Hydraulic Stabilization of Heat Network

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Abstract. The article analyzes changes in pressure in the heating network taking into account the variable daily heat consumption. The simulation assumes diversification of heat demand during the day due to significant differences in the distribution of hot water. Taking the decreases in hot water consumption by up to 70%, pressure losses were calculated on the sections of the district heating network. Changes in the flow rate are taken into account. The simulation assumed changes in water flow from 10% to 70% respectively. Completed calculations and results are presented in diagrams drawn up for different amounts of hot water consumption. They allowed determining the size of the changing pressure of the available heat network. Graphs of dependencies between changing flows and the corresponding pressure values illustrate the magnitude of these changes. In the case of central heating, the heat demand is determined in the so-called external air temperature calculation conditions. The heating plant works in accordance with an ordered diagram of heat loads. The amount of heat delivered to the recipient for central heating depends on the outside temperature. It is calculated on the basis of the heat load factor and the average heat demand of individual customers. In relation to the production of hot water, the unevenness of the hot water demand should be taken into account. This variable size, as a result of the day, is described by the hourly diversity factor. For such calculations, daily schedules of hot water consumption are developed. On their basis, the operation of the heat network was analyzed. The heating network section and the hydraulic system of the network were analyzed for existing pressure changes, which are caused by the variability of the heat demand for heating domestic hot water. The calculations and simulations carried out show that the calculated flows, and thus also the pressure losses in the considered network, are variable and depend on the distribution of hot water to consumers. These differences are significant and affect the choice of pumps, which can bring significant financial benefits throughout the year.

1. Introduction

For the purposes of the simulation, a heating plant and heating network for central heating and hot utility water were calculated, the demand for thermal energy was calculated. For central heating (co), the heat demand was calculated in computational conditions, i.e. for outside air temperature. The district heating plant works in accordance with a structured diagram of thermal loads. The amount of heat supplied to the recipient for the purposes of central heating depends on the variability of the outside temperature, which is conditioned by the weather. It is calculated using the thermal load coefficient and the average heat demand of individual customers. The heating plant operates differently in order to prepare hot usable water. There is an irregular demand for hot water (DHW) within 24 hours. This variability is described as the coefficient of variation in the demand for hot water. Therefore, to calculate the heat demand for DHW heating, daily schedules for hot water

consumption should be developed. On this basis, an analysis of the operation of the heat and heating network with a length of 2310 m was made. The hydraulic system of the network was analyzed for the occurrence of pressure changes caused by the variation of heat demand for heating domestic hot water.

2. Thermal networks, types, configuration

Thermal networks are usually divided into residential, municipal and industrial networks. It often happens that networks are mixed and support both industrial areas and housing estates. The spatial shape of the network depends on the terrain configuration. When designing a network, one should remember about economic criteria. Considering the system of heat supply from the heat source to the heat consumer, i.e. heating plant, heat distribution network and internal installations, significant savings can be achieved in the grid, in terms of both investment and operating costs.

Choosing the right arrangement of wires, proper arrangement and shape of the network, avoiding collisions with other elements of the network's infrastructure has a significant impact on the sum of the costs of the undertaking. Currently, pre-insulated heat pipes are the most popular and offered on the market. They are produced in various variants of insulation thickness and various diameters. Thanks to good insulating parameters, heat losses are minimized.

Pre-insulated pipe systems are equipped with an alarm system enabling quick detection of failures. In the present era, this is an element of the necessary reliability and safety of heating networks. The shape of the heating network is very important. The principles and direction of heat distribution to recipients depends on the mutual location of the heating plant and heat consumers, on the thermal density of the area, on the location of streets and on utilities.

3. Energy balance of the area

The energy law indicates the obligation to make a balance of heat demand for the heating subsystem. Such a balance can be made based on a spatial development study and individual unit thermal computing indices. On this basis, the balance of thermal needs for central heating and domestic hot water purposes was carried out on the premises of the balance units adopted for the analysis. Demand for computational heat is the basis for identifying evolving needs.

The actual heat consumption varies over time, due to the varying consumption of hot water as well as the thermo-modernization of the objects to which the heat is supplied. Due to economic reasons, the owners and users of buildings perform thermo-modernization treatments.

By improving the insulation of external walls and the replacement of window and door carpentry, the heat loss of buildings is significantly changed. The use of automation to control the operation of heat distribution centers has a large impact on the reduction of heat consumption.

4. Principles of heating network regulation

The heat demand of the recipients is always variable. In wide networks, mixed regulation is used. The parameters in the network are adapted to the largest number of recipients, and this is usually central heating.

Automatic local regulation is used for individual needs. For this purpose, heat stations should be designed, equipped with automatic regulators.

In thermal networks, we use:

- quality regulation; the temperature of the heating medium changes, while the amount of heating medium flow and flow rate remain constant,
• quantitative regulation; the constant value is the temperature at variable intensity of the heating medium,
• quantity and quality regulation, consisting of changing both the intensity of the flowing factor and the change in its temperature.

In flow quality control, we provide stable hydraulic conditions at constant flow. [1] In the case of quantity regulation, the amount of heat transported through the network depends on the amount of heating medium transferred. There is no dependence on its temperature in this case. In district heating systems, the supply water temperature is kept constant, and its quantity is changed by changing the flow resistance. When changing the amount of flowing water, the temperature of the return water will change, the height of these changes being the result of cooling. For heat demand for heating domestic hot water, quality control is not enough.

The flow temperature of the supply water should not fall below 70 °C due to the required domestic hot water temperature. The temperature 70 °C corresponds to the heating requirements, with an outdoor temperature of + 5 °C, according to the load diagram. In this case, the mains water temperature will remain constant throughout the summer (heating does not work in summer). To maintain a constant supply water temperature, it is best to use quantitative regulation.

5. Hydraulic calculations of thermal networks
For the analyzed section of the heating network, hydraulic calculations were made. Pipe diameters, flow velocity of the heating medium and pressure losses in the pipes due to frictional resistance and local resistances. The total pressure loss in the Hc duct is the sum of the losses caused by the friction resistance $H_t$ and the local resistances $H_m$

$$H_c = H_t + H_m$$

The frictional resistance is proportional to the length of the pipe. They are the product of partial losses $h$ and the length of computational segments $l$, calculated circulation.

$$H_t = \Sigma hl$$

Heat pipes are made of steel pipes of various roughness. For this reason, for the partial calculation of frictional resistance, the formulas in which the coefficient of friction depends only on the degree of roughness of the pipe walls should be used. The starting point for the calculation of pressure losses caused by frictional resistance in thermal conductors is the formula:

$$h = \lambda \frac{v^2}{2gd}$$

Where:
- $\lambda$ - coefficient of friction
- $v$ - speed
- $\gamma$ - specific gravity
- $g$ - acceleration of gravity
- $d$ - pipe diameter

In order to analyze the hydraulic system, the diameters of the district heating network were calculated, assuming unit pressure losses on the calculated sections of the network.

In order to analyze the operation of the heating installation and change the pressure in the network, the necessary calculations were made. The calculations take into account the change in the demand for
heat during the day due to significant differences in the consumption of hot water in accordance with Figure 1. [2]

![Figure 1. Differences in the consumption of hot water (24 hours)](image)

Assuming variable demand for hot water, calculations of pressure loss resulting from variable flows were made. [3] Piezometric diagrams for different values of consumption of hot water, ranging from 10% to 70%, respectively, allow determining the changing disposable pressures. Graphs of dependencies between changing flows and the corresponding pressure values illustrate the magnitude of these changes, Figure 2.
Figure 2. Change in pressure in the heating plant caused by the lack of balance in the reception of hot water by customers.

6. Plots of pressure lines in water networks
To illustrate the operating conditions of the analyzed heating plant and heating network, piezometric diagrams were made. The analysis of the heat network system made of pre-insulated pipes with the circulating pump on the return pipe was analyzed, Figure 3.
Figure 3. Change in pressure in the heating plant caused by the lack of balance in the reception of hot water by customers.

The pressure difference created by the pump overcomes the total flow resistance. Pressure graphs were made in a rectangular coordinate system with running circulation pumps. The necessity to maintain constant hydrostatic pressure during the stop of circulation pumps requires the use of systems stabilizing this pressure. In water heating networks, stabilizing systems are used in the heat plant. The analyzed network uses a system with supplementary-stabilizing pumps. The basic factors affecting the selection of the stabilizing system are: the minimum height of the stabilization pressure, the required pressure in the heating network and the heat source during circulation pumps operation and the variability of pressure in the heating plant and the network. It is in networks that transmit large powers that systems with supplementary-stabilizing pumps are used. These systems allow for the free regulation of the pressure in the network, both during the stop of circulation pumps and during their operation. In addition to maintaining pressure, the supplementary-stabilizing pumps turn on to make up for water losses caused by, for example, pipeline failure.

7. Conclusions
The calculations and simulations carried out show that the calculated flows, and hence the pressure losses in the network in question, are variable and depend on the hot water consumption of the heat consumers. The differences in pressure losses reach over 136 kPa, which is over 16% of the available pressure. With less extensive networks with fewer recipients, these differences are even more noticeable, as disproportions in the distribution of hot water within 24 hours are also more noticeable.

The most advantageous solution, in this case, is the use of pumps with variable performance characteristics. Pump regulation decreases energy consumption. Both during the heating season and
outside it there are similar differences in the demand for hot water throughout the day. In the whole year, this will provide significant financial benefits. Conducting further analysis of the network in question, one could focus on the differences in heat consumption of recipients caused additionally by weather changes. Automation controlling heat exchangers reduces heat consumption when the aura does not require maximum use of heat supplied to heat buildings. However, the process of these changes is characterized by high inertia and the effects of changes in heat utilization are delayed compared to changes in the recipient's conditions. This problem is more complicated and requires a broader analysis. Summarizing the calculations made for the analyzed section of the C-4 heating network, one can state that:

- in the case of hot water, the flow rate and pressure are variable within 24 hours, according to the consumption schedule,
- the pressure difference for the minimum and maximum demand for hot water is over 16% of the available pressure,
- in the case of the designed network system, it is proposed to use circulation pumps with variable, automatically regulated parameters,
- the pumps must cooperate with hot water heating nodes programmed in accordance with the hot water consumption schedule, which will allow for financial savings

References

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