Flue Gas Removal Systems Are a Key Issue in the Application of Condensing Boilers

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Abstract. This article is devoted to the most pressing issue of the use of condensing boilers in Russia for autonomous heat supply systems - the organization of smoke removal. If we compare a standard gas boiler with its condensing counterpart, then we can come to the conclusion that their differences lie not only in some innovations, but in radically different principles of operation. Yes, in both cases, the heating of the coolant occurs due to the combustion of the gas, but in the condensing boiler, the heating of the coolant is additionally performed with the help of exhaust gases. Moreover, the smoke removal system in this case produces the primary heating of the liquid - the exhaust gases, which contain a large amount of water vapor, first heat the coolant, and only then directly the gas heats it up to the specified temperature. It is thanks to all this that fuel savings occur - the efficiency of condensing boilers is 15-20% higher compared to standard units of this type. The set of domestic directives and regulations on autonomous heat supply in individual issues, focusing on foreign developments, at the same time has significant features in the requirements for the design and operating conditions of combustion products removal systems, especially for condensing boilers.

1. Introduction

Modern trends in the implementation of energy-saving solutions in the systems of heat generation and heat consumption of buildings for heating, ventilation and hot water supply currently, in most cases, lead to the use of non-energy efficient solutions, in particular, in some cases using heat pumps, solar power plants, wind power plants, in installations using biological resources and in combined devices. Justification of the energy efficiency of their application requires consideration in each specific case, taking into account all structural, operational climatic and economic factors.

Currently, gas boilers are one of the most common heating heat generators in the world. The most energy efficient of them, providing the highest technical and economic indicators, are condensing boilers. At the same time, in almost all cases of application of condensation heat-generating equipment, the energy efficiency of the technical solution is ensured due to the fuel component in operating costs, despite the growth of capital investments in installations. The support by many countries at the state level of energy-saving technologies and concern for environmental protection contribute to the active introduction of innovative technology that meets all standards. The priority task is to increase the efficiency and improve the environmental performance of heat supply systems. Thanks to this, in Europe, gas condensing boilers with high demanded characteristics occupy a leading position among equipment for heating and hot water supply. Since the third quarter of 2015, the EU countries have
decided to switch at new construction sites in the residential sector only to autonomous heating systems based on condensing heat generators, in some countries the installation of any other gas boilers, except for condensing ones, is prohibited.

When analyzing the issue, first of all, the research area should be limited to (individual) apartment or cottage systems, and, since for the first systems it is possible to use only gaseous fuels, we will limit ourselves to natural gas [1].

In the designs of gas condensing boilers of the overwhelming number of foreign and domestic manufacturers, scheme "a" is used, with the organization of the fuel combustion process in a "closed" furnace, and condensation boilers according to the scheme "b" with an open furnace are rarely used.

The horizontal design of the "closed" furnace (combining the gas burner into one volume with the furnace and the convective part) allows organizing the collection and removal of condensate from the boiler and the gas path by "gravity" and, which is especially important, to ensure the operation of pressurized premix burners [2-5] of complete premixing, exclusively in condensing boilers.

2. Methods

When operating a pressurized premix burner with a closed furnace for supplying combustion air, the following options for organizing the boiler aerodynamics are possible:

a) a blower fan (Fig. 1, a), which overcomes the aerodynamic resistance of both the burner and the air intake duct, and the heating surfaces of the boiler [3];

b) with a smoke exhauster (Fig. 1, b), which creates a vacuum in the “closed” furnace, sufficient to overcome the aerodynamic resistance of the burner, air intake duct and boiler;

c) with smoke exhausters creating a vacuum in the furnace (or zero overpressure) to overcome the aerodynamic resistance of the boiler with a blower fan (Fig. 1, c) operating in the air intake and premix burner.

![Figure 1](image.png)

**Figure 1.** Diagrams (a – c) of various types of condensing gas boilers and options for connecting to individual gas ducting air intake devices: 1 - gas burner; 2 - heat exchanger; 3 - smoke exhauster; 4 - air supply channel; 5 - smoke exhaust duct; 6 - blowing fan; 7 - condensate drain
Foreign manufacturers in all considered schemes (Fig. 1, a – c) allow excessive pressure of combustion products behind the boiler, in the connecting gas ducts and at the inlet to the chimney. Domestic standards unambiguously establish the requirement for the presence of rarefaction in them in all operating modes [4–8]. The latter is especially problematic for each scheme (Fig. 1), including for schemes with the installation of a smoke exhauster (Fig. 1, b, c). However, when analyzing the operation of the gas ducts and the chimney, we will be guided by the presence of a pressure point "0" in the outlet gas branch pipe of the boiler for all schemes of organizing the aerodynamic path.

The aerodynamic path of a condensing boiler with a "closed" firebox in all installation options, including apartment installations, must have separate channels (air ducts and gas ducts) for air supply and removal of combustion products, and by their design it can be classified:

• joint, coaxial design (coaxial for round gas ducts), in which the duct of the gas duct (Fig. 1, a) and the chimney is covered by an air duct (Fig. 1, b);
• separate version of air supply and removal of combustion products (Fig. 1, c).

In all versions for cold climatic zones of the Russian Federation, the air supply ducts when passing through the heated room must have external vapor and thermal insulation, with a thermal resistance of at least 3.0 m² K / W, excluding the formation of condensation on the outer surface of the thermal insulation and under it, on the surface of the duct wall.

With a coaxial design, the internal channel for the removal of combustion products must be thermally insulated to avoid overcooling the channel wall with cold air (including excessive condensation and possible freezing). The connecting flue ducts in the section from the boiler to the entrance to the chimney must be laid with a slope towards the condensing boiler with condensate drainage through the boiler, and in the chimney a condensation "pot" with a condensate drain must be provided in the lower zone.

When installing the connecting gas duct, it is necessary not to overlap the "living" section, ensure the tightness of the connections along the gas duct and condensate drainage, observe the necessary conditions for compensating the temperature expansion of the gas ducts. The materials from which the air ducts and gas ducts are made must comply with fire safety requirements, and the channels must have appropriate fire resistance limits [9–13].

The considered design features of condensing boilers and systems for air supply and removal of combustion products, which determine the conditions of their operation in all possible operating and climatic conditions of operation, must, in accordance with the requirements of the regulatory framework of the Russian Federation, ensure the absence (inadmissibility) of excessive pressure in all sections of the connecting gas ducts and chimneys pipes. The presence of a vacuum is a prerequisite for the operation of the aerodynamic path.

Thus, the presence of a vacuum in the connecting ducts is a mandatory requirement.

The calculation of the tract for the removal of combustion products and the chimney should be carried out for the most unfavorable conditions of its operation [14]. Checking for the presence of excessive static pressure in the chimney [15] is carried out according to the value of the defining Richter criterion (must be R <10):

\[
R = \frac{(\lambda + Bi)h_o}{(\rho_w - \rho)D_t} = \frac{(0.02 + 8 \cdot 0) \cdot 18.99}{(1.18 - 1.056) \cdot 0.075} = 30.6 > 10.
\]

\(i\) - pipe taper, \(i = 0\);
\(D_t\) - diameter of the chimney outlet from one boiler 0.075 m;
\(\lambda\) - coefficient of resistance to friction, for a steel pipe \(\lambda = 0.02\);
\(\rho_w\) - air density, taken at \(t = +25\) °C, \(\rho_v = 1.18\) kg / m³;
\(\rho\) is the density of combustion products for condensing boilers at the maximum operating temperature \(t = +60\) °C, \(\rho_w = 1.056\) kg / m³;
\(h_o = \rho w^2 / 2\) - dynamic head created by combustion products at the exit from the chimney at a speed of movement corresponding to the minimum excluding “blowing out” of the chimney at the outlet, \(w = 6\) m / s; \(h_o = 18.99\) Pa [16].
Thus, when the condensing boiler is operating in summer mode, it is impossible to provide vacuum in the chimney.

A more complete picture of the operating mode of the aerodynamic path of a condensing boiler with an individual chimney can be obtained by comparing the self-draft of the chimney and the pressure loss in the gas path.

For comparison, let us take: a 36 kW natural gas condensing boiler with a lower heating value of 36 MJ / m³, a burner excess air ratio α = 1.25, a flue gas temperature of 60 °C (it is possible to use polypropylene parts in the gas path by a number of manufacturers, the maximum operating temperature for which is 65 °C).

Flue gases are discharged according to the schemes (see Fig. 1) without taking into account the cooling of combustion products in the connecting gas duct (l = 1.5 m, two turns by 90 °) and the chimney (chimney height H = 10 m, the deflector head, so as the exit speed is less than the "blowing" speed) with a diameter d = 0.075 m and an estimated speed of movement of flue gases 2.72 m / s.

Chimney self-draft:

$$\Delta P_t = gH(\rho_w - \rho) = 12.16 \text{ Pa}$$

Pressure loss in gas ducts and chimney:

$$\Delta P_l = \sum_{i=1}^{n} \frac{\lambda_i l_i \rho w^2}{d_i^2} + \sum_{j=1}^{m} \xi_j \frac{\rho w^2}{2} = 14.78 \text{ Pa}$$

l_i – total length of gas ducts and chimney, l = 11.5 m;

$$\sum \xi_i$$ – is the total value of local resistances (two turns by 90°, \(\xi = 0.2\) and the chimney deflector \(\xi = 1.6\)).

3. Conclusions
The calculation performed shows that \(\Delta P_t < \Delta P_l\), i.e., the pressure loss in the aerodynamic tract for the removal of combustion products, exceeds the thrust created by a chimney 10 m high, which cannot provide vacuum in the summer period of operation of the condensing boiler when operating at rated power under no circumstances conditions.

The result will be even more unfavorable if the cooling of the flue gases is not neglected and the frequency of operation of the condensing boiler in the "on / off" mode when the load is reduced, if we consider a collective chimney for a multi-storey building, that is, several boilers. Therefore, the use of condensing boilers, due to the low temperature of flue gases, cannot meet the requirements of Russian regulatory documents for ensuring vacuum in chimneys and, according to formal signs, condensing boilers cannot be used. In this situation, it is necessary to make additions and changes to the regulatory documents that define the required list of measures and a system for monitoring their implementation for condensing boilers when organizing smoke removal.

In this case, the chimneys must, of course, be gas-tight, which is achieved by using non-combustible materials, using standardized gas duct sections sealing units.

It is possible to exclude the ingress of combustion products into the room by using combustion products removal schemes that isolate the trunk of the gas outlet from the room (Fig. 1, a, b).

The need to amend the regulatory documents is due to the urgency of the problem of resource and energy conservation, which is greatly facilitated by the introduction of condensation technology.

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