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DEVELOPMENT OF TECHNIQUE AND PROGRAM FOR ANALYSIS OF OPTIONS FOR TRANSITION TO A CLOSED HOT-WATER SUPPLY SCHEME FOR HEAT SUPPLY SYSTEMS

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Abstract: *The article describes the prerequisites for development of methodology for integrated assessment of options for transition to a closed hot-water supply scheme. For analysis of promising options for transition to a closed system of hot water supply, criteria have been proposed that influence the choice of possible solutions. Block diagrams of boundary conditions and independent variables were created. A pyramid of indicators which affect the operating costs of heating system over 25 years of its operation was formulated. A method and a program for selecting the optimal transition scheme to a closed hot-water supply system with calculation of weighting factors have been developed.*

Key words: *heat networks, hot water supply, heat supply system, method of selecting the optimal solution, weighting factors.*

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РАЗРАБОТКА МЕТОДИКИ И ПРОГРАММЫ АНАЛИЗА ВАРИАНТОВ ПЕРЕВОДА НА ЗАКРЫТУЮ СХЕМУ ГВС СИСТЕМЫ ТЕПЛОСНАБЖЕНИЯ

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Резюме: *в статье рассмотрены предпосылки разработки методики укрупненной оценки вариантов перевода на закрытую схему ГВС. Для анализа перспективных вариантов перехода на закрытую систему ГВС предложены критерии, влияющие на выбор возможных решений. Составлены блок-схемы граничных условий и независимых переменных. Сформулирована пирамида показателей, влияющих на эксплуатационные затраты системы теплоснабжения за 25 лет ее применения. Разработана методика и программа выбора оптимальной схемы перехода на закрытую систему ГВС с расчетом весовых коэффициентов.*

Ключевые слова: *тепловые сети, горячее водоснабжение, система теплоснабжения, методика выбора оптимального решения, весовые коэффициенты.*

Introduction

From July 27, 2010 the Federal Law No. 190 "On Heat Supply" (hereinafter FZ-190) entered into force, so most heat supply organizations and local self-government bodies were faced with the issue of transition of subscribers connected to hot water supply (HWS) through an open circuit to a closed circuit of HWS preparation [1, 2]. This obligation is enshrined in paragraph 9 of Article 29 of FZ-190. Taking into account the fact that more than half of the heat supply systems operating in Russia today are open, the question of choosing the most appropriate method for switching to a closed DHW preparation scheme is quite acute [3 - 6].

To date, there is no approved methodology for an integrated assessment of options for transition to a closed hot water supply scheme at the scale of settlements/cities. The only possible method for comparing options and assessing the cost of measures to organize a closed hot water supply system is the technical and economic study of each option for a given city. This work in itself requires significant costs, and therefore, local authorities are not ready to carry it out. As a result, the solutions included in the designed heat supply schemes are either not sufficiently substantiated, or there is no justification for the decisions taken.

Development of choice criteria for options of transition to closed HWS system

To analyze perspective options of transition to closed HWS scheme it is necessary to evaluate the criteria that affect the choice of each of the possible solutions [7]. Table 1 presents the main criteria and characteristic that they affect.

Table 1

The main criteria for choosing an option for transition to a closed HWS system

Criterion	Characteristic	Note
Heating season degree-day (HSDD)	Heat losses from the surface of the pipeline/hydraulic losses in the networks	The four-pipe system in comparison with the two-pipe one has a larger surface of heat exchange with the environment and a larger total length of the heating networks.
Source type	CHPP/boiler house	For a CHPP, the use of a four-pipe system is economically unreasonable.
Availability of space for additional equipment at consumer	Dimensions of basement of residential buildings	In case of lack of free space or inability to access it, installation of individual heating unit (IHU) is not possible.
Population density	The specific heat load of the region (Gcal/km^2)	At low population density, options with a developed heating network (four-pipe system or central heating system) are more expensive.
Capacity of cold water supply (CWS) networks	Hydraulic losses in the networks	When switching to IHU/central heat supply station (CHSS) options, the load on CWS networks significantly increases. In this case, for HWS, either a separate branch with cold water is required, or the option of connecting via a four-pipe system becomes appropriate.

Continuation of the table

The presence of HWS cut on the temperature chart	Temperature chart of the heating network	An additional factor in the transition to the four-pipe system, where the temperature cut can be abandoned.
The real heat load of the district	The presence or absence of a reserve capacity of the heating network	The increase in network water consumption for CHSS/IHU options compared with the four-pipe system and, as a result, the need for new networks.
The ratio of peak load for heating and hot water supply	Heat losses from the surface of the pipeline/hydraulic losses in the networks	The four-pipe system in comparison with the two-pipe one has a larger surface of heat exchange with the environment and a larger total length of the heating networks.
Soil type and the possibility of work performance	The density of urban development, improvement of the district, access to communications, etc.	The cost of pipeline laying directly depends on the complexity of construction and installation works.
The existing connection schemes	The ratio of the existing load connection schemes for HWS: open system/IHU/CHSS/four-pipe system.	Availability at the heat supply source of the appropriate equipment and experience of working with it of the operating organization.
Operation costs	Service life of pipelines and main equipment.	The four-pipe system, unlike CHSS/IHU, does not require regular technical inspection and replacement of the main equipment.

Table 1 considers exclusively basic assessing criteria of transitioning options to a closed HWS system. In a real project, this list can be reduced or expanded depending on the current situation in the considered project. Nevertheless, it is appropriate to divide the proposed criteria into two categories:

• Boundary conditions (according to the type of logical variables “true/false”);

• Independent variables (the value of which will vary in different projects and will be converted into natural or monetary equivalents).

Drawing up a block diagram of boundary conditions and independent variables

The positions 2, 3, 6, and 10 of the basic criteria shown in Table 1 can be proposed as boundary conditions. Figure 1 shows an explanatory block diagram for accounting these boundary conditions.

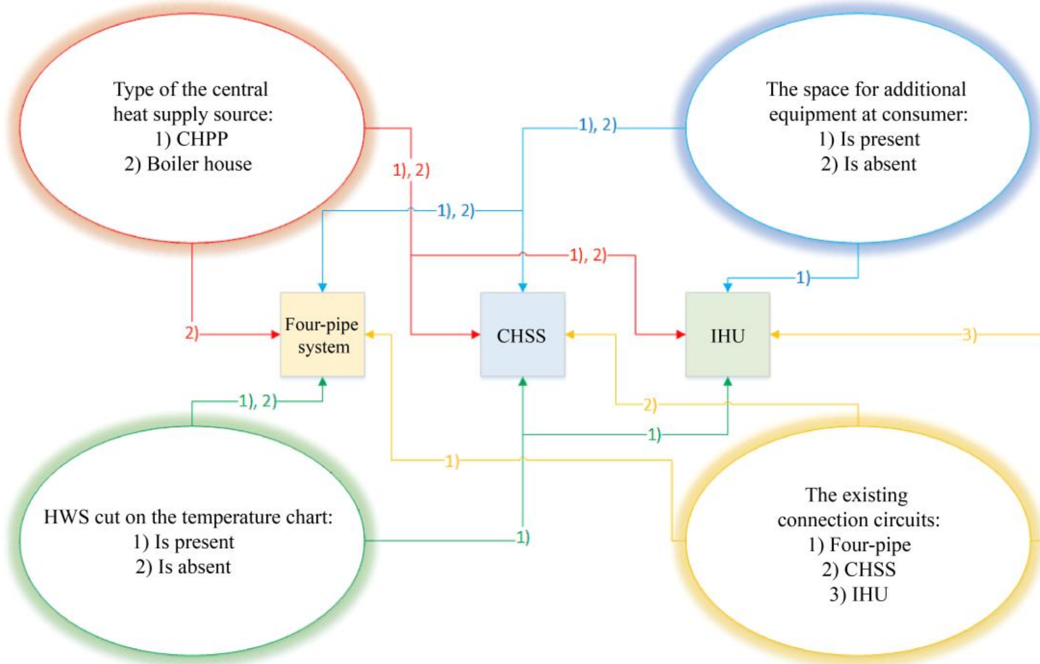

Fig. 1. Block diagram of boundary conditions

The other criteria presented in Table 1 (1, 4, 5, 7, 8, 9, 11) have a quantitative assessment (toe, kW·h, rub.) and are considered as independent variables. Fig. 2 shows an explanatory block diagram for accounting of independent variables data. The considered criteria include: heating season degree-day (HSDD), population density, capacity of cold water supply networks (CWS), real heat load of the district, the ratio of the peak load on heating and hot water supply, soil type, as well as the possibility of work performance and operating costs. These independent variables are presented in the diagram as gray squares and are connected to the indicators they affect.

A significant difference between the criteria of Fig. 2 from the positions shown in Fig. 1 is the presence of a natural and, as a result, cash equivalent, allowing one to quantify the impact of each position on the decision to choose a priority scheme for the district HWS. An important feature of this block diagram is separation of costs for capital investments and annual costs. The second indicator becomes extremely relevant when comparing heat and hydraulic losses, as well as the cost of repair work and replacement of the main equipment. It is further recommended that all economic indicators be added over a period of 25 years. Such an approach will allow a more objective assessment of the options for the CHSS/IHU and the four-pipe system, as it takes into account the nominal life of pipeline equipment, which is 25 years for metal products. In addition, the announced period will include major repairs and replacement of heat exchange equipment for options with installation of heating units according to the type of CHSS/IHU.

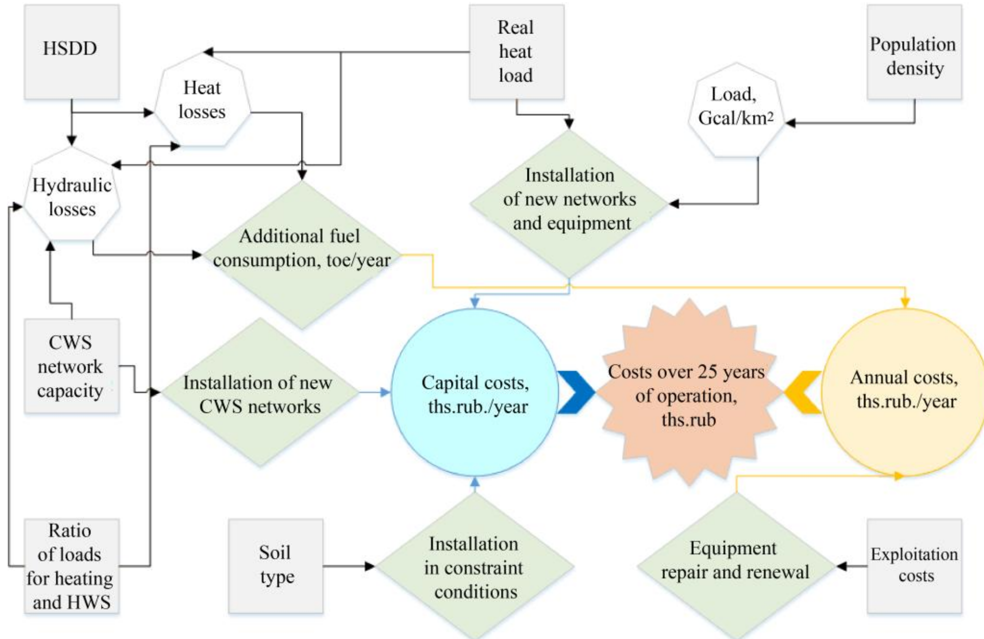

Fig. 2. Block diagram of independent variables

Thus, it is possible to compile an enlarged block diagram for assessing the options for transition to a closed HWS system taking into account the indicators presented in Figs. 1 and 2. Below is the basic calculation scheme in the framework of the developed methodology (Fig. 3).

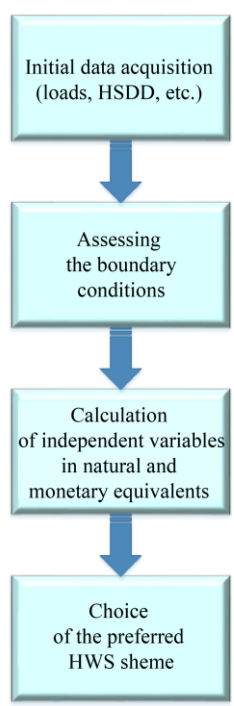

Fig. 3. Basic scheme for choosing the optimal HWS system

Development of a program for choosing the optimal HWS scheme

The final indicator for choosing the option of switching to a closed system, as noted in Fig. 2, are the cash costs over 25 years of operation of a newly introduced or reconstructed heat supply system. However, due to inflation, changes in market prices for equipment and other indicators that affect the final project cost, it is difficult to use accurate quantitative indicators to select the optimal solution. For this reason, the developed methodology is based on the analysis of a variety of relevant feasibility studies for various projects with selection of qualitative weighting factors for each of the criteria.

Based on these assumptions, a pyramid of indicators can be formulated that affects the operating costs of the heat supply system for 25 years of its application. Figure 4 presents this scheme, which is based on indicators that are affected by all 7 previously considered criteria (Fig. 2).

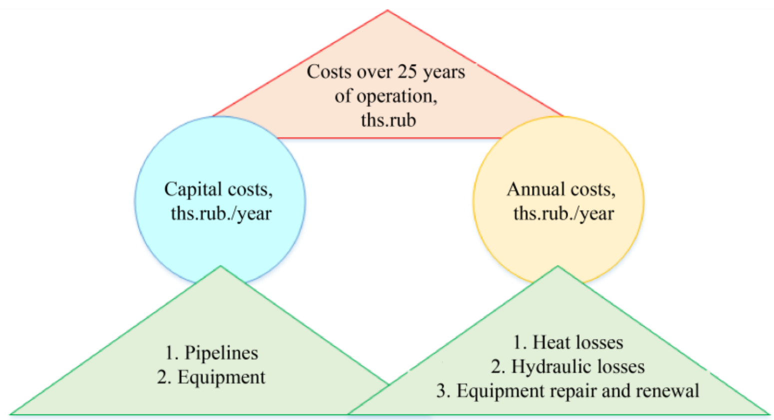

Fig. 4. Pyramid of costs over 25 years of operation

Fig. 4 shows that capital costs include 2 items, while annual costs include 3 items. Figures 5-7 present the interface of the program for choosing the optimal scheme of transition to a closed HWS system with the calculation of weighting factors. Here, a weighting factor equal to 1 approximately corresponds to costs of 100 million rubles.

City		Norilsk	
Heat load, Gcal/h		100	
Heating		80	
HWS		20	
Heat consumption, Gcal/year		500000	
Average network diameter, mm		80	
Analysis of boundary conditions:			
Source	CHPP	Boiler house	
Place for equipment	Yes	No	
Cut	Yes	No	
Scheme	4-pipe	CHSS	IHU
Input of independent variables			
HSDD			6000
Network length for an option with IHP, km			100
Tariff for electrical energy, rub./kWh			4
Tariff for heat energy, rub./Gcal			2000
Soil type (1 for dry, 1.14 for wet)			1

Fig. 5. Initial data input

Cost for network laying					
Dy, mm	Dry soil to spoil	Dry soil with disposal	Wet soil to spoil	Wet soil with disposal	
80	16225.7	17355.48	20801.72	22293.53	
100	19586.28	20833.91	24169.26	25782.91	
125	20981.97	22167.25	25508.4	27116.25	
150	22969.73	24211.56	27553.05	29160.9	
200	26883.82	28418.26	31470.69	33423.71	
250	33121.31	35089.88	37833.5	40132.87	
300	36037.88	37683.05	40680.13	42735.89	
350	42216.64	44354.67	46910.79	49507.08	
400	48161.93	50299.96	52823.73	55454.14	
450	54361.8	56618.46	59029.92	61783.43	
500	59855.17	62111.84	64493.78	67276.8	
			The ratio of wet and dry soils		1.14

Fig. 6. Intermediate calculations

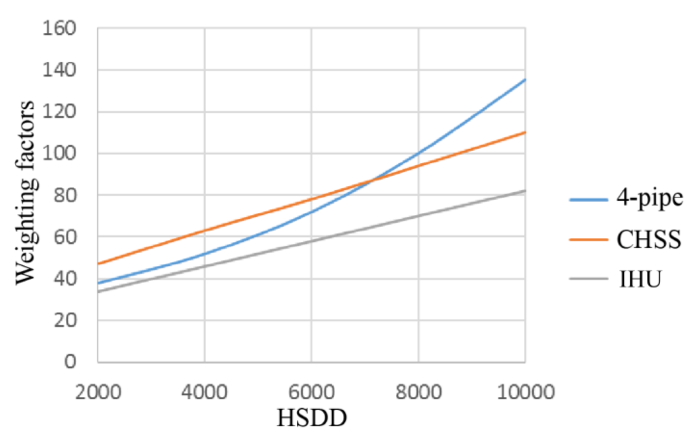

Fig. 7. Calculation results presented in the graphical form

Conclusions

Based on the results of the analysis, the following conclusions can be drawn:

• The final indicator for choosing the option of switching to a closed system is the cash cost over 25 years of operation of the newly introduced or reconstructed heat supply system. However, due to inflation, changes in market prices for equipment and other indicators that affect the final cost of the project, it is difficult to use accurate quantitative indicators to select the optimal solution.

• It has been established that when implementing a closed HWS system, the material characteristic of networks increases as follows: for 100% for a four-pipe network (when switching to a closed HWS system using a four-pipe scheme, it is required to lay 100% of the material characteristic of the pipelines of HWS networks from source to consumers); for 70% for a network with a central heat supply station (when switching to a closed HWS circuit via a CHSS, it is required to lay about 70% of the material characteristics of the pipelines of HWS networks from the central heating system to consumers); 0% for a network with IHU (main networks for HWS are not laid).

• The sharpest increase in heat losses is observed for the variant with a four-pipe system. So for HSDD equal to 9000, the equality of heat losses for the four-pipe heat network and the system with IHU is noticeable.

• About 55% of all costs are heat losses, which means that the HSDD indicator will be one of the most important when choosing a reconstruction option.

• The developed methodology proved its applicability when compared to a detailed feasibility study.

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