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Independent Heating Modules With Condensing Hot Water Boilers As Heat Generators As An Effective Alternative To Centralized Heat Supply.

Vladimir Pavlovich Kozhevnikov*, Valery Alekseevich Kuznetsov, Artyom Aleksandrovich Mochalin, Ruslan Yuryevich Titarenko, and Lubov Vladimirovna Sokolova

Belgorod State Technological University named after V.G.Shukhov, Russia, 308012, Belgorod, Kostyukov str., 46.

ABSTRACT

Development of a heat transfer agent for needs of different purposes consumers heating requires significant fuel consumption the cost of which is very high. Currently, the most widely used systems for different purposes heating of consumers in the Russian Federation are centralized systems. They have a number of disadvantages. Almost all of these disadvantages are absent in independent heating systems. Thus energy efficiency of heat-generating units used in such systems is not high enough. The reason for this is the significant heat losses with exhaust gases of boilers. In independent heating systems a condensing hot water boiler with separate heat production for heat and hot water supply, developed by the fellows of Belgorod State Technological University named after V.G. Shoukhov can be used quite effectively. This article provides a schematic diagram of the boiler and its piping, description of its operation, its benefits over traditional heat generating units without condensation of water vapors contained in exhaust gases.
Keywords: Centralized heat supply systems, independent heat supply systems, heat generating unit, condensation of water vapors, condensing hot water boiler.

Corresponding author

Introduction

For heat and hot water supply systems of residential, public and industrial facilities in Russia and the CIS countries about $ 1 billion tons of oil equivalent, the cost of which is already significantly higher than 1 trillion rubles a year is spent. In recent years, energy prices in Russia are close to the world ones. Therefore, the effect of saving of even a few percent of the fuel is many tens of billions rubles annually [1].

Another factor of fuel saving relevance in heat supply is the environmental factor. This factor includes not only reduction of harmful air emissions, including green house gases emissions, by means of less fuel burning, but also multi-fold reduction of specific quantities of pollutants generated in low power hot-water boilers, compared with their generation in high power hot water boilers [2].

Two main types of heating systems - namely, systems of centralized and decentralized heating are used for heat supply of industrial, civil and residential buildings nowadays in the world.

As the main successor to the Soviet Union, the Russian Federation is a country with a high degree of heat supply centralization. Currently, the predominant heat supply systems of residential, public and industrial facilities are centralized systems, comprising quarterly or district boiler, external heat networks and heat consumers, with heat points, where water-water heat exchangers (boilers) heat drinking and household cold water for hot water supply at the cost of a portion of heating water (see Fig. 1). The other portion of heating water is supplied directly into the heating system of heat consumer.

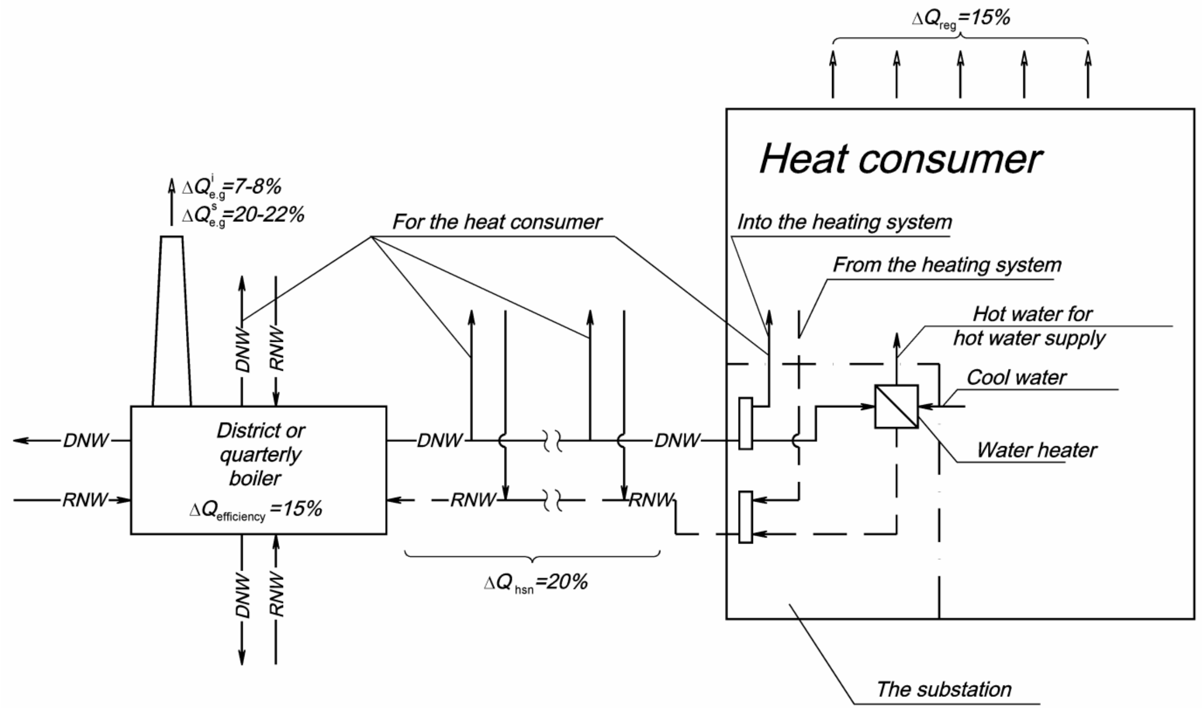

Figure 1: Schematic diagram of a centralized heating system of various objects: DNW - direct network water; RNW - reverse network water

As experience of centralized heating systems operation shows, they have a number of disadvantages listed below.

- These systems use hot water boilers with a thermal efficiency determined according to the fuel lower calorific value which does not exceed 91-92%, with waste heat losses of around $\Delta Q_{\text{у.г}}^{\text{н}} = 7 - 8\%$. At that latent heat of condensation of water vapors, which are certainly present in fossil fuels combustion products is ignored in the article of waste heat losses. Therefore, in estimating the efficiency of the same boiler, and under the same operating conditions but using the fuel higher calorific value it becomes equal not to 91-92% but to 78-80%, while the waste heat losses increase from 7-8% to $\Delta Q^{в}_{у.г} = 20 - 22\%$, most of which, namely about $\Delta Q_{пкд}$ = 15% can really and cost effectively be used for heating needs.

- Furthermore, even to achieve the aforementioned low efficiencies in traditional hot water boilers in order to obtain the exhaust gases temperatures of within 110-130°C it is necessary to have very extended surfaces of convective heat transfer, which depend upon inevitable reduction in the average temperature difference between heat transfer agents at minimum heat transfer coefficients and accordingly, heat transfer coefficients from fuel combustion products to heated system water. For these reasons, conventional boilers are very cumbersome, metal intensive and, consequently, expensive.
- Heat losses in external heat networks in most cases exceed $\Delta Q_{т.с.}$ = 20% (in some cases they reach 50%), maintenance and periodic reconstruction of the networks require high operating and capital costs. When reconstructing networks road paving, sideways and partially other underground utilities are being inevitably ruined, green plantations are destroyed.
- Because of a considerable thermal transmission distance with a large number of various purposes heat consumers it is difficult, and often even impossible, to ensure proper regulation of conformity of heat production to its consumption, which also causes a forced extra waste of fuel of not less than $\Delta Q_{рег}$. ≈ 15%.

Thus, heat losses and, therefore, fuel consumption in centralized heating systems according to paragraphs 1, 2, 3 are

$$\sum Q_{п} = \Delta Q_{КПД} + \Delta Q_{т.с} + \Delta Q_{рег.} = 15 + 20 + 15 = 50\%.$$

Elimination of these losses will reduce fuel consumption for heating by two times.

- As the experience of recent years showed, heat networks, as the most important element of life support systems, were not very reliable.
- In external heating networks there are significant losses of system water which was chemically treated and is an expensive heat transfer agent. These losses require appropriate feeding of heat networks in the organization of costly chemical treatment of water.
- 6. When using medium and high power hot water boilers in centralized heating systems specific quantities of generated harmful gaseous components, in particular nitrogen oxides increase by 3-5 times [2].
- The portion of fuel cost, e.g. natural gas, in heat cost estimating in case of centralized heating is about 25%, while the main part of the heat initial cost falls at heating networks maintenance and repair, as well as at restoration of urban infrastructure, affected by their reconstruction. Therefore, the initial cost of heat produced when passing from centralized heating to individual is reduced by 4-5 times, that is particularly of great social importance in the context of rising energy prices.

Today centralized heating systems are reasonably cost-effective only when thermal, nuclear or hydroelectric power station is used as a source of heat supply. In this case, thermal energy directed at meeting the needs of different heat consumers is a "byproduct" of primary production - the production of electric energy - and can significantly improve the efficiency of an electric power plant [3].

MAIN PART

Recently the energy policy of the Russian Federation also a trends towards the development of independent heating systems using modern small power hot water boilers, both of foreign and domestic manufacture.

Independent or decentralized heat supply systems compare favorably with centralized ones because in such systems, a heat source and consumers' heat receivers are combined in a single unit or placed so close to each other that heat transfer from the source to the receivers can be carried out without heating networks. In this case, accordingly, all mentioned above disadvantages typical for thermal networks are eliminated.

An important advantage of independent heating systems is their flexibility. Only local and individual (if desired by heat consumer) thermal load control is exercised in these systems. That is, it is possible to change the mode of heat producing units in a matter of minutes, while transient modes in conventional heating systems last for many hours. This significantly reduces capital and operating costs, and, moreover, ensures the best possible correspondence of the amount of heat generated to the real needs of consumers, which increases their comfort [3].

In addition, thanks to the researches of national experts in the field of ambient air protection, it is known that during combustion of gaseous fuel pollutants emission, in particular emission of nitrogen oxides, with exhaust gas of small power hot water boilers is substantially less than with exhaust gases of high power hot water boilers and thermal power plants.

That is gradual transition from centralized heating systems with a heat source in a medium of high power heating plant to independent systems will allow to reduce heat losses by at least 35% and to increase environmental safety of such systems.

However, the general and the main disadvantage of existing designs of water-tube and fire-tube hot water boilers, even of their best samples, is that their efficiency, measured by net calorific value of fuel is 90-93%, and waste heat losses are 6-8%. Efficiency of such boilers determined by higher calorific value of fuel will be 77-80%.

Under these conditions, in order to improve the efficiency of fuel consumption it is necessary to use water vapors condensation heat. When moisture content of exhaust gases x = 0.11-0.12 $kg/kg_{c.r.}$ their sensible heat is 195-220 kJ/m^3 and humidity heat is 315-325 kJ/m^3. If natural gas combustion products are cooled to a temperature below the dew point, which is 54-55 °C for them, then condensation of a part of water vapors contained in them will take place with latent condensation heat release [1].

Based on the foregoing, it appears that a very effective alternative to traditional hot-water boilers is the use of independent condensing hot water boilers with deep exhaust gases heat recovery as heat-generating plants [4-8].

An example of a device, usefully using the heat of condensation of water vapors contained in fuel combustion products is a condensing hot water boiler with separate production of water for heating and hot water supply [9, 10]. Schematic diagram of the boiler is shown in Fig. 2.

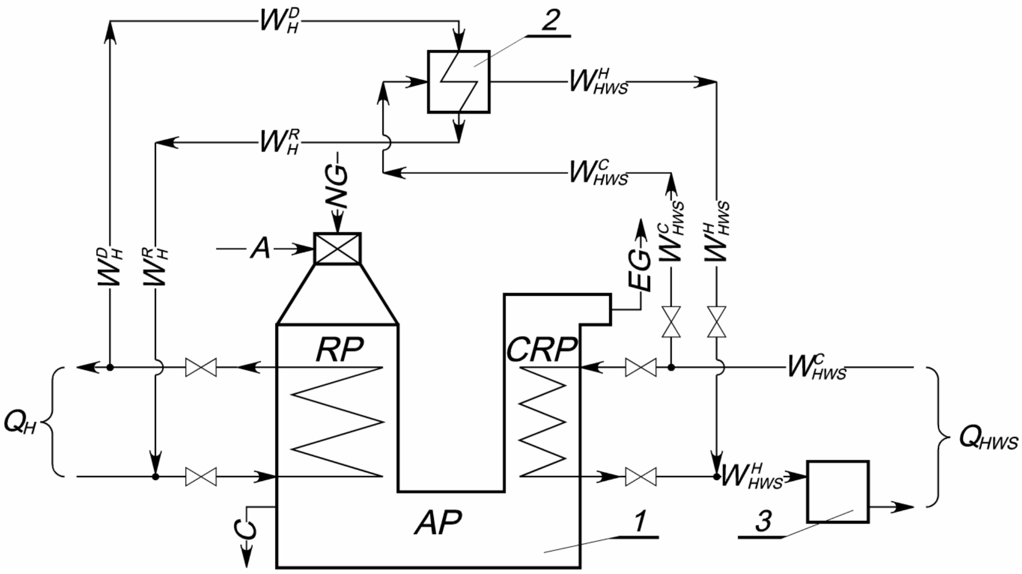

Figure 2: Schematic diagram of the condensing hot water boiler

1 – condensing hot water boiler; 2 - water-water heater; 3 – hot water storage tank; *RP* - radiant part; *CRP* - contact-regenerative part; *AP* - adiabatic part; *NG* - natural gas; *A*- air; W_H^R, W_H^D – return and direct heating water; W_{HWS}^C, W_{HWS}^H - hot and cold water for hot water supply; *EG* - exhaust gases; *C* - condensate; Q_H, Q_{HWS} - heat for heating and hot water supply.

This hot water boiler is a heat generator, consisting of a radiant part (RP), an adiabatic part (AP) and a contact-regenerative part (CRP). Its main feature is that it has two loops. Hot water for heating purposes is produced in the first (along combustion products) loop (high-temperature radiant part). In a heating season, this water with the temperature of 95 ° C is fed directly into the main riser of heat consumer's heating system. Hot water for hot water supply is produced in the second loop - the contact-regenerative part of condensing type. Here drinking quality water is heated against the rest of the combustion products sensible heat after the radiant part and the latent condensation heat of about 80% of exhaust gases water vapors. Hot water for hot water supply enters the storage tank or directly the distributing header of the hot water supply system. During summer, when there is no heating load, direct heating water is supplied into an auxiliary water-water heat exchanger (boiler), where a portion of water is heated for hot water supply. After cooling in the boiler return heating water is returned to the radiant part of the boiler. The overall heat rating and, accordingly, fuel consumption is reduced by the value of absent heating load. It is pertinent to note that in the proposed scheme of an individual boiler-house the required heat output of the boiler is 2 times less than in case of centralized heating, since a part of water (about 50%) for hot water supply is produced in the contact-regenerative part of the boiler. Continuously produced condensate can be used for feeding of heating water, its excess - for feeding and softening of water for hot water supply, or other needs. This eliminates the need for chemical treatment of water.

Natural gas combustion products burnt in RP furnace leave the radiant part with a temperature significantly higher than the temperature of exhaust gases of boilers traditionally used in heating systems. This fact allows to increase the average temperature difference between heat transfer agents compared with traditional boilers. In addition, the heat transfer coefficient in the radiant part take on its maximum possible value, which is caused by maximum values of the coefficient of heat transfer from gases to the heat transfer surface (due to high radiation component of the heat transfer). Then combustion products are cooled adiabatically in the adiabatic part to thermal and moisture balance at the temperature of wet-bulb thermometer, and then they are cooled to the temperature of $t_{y.r.} \approx$ 30-35 °C in the contact-regenerative part in ascending gas-liquid flow in the emulsified mode, transferring the latent heat of condensation of the most portion of water vapors. In this case, heat content of exhaust gases as they leave a condensing hot water boiler will range within 110-125 $kJ/kg_{c.r.}$, that is 4-4.5% of the higher calorific value of fuel. That is, an increment of the boiler efficiency when compared with conventional boilers will be about 15%.

Thus, independent heating systems in which condensing hot water boilers of the proposed design are used as heat-generating plants have a number of the following advantages over centralized heating systems.

- A condensing type heat generator with separate production of water for heating and hot water supply has higher (15%) efficiency, as measured by the higher calorific value of fuel.
- When installing the offered boilers directly at heat consumption objects costly and unreliable external heat networks and, consequently, their heat losses (15-20%) are eliminated.
- The adequacy of heat production for consumers within 24 hours at any time of a year is improved, which results in additional savings of about 15% of fuel.

The total fuel savings when using heaters with separate production of heat for heating and hot water supply is 45-50% and at the same time comfort of heat consumers increases.

Additional advantages of the proposed boilers are their smaller size (in 2-3 times) and lower material consumption (in 1.3-1.5 times) as compared with the best known prototypes.

Basic blocks and aggregates of the developed condensing hot water boiler passed experimental tests, both in laboratory and industrial environments that confirmed their high technical and economic indicators. Different design styles of the condensing hot water boiler, as well as its main components are covered by a number of patents of the Russian Federation.

CONCLUSION

In this paper we analyzed the shortcomings of centralized heating systems with a heat source in a district or quarterly boiler house. We proposed to use independent heat supply systems as an alternative to eliminate most of the disadvantages. It was offered to use condensing boilers with separate production of heat

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transfer agent for heating and hot water supply designed by the fellows of Belgorod State Technological University named after V.G. Shoukhov as heat-generating units for such systems.

SUMMARY

When using condensing hot water boilers with separate production of heat for heating and hot water supply as heat-generating plants in independent heat supply systems the overall fuel efficiency (due to the increase of thermal efficiency of the heat generating unit, elimination of external heat networks and improvement of the adequacy of heat production for consumers) is 45-50% and at the same time comfort of heat consumers increases.

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