Buxoro shahrida markazlashtirilgan isitish tizimini rekonstruksiya qilish loyihasini amalga oshirishda issiqlik tarmoqlarining energiya samaradorligini oshirish va ekologik komponentni yaxshilash

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Dolzarbligi: O‘zbekiston Respublikasi issiqlik energetikasining bugungi holati energiya manbalarining energiya samaradorligini oshirish va tabiiy resurslardan oqilona foydalanish, energetika sohasida, jumladan, sanoat, ijtimoiy va maishiy tarmoqlarni issiqlik bilan ta’minlash uchun zamonaviy materiallardan foydalanish bo‘yicha kechiktirib bo‘lmaydigan chora-tadbirlar ko‘rib chiqilgan.
Maqsad: issiqlik ta'minoti tizimiga zamonaviy texnologiyalarni joriy etish va issiqlik energiyasini tashishda yo'qotishlarni sezilarli darajada kamaytirish, qazib olinadigan yoqilg'i va tabiiy resurslar iste'molini kamaytirish, ekspluatatsiya va ishlab chiqarish xarajatlarini kamaytirishni ta'minlash. Shuning uchun energiyani tejash bo'yicha asosiy e’tibor issiqlik energiyasini tashish va iste'molini samarali nazorat qilish sohasiga qaratilishi kerak.
Usullar: Issiqlik ta'minoti tizimlarini qiyosiy tahlil qilishning xalqaro tajribasi va usullari qo'llaniladi.**Natijalar:** elektr energetika tizimlarining qisqa muddatli holatlarini tadqiq qilish asosida, 14-tugunli IEEE test sxemasi misolida tahlil qilindi. Quyosh elektr stansiyalari va AB tizimlarining tizim chastotasiga ta’sirini baholash natijalari keltirilgan.
Natijalar: energiya tejash chora-tadbirlarini amalga oshirish katta ijtimoiy samara beradi, chunki bu Buxoro shahridagi iste’molchilarni issiqlik va issiq suv bilan ta’minlashning ishonchliligi va barqarorligini oshiradi, issiqlik energiyasi ishlab chiqarishda yoqilg‘i sarfini kamaytiradi, atrof-muhit holatini yaxshilaydi. Buxoro shahridagi markazlashtirilgan issiqlik ta’minoti tizimini rekonstruksiya qilish va issiqlik ta’minoti korxonalarining energiya samaradorligini oshirish loyihada nazarda tutilgan ekologik chora-tadbirlarga rioya qilgan holda atrof-muhit va aholi salomatligi uchun salbiy oqibatlarni sezilarli darajada kamaytirishga olib keladi.
Kalit so'zlar: Isitish tarmoqlari, energiya tejash, energiya samaradorligi, issiqlik izolyatsion material, issiqlik magistral, ko'pikli poliuretan izolyatsiyasi, issiqlik energetikasi, ekspluatatsiya

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Повышение энергоэффективности теплосетей и улучшение экологической составляющей при реализации проекта реконструкции централизованного теплоснабжения в г. Бухаре

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Актуальность: современное состояние теплоэнергетической отрасли Республики Узбекистана требует принятия неотложных мер для повышения энергоэффективности энергоносителей и рациональному использованию природных ресурсов, применения современных материалов в энергетической отрасли, в том числе и для теплоснабжения объектов производственного, социального и бытового сектора
Цель: внедрение современных технологий в системе теплоснабжения и обеспечение значительного уменьшения потерь при транспортировке тепла, сокращение потребления ископаемых энергоносителей и природных ресурсов, снижение эксплуатационных и производственных расходов. Поэтому основные усилия по энергосбережению должны быть сконцентрированы именно в сфере транзита и эффективного контроля потребления тепла.
Методы: используется международный опыт и методы сравнительного анализа систем теплоснабжения.

Результаты: реализация энергосберегающих мероприятий даст большой социальный эффект, т.к. позволит увеличить надежность и стабильность обеспечения потребителей г. Бухары теплом и горячей водой, снизит расход топлива при выработке тепловой энергии, а также улучшит состояние окружающей среды. Реконструкция системы централизованного теплоснабжения и повышение энергоэффективности теплоснабжающих предприятий в городе Бухаре приведет к значительному уменьшению негативных последствий для окружающей среды и здоровья населения при условии соблюдения природоохранных мероприятий, предусмотренных проектом.
Ключевые слова: Тепловые сети, энергосбережение, энергоэффективность, теплоизоляционный материал, теплотрасса, пенополиуретановая изоляция, теплоэнергетика, эксплуатация.

Improving the energy efficiency of heating networks and improving the environmental component in the implementation of the project for the reconstruction of centralized heating in the city of Bukhara

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Relevance: in recent years, due to the energy transition taking place in many countries of the world, energy transition processes are taking place in Uzbekistan. The transition is associated with a turn to green energy and serious problems of diversification of energy sources, development of market relations, digitalization and intellectualization of the energy sector. In such conditions, at all stages of the transition, it is necessary to ensure the reliability of electricity supply to consumers and the provision of electric power systems (EPS) in various modes. Therefore, conducting a study on the use of reliable methods for providing consumers with high-quality electrical power, including when operating wind and solar power plants with unstable modes, is relevant. One of such methods is operational demand response.
Aim: analysis and justification of the use of demand management methods for the operational balancing of deficit modes with unstable generation of wind and solar electricity sources.
Methods: international experience and methods of comparative analysis of demand management are used.
Results: in the green transition and implementation of market relations in the EPS of Uzbekistan with wind and solar installations, it is necessary to use operational demand response methods for effective balancing of the unstable operation of wind and solar installations. Based on the analysis, appropriate proposals were made for the application of demand response methods.
Keywords: Heating networks, energy saving, energy efficiency, thermal insulation material, heat main, polyurethane foam insulation, thermal power engineering, operation and maintenance.

Kirish (Introduction)

In the modern world, energy conservation is a priority and pressing issue. This is due to the depletion of fossil fuels, the high cost of their extraction, and environmental concerns. Energy conservation is the efficient use of energy resources through the application of innovative solutions that are technically feasible, economically feasible, environmentally and socially acceptable, and do not alter traditional lifestyles. Energy conservation in any field essentially boils down to reducing unnecessary energy loss [1-4].

Decree of the President of the Republic of Uzbekistan dated January 28, 2022 No. UP-60 "On the Development Strategy of New Uzbekistan for 2022-2026", Resolution of the President of the Republic of Uzbekistan No. PP-57 dated February 16, 2023 "On measures to accelerate the implementation of renewable energy sources and energy-efficient technologies in 2023" as well as other regulatory documentsCabinet of Ministers of the Republic of Uzbekistan, relating to this activityenergy [5,6], push all consumers towards energy conservation.

An analysis of modern heating systems in Uzbekistan shows that the efficiency of outdated heating networks is significantly lower than the key parameters established during their design. This is due to significant wear and tear on the networks and the deterioration of the thermal insulation materials used in the heating mains over long periods of use.[7-9,10-12,18] .

The use of obsolete thermal insulation materials, such as glass wool, mineral wool, and basalt coating, whose properties deteriorate over time and with changing external factors, leads to wear and tear and accidents in heating mains. This is a major source of environmental pollution from pipe leaks.[7-

9,13,14].

The introduction of modern technologies in the heat supply system will ensure a significant reduction in losses during heat transportation.An analysis of losses in heat production, distribution, and consumption shows that the majority of losses—up to 30%—occur during transportation of thermal energy. Therefore, the primary energy conservation efforts are focused on heat transit. Modern energy-saving technologies play a key role in increasing energy efficiency.10-12, 15-17].

Energy-saving technology is a new or improved technological process characterized by a higher efficiency of fuel and energy resources (FER). The introduction of energy-saving technologies into the economic activities of both businesses and individuals at the household level is a key step in addressing many environmental issues, including climate change, air pollution (e.g., emissions from thermal power plants), the depletion of fossil fuels, and others.10-14, 16-18].

The primary method for laying heating networks in the Republic of Uzbekistan is laying pipes with mineral wool insulation in impassable channels and trenches. Long-term operational experience has shown that the use of mineral wool (slag wool) as an insulating material does not ensure a reliable and cost-effective heat supply to consumers. During operation, the thermal insulation properties of thermal insulation structures are sharply reduced due to the high frequency of pipe damage due to external corrosion, moisture, and insulation degradation. This leads to significant heat losses (2-3 times higher than standard values), as well as significant losses of coolant, i.e., process water, in heating networks.[8,14,18].

1. Methods and materials

As research shows, current technology was used in Western Europe in the late 1970s; therefore, there is no long-term experience with the real-life life of metal pipes, polyurethane insulation, or plastic coating. Given that if the water chemistry in the networks is correct, there should be no internal corrosion at all, the current consensus in the district heating industry is that the average service life is at least 50 years. In fact, the service life may be significantly longer, with some estimates approaching 100 years [8,9-12].

The failure rate of pipes is very low when they are new (approximately 0.02 annual breaks per km, corresponding to one break every 50 years). Since replacing a 12-meter section of pipe is common practice, a maintenance policy based entirely on repairs means that the entire pipeline will only be replaced after 4,000 years. However, according to Finnish statistics, this rate increases with pipe age and is approximately 0.12 m for the oldest pipes (i.e., 25-30 years). We hypothesize that this rate will continue to increase, as shown in Figure 1.

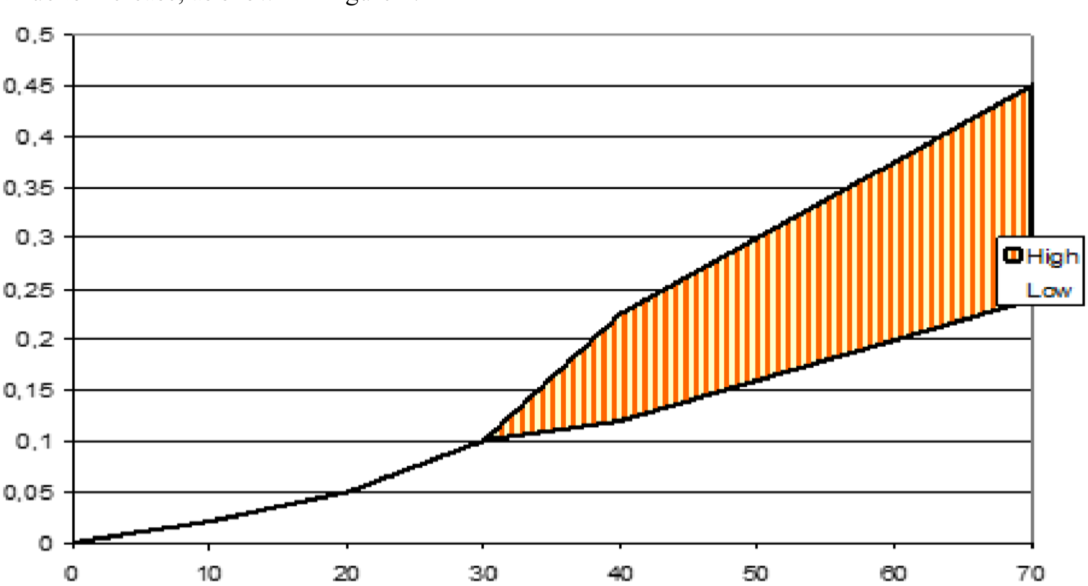

Figure 1. Estimation of pipe rupture frequency depending on service life

Currently, a project to modernize and reconstruct the boiler house and heating networks, as well as install modern individual heating units (IHUs) in residential buildings and industrial premises, is being implemented in the city of Bukhara in collaboration with Bukharaenergomarkaz JSC. This project covers a significant portion of the city's residential area and industrial enterprises. An environmental impact assessment for the project to reconstruct the centralized heating system and improve energy efficiency in Bukhara has shown that the area in question can be classified as having an acceptable environmental status in terms of air quality, soil, groundwater, and soil and vegetation cover. Environmental issues in the area include a high degree of accident risk at the existing Bukharaenergomarkaz JSC boiler house due to the deterioration of equipment operated for 42-45 years, and at the heating networks due to their severe deterioration. The project provides for: - installation in the boiler house of JSC Bukharaenergomarkaz of a modern highly efficient hot water boiler with a capacity of 40 MW. It has a high design efficiency (94.3%) and low nitrogen oxide emissions due to a specially developed design; - modernization of two existing steam boilers GM - 50; - replacement of 5,550 m of the central heating (DH) network with installation of pre-insulated pipes with factory thermal insulation; - installation of 264 individual heating points (ITP) in selected apartment buildings and public buildings; 357 - partial reconstruction of the electrical distribution network; - supply of equipment, tools and vehicles for organizing technical maintenance of the boiler house and networks. Thanks to the implementation of the proposed project, production efficiency will increase from 82.0% to 93.4%, the efficiency of the heating system will increase from 78.3% to 93.4%, and heat sales will increase from 144,570 to 202,943 Gcal/year. Ground-level concentrations of pollutants generated by the Bukharaenergomarkaz JSC boiler house after the reconstruction will not exceed permitted air pollution quotas. The atmospheric air quality in Bukhara will remain unchanged after the implementation of the proposed project and will remain within permissible limits. The existing water supply networks will serve as the source of water for household, drinking, and industrial needs of the Bukharaenergomarkaz JSC boiler house after the reconstruction, as they do now. Water consumption of JSC Bukharaenergomarkaz after the project implementation will amount to 470.3066 thousand m3/year, including 470.0 thousand m3/year for production needs, and 0.3066 thousand m3/year for domestic and household needs. The enterprise's wastewater disposal scheme will not change after the reconstruction: domestic wastewater is discharged into the sewer network (1810 m3/year), and conditionally clean industrial wastewater is discharged into the Chekmak collector (22505 m3/year).Organization system on the territory of a construction site during the reconstruction of an existing boiler house

The replacement of the deteriorated waste collection, temporary storage, and transfer pipeline at Bukharaenergomarkaz JSC will eliminate its impact on soils, groundwater, and surface water. Industrial waste generated during the operation of Bukharaenergomarkaz JSC's boiler house is primarily transferred to specialized organizations for recycling, while municipal solid waste is transported to a landfill. Specially designed areas or containers are provided for the temporary storage of generated waste. An analysis of alternative design options showed that the proposed heating system implementation is optimal. The project considers the most likely emergency situations associated with heat loss in the heating main, explosions, and fires when using natural gas as a fuel, and analyzes their consequences. Implementation of the proposed project will reduce the accident rate during the operation of boiler house equipment and on the heating main.

2. Results and discussion

The analysis results show that the average age of BEM pipelines is currently 41 years. The established standard service life is 25 years, meaning all pipes used in the network have exceeded their service life. Modern DH systems have several benchmarks that heating companies constantly monitor and adhere to in their operations. Heat distribution efficiency indicators and the current status of BEM are shown in Table 1.

Table 1. Heat distribution efficiency indicators, Western standards and the current status of BEM

OPEX component	Typical Western standards	BEM standards	Comments
Electricity for the pumping station	8 kWh/MWh	Total electricity consumption in 2015/2016 was 28 kW/MWh 50% is estimated for pumping	There are opportunities to reduce costs through optimization, automation and control, product delivery procedures, etc.
Network heat losses (including actual heat losses and measurement error)	10% of heat production	The estimated value of absolute heat loss is 2025%. No measurements or incorrect actions have been observed in recent years.	Not monitored after pipe installation. Dependent on the pipe technology, network geography, and heat load density.
Network water losses	1.6 m3 pa/network m3	The CHI standards cannot be compared simply because they have an open hot water supply system. Furthermore, no measurements have been performed on the system.	Indicates the indirect condition of pipelines Make-up water is a variable cost, classified as an expense cost.
Pipeline faults	0.02-0.15 failures per km.	Reliable data is not available.	Directly indicates the condition of pipelines.

There are two alternative methods for solving urgent pipe repair or replacement needs:

1. Keep unplanned pipe breaks to a minimum and systematically replace a certain percentage of pipes per year;
2. Repair pipeline ruptures when they occur.

The period for replacing pipes is given in Table No. 2.

Table 2. Replacement of pipeline.

BEM-1	Pipeline replacement
Description	The average age of the pipelines is approximately 41 years, and all pipes have exceeded their service life. The primary assumption of this project is the replacement of all main district heating pipes in the BEM boiler house area with modern underground district heating pipes. Hydraulic modeling using modern software was used to optimize the new shopping center network. Hydraulic modeling primarily determines pressure and heat losses in the network using verified system inputs.
Investments	Pre-insulated, channel-laid underground piping systems are among the most advanced technologies available today. The system consists of steel pipes, polyurethane insulation, and a high-density polyethylene outer casing. The following European standards apply: 1. EN 253 - Installation of pipes 2. EN 448 - Fittings 3. EN 488 - Steel valve 4. EN 489 - Mounting assembly 

The VEM network consists of a fairly long pipeline from the VEM to the boiler house and five separate DH sections in the residential area. A phased commissioning is recommended so that all heating stations are installed within the first year, and the corresponding DH sections are installed within the second year, as shown in Fig. 2.

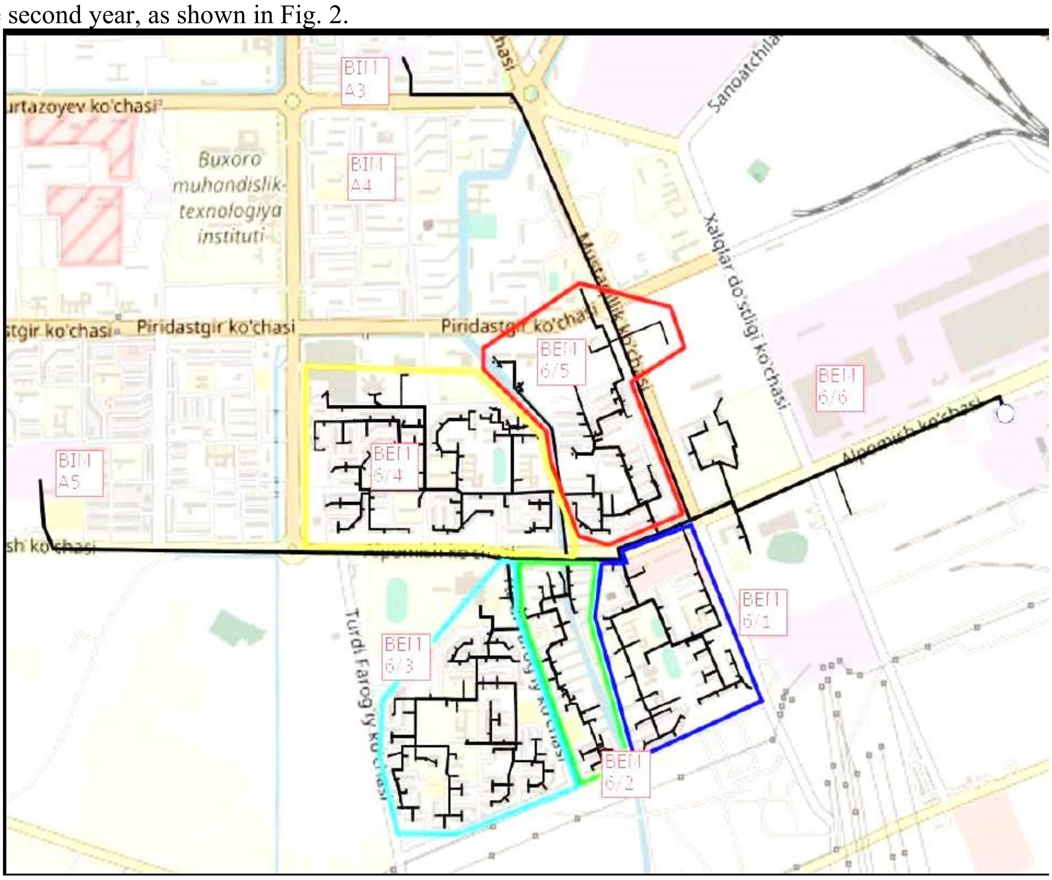

Figure 2. Bukhara Electric Power Station is a pilot zone. Network replacement zones are shown with colored lines.

Table 3. Summary table of heating network replacement by diameter

Since the replacement of existing pipes is minimal, new pipeline routes can be used, but calculations were based on existing routes to ensure the clarity of the DH network model. Suggestions for network sizing are provided below.
Design solutions, networks
Flow in the DHW pipeline +20% of the DHW
Temperature chart, in winter 120/70°C
Temperature chart, summer 70/40 oC
Pressure loss/transmission 0.7 bar/km
Pressure loss/distribution 1 bar/km
Pressure loss/consumer 2 bar/km.

The district heating network was modeled using the Finnish EPANET system.[1], based on a hydraulic model of all existing main pipelines and all hydraulically relevant components (pumping stations, valves, etc.) that are used to calculate the hydraulic model.

A network model was also created to analyze whether two adjacent boiler plants belonging to the BIM network could be connected to the BEM network. The results showed that if new pumping stations with heat exchangers were built in place of the BIM boilers, the BEM network capacity would be sufficient to supply heat to these two additional areas. The modeling results are shown in Figure 3.

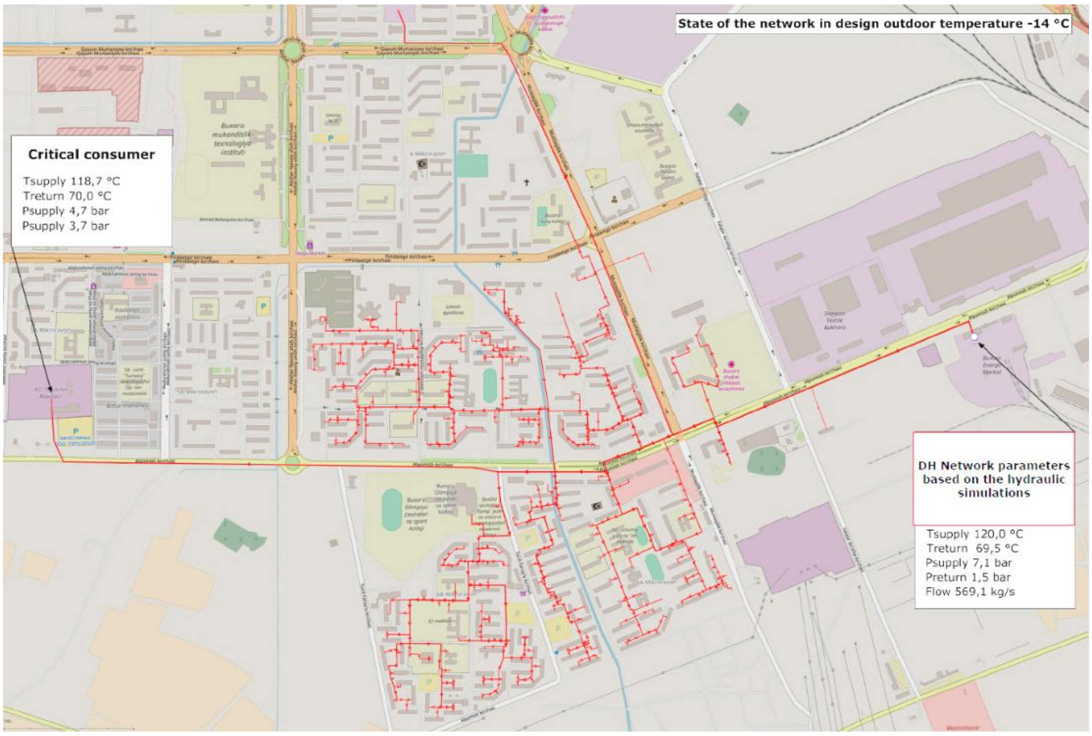

Figure 3. Modeling results and network sizing. BEM pilot area.

These parameters and the installation of the central heating point facilitate proper cooling in the network; they ultimately lead to the need for smaller pipe sizes. A summary of pipe sizes and the appropriate lengths for each pipe section is shown in Table 3.

We recommend using pre-insulated polyurethane foam pipes. Pre-insulated polyurethane foam pipes consist of a steel inner pipe, a protective shell pipe, and polyurethane foam insulation. The annular space between the steel inner pipe and the protective shell is filled with a polyurethane foam compound.

Features of pre-insulated polyurethane foam pipes.

The main requirements for polyurethane foam insulation of pre-insulated pipes can be formulated in general as follows:

- sufficiently high density of the polyurethane foams used (usually from 60 to 100 kg/m³);
- high mechanical properties of polyurethane foam;
- high heat resistance of polyurethane foam (up to 150°C);

[1]EPANET is a widely used pressure network simulator, distributed as public domain software by the US Environmental Protection Agency. Many free and commercial simulation programs are based on EPANET. FCG uses its own hydraulic simulation software based on EPANET, called FCGnet.

- the thermomechanical properties of polyurethane foam must be maintained for decades of operation;

Experience shows that installing polyurethane foam (PUF) pipes instead of traditional ones reduces heat loss in external pipeline networks severalfold, extends their service life (up to 30 years or more), and reduces accident rates, as evidenced by the over 30-year history of using PUF pipes in Europe and the United States. Polyurethane foam is used for thermal insulation of main oil pipelines, which have extremely high reliability requirements. A design using a steel and polyethylene protective shell reliably protects the steel pipe from external corrosion. For example, in Moscow, where large-scale re-installation of PUF-insulated pipes is underway, the accident rate for heating mains is decreasing by approximately 20% annually.

Figure 4. PPU pipes for heating and water supply (heating).

Figure 5. Tee branch of PPU-OC.

Heating pipes with polyurethane foam insulation consist of a steel pipe, a layer of polyurethane foam insulation, and a protective sheath made of polyethylene or galvanized steel. Heat-shrink sleeves are used to insulate welded joints of heating pipes. During joint insulation, the polyurethane foam components are injected (poured) into the space between the pipes relative to the sleeve. Heating pipes with polyurethane foam insulation are manufactured with a moisture control system (MCS), which allows for the detection of damage to the protective sheath or steel pipe.

Polyurethane foam (PUF), used in the manufacturing of heating pipes, is produced from liquid components, which are dosed and mixed using specialized casting equipment. These foams are easily produced both in industrial facilities and directly on-site. The foaming and curing reactions of PUF are quite rapid. Rigid polyurethane foams can have densities ranging from 30 to 80 kg/m³ or more, have a gas phase content of 92-97%, and typically contain isolated cells with a diameter of 0.2-1.0 mm.

Heating pipes with polyurethane foam insulation, when assembled, form a single structure thanks to the adhesion (bond) between the steel pipe, the insulating layer of polyurethane foam (PUF), and the bond between the PUF foam and the outer waterproofing shell. This condition is essential to ensure the proper operation of the piping system during operation. Strong adhesion of the heating pipe assemblies (steel pipe, polyurethane foam, polyethylene or galvanized shell) is achieved during the manufacturing process through strict adherence to production technology, namely:

- preliminary mechanical cleaning of the outer surface of the steel pipe;
- maintaining the temperature regime for high-quality foaming of polyurethane foam;
- correct selection of polyurethane foam composition (PUF component system);
- mandatory processing of the inner surface of the polyethylene shell to create roughness to improve the adhesion of polyurethane foam to the polyethylene shell.

Characteristics of heating pipe thermal insulation:

- compressive strength at 10% deformation in the radial direction is not less than 0.3 MPa;
- the density of polyurethane foam is not less than 60 kg/m³;
- water absorption when boiling for 90 minutes is no more than 10% by volume.

The use of polyurethane foam pipes in the heating and hot water supply system allows:

- increase service life to 30–40 years (old types of pipelines – 5–10 years);
- reduce coolant losses by 10 times to 2% (old types of pipelines 20 – 40%);
- reduce costs: capital costs by 15–20% (no need to build canals or chambers for installing shut-off valves), operating costs by 9 times, and repair costs by 3 times;
- the presence of an operational remote control system (ORCS) allows for the identification and elimination of any defects that may arise (wetting of polyurethane foam) and, as a result, the prevention of accidents typical for heating networks of other designs;
- no protection from stray currents or drainage system required.

Advantages of polyurethane foam insulated heating pipes:

Research confirms that polyurethane foam insulation has the lowest thermal conductivity of modern thermal insulation materials, ranging from 0.025 to 0.033 W/m°C depending on its density and the resulting minimal insulation thickness (5 cm of polyurethane foam is equivalent in thermal conductivity to approximately 10 cm of mineral wool). This property of polyurethane foam allows it to achieve the highest possible thermal and energy-saving characteristics, such as:

- high durability (the service life of polyurethane foam is over 30 years with full preservation of its properties);
- high mechanical strength of the material;
- polyurethane foam insulation is monolithic, seamless, and does not form “cold bridges”;
- operating temperature of polyurethane foam up to 140°C, with short-term exposure - up to 150°C;
- resistance to moisture (water absorption by weight is only 2%).
- high and durable adhesion (stickiness) to the pipe surface and waterproofing casing.
- Polyurethane foam is inert to alkaline and acidic environments, protecting the pipe from external corrosion and chemically aggressive environments, significantly extending the service life of the pipeline.
- polyurethane foam is non-toxic and safe for humans

3. Conclusion

An analysis of energy systems in developed countries confirms that the heating system is a fundamental sector of the national economy and is essential for creating comfortable, sanitary, and comfortable living conditions in residential buildings, educational and healthcare facilities, and other administrative and public buildings. Poor or absent heating and hot water supply increases the prevalence of hypothermia-related illnesses among the population.

In densely populated residential areas with high-rise buildings, district heating is the least expensive long-term heating option for providing heating services to the population.

All-in-one heating systems at the apartment level result in higher gas consumption, and the alternative of using fully electric systems is expensive and also places increased strain on the city's electrical grid.

As a result of the application of modern energy-saving technologies and equipment in centralized heating systems, the level of provision of heat and hot water supply services in the pilot district of Bukhara will be competitive with other methods of heating premises and obtaining hot water.

As a result of the project, approximately 11,202 households are expected to receive district heating services, allowing approximately 36,000 residents of Bukhara to receive heat and hot water services in accordance with established requirements.

Gas savings calculated using the notional gas savings assessment methodology used in developing feasibility studies for thermal power plants in the Republic of Uzbekistan amount to 2,032,000 cubic meters. However, according to an international consultant, gas savings will amount to up to 21.93 million cubic meters annually, allowing a portion of this volume to be used for export. It should be noted that gas exports are one of the leading export indicators in the Republic of Uzbekistan. Therefore, the project is attractive for increasing the country's export potential.

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