Hydraulic Control Method for Heating Systems of High-Rise Buildings

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Abstract. The following article reflects the ideas of possibility to increase energy efficiency of heating systems in high-rise buildings. The article also includes the principle ways of high-rise building heating systems operation as well as traditional engineering decisions aimed at the elimination of the increased pressure effect in heaters. The main disadvantages of such decisions are also presented for the reader. Moreover, the article offers the way of operation for the above-mentioned systems together with the equipment that implements this operation. An economic impact from such energy-saving technology application has been also evaluated.

1. Introduction
The problem of feasibility of high-rise buildings construction constantly causes heated discussions among architects, engineers, social scientists, psychologists, ecologists, medical workers and security specialists. Nowadays, we have to admit that uncontrolled urban sprawl negatively influences on well-being of society. «Horizontal» urban expansion leads to the increase of energy supply costs for cities as well as makes the distance between our homes and working places much longer. For instance, from 1990 till 2000 the average distance, which one person had to drive during one day in the United Kingdom, increased from 2.4 to 40 km.[1].

By now it is possible to surely proclaim that average number of storeys of newly built buildings will increase from year to year.

A building height growth causes escalation of complexity of constructional, architectural and planning decisions. This complexity also concerns the heating systems [2]. The following article describes one of the ways of high-rise buildings heating systems operation, able to ensure the increase of energy efficiency, promote energy savings, decrease the steel intensity of the system, reduce the maintenance costs and make the space necessary for placement of such systems much smaller.

2. Existing state of affairs
In case a building is connected to the central heat source, the structures of heating systems differ dramatically from the structures of the same systems, but applied for low-rise buildings. Such difference is caused by the permissible characteristics of hydraulic pressure that could be noticed on the heaters of consumers [3,4].

As it is seen on the Figure 1, the heaters located on lower levels are under higher pressure than those located on upper levels. The higher the building is, the higher it is the possibility that hydraulic pressure, created by the difference of levels, will exceed the redline of heating appliances [5].
Nowadays, there are a few existing methods of central heating supply for complex constructions, such as high-rise buildings [6-9]:
1) Vertical zoning of heating system, in which the height of zone is defined by the value of permissible hydraulic pressure for heaters and armature located on lower levels;
2) Installation of pressure controllers for the heaters;
3) Installation of appliances and armatures capable to withstand higher pressure.

Each of the above-mentioned methods has its own advantages and disadvantages. The most widespread method that is widely used in Russia nowadays is the way in which the zoning of heating systems is used. (see Figure 2).

It is clearly seen on the Figure 2 that, such way of heaters connection ensures equal hydraulic pressure characteristics for all zones, but it leads to the increase of steel intensity and system complexity. Moreover, if to apply some of the variants of such system layouts it may cause the necessity to create apparatus floors on each level according to the way of how zoning is implemented.

3. Alternative method of providing necessary characteristics for heat carrier in the heating systems of high-rise buildings.
This article contains the ideas about one of the alternative methods of providing necessary characteristics for heat carriers in a heating system. The main sense of the traditional method (zoning) is that an excessive pressure is created in the system from the very beginning, this pressure is
necessary for proper functioning of equipment located on the upper levels, meanwhile the rest of equipment is protected by “reset” of surplus parameters with the help of adjusting devices. The way in which a heating system of high-rise buildings would use the equipment allowing to carry out the recuperation of remaining head [10,11] would be an alternative method to the above-mentioned traditional one (Figure 3).

A new way of usage of surplus head in the heating systems of high-rise buildings consists in the following: hydraulic turbine (Position 1 on the Figure 3), which is installed on the return pipeline of the system, is connected with the pump (heater) impeller (Position 2 on the Figure 3) by the shaft. Actuating medium, water is used as an actuating medium in our case, is transported by step-up pump (Position 3 on the Figure 3), to the heaters located on the upper levels. Further, a heat carrier with surplus head passes through turbine (Position 1 on the Figure 3). Kinetic energy of the stream transforms into rotatory work of the shaft. Then the rotary moment is transmitted to the heater impeller (Position 2 on the Figure 3).

While passing though the turbine fins the surplus head of the heat carrier steam is dissipated. Through this procedure the optimal characteristics of water may be reached, that would guarantee proper functioning of heating appliances located on lower levels avoiding their placement in the increased pressure zone.

It is possible to see this effect on the piezometric graph (Figure 4)
The work of the system in the hydrostatic mode is guaranteed by the pump (Position 4 on the Figure 3), which is installed on the bypass pipeline. Heat carrier stream transported by the pump (Position 4 on the Figure 3) triggers the turbine wheel. Rotational moment from the shaft, which connects the turbine, is transmitted to the heater, so that the system statics is well preserved.

4. Economic impact

The method that is examined in the present article is an alternative method with respect to the traditional one. It consists in a simple energy-saving measure touching upon only one component of one of the independent part of energy-saving sphere [12,13].

It is necessary to take the standard layout of heat supply for high-rise buildings, with its division into zones, and compare it with the layout, where devise capable to carry out the recuperation of surplus head is used [14].

Let us assume that we have the heating system of 27-floors building, the height of the riser pipe is 80 m, its diameter is 25 mm, coolant flow is 2,6 m3/h.

In order to calculate the general capital investment for implementation of the heating system project, we may take into account the approximate pricing characteristics of the equipment[15,16,17]. They may include:

- steel intensity;
- cost of pumping equipment;
- other equipment and armature.

The cost of standard layout:

Steel intensity: The cost of water and gas pipelines, according to State Standard 3262-75[18] accounts for 29700 rubles for 10 m.

For implementation of the project, it is necessary to use 240 m of pipelines, 160 m of which are used for upper zone and 80 m are for lower one.

\[ C_{\text{steel}} = 24 \times 29700 = 712800 \text{ rub}. \]

Pumping equipment.

Step-up pump produced by the company Wilo IPh-W 32/170-2,2/2, guarantees the head of 40 m, costs 189 180 rub.

Pressure controller «after itself» produced by the company Danfoss of the line AVDS [19], costs 47 420 rub.

Approximate overall cost of the system makes up:

\[ C_{\text{overall}} = C_p + C_a + C_{\text{reg}}, \text{rub}. \]

\[ C_{\text{overall}} = 712800 + 189180 + 47420 = 949400 \text{rub}. \]

The cost of the system with usage of recuperation device, proposed in the present article accounts for:

Steel intensity: The cost of water and gas pipelines, according to State Standard 3262-75 accounts for 29700 rubles for 10 m.

For implementation of the project, it is necessary to use 160 m of pipelines.

\[ C_{p} = 16 \times 29700 = 475200 \text{ rub}. \]

Pumping equipment.

Step-up pump produced by the company Wilo Stratos 25/1-10 PN10 [20] guarantees the head of 10 m, has a price of 79 020 rub.

Approximate cost of the equipment due to its uniqueness is about 80 000 rub.
Approximate overall cost of the system makes up:

\[ C_{\text{overall}} = C_p + C_n + C_{\text{equip.}, \text{rub.}} \]  \hspace{1cm} (2)

\[ C_{\text{overall}} = 475200 + 79020 + 80000 = 634220 \text{rub.} \]

The calculation is made non-registering the cost of intermediate apparatus floor, additional piers and equipment.

Basing on the calculations, we can clearly see the cost cutting tendencies in case of implementation of a high-rise building heat supply project by example of one riser pipe following the new method.

For evaluation of economic efficiency of implementation of proposed method at this stage, it is enough to compare the expenses on electricity consumed in the course of two methods.

The cost of electricity for companies and legal entities in Vladivostok accounts for \( C_d = 3.32 \text{ rub.} \) (day time) \( n \), \( C_n = 1.21 \text{ rub.} \) (night time) for double-rate tariff.

The amount of days of heating period in Vladivostok is \( z = 198 \) days.

Expenses on electricity consumption for standard method:

Step-up pump produced by the company Wilo IPh-W 32/170-2,2/2 has a capacity of 2,2 kW, which equals to 0,0022 MJ.

1 kWh = 3.6 MJ

Cost of the electricity consumed during the nighttime:

\[ K_n = \frac{N \cdot 3600 \cdot 8 \cdot C_n}{36} \]

\[ K_n = \frac{0.0022 \cdot 3600 \cdot 8 \cdot 1.21}{36} = 21.3 \text{rub.} \]

Cost of the electricity consumed during the daytime:

\[ K_d = \frac{N \cdot 3600 \cdot 16 \cdot C_d}{36} \]

\[ K_d = \frac{0.0022 \cdot 3600 \cdot 16 \cdot 3.32}{36} = 116.9 \text{rub.} \]

Total electricity consumption cost per day is:

\[ K = K_d + K_n = 21.3 + 116.9 = 138.2 \text{rub./day} \]

Total cost of electricity consumption during the whole heating period:

\[ K_{\text{total}} = K \cdot z = 138.2 \cdot 198 = 27356.5 \text{rub.} \]

Expenses on electricity consumption for proposed method:

Step-up pump produced by the company Wilo Stratos 25/1-10 PN10 has a capacity of 0.19 kW, which equals to 0,00019 MJ.

1 kWh = 3.6 MJ.

Cost of the electricity consumed during the nighttime (according to expression 3):

\[ K_n = \frac{0.00019 \cdot 3600 \cdot 8 \cdot 1.21}{36} = 1.8 \text{rub.} \]

Cost of the electricity consumed during the daytime (according to expression 4):

\[ K_d = \frac{0.00019 \cdot 3600 \cdot 16 \cdot 3.32}{36} = 10.1 \text{rub.} \]
Total electricity consumption cost per day is:

\[ K = K_d + K_r = 1.8 + 10.1 = 11.9 \text{ rub / day} \]

Total cost of electricity consumption during the whole heating period:

\[ K_{\text{total}} = K \cdot z = 11.9 \cdot 198 = 2356.2 \text{ rub.} \]

Reasonability of usage of the proposed method is evident. Reducing of electricity consumption leads to significant savings of fuel, burnt for acquiring additional energy. Consequently, it leads to decrease of harmful substances emission into atmosphere.

The calculation is made by using approximate and average characteristics. Implementation of the method will be considered successful even with calculation error of 100%.

5. Conclusion

As the result of our investigation, we developed a fundamental method allowing carrying out the recuperation of surplus pressure in the heating systems of high-rise buildings. Several advantages of the new method, which is an alternative one with respect to the traditional method, were identified. There are the following advantages:

- Usage of the new methods allows avoiding the application of standard ways of high-rise buildings heating system planning with its division into zones;
- Newly proposed method allows carrying out the recuperation of surplus head in the heating systems of high-rise buildings and getting the resources saving results at the same time;
- Significant decrease of steel intensity;
- Cutting of expenses on installed equipment and armature.

There appears an opportunity to install less-capacity step-up pumps, especially taking into account that the capacity of the pumps directly depends on their price;
- Saving of electricity consumption by the system;
- The need to organize additional apparatus floor disappears.

Made calculation demonstrates the economic efficiency of application of new regulation method.

References

[1] Ross Donald E 2004 HVAC Design Guide for Tall Commercial Buildings (Atlanta)
[2] Shechukina N M 2007 Modern high-rise construction (Moscow: GUP “ITC of Moscomarchitecture”) p 440
[3] Boguslavskiy L D, Livchak V I and Titov V P 1990 Energy saving in heat supply systems, ventilation and air conditioning systems: reference book (Moscow: Stroyizdat) p 624
[4] Bogoslovsky V N, Pitchers Yu Ya and Malyavina E G 1982 Climatic design and operation of buildings with efficient use of energy Proceedings of the international Symposium “Building climatology” (Moscow) pp 14–19
[5] Set of Rules 60.13330.2012 – heating, ventilation, and air conditioning
[6] Bashmakov V I, Borisov K B, Zajicek M G, Lebedev O V, Lunin A A and Myshak A D Analysis of the real estate sector of Russia. Identifying the need to change the system of regulation of energy efficiency Implemented with the support of Association “Rosizol”, NAPPAN and APPP
[7] Brodach M M 2007 Engineering equipment high-rise buildings (AVOK-press) p 320
[8] Boguslavskiy L D 1990 Saving heat in residential buildings (Moscow: Stroyizdat) p 192
[9] Golubkov A N 2005 Experience in the design and operation of engineering systems new high-rise residential complexes of Moscow (Moscow: ABOK) 2/2005
[10] Makarov D A, Likhachev D I, Chernenkov V P, Eskin A A and Revenko D O 2014 Method of operation of the heating system (RU Patent 2577714)
[11] Makarov D A, Chernenkov V P and Likhachev I D 2015 Optimization of pump-throttling
substation of heating networks *Applied Mechanics and Materials* vol 792 pp 375–378
DOI:10.4028/www.scientific.net/AMM.792.375

[12] *Balancing of differential pressure in heating systems: Danfoss Hydronic Balancing* (Nordborg: Danfoss A/S)

[13] *GOST R 51541-99 and Energy efficiency. The composition of indicators. General provisions*

[14] *RD 50-374-82 “guidelines for the composition and content made to the standards and specifications of standards of consumption of fuel and energy per product unit (work)”*

[15] Dmitriev A N, Kovalev I N, Tabunschikov Y A, Shilkin N V 2005 *Guidance on evaluation of economic efficiency of investments in energy saving measures* (Moscow: AVOK-PRESS)

[16] Prokhorov V I 2003 Energy balance of the building systems and the return on new technological solutions *Of a modern system of heat and ventilation: collected works* (Moscow: MGSU) p 818

[17] Naumov A L and Chapko D C 2015 The class Definition of energy efficiency operated residential apartment buildings *Energy saving* 8

[18] *GOST 3262-75 Water-supply and gas-supply steel pipes*

[19] *Product catalogue Danfoss “Hydraulic temperature controllers, pressure and flow rate” RC.08.H12.50*

[20] *Katolog products Willo A2 “pumps with wet rotor”*