Rational Heat Schemes Using Condensing Boilers in Local Heat Supply Systems

P Khavanov, A Chulenyov

1Heat and Gas Supply and Ventilation department
National Research Moscow State University of Civil Engineering, MGSU
Moscow, Russia

E-mail: roverti@mail.ru, ChulenevAS@mgsu.ru

Abstract. Within the framework of this publication, thermal diagrams of autonomous heat supply systems using condensing heat generators are considered. The insignificant Russian experience of using small condensation boilers in residential construction shows that it is often used to simply replace traditional equipment with condensation technology in existing (or traditionally used) heat schemes, for example, with protection of the boiler from “cold return” by recirculating heat carrier or installing a hydraulic regulator. The consequence of this is almost completely lost the effect of the use of condensing boilers. At the same time, even using the heating temperature schedule of quality regulation 80-60°C and applying water heating to the DHW target up to 45°C you can achieve the effect of the boiler operation in the condensation mode, depending on the construction area, up to 75% of the total working time per year, generating about 70% of thermal energy in the annual cycle. However, it must be borne in mind that the efficiency of the condensing boiler is determined by the part of the latent heat of water vapor in the combustion products, which can be obtained with partial condensation. If this part is small, for example, when cooling the flue gases to 50-45°C (on gas), then the efficiency gain is only 1-3%.

1. Introduction

The active development of decentralized heat supply systems is a consequence of the significant volumes of new cottage construction in suburban and rural development areas, as well as the implementation of large-scale housing construction and the reconstruction of old urban development [1]. Expanding the scope of application of decentralized heat supply contributes to the increase in the number of atypical objects erected both in the cottage and in urban development, where there are often problems in obtaining limits for the supply of thermal energy arising from the lack of available capacities of centralized sources and heating networks.

The steady growth trend in the number of roofed, built-in, built-in and stand-alone autonomous boilers that provide heat to individual buildings (less commonly a group of buildings), with a thermal capacity from 30 kW to 3.5 MW is confirmed in recent years and can be assessed for various regions as 40–80% of the thermal capacity entered in the housing and communal services [2, 3].

The modern system of decentralized heat supply is a complex set of functionally interconnected equipment, including an autonomous heat generating installation and engineering systems of the building (hot water supply, heating systems for various purposes and ventilation). The requirements imposed by consumers of the heat of a modern building to the parameters and characteristics of the
coolant, the conditions for monitoring and controlling the heat supply modes, the duration of operation, pose a whole range of heat engineering tasks for the heat generating installation, significantly complicating its structure [4].

2. Methods

Technical solutions for thermal circuits of autonomous sources should take into account the peculiarities of the initial conditions: by the type of fuel used; type of heat generator; source water quality; conditions of hot water consumption; on the design of heating systems (central, floor, including heating of water in the pools); on the operation modes of the ventilation systems, etc. These technical solutions require careful justification of the choice of the thermal-hydraulic circuit, analysis of the working conditions, ensuring the reliability of operation and protection of the equipment from off-design operating modes.

Issued by the State Construction Committee of Russia, the Code for Designing SP 41-104-2000 “Designing Autonomous Heat Supply Sources” [5], due to objective factors, covers only the basic requirements for constructive solutions and cannot contain an exhaustive amount of recommendations for design (in particular, p.5 “Boilers and auxiliary boiler room equipment “, p. 6" Water treatment and water chemistry regime ", etc.)

Autonomous heating systems are most common in low-rise buildings and in the chronology of development are based on water systems with natural circulation of the coolant [6]. Such heating systems are easy to use, resistant to power outages, however, they have strict design requirements, considerable metal consumption, require a relatively large amount of installation work, have a limited range of stable regulation of the thermal-hydraulic mode [7].

Modern operational, structural and technical requirements for heating systems and, in particular, for their hydraulic stability with local regulation of heat output, low material consumption, automation of all management processes of the heat generator and the system as a whole, as well as the introduction of plastic, metal-plastic pipes and on their basis low-temperature systems of radiant heating (mounted in the floor construction with reduced parameters of the coolant), the expansion of specific functions are assigned x on the heating system (for example, heating water in the pool, maintaining the thermal regime of the greenhouse, winter garden, garage, etc.) - all this led to the widespread introduction of pumping induction of heat carrier movement into autonomous heating systems. Security and automatic control systems, gas burners [8-10], furnaces and circulation pumps, and, consequently, the heating system as a whole cannot function without an uninterrupted power supply system.

Taking into account the peculiarities of architectural planning decisions and the requirements of the technical specification, the thermal scheme of an autonomous source of heat is charged with the complex problem of thermo-hydraulic linking several (sometimes 5 or more) concurrently operating, having hydraulic and thermal interdependence of heating systems of various designs with different operating parameters (often in a complex heating tasks included and the system of forced ventilation). The load on the heating system is determined by the external conditions and almost linearly depends on the outside temperature, which has led to the use of a fairly simple and effective method of quality control of the system's power due to a change in the temperature of the coolant supplied to the heating system at its constant flow rate [11]. The calculated parameters of the coolant at maximum load in different countries are normalized by the values of the flow and return coolant temperatures with regulate schedules: 95–70°C; 90–70°C; 80–60°C. However, elements of the quantiative method are used more and more widely in heating systems, for example, controlling the flow rate of heat transfer fluid through separate heating devices using thermostatic valves, which allows you to independently set the air temperature in each room in accordance with customer requirements.

It is fundamentally important for low loads and lower coolant parameters (periods with partial load), especially when using low-temperature systems of radiant heating, to protect the heat generator from unacceptably low coolant temperatures at the entrance to it and from operating modes with coolant flow rates below the minimum acceptable by the plant manufacturer to prevent the danger of local overheating of the structure. The hydraulic scheme of the autonomous heating system (heating and hot
water supply) is even more susceptible to external influences of the peaks of heat consumption for hot water supply, and as a result, it must be carefully worked out and protected from “abnormal” hydraulic modes. The above explains the introduction of new hydraulic circuits of autonomous heating systems (heating) using the principle of zoning and dividing the hydraulic scheme into two parts with conditionally independent organization of circulation of the coolant in the circuits of the heat generator and heat consumers connected by a common balancing element for hydraulic coupling in variable modes - collector of small differences pressure (often called "hydraulic distributor", "hydraulic arrow") [12-14].

When developing a thermal scheme for condensing boilers, it is necessary to use all available means to reduce the return water temperature to values close to 30 °C. These can be the use of low-temperature systems and the use of return heat carrier from the heating system as a heat transfer fluid for underfloor heating, heating systems for ramps, ramps and platforms, and devices I and II for heating the DHW water, etc.

However, taking into account the climatic conditions and the corresponding seasonal variable operating modes of the equipment, it should be noted that the only real means of obtaining a stable and fairly complete effect from the use of condensing boilers is the development and use of thermal circuits and heating systems with a low-temperature schedule of quality regulation - 60-40°C. With the introduction of low-temperature systems, however, investments not only in the heating system, but also in the whole complex of equipment considered in this article, will significantly increase.

The main tasks assigned to the heat source heat scheme are determined by the goals of ensuring the most efficient use of generated heat, rational conditions for the distribution of heat and coolant flows between consumers, compliance with the passport data for heat carrier parameters and other heat exchangers, and possibilities for balancing the heat circuit by modes heat consumption, time of operation and others.

An important condition for the implementation of the formulated tasks is the adaptation of the entire equipment of the thermal circuit to the type of heat generator, taking into account the requirements for ensuring its heat-hydraulic mode of operation.

Today, the practice of designing autonomous boiler houses in condensing boilers in the country is practically not mastered, and the use of condensing boilers is often limited to replacing the traditional ones in the reconstruction of existing boilers [15-16]. Such replacement of boilers while maintaining the thermal scheme and conditions of operation of consumers minimizes all thermal and economic effects and does not justify the high cost of expensive condensing equipment.

When using condensation boilers, thermal efficiency will primarily depend on the possibilities of providing condensation operation mode, which will be directly determined by the temperature of the coolant at the inlet to the condensing heat generator. In traditional (non-condensing) heat sources, in all operation modes, it is required to ensure the return water temperature not lower than 52–55 °C (the temperature of the dew point of flue gases on gaseous fuel), for which their operation is regulated [17].

For condensation sources of heat, opposite the calculated and most efficient working conditions in the condensation mode will be the lowest temperature of the return heat carrier at the inlet.

The lower this temperature, the higher the efficiency of the heat source, and not only because of the provision of the condensation mode, but also due to an increase in the fraction of the recoverable heat of vaporization of the water vapor from the combustion products.

At the same time in the climatic conditions of Russia it is impossible to provide condensation mode during the entire period of operation during the year.

It should also be noted that reducing the temperature of the coolant at the boiler inlet can significantly expand the possibilities of using low-temperature coolants obtained from alternative sources - solar collectors, heat pumps, etc. These devices are most harmoniously included in thermal schemes with condensing boilers, providing a continuous low-temperature coolant, for example, for hot water supply.
Thus, in thermal schemes with condensing boilers, all methods of raising the return water temperature (heating, recycling, etc.) should be excluded, and for consumers of the heating system and hot water supply it is desirable to convert to the lowest possible coolant parameters:

- For a heating system of 80–60°C; 70–55°C or 60–40°C;
- For the system of hot water heating water up to 50°C or 45°C [18-19].

The latter provisions significantly increase the cost and operation of the systems themselves (often by a factor of 2), but this makes it possible to achieve the full effect of using the heat of condensation of water vapor from combustion products and to obtain up to 7–9% fuel economy when operating condensing boilers on natural gas.

Figure 1. Thermal circuit for use in cottage construction: GBD – gas burner device; CU – the control unit; TB – tank battery; HS – heating system; HE - heat exchanger.

It is possible to use the hydraulic regulator of the HR, however, it must be justified by the hydraulic mode necessary for the condensation boiler and the elimination of the recirculation mode through the HR that raises the temperature of the coolant at the entrance to the heat generator.

For a condensing boiler, there is no need for a HR, also because almost all condensing boilers are equipped with “premix” GBD with modulated power in a wide range, this allows you to adjust the output power to the HS heating system (boiler circuit) not by the flow rate of the heat carrier, but by way without changing the hydraulic mode.

Thermal schemes of cottage heat supply with independent connection of heating systems (through a heat exchanger) are economically unjustified and technologically unjustified.
The use of open thermal circuits (with water pumping for the purpose of hot water supply from the boiler circuit) is impossible due to the conditions of scale generation in the boiler and on the surfaces of auxiliary equipment.

The boiler circuit water must undergo anti-scale chemical treatment, the same level as for conventional water boilers, despite the fact that in the scheme under consideration the temperature may be lowered, but its short-term heating may occur in the on-off mode of GBD.

3. Conclusions
Noting the main feature of the dependence of the efficiency of a condensing boiler on the temperature of the "return" water, it should be noted that they can be used in combination with unconventional heat sources: solar collectors, heat pumps - generating low potential energy. So on fig. 2, as an example, is a schematic diagram of an autonomous TSU with condensing boilers and solar installations (solar collectors) connected to the low-temperature part of the heating and hot water supply system.

Thus, the considered thermal scheme (fig. 1) for use in cottage construction is the most rational with condensation boilers and allows the use of heat engineering and hydraulically beneficial modes of their work.

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