

Substantiation of a Choice of Construction of The Thermal Networks In Monolithic Isolation of Polyurethane

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Abstract. The technical condition of thermal networks in many ways determines the quality and the reliability of a heat supply. When replacing worn out networks, thermal networks constructions with monolithic insulation made of polyurethane foam, so-called ‘pipe in pipe’ (PIP) are used. There are several varieties of PIP pipelines, differing in the pipe material, the connection method, the service life. The article compares three options: the first option – steel pipes in monolithic insulation made of polyurethane foam (PUF) with an outer shell made of rigid polyethylene; the second option – flexible polymer pipes made of cross-linked polyethylene (for example, ‘Isoproflex’); the third option – corrugated pipes made of stainless steel (for example, ‘Casaflex’). Researches were carried out on the basis of variant design of thermal networks with various expenditure of the heat carrier for the connected consumers. As a comparative parameter characterizing the material capacity of the compared variants, the reduced area of the longitudinal section is used. Graphs illustrating the dependence of the cost of construction of the thermal network for three compared materials are given. The cost calculations take into account the cost of pipes, fittings and the cost of installation works. As criterion for comparison of options for construction of the thermal network are used the discounted costs, the result of the comparison of which showed that economically feasible is a variant of the thermal network of plastic pipes with insulation of polyurethane foam.

1. Introduction

Thermal networks are one of the main elements of central heating systems. Their technical condition largely determines the quality and reliability of heat supply [1-3]. Unfortunately, the considerable part of the heat pipelines which are in operation now is in bad condition and is characterized by large thermal losses and leaks of the heat carrier. Old thermal networks are replaced while removing damage or during planned repairs [4-8].

Currently, the constructions of thermal networks with monolithic insulation made of polyurethane foam, so-called ‘pipe in pipe’ (PIP), most of which are laid by a non-channel way, are widely used [9-15]. At the same time, each manufacturer advertises its products, highlighting its advantages, but often keeps silent about the shortcomings. In this regard, the task of studying and comparison of technical and economic indicators of methods of laying thermal networks is actual as will allow to minimize expenses, and, respectively, to reduce the cost of heat which is released to the consumer [16-20].

2. Description of the compared options

As a result of the review of the existing structures of PIP thermal networks, three variants with



different technical and economic characteristics were selected for further comparison.

The first variant – steel pipes in monolithic insulation made of polyurethane foam (PUR) with an outer shell of rigid polyethylene.

The second variant – flexible polymer pipes made of cross-linked polyethylene (for example, ‘Isoproflex’).

The third variant – corrugated pipes made of stainless steel (for example, ‘Casaflex’), produced in long segments.

The listed options differ from each other in cost, service life, connection method, length of produced pipe segments. Therefore, the choice should be based on a comparison of capital and operating costs. At the same time, the estimated flow rate of the coolant of the connected consumers is an important factor. Comparison of the above options was carried out in accordance with the algorithm shown in figure 1.

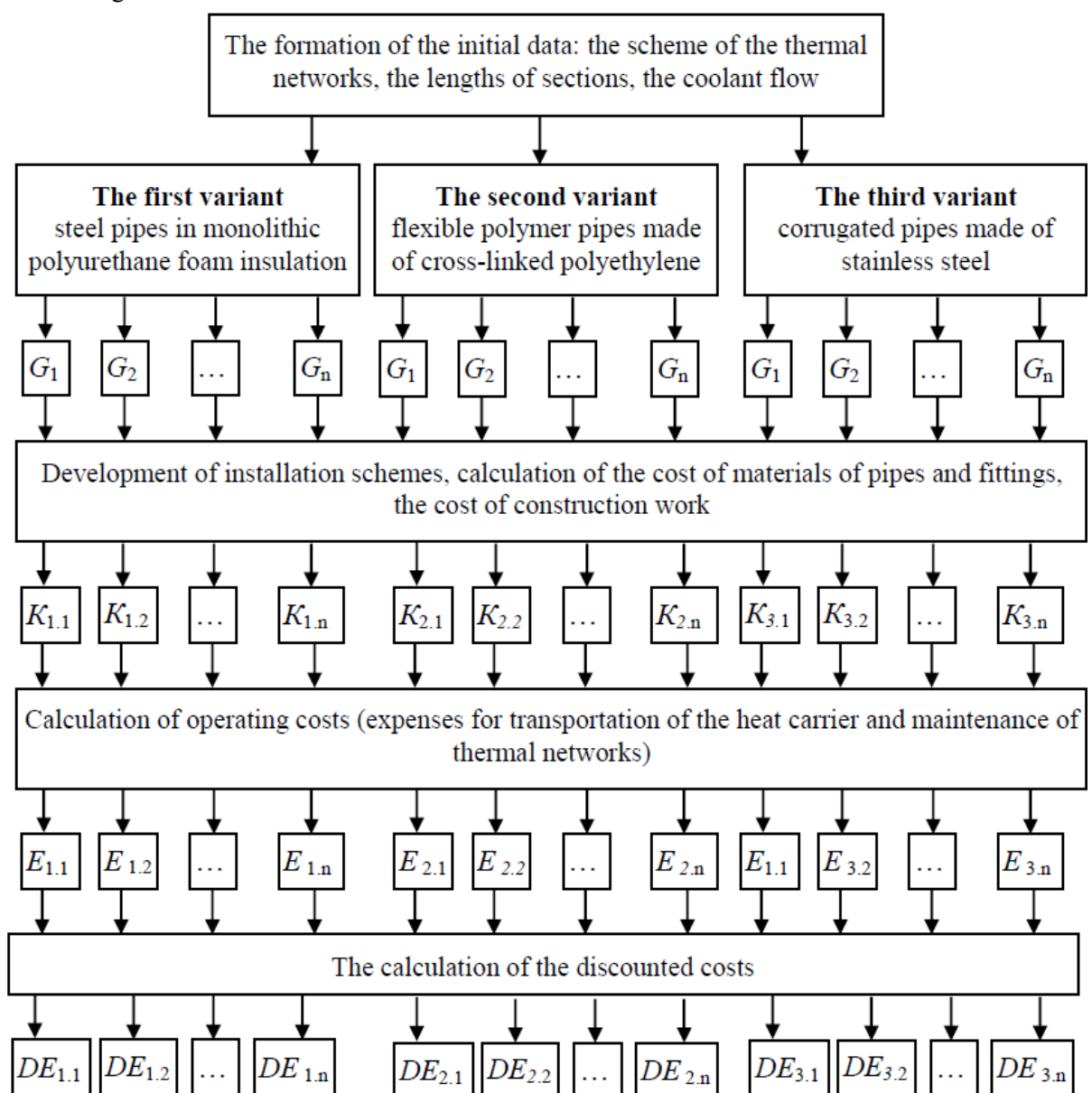


Figure 1. The sequence of calculations in comparison of variants of thermal networks constructions.

For carrying out researches, the schemes of the thermal networks with the consumers having various average consumption of the heat carrier were formed: $G = 0,1; 0,5; 1; 2; 5; 10$ kg/s.

3. Results and discussions

For each scheme the project of a thermal network was developed on the basis of three above-described options of designs of laying: hydraulic calculation is carried out, installation schemes are developed, specifications of necessary materials are made and the cost of construction works is calculated.

As a comparative parameter characterizing the material intensity of the compared variants, the reduced area of the longitudinal section S_{RED} is used. It is determined by the equation

$$S_{RED} = \sum l_i \cdot d_i, \quad (1)$$

where l_i – is the length of the i-th section, m; d_i – is the diameter of the i-th section, m.

For figure 2 graphs showing the dependence of the reduced area of the longitudinal section on the average flow rate of the heat carrier of the connected consumers are given.

As a result of the analysis of the obtained dependencies (figure 2) it is revealed that the S_{RED} index is the most important for corrugated pipes (the third option), and for smooth polyethylene and steel pipes differs slightly. This is because the increased pressure loss inside the corrugated pipes requires the selection of a larger diameter.

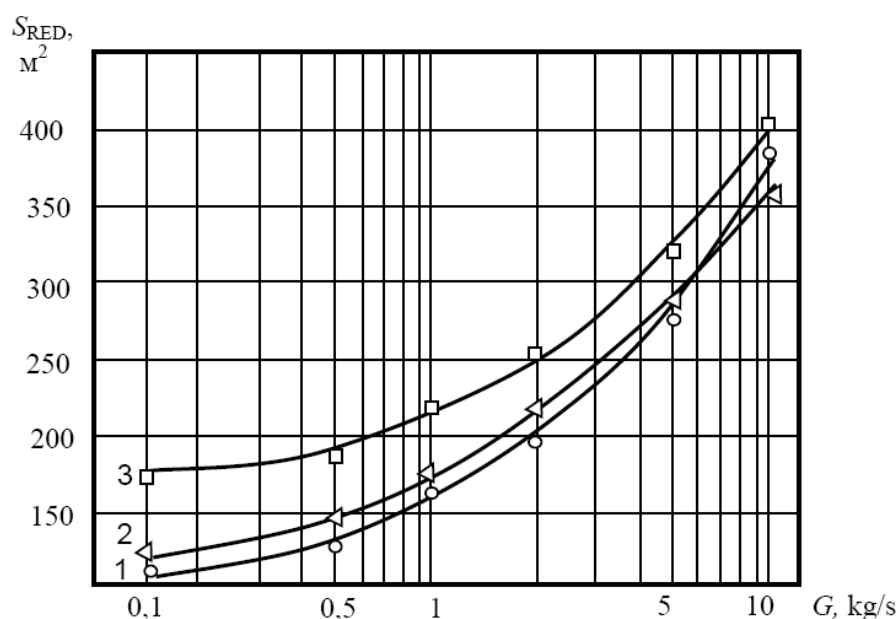


Figure 2. Dependence of the reduced area of longitudinal section S_{RED} on the average flow rate of the heat transfer of the connected consumers G :
1 – steel pipes; 2 – pipes made of cross-linked polyethylene ‘Isoproflex’;
3 – corrugated pipes of stainless steel ‘Casaflex’

The costs of materials required for the implementation of each option are calculated, based on which the distribution of the cost of pipes and fittings as a percentage of the total cost of materials was determined (figure 3). The comparison shows that in the option with steel pipes the largest share of the cost falls on the fittings and materials for insulation of the joints. This is due to the features of production and construction technology – steel pipes (the first option) are produced in short segments (6-12 m), that leads to a large number of joints during installation. Two other variants (the second and

the third) have fewer joints, as they are produced in long segments (100-200 m).

Capital costs include also the cost of installation and earthworks which were also calculated for the compared options. The graphs illustrating the dependence of the capital costs for the construction of the thermal network on the average consumption of the heat carrier of the connected consumers are shown in figure 4, a. The prices are accepted for March 2018 for the Central region of the Russian Federation. The most expensive option is from 'Casaflex' pipes, its cost is 1,5–2 times higher than for plastic pipes, and 3-3,5 times higher than for steel pipes.

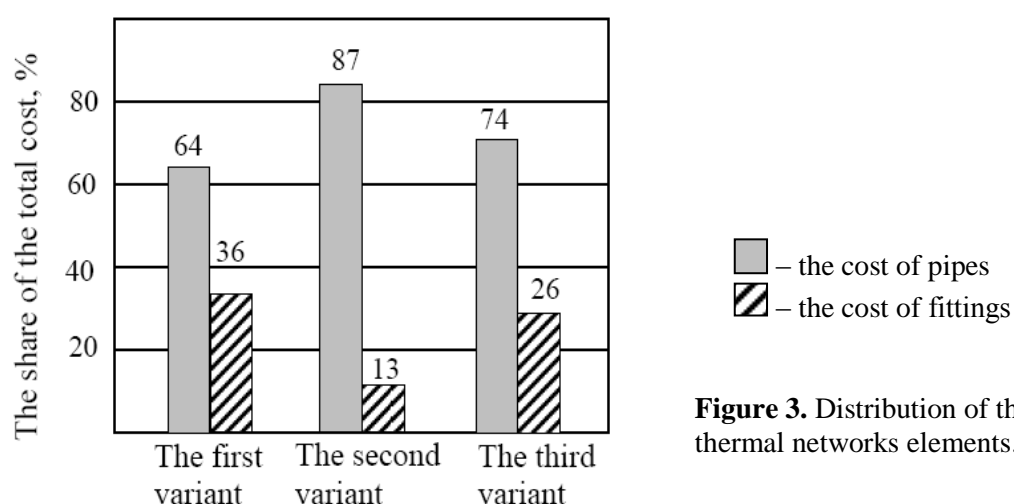


Figure 3. Distribution of the cost of thermal networks elements.

Another important parameter when comparing options is the amount of operating costs. In the calculations, account was taken of the pumping costs of the heat carrier and maintenance costs of thermal networks. Both of these components practically do not depend on the type of the construction of the thermal networks, except for the increased expenses on circulation of the heat carrier for the corrugated pipes 'Casaflex' in the case with consumers of big thermal power (over 500 kW). This is due to the fact that the range of produced pipes of this brand is limited (the maximum diameter is 143 mm), and the selection of small diameters of pipes at high heat carrier consumption leads to increased pressure losses. The results of the calculation of operating costs are shown in table 1.

Table 1. Results of calculating the operating costs of the compared variants of the thermal network's construction.

Average consumption of the heat carrier of the connected consumers G, kg/s	Annual operating costs E , rubles/year		
	Steel pipes in monolithic insulation of polyurethane foam (The 1 st variant)	Pipes made of cross- linked polyethylene 'Isoproflex-A' (The 2 nd variant)	Corrugated stainless steel pipes 'Casaflex' (The 3 rd variant)
0,1	316118,4	315772,6	316189,9
0,5	324889,5	325252,2	326601,6
1	339831,7	340155,4	340657,2
2	370701,5	370957,6	383962,8
5	457406,3	474324,5	664034,8
10	665145	679638,7	1221766

As criterion for comparing the variants of laying the thermal networks, the discounted costs DE , rubles/year, were chosen; it is determined by the formula

$$DE = K + \sum_{t=1}^{T_{PO}} \frac{E - E_a}{(1+r)^t}, \quad (2)$$

where K – is the capital cost, rubles;

T_{PO} – is duration of the settlement period of work, years;

r – is the estimated discount rate, (in the calculations $r = 0,1$ was accepted);

E – is amount of annual operating costs, rubles /year;

E_a – is depreciation, rubles/year (in calculations $E_a = 0,02 K$ was accepted); t – is the step of the calculation period equal to one year.

The results of the discounted costs calculation for the compared variants are shown in figure 4, b. At the same time, it is accepted in the calculations that the estimated service life of steel pipes (the first option) is twice less than in the second and third option. With this in mind, despite the lowest capital costs for the construction of a thermal network of steel pipes, this option is not the most profitable by the criterion of discounted costs.

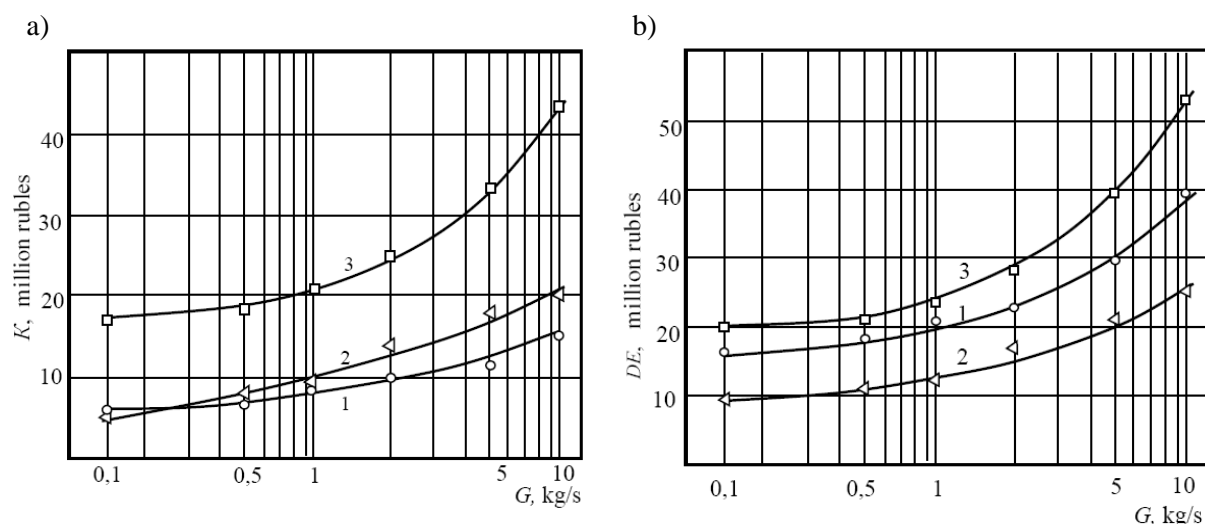


Figure 4. Dependence on the average consumption of the heat carrier: a – capital costs; b – discounted costs; 1 – steel pipes; 2 – cross-linked polyethylene pipes ‘Isoproflex’; 3 – corrugated stainless steel pipes ‘Casaflex’

4. Conclusion

Thus, the conducted researches allow to draw a conclusion that in the range of the investigated consumption of the heat carrier of the connected consumers, the option of construction of the thermal network from polyethylene pipes will be expedient. The values of the temperature and pressure of the heat carrier can serve as a limitation for their application. In addition, the results obtained in the work can be corrected when using pipelines of other manufacturers or during construction in other regions.

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