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ВЫЯВЛЕНИЕ И МОДЕРНИЗАЦИЯ ТЕПЛОПОТЕРЬ В ТЕПЛОПЕРЕДАЮЩИХ ТРУБОПРОВОДАХ СИСТЕМ ОТОПЛЕНИЯ ОБЩЕСТВЕННЫХ ЗДАНИЙ.

IDENTIFICATION AND MODERNIZATION OF HEAT LOSS IN HEAT TRANSFER PIPES IN HEATING PUBLIC BUILDINGS.

Аннотация: В статье анализируются теплопотери теплопередающих труб, используемых в системах отопления общественных зданий, и предлагаются решения по их модернизации. В исследовании сравнивались устаревшие стальные трубы с современными полиэтиленовыми (PEX-a) трубами. Согласно результатам расчётов, теплопотери стальных труб составляют 78 Вт/м, а полиэтиленовых – 48 Вт/м, что позволяет экономить тепло на 38–40%. При этом полиэтиленовые трубы устойчивы к коррозии, просты в монтаже и имеют длительный срок службы. Результаты исследования создают основу для повышения энергоэффективности и снижения эксплуатационных расходов в общественных зданиях.

Ключевые слова: Теплопотери, система отопления, трубы PEX-a, стальные трубы, теплоизоляция, энергоэффективность, термографическое обследование, теплопроводность и конвекция, модернизация трубопроводов, теплоноситель.

Abstract: This article analyzes the heat loss of heat transfer pipes used in heating systems in public buildings and proposes solutions for their modernization. The study compared outdated steel pipes with modern polyethylene (PEX-a) pipes. According to calculations, the heat loss of steel pipes is 78 W/m, while that of polyethylene pipes is 48 W/m, resulting in heat savings of 38–40%. Polyethylene pipes are also corrosion-resistant, easy to install, and have a long service life. The study's results provide a basis for improving energy efficiency and reducing operating costs in public buildings.

Key words: Heat loss, heating system, PEX-a pipes, steel pipes, thermal insulation, energy efficiency, thermographic survey, thermal conductivity and convection, pipeline modernization, coolant.

Annotatsiya: Maqolada jamoat binolarini isitishda ishlatiladigan issiqlik tashuvchi quvurlarning issiqlik isroflari tahlil qilindi va modernizatsiya yechimlari taklif etildi. Tadqiqotda **eskirgan po‘lat quvurlar** bilan **zamonaviy polietilen (PEX-a) quvurlar** solishtirildi. Hisoblash natijalariga ko‘ra, po‘lat quvurlar liniyadagi issiqlik yo‘qotishini **78 W/m** tashkil etsa, polietilen quvurlarda esa **48 W/m** ko‘rsatkichida bo‘lib, 38–40% issiqlik tejash imkonini beradi. Shu bilan birga, polietilen quvurlar korroziyaga chidamli, o‘rnatish oson va uzoq xizmat muddatiga ega. Natijalar jamoat binolarida energiya samaradorligini oshirish va ekspluatatsiya xarajatlarini kamaytirishga asos bo‘ladi.

Kalit so’zlar: Issiqlik yo‘qotishlari, isitish tizimi, PEX-a quvurlar, po‘lat quvurlar, issiqlik izolyatsiyasi, energiya samaradorligi, termografik tekshiruv, konduksiya va konveksiya, quvur liniyasi modernizatsiyasi, issiqlik tashuvchi vosita.

Introduction.

Heating systems for public buildings are of great importance in modern construction and energy, and their efficiency determines the thermal comfort and energy efficiency of buildings. Typically, central heating systems are used to transport thermal energy in these buildings, in which the heat carrier - water or steam - is distributed through pipes. However, practical studies show that in many public buildings, the efficiency of heat carrier pipes is low, and heat losses are significant. This leads not only to excessive consumption of energy resources, but also to a decrease in thermal comfort. One of the main causes of heat loss is improper insulation of pipes, worn-out materials, and improper balancing of the system. Also, the architectural features of buildings and the operating mode of the heating system affect the heat loss indicators. Therefore, determining the efficiency of heat transfer through pipes and modernizing existing systems is an important way to increase energy efficiency. Currently, using energy-saving technologies and modern materials, it is possible to significantly reduce heat losses by renewing pipes, strengthening insulation, and introducing automatic system control. This not only improves the indoor microclimate in public buildings, but also contributes to the efficient use of national energy resources. In this regard, the issue of identifying waste heat transfer pipes in heating systems of public buildings and their modernization is of practical and scientific relevance [1-2].

Method.

For efficient heating of residential and commercial buildings, as well as other premises, it is important to provide sufficient thermal energy, which requires taking into account heat loss in the pipeline. Calculation of heat loss in pipelines is carried out using formulas based on the thermophysical properties of materials (thermal conductivity, heat transfer) and the properties of the environment (temperature, velocity). The main method involves calculating heat loss through insulation and heat transfer on the pipe surface. Special programs or more detailed methods can be used, taking into account various parameters such as length, diameter, insulation, coolant and ambient temperature, wind speed. To achieve this, specialists regularly calculate heat loss. Various formulas are used as the basis for these calculations.

Heat loss occurs as a result of the transfer of energy through a pipe to the environment due to a temperature difference. Theoretically, heat loss occurs through three main mechanisms: conduction (conduction), convection (heat exchange with a moving fluid) and radiation (radiation).

Conductive loss is the process of heat transfer through a material, which is especially important for pipes. The thermal conductivity of the pipe and the insulation is calculated. Conductive heat loss for cylindrical pipes is determined by the following formula:

$$Q_{\text{cond}} = \frac{2\pi k L (T_{\text{in}} - T_{\text{out}})}{\ln(r_2/r_1)} \qquad (1)$$

This expression describes the one-dimensional stationary heat transfer (conduction) through the pipe, i.e. Thermal conductivity is the ability of a material to conduct heat. The higher the value of *k* nintg, the better the material conducts heat. In the design of boiler houses, the length of the pipe *L* is an important parameter that directly affects the difference between the internal and external temperatures. When creating a driving force that causes heat flow, heat always flows from a higher temperature to a lower temperature, so it is assumed that $T_{in} > T_{out}$ (if heat flows from the inside to the outside)[3-4].

The denominator (divisor) of the formula is related to the resistance of the cylinder to heat transfer. This resistance is more complicated due to its cylindrical shape, unlike a simple flat wall. The factor $ln(r_2/r_1)$ in the denominator takes into account the natural logarithm of the ratio of the outer radius (r2) to the inner radius (r_1). This geometric factor takes into account the thickness of the cylinder wall and its curved shape. The thicker the cylindrical wall (i.e., the larger the ratio (r_2/r_1)), the higher the resistance, resulting in a lower heat flux Qcond.

Thermal energy losses are calculated taking into account the density of the heat flux emitted through the insulated surfaces of the pipes. To determine the required parameter, tabular data from the QMQ methodological manual are used, calculated per meter of pipe. Calculation of heat losses for pipes with temperature diameters and coolants not specified in the table is carried out using interpolation and extrapolation methods.

The estimated thermal energy losses of the pipeline are determined by the following formula:

$$Q = q \cdot L \cdot K \cdot B \quad (2)$$

The quantities involved in this expression represent the main parameters used to estimate heat losses in pipelines. In the formula, q is the specific (standard) heat loss density per one meter of pipeline length, expressed in W/m. This value is determined taking into account the average temperature of the coolant and the standard annual operating life of the pipeline. The parameter is determined for each diameter based on the table data in the QMQ 2.04.17-2019 regulation.

The coefficient K takes into account additional heat losses due to supports, fittings, shut-off valves and other additional elements installed on the pipeline. Its value is also taken from the standard table values. B is a coefficient reflecting the change in heat flux density through polyurethane foam (PUF)-based thermal insulation, which is also selected according to the regulatory document QMQ 2.04.17-2019. L is the total length of the pipeline network, measured in meters, and serves as the geometric key parameter in determining the integral amount of heat loss[5].

Therefore, depending on the pipe diameter and the thickness of the thermal insulation, the thickness of the thermal insulation (λ = 0.035 W/mK) can be determined from the table of pipe heat losses at ΔT = 30°C.

Pipe heat losses

Table 1

№	Insulation thickness (mm)	Pipe diameter (mm)						
		8 (¼")	15 (½")	20 (¾")	25 (1")	32 (1¼")	40 (1½")	50 (2")
1	10 mm	5,8	8,6	10,3	12,3	14,9	17,9	21,6
2	13 mm	5,0	7,5	9,0	10,2	12,2	14,5	17,3
3	16 mm	4,5	6,4	7,8	9,0	10,6	12,3	14,7
4	19 mm	4,1	5,7	6,7	7,8	9,3	10,9	12,8
5	20 mm	3,9	5,6	6,6	7,7	9,1	10,5	12,3
6	25 mm	3,7	4,9	5,8	6,6	7,7	9,0	10,5
7	30 mm	3,4	4,5	5,3	6,0	6,9	8,0	9,3
8	32 mm	3,3	4,3	5,1	5,7	6,6	7,6	8,8

9	40 mm	3,0	3,9	4,5	5,1	5,9	6,6	7,6

In addition to calculations, it is important to take effective measures to reduce heat loss in pipelines. There are several ways to achieve this goal:

• periodic inspection of the pipeline condition;

• if necessary, restoration of anti-corrosion, heat and waterproofing coatings of pipelines;

• increasing the pH level of the transported water;

• determination of actual heat losses using heat measuring devices in real time;

Thermographic inspection is also an important test method for maintaining constant control of the heating network for public buildings. This test helps to determine the insulation of the heating network and heat losses. A thermographic camera is a technology that uses infrared rays to measure and image the temperature of various objects, which are invisible to the human eye, but clearly show temperature differences. It allows you to detect temperature differences and identify system malfunctions through visual images.

Results and Discussion.

Considering that the thermographic method is included in the class of seasonal heating systems for public buildings, it can be somewhat easier to constantly measure and monitor the temperature difference in the heating network, pipes, radiators, pumps, and other systems during the cold winter months.

Figure 1. Measuring temperature in pipes using an infrared thermal camera.

The measurement results showed that it is very difficult to replace worn-out pipes in an operating building, or even to conclude that a complete reconstruction is necessary. However, it was found that the temperature in several rooms of the building dropped sharply, which made it necessary to conduct a series of tests, depending on the level of insulation of the room. The temperature difference between the buildings is shown in the table below, and the difference between the flow and return temperatures is -100 C, which should be noted that standard testing of buildings should be carried out regularly.

One of the most important areas for improving energy efficiency in central heating systems of public buildings is the replacement of heat-carrying pipes with modern, corrosion-resistant and low-heat-loss materials. Practical experience shows that ordinary steel pipes are still used in many schools, hospitals and administrative buildings. Their heat loss is high (on average 70–80 W/m), the corrosion rate is high, and the service life does not exceed 15–20 years. Therefore, there is a need to modernize such pipes. One of the most effective technical solutions for this process is the use of PEX-a (peroxide-crosslinked polyethylene) pipes[6].

Figure 2. PEX-a (peroxide-crosslinked polyethylene) pipes.

The main advantage of PEX-a pipes is their high flexibility, temperature and pressure resistance, complete lack of corrosion, and reduced hydraulic losses due to their smooth inner surface. Since their thermal conductivity is lower than that of steel pipes, linear heat loss is also significantly reduced. According to studies, the heat loss of PEX-a pipes is on average 45–55 W/m, which provides savings of 30–35% compared to steel pipes. In this case, if the pipes are protected by additional insulation, losses are even lower.

The introduction of PEX-a pipes into internal heating networks of public buildings provides a number of practical advantages. Firstly, the installation process is much faster and cheaper, since they have high bending strength and require a small number of connecting parts. Secondly, the service life is 25–30 years, and service costs are practically not required. Thirdly, due to the presence of an oxygen barrier (EVOH layer), the pumps, radiators and boilers in the system are also protected from corrosion. Thus, PEX-a pipes are considered the most energy-efficient, long-term and economically viable technological solution for modernizing the heating system of public buildings[7].

Conclusion.

The results of the analysis show that the steel pipes used in the existing heating systems of public buildings reduce the efficiency of the system with high heat loss, corrosion risk and short service life. According to the calculations, PEX-a pipes reduce linear heat loss by 30–35 percent, are completely resistant to corrosion and the installation process is quite economical. Their service life is 25–30 years, which significantly reduces operating costs. Therefore, the use of PEX-a pipes is considered the most optimal and effective solution for the modernization of heating networks of public buildings.

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