of the processes of heat-and mass transfer occurring during the combustion of pulverized coal in the combustion chamber [24].

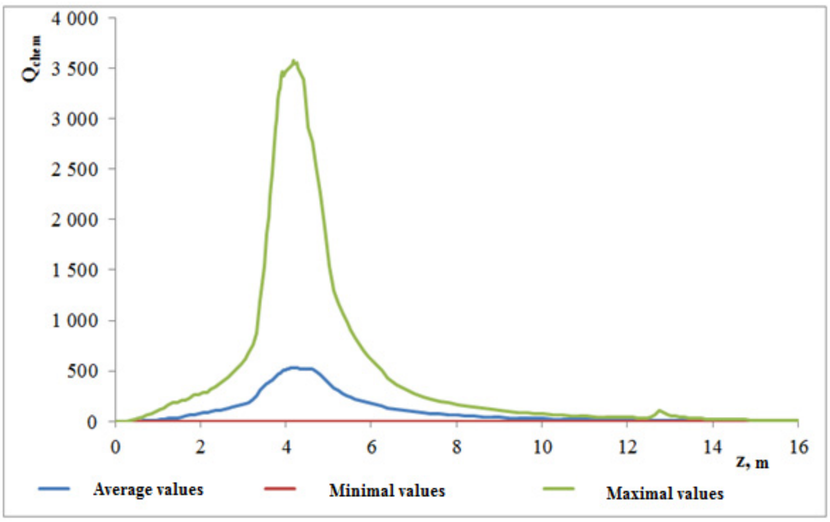


Figure 11 – The distribution of the energy released by chemical reactions, the height of the combustion chamber of the boiler BKZ-75

4 Conclusions

The results of computational experiments lead to the conclusion that the temperature reaches its maximum value in the region close to the location of burners.

Four flame emanating from the burner to form in the center core of high temperature combustion chamber with the combustion temperature ~ 1400 °C. As approaching to the exit of the combustion chamber temperature decreases monotonically, and its output value is ~ 925 °C. In the field of carburetion of combustible substance and oxygen chemical reactions go with the greatest allocation of heat. Besides, in process of coal-dust stream advance to the exit, the intensity of chemical reactions is weakening, and the output energy of chemical reactions is makes all 15.64 kW / m^3, compared with 3470 kW / m3 in the field of belt of torches.

In general, conducted in the computational experiments reflect the real picture of heat transfer processes happening when combustion of pulverized coal into the furnace of industrial boilers, and allow similar experiments with any kind of fuel, and for any boiler of Republic of Kazakhstan.

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