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NEW SCHEME OF CONTROL AND AIR SUPPLY IN A LOW-POWER HOT WATER BOILER

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Abstract

The article presents the state of solid fuel reserves and their share in the world energy sector. The air pollution caused by the operation of heating devices using solid fuels is a significant problem. In order to improve the air quality, heating device producers take constant measures to improve their products. However, the emission results achieved during an initial test of heating devices in the laboratory may be much worse during operation in real operating conditions. The ways of increasing the efficiency of the boiler by improving its design for combustion in full-layer mode are shown. The results of the testing of the improved KBTC-0.2 hot water boiler is presented and the technical and economic indicators are determined, which indicate an increase in the efficiency of the boiler.

Keywords: boiler unit, grate, furnace, coal, ash.

ТӨМЕН ҚУАТТЫ ЫСТЫҚ СУ ҚАЗАНДЫНДА БАСҚАРУ ЖӘНЕ АУА БЕРУДІҢ ЖАҢА СҰХБАСЫ

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Аңдатпа

Мақалада қатты отын қорының жағдайы және олардың әлемдік энергетикалық сектордағы үлесі берілген. Қатты отынды пайдаланатын жылыту құрылғыларының жұмысы нәтижесінде ауаның ластануы маңызды мәселе болып табылады. Ауаның сапасын жақсарту үшін жылу құрылғыларын өндірушілер өз өнімдерін жақсарту бойынша тұрақты шараларды жүзеге асырады. Дегенмен, зертханада қыздыру құрылғыларын бастапқы сынау кезінде қол жеткізілген эмиссия нәтижелері нақты жұмыс жағдайында жұмыс істегенде әлдеқайда нашар болуы мүмкін. Толық қабатты режимде жану үшін оның конструкциясын жақсарту арқылы қазандықтың тиімділігін арттыру жолдары көрсетілген. Жақсартылған КВТС-0,2 ыстық су қазандығын сынау нәтижелері ұсынылып, қазандықтың ПӘК артқанын көрсететін техникалық-экономикалық көрсеткіштері анықталды.

Түйін сөздер: қазан қондырғысы, тор, пеш, көмір, күл.

НОВАЯ СХЕМА УПРАВЛЕНИЯ И ПОДАЧИ ВОЗДУХА В МАЛОМОЩНОМ ВОДЯНОМ КОТЛЕ

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Аннотация

В статье представлено состояние запасов твердого топлива и их доля в мировой энергетике. Загрязнение атмосферного воздуха, вызванное работой отопительных приборов, работающих на твердом топливе, является серьезной проблемой. Для улучшения качества воздуха производители отопительных приборов постоянно совершенствуют свою продукцию. Однако результаты эмиссии, полученные при первоначальном испытании нагревательных приборов в лаборатории, могут быть значительно хуже при эксплуатации в реальных условиях эксплуатации. Показаны пути повышения КПД котла за счет усовершенствования его конструкции для сжигания в полнослойном режиме. Представлены результаты испытаний усовершенствованного водогрейного котла КВТС-0,2 и определены технико-экономические показатели, свидетельствующие о повышении КПД котла.

Ключевые слова: котельный агрегат, колосник, топка, уголь, зола.

Introduction

Among fossil hydrocarbon fuels, coal in the world fuel and energy balance accounts for one third of the world's primary energy and about 40% of the fuel used to generate electricity (Figure 1). At the same time, this energy equipment emits into the environment a huge amount of not only chemical waste but also physical waste in the form of radiation and waste heat, which inevitably causes the atmosphere to warm up [1].

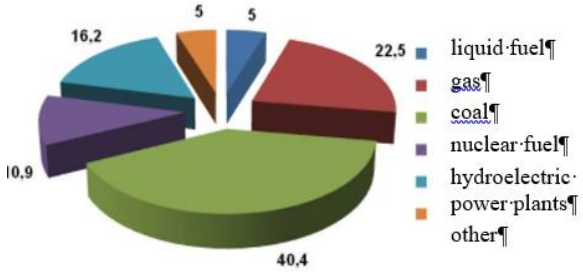


Figure 1. World fuel and energy balance.

Coal reserves in Kazakhstan amount to 35.8 billion tons or 3.6% of world reserves, and the share of Kazakhstan in global coal production is 3.7% [2]. Among the CIS countries, Kazakhstan ranks third in terms of coal reserves and production, and first in terms of coal production per capita. Coal mining companies of the country produced 109.2 million tons of coal in 2020 (website of the Ministry of Foreign Affairs of the Republic of Kazakhstan) [3]. It is easy to calculate that Kazakhstan has enough coal for more than 300 years. Today, 74% of electricity is generated by coal, and, of course, no matter how tough conditions are set at the international level, the state, having such reserves and potential, it is very difficult to abandon coal generation [4]. Therefore, we should look for ways out of this situation.

About 30% of thermal energy is produced by small boiler houses with a capacity of less than 100 Gcal/hour. It should be noted that the technology of layered combustion of solid fuels and the design of boilers with layered furnaces appeared in the second half of the 19th - first half of the 20th centuries (in Russia, these are the works of A.V. Vikhrov, L.K. Ramzin,

V.G. Shukhov, T.T. Usenko and many others) [5]-[7]. Due to the transition to the combustion of liquid and gaseous fuels, as well as the flaring of solid fuels in a suspended state, there was a certain failure in the development of layered combustion of solid fuels. Orientation to a new direction of combustion processes has reduced attention to layered combustion, which caused the technical backwardness in this matter.

However, there is a need to continue such research in relation to small-scale power generation, which is explained by the following factors. First, the known approaches to solving the problem of efficient combustion of solid fuels are suitable mainly for large power boilers of thermal power plants. In low-power boilers, this problem is solved in other ways due to the specifics of their operating conditions and the small size of the equipment. Secondly, after the adoption of the law "On the Protection of Atmospheric Air" (dated March 11, 2002) [8], control over compliance with environmental requirements was strengthened, in accordance with which the standards for emissions of nitrogen oxides into the atmosphere were tightened. Thirdly, the operating personnel, including the management of industrial and heating boilers, are not sufficiently trained to solve the economic and environmental problems posed to them in recent years.

The entry into the atmospheric air of huge volumes of fuel combustion products from low-power boilers, industrial furnaces, as well as exhaust gases from vehicles, changes the composition of the atmospheric air, bringing the concentration of harmful substances closer to those that are dangerous in terms of biological effect on humans.

The real efficiency of water-heating boilers of low power (0.3-3 MW) with layered furnaces using low-quality coals turned out to be in the range of 30-60% against the standard 75-80%. The main reasons for the low efficiency of low-power boilers with layered furnaces are: low level of operation, which depends on the ergonomics for the staff, poor fuel quality, technical imperfection: these boilers can only work on selected fuels.

When designing boilers, as a rule, the calculated values of the main energy characteristics of coals are used, such as the lower calorific value, the yield of volatile indicators, humidity, the composition of mineral impurities, the property of the solid combustible residue and sulfur content. These characteristics determine the various problems associated with the combustion of solid fuels in boilers [9], [10].

Solid emissions in the combustion products of coal boilers consist mainly of ash particles and unburned carbon. The concentration of solid particles in the flue gases downstream of the boiler (before the ash collector) is determined mainly by the ash content of the fuel, and, in addition, by the method of combustion [11], [12].

The disadvantages of the design of solid fuel boilers for long-burning include inefficient fuel combustion and a limited volume of the furnace, which leads to the need for frequent fuel loading. In addition, there is a relatively large percentage of unburned fuel, especially with high moisture content and high ash content, which increases the cost of heating [13]-[15].

A household heating boiler with top fuel loading is known. The boiler contains a grate, an ash pan, a fuel pipe, and a cylindrical body with a branch pipe for removing combustion products. The grate is made of two rotary parts of the grate. (The patent of the Russian Federation for utility model No. 98550 МПК A24H 1/08, publ. 20.10.2010, bull. No. 29).

The known boiler is a low-power domestic boiler, and its use is limited for this reason. The boiler is designed mainly for housing and communal services, small and medium-sized businesses. The technical disadvantage of the boiler is the loss of small fractions of coal, spilling along with the ash through the grate.

An industrial heating boiler with a layer furnace and manual control is known. The boiler includes a housing with a brace and a loading door, a heat exchanger in the upper part, a grate, and an ash pan (Chemist's Handbook 21. Chemistry and chemical technology pp.106-108). The disadvantage of this boiler is that fuel loading, drilling of the burning layer, unloading of slag and ash is carried out manually.

The boiler consists of a lining body, the furnace of which includes a grate made of grate beams with a manual lever drive, an ash pan with an unloading door at the base and a lever device for opening and closing. (Layer furnaces of boilers on the website https:\\www.kotel-mail.ru/grate-furnaces-boilers.html).

The disadvantages of this type of boiler with a layered furnace are the complexity of the design of the grate, consisting of a set of rotary elements, kinematically connected to the lever at the front of the boiler, and the loss of fine fuel fractions through the movable grate.

The boiler contains a hull with lining and a water circuit inside. The boiler furnace includes a grate and an ash tray under it (utility model of the Russian Federation No. 46563, IPC F24Y 1/00, publ.10.07.2005, bul. No. 19). The disadvantage of the boiler is the loss of small coal fractions through the grate, going into the ash pan together with the ash. Another disadvantage is the manual cleaning of the grate from slag due to their runoff over the grate.

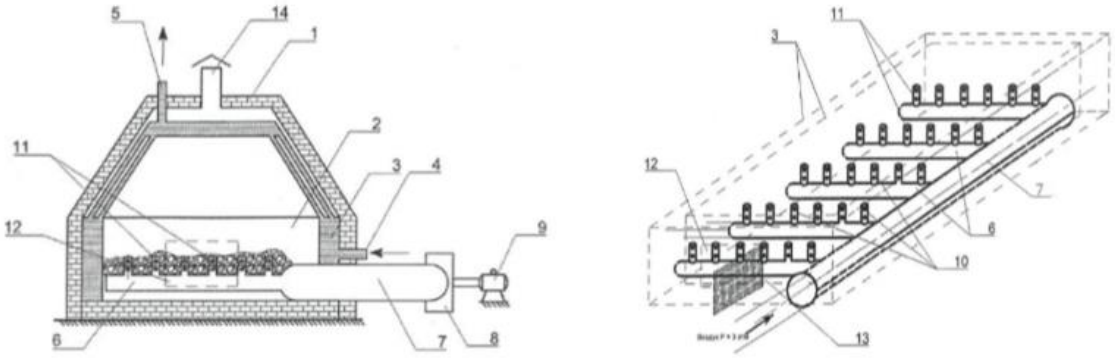
Most enterprises, especially in rural areas in schools and kindergartens, are supplied with several small-capacity hot water boilers of the KBTC-0.2 hot water boiler type for burning solid fuels. Similar boilers have a fuel combustion chamber in a dense layer and are equipped with a grate system. Such designs of boilers are not subject to control after loading the fuel, therefore, loading should be carried out taking into account the heating temperature and, if necessary, additional loading of fuel. In addition, boilers equipped with a grate system require a certain amount of air exhaust. After the fuel is loaded, the extra fine particles of fuel, together with the air, are drawn into the atmosphere, forming a dark hoof (together with the exhaust gas) after loading. The remaining fine particles through the grate enter the ash pan and are irretrievably removed along with the ash. Thus, the loss of solid fuel in grate boilers, depending on the degree of grinding, reaches up to 10-15%. Therefore, the improvement of the design of existing boilers or the development of a new design for such types of boilers is an urgent task.

The purpose of the research: is to increase the efficiency of heat transfer and reduce harmful emissions into the environment during the combustion of solid fuel in a fixed bed in water-heating solid fuel boilers of low power, by improving the design of the combustion chamber to control the air supply to the fuel combustion zone.

1. METHODOLOGY

To increase the efficiency of fuel combustion in a dense layer, an improved boiler design developed by the authors [16] is proposed. The developed furnace and the design of the low-power boiler as a whole have a number of characteristic differences from existing boilers.

In the proposed hot water boiler, fuel is loaded in the lower part of the reaction chamber of which a number of horizontally installed air supply pipes with vertical nozzles are placed, which ensures, with the exception of the grate, the loss of fine fuel particles with savings of up to 15-20%. Radial holes on vertically mounted nozzles (which can be made in two rows) allow directing the airflow in a horizontal direction over the entire layer, and ensure more complete combustion of the loaded fuel layer, thereby increasing the efficiency of the boiler.



а) б)

Figure 2. Vertical section of the boiler (a) and placement of nozzles for air supply (b).

Figure 2 shows a diagram of the proposed hot water solid fuel boiler. The boiler contains housing (1), a combustion chamber (2), a container filled with water (3), connected to the inlet pipes (4), and an outlet (5) of water. In the lower part of the reaction chamber (2) of the boiler, there is a row of horizontally installed air supply pipes (6) connected to an air distributor pipe (7) connected to a fan (8), and an electric motor (9). Horizontally mounted air supply pipes (6) are equipped with vertically mounted nozzles (10) with radial holes (11). In the side part of housing (1), an opening (12) is made for loading fuel, cleaning from ash, and servicing the combustion chamber (2). A sealed door (13) is installed in the opening (12). Combustion products are removed from the boiler through pipe (14).

The solid fuel water heating boiler works as follows. Fuel is loaded into the combustion chamber (2) through the opening (12) above the level of the injectors (10) by 5-10 mm. The air supplied through supply pipes (6) and nozzles (10) supports the combustion of the fuel. Flue gases, rising through chamber (2), heat the coolant-water in tank (3). The heated water exits the boiler through the five outlet pipes, instead, it enters the water for heating through the four inlet pipes. When the required temperature in the heated room is reached, the electric motor (9) is turned off and the air supply is stopped.

2. DISCUSSION

An industrial water heating boiler of low power, including a body with a furnace and a water circuit, a grate in the lower part of the furnace, and an ash pan above it, characterized in that the grate is made deaf, consisting of at least two rotary parts, and the boiler is equipped with a manifold for supplying air to the combustion zone, consisting of pipes with holes, and installed in the furnace above the grate.

An industrial water heating boiler of low power consists (Figure 1, Figure 2, Figure 3) of a body (1) with a water jacket (2), for example, of heat-resistant pipes with inlet and outlet pipes (3), (4); ash pan (5), loading door (6) and ash pan door (7). Inside housing (1), above the ash pan (5), a blind grate (8) is installed, consisting of two rotary parts (9), and (10) with levers (11) for turning them. An air collector (12) is installed above a grate (8) for supplying air into the layer of coal loaded on the blind grate. The collector (12) consists of pipes (13) with holes (14) along them, through the inlet pipe (3) and outlet (4) water jacket (2) of the boiler connected to a water circulation system, such as a heating system (not shown). Through the loading door (6,) a portion of coal is loaded into body (1) of the boiler on a deaf grate (8) and ignited. At the same time, the air is supplied to the boiler furnace through the collector (12). Then, through the loading door (6), coal is loaded onto the blind grate (8), evenly distributing it over the surface. The coal burns and the resulting hot gases, rising up, wash the pipes of the water jacket (2) and

heat the water flowing through them, which is discharged to the consumer through the outlet pipe (4). During the combustion of coal in the combustion zone on grate (8), ash and slag are formed, which are periodically unloaded into the ash pan (5). To do this, handles (1) of the handle (11) (Figure 4, Figure 3) rotate parts (9), (10) of the grate (8) at a certain angle γ, them, and pour ash and slag into the ash pan (5) and remove from it.

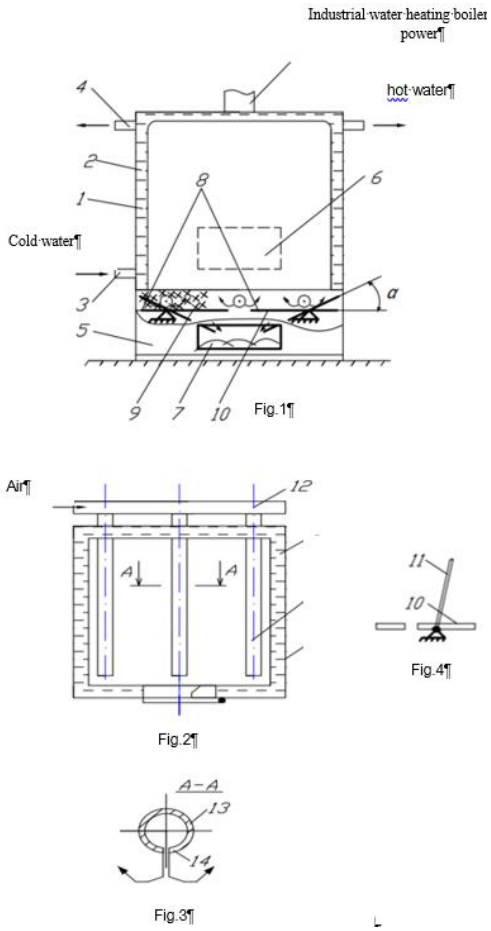


Figure 3. Industrial water heating boiler of low power

In a particular case, the ash and slag are poured into a container installed in the ash pan (5) (not shown) and removed from it as it is filled. The proposed design is a hybrid between complex industrial boilers and simple domestic ones.

Figure 1 schematically shows a water heating boiler, front view; Figure 2, too, view from above; Figure 3 section along a-a in Figure 2; Figure 4 shows part of the grate with the drive lever.

3. Results

According to the proposed scheme, a boiler house was reconstructed, which works to heat the building of a secondary school in the village. Kok - Zhaiyk, Kokpektinsky district, East Kazakhstan region. In the boiler room, 3 boilers KBTC - 0.2 were installed and work in parallel. Loading of coal was carried out manually, and re-equipment was carried out in the middle boiler, by installing a means of air supply.

All three boilers were started simultaneously with the same fuel load. When the water temperature on the supply line reached the required temperature, the air supply to the middle

boiler was stopped by turning off the blower fan. The combustion process in the boiler furnace was stopped. In the furnaces of non-equipped boilers, the combustion process continued and the combustion process was reduced by closing the grate doors. However, the combustion process was not particularly controlled. When the water temperature on the supply line drops to the permissible minimum value, the fan turns on. Upon completion of coal combustion in the two outermost boilers, fresh fuel was not loaded. The reconstructed boiler worked until the complete combustion of the fuel. In terms of operating time, the duration of the reconstructed boiler was more than 30% longer than standard boilers. Upon completion of combustion, ash was unloaded from all furnaces simultaneously and the process was repeated. A general view of the placement of nozzles for air supply and the boiler room is shown in Figure 4.

Figure 4. General view inside the furnace (a) and boiler room (b).

According to preliminary calculations, the operation of the converted boiler during the heating season made it possible to save up to 30% of coal. This achievement is due to the following phenomena: elimination of the loss of small particles (well combustible) of the fuel through the grate; reducing the loss of especially fine particles of fuel to a minimum, leaving flue gases (due to high exhaust during the operation of the grate); by reducing the extraction of flue gases, ensuring the completeness of combustion of the formed gas above the fuel layer (by increasing the combustion time); the possibility of stopping the combustion of fuel in the furnace when a sufficient temperature of the coolant (water) is reached by eliminating the air supply.

Conclusion

The proposed scheme of fuel combustion in a hot water boiler is based on: ensuring the completeness of combustion of fuel loaded in the lower part of the reaction chamber in a dense layer by supplying a manifold for supplying air to the combustion zone, consisting of pipes with holes, and installed in the furnace above the grate; reducing the exhaust velocity of flue gases, due to the execution of the grate deaf (without slotted) ensuring the duration of stay in the chamber; afterburning of the formed volatile gas in the chamber due to additional air supply.

Based on a preliminary test of the improved КВТС - 02 hot water boiler to determine the technical and economic efficiency, the following indicators were obtained: a decrease in fuel consumption compared to the standard one by 25-30%; reduction of the release of toxic elements by 15-20%.

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