Problems and Need for Alterations in Design of Hot Water Supply in Apartment Buildings

A S Unzhakov

1V.P. Larionov Institute of Physical and Technical Problems of the North Siberian Branch Russian Academy of Sciences, 1 Oktyabrskaya Street, Yakutsk 677980, Russia

E-mail: north.ykt@mail.ru

Abstract. The water supply system and structure used in apartment buildings have been described. Urgent issues of a hot water supply design currently faced by consumers have been identified. Solutions to the problem of hot water supply in apartment buildings have been proposed.

1. Historical background
Modern energy production is a compound infrastructure complex, the foundations of which were laid in the Soviet years. The priority of those times were rapid development of new territories, implementation of global and strategic objectives of providing electricity and heat, prompt housing of the world's largest state territory in the shortest possible time and at the lowest cost. An effective method for solving the above-mentioned issues was construction of apartment buildings with central power supply. Comfortable environment and rational use of energy resources were secondary factors in apartment building design, that affected the principle of designing and building indoor heating network and hot water supply networks. The issue of hot water supply becomes especially relevant under below-freezing outdoor air temperatures in the regions of the Far North, notably, in the Republic of Sakha (Yakutia).

With the following regulatory documents in force: Federal Law № 261 of November 23, 2009 "On Energy Saving and Energy Efficiency Improvement ..." [1]; Federal Law № 416-FL «On Water Supply and Sanitation» from December 7, 2011 [2]; Building Standards and Rules 2.04.01-85 "Internal Water Supply and Sewerage of Buildings" (Order of the Ministry of Construction of Russia dated December 16, 2016 № 951/pr). [3]; Sanitary rules and norms 2.1.4.2496-09 "Hygienic requirements to ensure safety of hot water supply systems. Amendment to SanRaN 2.1.4.1074-01" dated April 07, 2009 № 20 (amended April 02, 2018) [4] a clear state policy change is evident in regard of rational use of energy resources and its accounting, including hot water supply, i.e. establishment of requirements for the quality, temperature regime of hot water supply, the need to install metering devices for supplied resources.

2. Schemes of hot water supply
There are several ways (schemes) of providing hot water supply (hereinafter referred to HWS) in apartment buildings:

An open HWS system is a system in which hot water supply is conducted from the heating system, which advantages are as follows:
- relatively small investment during installation;
- simplicity of design;
- no heat exchangers.

However, there are also some shortcomings of the system:
- low water quality, namely, occurrences of oil products in the water from the stuffing box packing of valves of large diameters of the heating system, rust, scale, reagents, and chemicals used in water treatment to reduce corrosion, which does not correspond to the quality of hot water supply according to Sanitary rules and norms 2.1.4.2496-09 "Hygienic requirements to ensure the safety of hot water supply systems. Amendment to SanRaN 2.1.4.1074-01" dated April 07, 2009 N 20 (amended April 02, 2018) [4];
- non-compliance with the HWS temperature regime, namely, exceeding the threshold of +65°C, which does not comply with Building Standards and Rules 2.04.01-85 "Internal Water Supply and Sewerage of Buildings" (Order of the Ministry of Construction of Russia dated December 16, 2016 № 951/pr) [3].

The use of such a HWS scheme has an extremely negative effect on the health of the population, namely, it increases the number of skin diseases, indigestion, mucous membrane irritation cases, and other consequences. Since the temperature regime of the heating system is significantly higher than the hot water temperature regime, and the hot water temperature preparation system is often lacking or is out of order, thermal injury is not uncommon.

In addition, the presence of rust, boiler scale, reagents, and chemicals in the heat supply system leads to rapid wear of metal HWS networks, namely, pipelines, shut-off valves, filters, mixers, etc.

An open HWS system is quite common in the Russian Federation, including almost all apartment buildings with centralized heat supply in the settlements of the Arctic zone of the Republic of Sakha (Yakutia).

A closed HWS system is an autonomous system, where the water circulation goes through a separate circuit.

In this article, another criterion of classification of HWS systems will be considered in some detail, namely, two-pipe (with a return pipeline) and single-pipe (without a return pipeline) systems.

2.1. Direct supply of hot water from the heat generation source to an elevator unit of an apartment building:

- without a return pipeline. The structural thermal scheme of this method is shown in figure 1.

![Figure 1](image-url) Dead-end scheme of hot water supply: 1-water heater; 2-distribution risers.

In the scheme, hot water does not circulate in the system. In order to get the water of the desired temperature, it must be drained through a tap.
- with a return pipeline.
If the main heating networks are long haul, and the height of the risers is limited, a scheme with looped delivery main is used. A circulation pump is installed on the delivery pipelines. The structural thermal scheme of this method is shown in figure 2.

![Figure 2](image)

**Figure 2.** Scheme with return main pipeline and lower distribution: 1 - water heater; 2 - distribution risers; 3 - diaphragm (additional hydraulic resistance); 4 - circulating pump; 5 - check valve.

A more advanced scheme of HWS is implemented when the upper distribution lines where the collection circulating pipeline is closed in a loop. Water circulation in the pipeline ring in the absence of water intake is under the action of the gravitational head, arising in the system due to the density difference between cold and hot water. The chilled water in the risers flows down into the water heater and displaces the higher temperature water. In this way a continuous water exchange takes place in the system. A structural thermal diagram of this method is shown in figure 3.

![Figure 3](image)

**Figure 3.** Scheme with the return piping and upper distribution: 1 - water heater; 2 - supply riser; 3 - distribution risers; 4 - circulation network.

2.2. Providing HWS by heating and circulating water

Providing HWS by heating and circulating water in the HWS through a heat exchanger is the most rational way in terms of energy efficiency and compliance with HWS temperature requirements, which is not below 60 °C and not above 65 °C. This has been approved in paragraph 5.2.1 Set of rules 30.13330.2016 "BSaR 2.04.01-85 The Internal Water Supply and Sewerage of Buildings" (Order of the Russian Ministry of Construction dated December 16, 2016 № 951/pr) [3]. Better quality of the
temperature regime is due to the closest location of heat exchangers to the places of water intake. That leads to the least inertia in the temperature control mode. The structural thermal scheme of this method is shown in figure 4.

![Figure 4. The scheme of hot water supply by heating and circulation of water in the HWS circuit through a heat exchanger.](image)

However, even when using this HWS scheme, there are problems in the timely hot water for the end users in apartment buildings. In case of upper distribution of hot water pipelines (Fig. 3), the most remote end consumers are apartments of the first floor. In case of lower distribution of pipelines, the most remote end consumers are apartments of the top floor. As a consequence, the higher the building, the longer are the in-house HWS networks (figure 5), the more cooling of hot water occurs in the absence of active water intake. Besides, the more cooled hot water must be drained by the consumer to obtain hot water corresponding to the temperature standard of +60 to +65 °C. Since over the past 20-30 years the apartment buildings have more than 8 floors, the quality of HWS to end users remains low.

![Figure 5. Axonometric scheme of HWS for multicomartment and multi-sectional buildings.](image)
3. Areas of financial and operational responsibilities of HWS networks
In accordance with paragraph 2 of the Resolution of the Government of the Russian Federation of August 13, 2006 № 491, updated March 26, 2014. "On approval of the rules of maintenance of common property in an apartment building, etc." [5], the outer boundary of the water supply networks and the boundary of operational responsibility is the outer boundary of the wall of an apartment building. Thus, to ensure the quality of HWS, namely, to ensure circulation in the loop of HWS through the return pipeline, it is necessary to consider financial and operational responsibilities of the supplying company (to the outer boundary of the wall of an apartment building) and the company servicing an apartment building (inside an apartment building).

Since the early 2000s, in the territory of the Russian Federation, resource supplying companies reconstruct HWS networks to ensure circulation in the loop of HWS through the return pipeline. For instance, a main supplying organization - with the 70% share of the hot water market - has installed more than 48 km of HWS return pipelines in Yakutsk during 2005 – 2020. That increased the total HWS return pipelines installed in the organization networks from 29.3% to 91.4%.

The operation activity of domestic hot water networks by maintenance organizations is an issue that is difficult to statistically analyze and investigate. This is due to a large number of local maintenance organizations, the lack of a unified database of the technical condition of the internal engineering networks. However, there is no rate for maintenance of the internal utility networks in "The List of minimum facilities according to service rate" annually approved by municipalities, which is used by maintenance organizations to assess the cost of services. As a result, since there is no rate and no possibility for subsequent reimbursement of repair costs to the consumers, repair of such networks (heat exchangers, pumps, and pipelines) is not done.

4. Calculation principle of the resource provider with consumers for HWS according to the rate approved by the State Committee on Price Policy of the Republic of Sakha (Yakutia)
In accordance with paragraphs 38 and 42 of the Resolution of the Government of the Russian Federation of May 6, 2011 № 354 "On the provision of public services to owners and users of premises in apartment buildings and houses". [6], utility charges are calculated according to the rates for the consumers. The utility charges are set by the resource supplying organization in accordance with procedures of the Russian Federation legislation on state rates regulation based on the metered values for the billing period.

According to the statistical data analysis of hot and cold water meters of the consumer group in an apartment building with HWS circulation through the return pipe, the ratio of hot and cold water consumption is on average 1:1.5-2. At the same time, according the statistical data analysis of water meters of the similar consumer group in an apartment building without HWS circulation through the return pipe, the ratio is 1.5-2:1. This happens due to draining water from the HWS pipeline to obtain water of the required temperature, or refusal to use cold water in the faucet because of the low temperature of hot water. Thus, there is a 1.5-2 times overconsumption of hot water. An average family, consisting of 3-4 persons, consumes 2-3 m³/month and 24-36 m³/year. In particular, in accordance with the Resolution of the SCC of the Republic of Sakha (Yakutia) of December 17, 2020 № 291 "On adjustment of long-term tariffs for hot water in 2021" [7], overpayment for overconsumption of hot water per family will make 443.8-665.7 rubles/month or 5325.6-7988.4 rubles/year for Yakutsk residents.

According to Rosstat [8], on January 1, 2021 the population of Russia was 146.171 million people, and, in 2020, the share of people living in apartment buildings was 71.4% or approximately 104.366 million people. Since the majority of the population of Russia lives in apartment buildings, the above-mentioned problem is large-scale and significant, and it requires a solution at the state level by amending the legislation of the Russian Federation. That would lead to mandatory changes in the HWS architecture in multi-apartment housing stock and the calculation principles for its consumption.
5. Possible solution to HWS problem in apartment

5.1. To provide measures at the legislative level and oblige resource supplying and maintenance organizations of apartment buildings to provide quality HWS reconstruction and retrofitting of HWS networks with necessary equipment (heat exchanger, return pipes, etc.) are required or they should be restored if inoperable

At the moment, there are no levers of influence that legally oblige resource supplying and maintenance organizations of apartment buildings to provide high-quality HWS. There is a judicial practice of forcing the above-mentioned organizations to fulfill their obligations to provide quality HWS, but this measure is not a systemic solution to the problem. Besides, it requires time and additional financial expenses. Application of the derating factor to the tariff could be of maximum effect in solution of the problem of HWS, as it would provide high-quality HWS without income loss for the supplying organization as described below.

5.2. Application of the derating factor according to the regional State Committees on Price Policy to tariffs for HWS in apartment buildings with no hot water circulation

Correctional derating factors are already applied by the regional State Committees on Price Policy, for example, in tariffs for electric power for rural areas or urban apartments (houses) without gas stoves. It is a theoretically possible remedy, but one should note here that a loss of income of the supplying organization can lead to its request to the regional State Committee on Price Policy to increase rates for HWS which will have a negative impact on the end user. However, the loss of income of the supplying organization while applying derating factor can be an incentive to equip HWS networks with return pipelines.

The method of derating factor calculation can be based on calculation of the water volume drained through the faucet until the hot water corresponds to the temperature regime. In this case, the volume of the discharged water can be calculated by the diameter and length of the HWS supply pipeline. And, the frequency of water discharge should be calculated, respectively, in the morning (after the night cooling of hot water in the pipeline) and in the evening (from 21.00 to 24.00), in the period without active water intake.

5.3. Application of individual metering devices for HWS, measuring in total both the volume of the consumed water and its temperature

Application of individual metering devices for HWS, overall measuring both the volume of water consumed, and its temperature also requires legal approval. Currently, metering devices with such features are used in heating networks. Resource supplying and maintenance organizations are not interested in use of such meters in HWS networks due to the inconsistency of the HWS temperature mode, which decreases an income, as compared with the HWS calculation principle not considering the temperature mode. In addition, existing automated calculation programs for supplied HWS services do consider two components of metered values, such as the water volume and hot water temperature.

6. Conclusion

Comfortable environment and rational usage of energy resources in Soviet times were secondary factors in the design of apartment buildings, which affected the design principle and the system of in-house heating and HWS networks. For several decades, the quality of HWS remained inaccessible.

With a number of federal laws, SNiP, SanPiN entering into force, a clear change in state policy on energy resource rational use and calculation, including HWS, was evident. Specifically, there are a necessity to set requirements for the quality and temperature of HW and an urgent need to install metering devices for supplied resources.

Regarding HWS schemes, the lack of circulation in the HWS system due to the lack or malfunction of the return pipe has been identified as a major factor.
One of possible solutions to the problem of HWS in apartment buildings could be amendments in legislation regulating HWS, as well as application of the derating factor to HWS tariffs in apartment buildings without hot water circulation, using individual metering devices for HWS, measuring both the volume of water consumed, and its temperature.

7. References
[1] Federal Law № 261 of November 23, 2009 "On Energy Saving and Energy Efficiency Improvement ..."
[2] Federal Law № 416-FL «On Water Supply and Sanitation» from December 7, 2011
[3] Building Standards and Rules 2.04.01-85 "Internal Water Supply and Sewerage of Buildings" (Order of the Ministry of Construction of Russia dated December 16, 2016 № 951/pr)
[4] Sanitary rules and norms 2.1.4.2496-09 "Hygienic requirements to ensure the safety of hot water supply systems. Amendment to SanRaN 2.1.4.1074-01" dated April 07, 2009 № 20 (amended April 02, 2018)
[5] Resolution of the Government of the Russian Federation of August 13, 2006 № 491, updated March 26, 2014. "On approval of the rules of maintenance of common property in an apartment building, etc."
[6] Resolution of the Government of the Russian Federation of May 6, 2011 № 354 "On the provision of public services to owners and users of premises in apartment buildings and houses"
[7] Resolution of the SCC of the Republic of Sakha (Yakutia) of December 17, 2020 № 291 "On adjustment of long-term tariffs for hot water in 2021"
[8] Federal State Statistics Service https://rosstat.gov.ru/