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# Reserves for Increasing the Energy Efficiency and Environmental Facility of Marine Boilers through the Application of Automation Tools

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*ABSTRACT*

Every year, more and more attention is paid to the problem of energy efficiency of ship power plants. Among the heat losses in a steam boiler, the largest are the losses with the output gases, which mainly determine its efficiency. Solving the problem of reducing these losses is an urgent task, which is the main goal of the work being performed. Its scientific novelty is the substantiation of the improvement of the automatic control system of the aggregated combustion device in order to reduce heat losses with the output gases. The work proposes to improve the algorithm of the control unit of the combustion device in order to ensure the fulfillment of the condition of the dependence of the volume of air injected into the combustion space during ventilation on the concentration of explosive gases dissolved in it. For the practical implementation of this solution, the use of a system of automatic control of the quality of the combustion process with signal transmission to the control unit of the combustion device is proposed. The proposed method of improving the operation algorithm of the combustion device control unit will minimize heat loss with the output gases $Q_2$ and will ensure a reduction in emissions of harmful substances into the environment.



## 1. Introduction.

Every year, more and more attention is paid to the problem of energy efficiency and environmental friendliness of ship power plants. This is caused, firstly, by the fact that maritime transport is one of the largest energy consumers, secondly, by the high cost of energy resources, and thirdly, by the harmful impact of combustion products on the environment.

## 2. Relevance of research.

According to Resolution MEPS.213(63), marine vessels must have an energy efficiency management plan. Among the significant list of requirements for increasing the ship's energy efficiency, it is worth paying attention to the following [1]:

- optimization of the operation of the ship's power plant by reducing mechanical losses and heat losses;
- maintenance of the devices of the ship's power plant by using advanced diagnostic systems, which can be a necessary means to control the high efficiency of the ship's power plant;
- beneficial use of various types of thermal energy through the use of modern recycling systems;
- use of alternative types of fuel.

Among the implemented methods of increasing the energy efficiency of steam boilers, the following are known today:

- a high degree of shielding of the furnace space, which contributes to the maximum transfer of heat by radiation to radiant heating surfaces;
- the use of steam-generating heating surfaces (pipes) of

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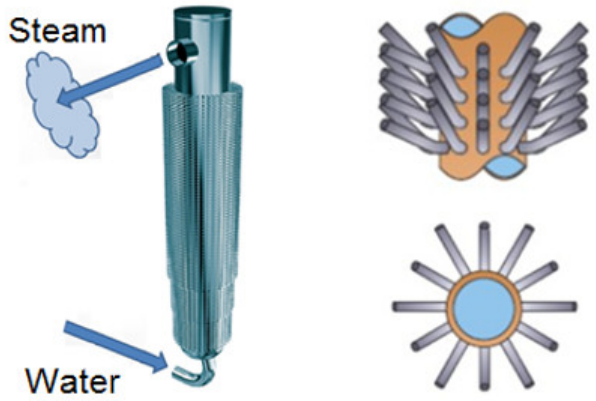
special structures (Fig. 1), thanks to which the heat transfer process intensifies in the process of washing them with flue gases;

Figure 1: Steam-generating heating surfaces of special structures.




Source: alfalaval.com.

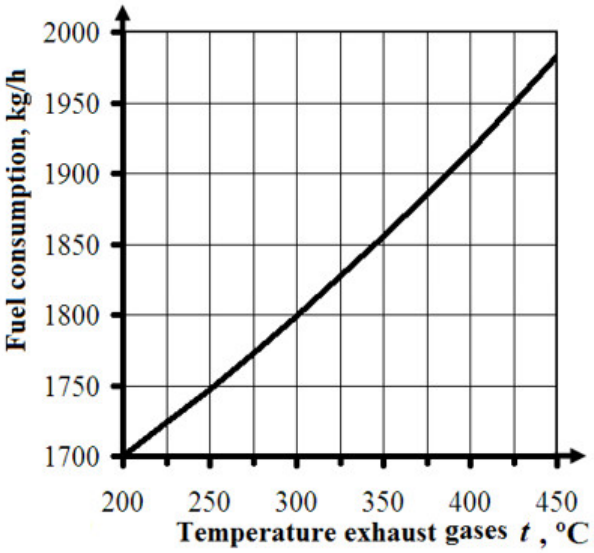
- combining the furnace (autonomous) part of the boiler with the disposal part (composite boilers);
- combining elements of the fire tube and water tube parts of the boiler - fire tube and water tube boilers;
- a high degree of automation of the combustion device of the boiler, with the possibility of setting the optimal ratio of the fuel-air mixture to ensure the process of complete fuel combustion;
- ensuring the cleanliness of the internal and external heating surfaces, in order to maintain the maximum heat transfer coefficient k;
- preliminary heating of the coolant/air before it is fed to the boiler/boiler furnace, due to heat recovery from other heat engines;
- thermal insulation of the boiler body.

Among the heat losses in the steam boiler, the largest are the losses with the output gases $Q_2$, which can, depending on the influence of various factors, reach up to 25% [2]. Therefore, they mainly determine the efficiency of the boiler. Solving the problem of reducing these losses is an urgent task, which is the main goal of the work being performed. Its novelty is the rationale for improving the system of automatic control of the burner in order to reduce heat loss.

## 3. Presentation of the main material.

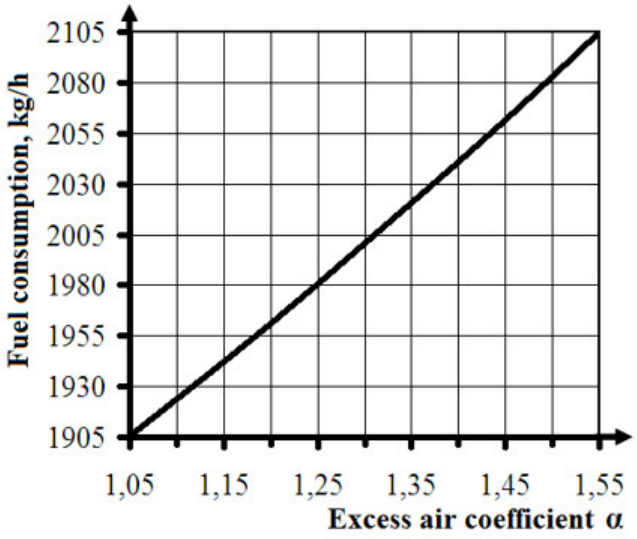
Heat loss with gases leaving the boiler $Q_2$ increases with an increase in the volume of combustion products that are formed during fuel combustion, i.e., with an increase in the coefficient of excess air - $\alpha$, and with an increase in the temperature of the exit gases. This, as a result, leads to an increase in fuel consumption. The results of calculating the fuel consumption of the Aalborg Mission OL auxiliary boiler depending on the temperature of the outgoing gases and the coefficient of excess air are shown in Fig. 2 - 3.

Figure 2: Dependence of fuel consumption on the temperature of the exhaust gases.




Source: Authors.

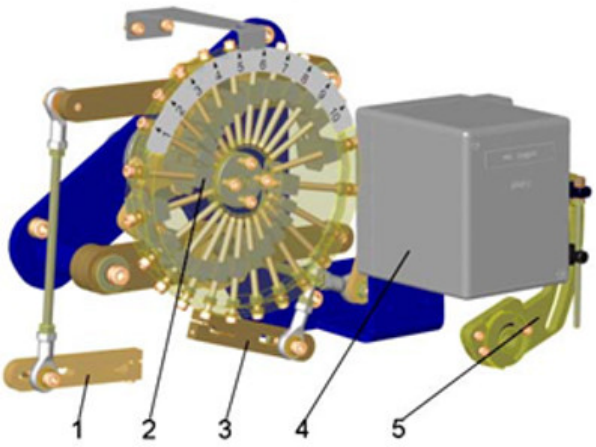
Figure 3: Dependence of fuel consumption on the excess air coefficient.




Source: Authors.

In order to reduce heat losses, considerable attention is paid to the perfection of the combustion process using automatic control systems equipped with a fuel-air mixture composition regulator (Fig. 4). These regulators make it possible to adjust the optimal composition of the fuel-air mixture with the minimum coefficient of excess air $\alpha$, depending on the boiler load, which creates optimal conditions for ensuring the complete combustion of organic fuel, and therefore reducing heat losses $Q_3$ from chemical incomplete combustion of fuel and $Q_2$ with gases leaving the boiler.

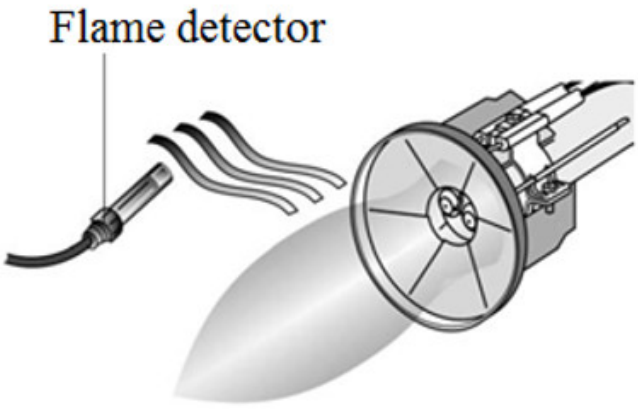
Figure 4: Fuel-air mixture composition regulator. 1, 3 - drive levers for air dampers; 2 - control disc; 4 - servo motor; 5 - fuel flow regulator drive lever.




Source: saacke.com.

According to the International Register of Shipping (INTLREG) [3] automatic combustion devices are equipped with means of monitoring (Fig. 5) the presence of a torch in the nozzle (flame sensors), in the absence of which a signal is sent to control unit, as a result of which, in turn, the electromagnetic valves located on the fuel line are blocked, thus stopping the supply of fuel to the fuel injectors.

Figure 5: Control of the state of the torch by the flame sensor.




Source: weishaupt-corp.com.

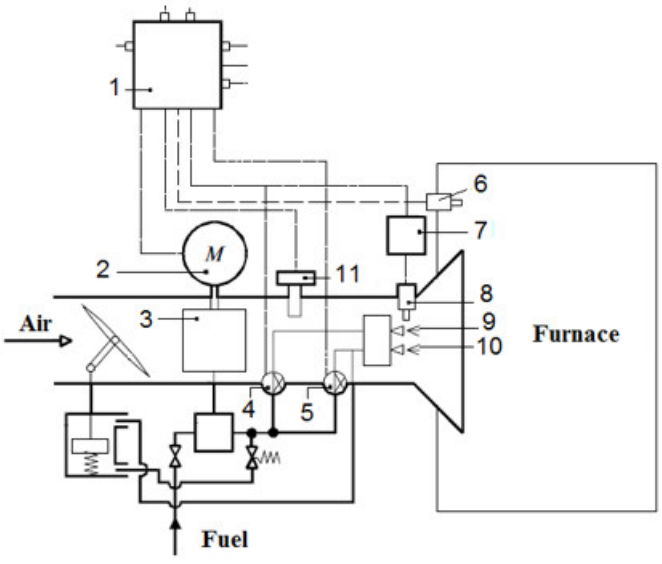
According to the requirements of the International Register of Shipping (INTLREG) [3], the unlocking of the electromagnetic valves and, accordingly, the fuel supply to the nozzle will be possible only after ensuring the fulfillment of a number of mandatory conditions, one of which is the ventilation of the combustion chamber. This operation is extremely important and necessary, as it ensures the removal of fuel vapors from the combustion chamber, excessive concentration of which can lead to an emergency situation, as a result of their detonation, when the fire is extinguished.

During ventilation of the combustion space, there is a loss of useful heat generated during the combustion of organic fuel with the output gases $Q_2$.

It is also worth noting that during the combustion process, uncontrolled failures in the automatic control system of the combustion device quite often occur, as a result of which the fuel supply to the nozzles is blocked and, according to the programmed algorithm of actions, further ventilation of the combustion space with corresponding additional useless heat losses. One of the reasons for such blockages is false signals to the control unit from flame sensors, which have the following disadvantages: low selectivity, sensitivity to extraneous illumination [4]. Also, false signals of flame sensors are associated with contamination of their photosensitive elements (lenses), for example, a trace of a layer of soot deposits.

In order to reduce heat losses with the output gases $Q_2$, in this paper, it is proposed to improve the algorithm of the control unit of the furnace device by ensuring the fulfillment of the condition of the dependence of the volume of air forced into the furnace space during ventilation, from the concentration of explosive gases dissolved in it. For the practical implementation of this solution, it is proposed to use a system of automatic control of the quality of the combustion process with signal transmission to the control unit of the combustion device (Fig. 6).

Figure 6: Basic kinematic diagram of the furnace device: 1 - control unit; 2 - electric motor; 3 - fan; 4, 5 - electromagnetic valves; 6 - gas analyzer probe; 7 - transformer; 8 - electrode; 9, 10 - fuel injectors; 11 - flame sensor.



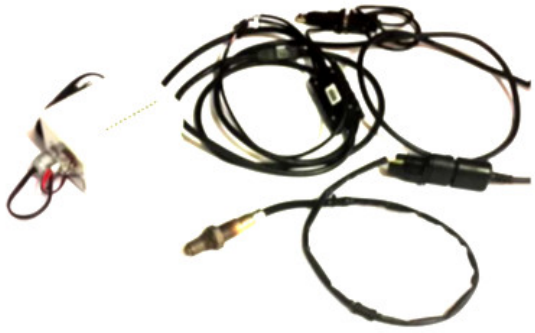

Source: Authors.

Thus, the need to ventilate the furnace, or the duration of ventilation before igniting the fuel-air mixture, should continue depending on the concentration of explosive gases in the furnace space. In this case, during false stops of the combustion device, it is possible to achieve the minimization of heat loss with the output gases $Q_2$, since the expediency of performing ventilation and its duration will be based on the result of the

signal received by probe 6 of the system of automatic control of the quality of the combustion process and transmitted, respectively, to the control unit 1, which, in turn, will regulate the time periods between the injection of air by the fan 3, the opening of the electromagnetic valves 4, 5 and the supply of voltage to the transformer 7 of the electrode 8 for igniting the fuel-air mixture supplied by the nozzle 9.

Analyzing the concentration of explosive gases dissolved in the furnace space is possible through the use of gas analysis systems (Fig. 7).

Figure 7: Portable combustion process quality control system [5, 6].



Source: Patent Nº 5585547 USA.

These systems are also equipped with the function of gas analysis of fuel combustion products, which makes it possible, depending on the results of the analysis, to adjust the settings of the regulator of the composition of the fuel-air mixture of the combustion device, which will ensure the reduction of emissions of harmful substances into the atmosphere, namely, during the formation of products of incomplete combustion ($H_2$, $CH_4$, CO, etc.), the concentration of which depends on the perfection of the fuel combustion process.

## Conclusions.

1. The data analysis of implemented methods of increasing the energy efficiency of ship steam boilers is summarized in order to determine the prospects for their further improvement.

2. In order to reduce heat losses with exhaust gases, it is proposed to improve the operation algorithm of the combustion device control unit by ensuring the condition of the dependence of the volume of air injected into the combustion space during ventilation on the concentration of explosive gases dissolved in it.

3. For the effective implementation of this improvement, it is necessary to analyze the systems of automatic control of the quality of the combustion process in order to find the optimal operating conditions for the given conditions, as well as the development of appropriate software that will meet the functional requirements.

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