

# Use of condensing economizers with developed surfaces to improve the energy efficiency of conventional gas-fired heat generators in boilers

*Dmitriy Kosorukov\** and *Andrey Aksenov*

Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

**Abstract** The current financial and economic programme in the Russian Federation is aimed at increasing energy efficiency in all areas of society. The most effective way of increasing the efficiency of boiler plant operation is to improve the technology of deep heat recovery from the heated flue gas from the chimney system of hot-water boilers. The physical essence of this phenomenon consists in cooling the escaping high-temperature combustion products of gaseous fuel, through contact with the cold surface of the heat exchanger, to a temperature below the dew point under the pressure in the convective bundle of the boiler. In this regard, we set a goal to develop the most efficient design of condensing economizer, which would allow us to obtain fuel economy of gas boiler at the level of operation of condensing heat generators. A practical model of a condensing economizer for increasing the efficiency of heat generators based on convection-type gas boilers has been created. A study has been carried out, the results of which allow us to conclude on the effectiveness of its use for individual and local heating of residential and public buildings.

## 1 Introduction

The predominant method of heat energy provision in the form of heated water in most cities of our country is the centralized power supply to the customers from different kinds of heat generation points: CHPs, RTSs or the use of district heating boilers[1]. So far, the level of technical readiness of heating networks for the heating season mostly does not meet the requirements of the currently adopted national operating standards[5]. Connection to the existing linear objects of centralized power supply in an individual residential area is currently economically inexpedient. In this regard, it is inevitable to build independent heat

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\* Corresponding author: [pauleyta97@mail.ru](mailto:pauleyta97@mail.ru)

supply sources - individual heat generators, allowing to establish and maintain a separate temperature regime of each separate object. Such technological solution will be more rational economically than the ones which are currently being used[8].

The flue gases from gas-fired hot water boilers contain suspended water vapor from the high-temperature hydrogen oxidation reaction, which condenses on the heat exchanger surfaces due to contact with the cold convective part and transfers the latent heat energy of steam production (the heat of water vapor condensation) to the moving liquid inside it, thus increasing the temperature of the moving liquid and decreasing the fuel consumption for compensation for the engineering heat loss [7].

In most European countries the technology for recovery of latent heat from flue gases is realized through the wide implementation of condensing technology in heating systems, which includes an additional stainless steel, or silumin surface on which condensate from natural and liquefied gas combustion products precipitates. Mainly in the EU countries, decentralized and low-temperature district heating systems have been historically widespread, which also characterizes the use of technology for utilization of excess heat from boiler units in the form of equipping heating units with condensing boilers. The installation of additional utilization tail surfaces behind the heat generating units is not performed. These technological solutions are used in the USA, where the high-temperature heating system is also widespread, and in the Baltic States, where the existing heating facilities left over from the USSR are being modernized as part of the EU energy efficiency programme.

In Russia such technologies are not as common as in the EU despite the fact that the construction of heat generators based on floor standing or wall mounted condensing boilers has been going on for more than 10 years. There are several reasons why similar solutions are not accepted for installation of heating systems in the Russian Federation but the most important one which limits the wide dissemination is the prevalence of high-temperature heating systems in the facilities built before 2010, for which such projects are physically meaningless since the condensation of water vapors at boiler furnace pressure occurs at a return water temperature not exceeding 55 °C[9]. Such a return temperature can only be achieved by designing a low-temperature heating system, e.g. under-floor heating or warm ceilings. Such an approach is simply not possible with the refurbishment of existing systems. The global economic crisis has caused a dramatic slowdown in the construction of industrial buildings. This situation has led to a reduction in the popularity of condensing hot water heat generators[11].

In the current environment, there is a particular need to create a technological way to increase the economic efficiency of the current high-temperature systems to the level of low-temperature systems[10].

For this reason, the best solution for recovering the latent heat of water vapor condensation from the flue gases is to install an additional heat exchanger - a condensing economizer - in the heat generating plant. Condensing economizers are not yet used as a way to increase the efficiency of individual heat generators, although the technological effect of them is expressed in the reduction of the temperature of the heated flue gases, utilization of

latent heat of water vapor condensation and increasing the efficiency of the heat generating unit for higher heating value of fuel in numerical values prevails over the savings from the installation of the condensing boiler. The financial gain is much greater as the price of such a heat exchange device is several times lower than that of a condensing boiler[13].

In view of the need to prove rationality of using condensing heat exchangers in order to increase efficiency of gaseous heat generators of convection type, we have developed and produced a practical example of such a heat exchanger. The performed experiment and valuable calculations indicated effectiveness of its application for individual boilers using gaseous fuel in Moscow [15].

## 2 Methods

A 38 kW LOGANO G234 WS wall mounted conventional double circuit gas condensing boiler with a BUDERUS designed partial gas premixing burner and a condensing economizer of channel-type heat exchanger design with horizontal finned flue gas passages were used as equipment[14]. The unit in use represents a heat exchanger assembled from aluminium profiles used for cooling various units and installations. At the rear, rectangular channels of hard rubber seals are formed into which liquid flows. Connectors are provided for connection to water systems. The heat exchanger is installed directly in the boiler flue gas venting system. This surface enhances the looping of the liquid, creating a counter-flow system, increasing the heat transfer from the flue gases to the water and increasing the heat flow. The heat exchanger is connected to the chimney and flue gas system of the heat generator by means of a direct installation in the draught diverter. The structure of the laboratory model to perform the experiments is shown in Figure 1.



**Fig. 1.** Experimental installation of a condensing economizer

The nature of the operation of a condensing heat exchanger with a developed area can be described as follows; when a gas-fired boiler is used to heat water for hot water supply up to 60 °C, high-temperature flue gases arise at an average outlet temperature of 80 °C[4]. The flue gases pass through the draught diverter of the cast-iron atmospheric boiler and through

the finned profile channels, where they increase the calorific value of the liquid flowing through the corrugated stainless tubes with  $t_{col} = 20$  °C (liquid from the HTW pipeline of the building, which is slightly heated due to the passage through the heated rooms). The flue gases are then inverted and discharged from the system into the chimney[8].

During the laboratory work, the following parameters were measured: temperature of combustion products at the heat generator outlet -  $t_{vhcot}$  °C, temperature of hot gases after the economizer -  $t_{vhek}$  °C, total fluid flow through the heat generator -  $L_{vod}$  m<sup>3</sup>/h, fluid flow through the economizer -  $L_{ek}$  m<sup>3</sup>/h, fluid temperature after the economizer -  $t_{vodpost.ec}$  °C, gas flow rate through the heat generator -  $B$  m<sup>3</sup>/h.

The following constant values were taken into account in calculations: fluid inlet temperature to economizer -  $t_{col}=20$  °C, net calorific value of natural gas at given composition (Urengoi gas field) -  $Q_n=37310$  KJ/m<sup>3</sup>.

### 3 Results

As a result, the study found that the proportion of heat energy received as a result of condensation of water vapor from the heated gases to the total amount of energy given to the fluid in the economizer was 15% and the proportion of heat energy from water vapor deposition from combustion products in the economizer to the total energy from gaseous fuel oxidized in the heat generator was 7%[9]. Such data are fully consistent with the data that can be measured in energy efficient boilers, where the proportion is estimated to be between 7 % and 9 % at rated operation[10].

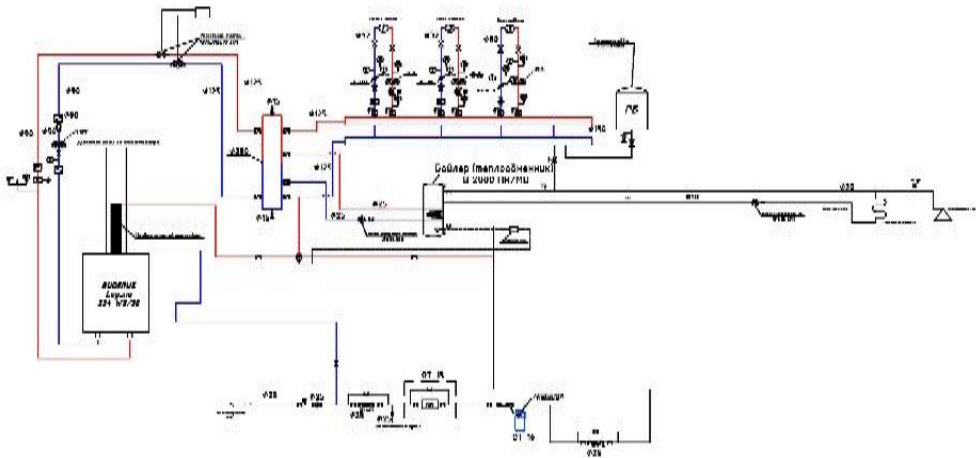
After performing an experiment with tube-in-tube economizer design [3], all the design disadvantages of the previous model were taken into account, such as small contact of the tube with liquid and the inner tube of the economizer, which reduced intensification of heat exchange between the heated combustion products and the tube surface [12]. Other disadvantages can be ascribed to a shortcoming of the heat transferring surface construction itself, which caused poor flow around the tube by combustion gaseous fuel products and slow removal of condensate drops from the heat exchange area and which led to surface drying and increase in moisture content of flue gases[4]. In the new laboratory model all the drawbacks of the old experiment were taken into account and in the new model similar shortcomings are absent as the walls of the flue gas channels are vertical with trapezoidal ribs that do not allow the condensate droplets to linger on the surface and increase the moisture content of heated combustion products, reducing the efficiency of economizer. These modifications allowed us to balance out the beneficial effects of the condensing boiler and the economizer.

### 4 Discussion

Based on the results of the study, it can be concluded that the use of an economizer with a developed finned surface compared to a condensing heat generator is financially viable [2].

For example, the price of condensing heat generator Buderus 38 kW capacity is 191 918 rubles, and the price of gas heat generator BUDERUS LOGANO G234 WS with atmospheric burner partial premixed is 143 780 rubles, the price of condensing economizer, produced for the customer in factory conditions is 10000 rubles[6].

The laboratory practice carried out allows us to conclude: the technological effect of these two concepts is the same, however, the installation of the condensing economizer does not require the mandatory use of low-temperature heat supply systems, whereas the economics of the heat generator are greatly reduced when it is connected to an existing high-temperature heating system[13]. If desired, the fluid heated in the condensing economizer can be utilized for heating make-up water and cooling potable water heating in an indirect storage heat exchanger, thus reducing the need to run the heat generator frequently for heating hot water and saving fuel gas[10]. In addition, the heated fluid can be used as a heat transfer medium for under-floor and wall heating, for which it is necessary to use an economizer with a larger area and a smaller tube winding pitch. A version of the heat map for a gas-fired reconstructed boiler house is shown in figure 2.



**Fig. 2.** An example of a thermal scheme for a gas-fired individual heating boiler with a condensing economizer

## 5 Conclusion

1. The problem of using condensing economizers in the construction of different types of buildings and structures lies in the forthcoming expansion and adoption of a constructive approach. It is established that the financial result of its operation will be achieved in the initial year of its use, and the payback time of the installation is less than the one of the condensing boiler.
2. The experimental dependencies found can be used to create a real production sample of an economizer.
3. The methodology applied is effective for increasing the energy efficiency of heat generating plants and for reducing emissions of carbon monoxide and high temperature nitrogen oxides

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