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ALGORITHMS FOR CONSTRUCTING MATRIXES OF ROUTES OF PIPELINE NETWORKS BY USING THE METHOD OF GRAPH THEORY.

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Abstract.. This article discusses algorithms for constructing and optimizing the functioning of gas pipeline multi-circuit networks using the graph theory method and software for optimal control, analysis and synthesis of pipeline systems.
Keywords. Mathematical model, gas pipeline, multi-circuit network, algorithm, pipeline systems, gas consumption, gas transport, gas, numerical method, graphs, program.

1.Introduction. Technical progress in various areas of the national economy of the Republic largely depends on the degree of use of automation tools, information technologies and the level of automation of management processes. However, the capabilities of modern computer systems and the development of mathematical modeling methods are not fully used due to the informalization of many problems, as well as the imperfection or absence of a number of algorithms that make it possible to analyze the functioning of an object, process incoming information and make appropriate decisions on optimal management of multi-connected systems. In this regard, the development and research of computer models, computational algorithms and on their basis the creation of object-oriented software in this direction is an urgent problem for the further development of automation of scientific research for various subject areas, in particular pipeline systems.

Every real energy network, including a gas network, is equivalent in its topological structure to a graph. It is difficult to calculate and analyze the inconsistency of the source information of networks with more than one ring. In these cases, it is necessary to refer to Kirchhoff's laws and the corresponding closing relations. Nevertheless, the network topology is diverse, as evidenced, in particular, by the schemes of urban heat supply networks in Kazakhstan and the Russian Federation [1, 3, 4].

The method for solving the resulting system of mixed (linear and square) equations can be unified, but each of the networks differs in the number of water sources, heating units (boilers, thermal power plants), the number of connected consumers and the volume of their consumption, and others. A similar pattern is also observed for gas supply networks.

In such conditions, the main burden of hydraulic or economic calculation should be concentrated on the stage of network topology formation, for which graph theories are used. Moreover, with minimal initial information about the network, it is necessary to develop the maximum final information required in the process of hydraulic or economic calculation of the network.

Currently, topological matrices describing the graph model of engineering, in particular pipeline networks, are widely used. Mathematical statements and models of problems related to the design, analysis and optimization of pipeline networks (TS) are described using these matrices. However, the construction and various operations on them, as well as the preparation of the necessary information for this purpose, meet serious difficulties due to the large dimension and structural feature of the matrices. In this regard, the creation of automation tools for these processes is of great importance. This paper provides descriptions and texts of algorithms for machine construction of matrices and Offers a new approach to modeling optimal gas distribution systems based on the application of graph theory.

2. Problem formulation. Let G - cyclic graph of the pipeline network (TC), M – selected in it МД, and A_{cr} и A_{tr} – the corresponding matrix is known. In addition, the set of fundamental FC contours is defined in the following way:

Add to M -th chord (remember that the chords are numbered with numbers $n, n+1,..., m$) and assign a number to the resulting contour n;

$a2$. Repeat $a1$ for $n+1, n+2,..., m$-th chord. The result of this process will be a set of fundamental contours (FC).

Obviously, each FC contains only one chord with respect to , the direction of which is taken as the positive direction of the given fundamental contour (FC).

The matrix of the FC set is expressed by and in the following form $Bf = [Bf_t, E] = [-A'_{cr} \times OA'_{tr}, E]$,

where A'_{cr} and OA'_{tr} – the transpose of the matrix for A_{cr} and OA_{tr}, dimentions $k \times (n-1)$ and $n-1$; E - the identity matrix of dimension k; Bf, Bf_t - matrix ФК and its submatrix, corresponding arc M, dimention $k \times m$ и $k \times (n-1)$.

Matrix Bf, being equivalent to the matrix B, it has the following advantages over B, which determine the effectiveness of its application: first, the construction Bf does not need the information contained in the rows $K1$ and $K2$ table 3.1; second, it is not necessary to define the entire matrix and store it in computer memory, but only to have its first part

$$Bf = -A'_{cr} \times OA'_{tr}.$$

3. The algorithms for constructing. The algorithm for constructing fundamental contours is based on this relationship.

Assigning zeros to the elements Bf.

$S1$. Solve $S2$ for $i = 1,2,...,k$ and $j = 1,2,...,m$.

$S2$. Let $Bf(i, j) = 0$ and $i = 0$.

$S3$. Take $i = i+1$ and $j = 0$.

$S4$. Take $j = j + 1$ and $ij = 0$.

$S5$. Take $ij = ij + 1$.

In the matrix multiplication operation OA'_{tr} and A'_c only non-zero elements are involved.

$S6$. If $OA_{tr}(ij, j) \neq 0$ and $A(n+1i-1, ij) \neq 0$, then solving $Bf(i, j) = Bf(i, j) - A(n+1i-1, ij) \times OA_{tr}(ij, j)$, else go to $S7$.

$S7$. If $ij < n-1$, then go to $S5$ else go to $S8$.

$S8$. If $j < n-1$, then go to $S4$ else go to $S9$.

Add to matrix Bf_t by matrix E.

$S9$. Take $Bf(i, n+i-1) = 1$.

Chek for end of algorithm – go from one row of matrix to another row of matrix A'_c.

$S10$. If $j < k$, then go to $S3$ else go to $S11$.

$S11$. The end.

Matrix Bf built.

We have established a relationship between the matrices T and OA_{tr}. It is easy to see that if you select from OA_{tr} those columns that correspond to the end vertexes $U_1, U_2, \ldots, U_L$ the graph in question G, transpose and change the signs of their elements to opposite ones, then we get a matrix T. This is done in two ways..

<u>First way.</u> All destination nodes (except the base) are numbered $1, 2, \ldots, L$, and the remaining vertices in an arbitrary order. Then the matrix is obtained OA_{tr} next structure:

$$OA_{tr} = [OA_{tr1}, OA_{tr2}],$$

Then we take that

$$T = -OA'_{tr1}.$$

<u>Second way.</u> The vertexes are numbered in any order, as in the General case. Known matrices A and OA_{tr}. Use A to determine the end points. Viewing a row-by-row matrix A definite that rows, for which

$$abs\left(\sum_{j=1}^{m} a_{ij}\right) = mk_i,$$

where mk_i – number of non-zero elements i-th row A $(1, 2, \ldots, n-1)$. These lines correspond to the end vertices $U_1, U_2, \ldots, U_L$. Then selecting from OA_{tr} columns with numbers $U_1, U_2, \ldots, U_L$, transposing and changing the signs of their elements to the opposite, we find T.

The following algorithm is based on the second method.

<u>Note.</u> Matrix T, obtained using a modified algorithm, has the dimension $L \times (n-1)$, and not $L \times m$, that occurred during the application of the General algorithm. In addition, trace numbers are determined by line numbers T, then, the first route is the one that connects the vertexes n and U_1; the second route is the one that connects n and U_2 and etc.

Let's present a modified algorithm for constructing the trace matrix.

Assigning zeros to the elements T.

$S1$. Solve $S2$ for $i = 1, 2, \ldots, L$ and $j = 1, 2, \ldots, n-1$.

$S2$. Put $T(i, j) = 0$.

$S3$. Put $L = 0$, $i = 0$.

$S4$. Put $j = 0$; $i = i + 1$; $mk = 0$; $LS = 0$.

mk – number of non-zero elements i-th row of matrix A, and LS – an algebraic sum of the same elements.

Starting the search for end vertices G with using A.

$S5$. Put $j = j + 1$.

Begin view i-th row of A.

$S6$. If $A(i, j) \neq 0$, then go to $S7$ else go to $S8$.

$S7$. Put $LS = LS + A(i, j)$; $mk = mk + 1$.

Checking for the end of viewing i-th row A.

$S8$. If $j \leq m - 1$, then go to $S5$ else go to $S9$.

$S9$. If $abs(LS) = mk$, then go to $S10$ else go to $S13$.

Renumbering of end vertexes, i.e. moving from the set $U_1, U_2, ..., U_L$ to the set $1, 2, ..., L$.

$S10$. Put $L = L + 1$.

Selection of columns OA_{tr}, corresponding to the end vertexes G and building matrix T.

$S11$. Solve $S12$ for $ij = 1, 2, ..., n - 1$.

$S12$. Put $T(L, ij) = -OA_{tr}(ij, i)$.

Checking for the end of the algorithm

$S13$. If $i < n - 1$, then go to $S4$ else go to $S14$.

$S14$. The end.

Matrix built.

4.Example. To illustrate the method and process of preparing the initial information, as well as the form of the results obtained using algorithms, let's look at an example.

Let the graph shown in Fig. 1 describe the vehicle under consideration

.

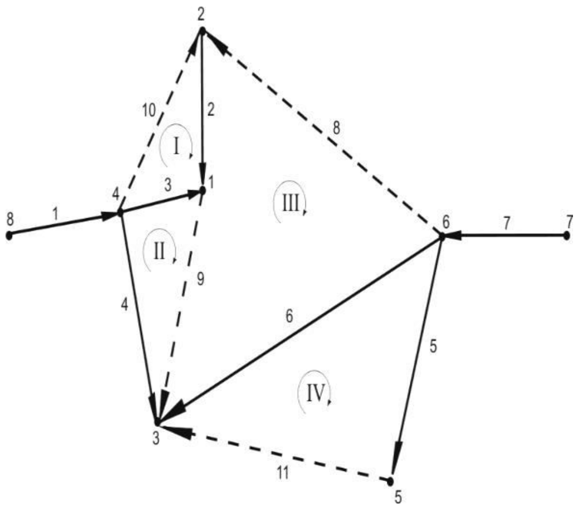

Fig. 1. Graphical representation of the vehicle

Solid lines indicate MD arcs, and dotted lines indicate chords. In the column: $m = 11$, $n = 8$, $k = 4$, two sources with numbers 7 and 8 are finite; four basic contours formed by sets of arcs {2,3,10}, {3,4,9}, {2,6,8,9} and {5,6,11}; two routes formed by sets of arcs {1,4} and {1,4,6,7}.

Information about the graph in question is given in table. 1.

Table 1.

№ arcs	МД arcs (tops G)	**Chords**
	1 2 3 4 5 6 7	8 9 10 11
$M1$	8 2 4 4 6 6 7	6 1 4 5
$M2$	4 1 1 3 5 3 6	2 3 2 3
$M3$	4 1 4 8 6 3 6	
$K1$	0 1 2 0 4 3 0	0 2 1 4
$K2$	0 3 1 2 0 4 0	3 3 0 0

For this example, using the above algorithms, the results are obtained in the following forms:

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$$\begin{array}{ccccccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 \end{array}$$

$$A=[A_t,A_c]=\left(\begin{array}{ccccccc|cccc} 0 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 & 0 & -1 & 0 & 0 & -1 & 0 & -1 \\ -1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{array}\right)\begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \end{array}$$

$$\begin{array}{ccccccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 \end{array}$$

$$B=[B_t,B_c]=\left(\begin{array}{ccccccccccc} 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & 1 & 0 & -1 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 1 \end{array}\right)$$

Algorithms 3 and 2 give the same result

$$\begin{array}{ccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 \end{array}$$

$$T=\begin{pmatrix} 1 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & -1 & -1 \end{pmatrix}\begin{array}{c} 1 \\ 2 \end{array}.$$

Inverse matrix OA_{tr} for the matrix truncated by the 8th row A_{tr} and looks like:

$$\begin{array}{ccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 \end{array}$$

$$OA_{tr}=\begin{pmatrix} -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & -1 & -1 & -1 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}\begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{array}$$

On Fig. 2 the same graph is shown, which shows the set of fundamental contours constructed by the computer itself in accordance with the selected MD. The fundamental contours are constructed from the following sets of arcs {2,3,4,6,8}, {3,4,9}, {2,3,10} и {5,6,11}.

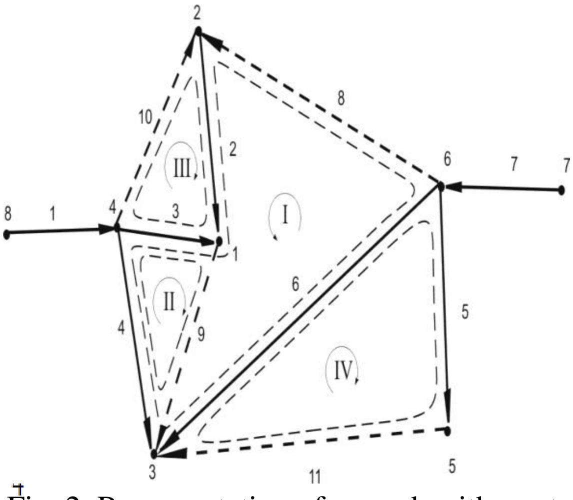

Fig. 2. Representation of a graph with a set of FC

The resulting FC matrix has the form

$$\begin{array}{ccccccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 \end{array}$$

$$B=[Bf_t,E]=\left|\begin{array}{ccccccccccc} 0 & 1 & -1 & 1 & 0 & -1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 1 \end{array}\right|\begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array}$$

- When calculating the GP of high and medium pressure of the radiant structure, a much simpler algorithm is used, consisting of the following steps:
- □ by Qi needs and security coefficients $К_{об.i}$ the consumer, starting from the end node, is determined by the district expenses;
- □ according to the section (transit and dead-end) costs, taking into account the reservation and the

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range of pipes, section diameters are selected to ensure a preferably constant pressure drop (or its square) to the end points of the entire network;

- based on the lowest allowable pressure value in the consumer connection nodes, the nodal pressures are calculated.
- In the calculations of gas distribution pipelines of high and medium pressure, you can use the formula [2]

$$P_н^2 - P_к^2 = 1{,}62\lambda \frac{Q^2}{d^5} \rho_{ст} P_{cm} l .$$

Here Q – commercial flow rate (Nm3 / hour); d – internal diameter; $\rho_{ст}$ – gas density under normal conditions T=273,15 K; P_{cm} =0,1013 MPa; l – section length.

When calculating the main gas pipeline and gas collection collectors (P>1.2 MPa), the formula takes into account the super-compressibility of gas Z [2]

$$P_н^2 - P_к^2 = 1{,}62\lambda \frac{Q^2}{d^5} \rho_{ст} P_{cm} \frac{T}{T_0} Zl .$$

The value of the coefficient of friction resistance λ, according to SNiP II-37-76, in the form of a monomial approximation is calculated depending on the gas flow mode in the gas pipeline:

1) in the region of the laminar flow regime at Re<2000 – according to the Stokes formula

$$\lambda = \frac{64}{\text{Re}};$$

1) at a critical flow regime corresponding to 2000<Re<4000, according to the Zaichenko formula

$$\lambda = 0{,}0025\sqrt[3]{\text{Re}};$$

2) for turbulent flow modes, when Re>4000, the formula

$$\lambda = 0{,}11\left(\frac{k}{d} + \frac{68}{\text{Re}}\right)^{0,25},$$

where k – equivalent roughness of the live section of the gas pipeline.

If it is necessary to Refine the data in turbulent flow regimes, the generalized leibenzone formula can be used [7].

The Reynolds number Re used in calculating the coefficient is defined as

$$\text{Re} = \frac{wd}{\nu} = \frac{4}{\pi}\frac{M}{\mu d},$$

where ν, μ – kinematic and dynamic viscosity of the transported gas – w - mass flow rate of the gas, which remains constant at variable pressure.

The agreement of the pipe range with the calculated diameter is made if the diameter obtained during the calculation is $d < d_{гр}$, then d you need to round it to a smaller standard diameter, and if $d > d_{гр}$, up to a large standard diameter. When $d = d_{гр}$ it is better to round to a larger standard diameter. Figure 3 shows the values $d_{гр}$ for standard low-pressure network diameters used in design practice [5].

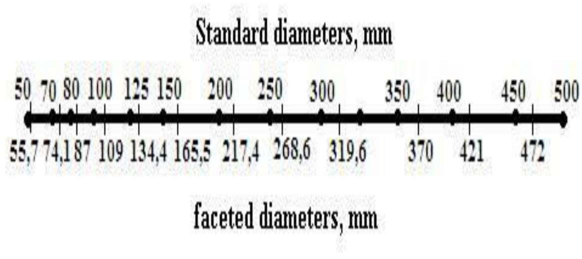

Fig. 3. Nomogram for rounding the diameters of low-pressure gas pipelines to standard ones

With known site indicators, hydraulic losses on the site are found, thus, by the monomial formula [2]

$$\Delta P_i = k\frac{Q_i^\alpha}{d^\beta} l_i, \qquad (A)$$

where the α и β exponents of degrees and depend on the gas flow regime and the equivalent pipe roughness.

In this case, the pressure loss has the form

$$\Delta P_i = P_{нi} - P_{кi} \qquad (B)$$

for low pressure network and

$$\Delta P_i = P_{нi}^2 - P_{кi}^2 \qquad (B')$$

for high and medium pressure networks.

In General, the formulas (B) and (B'), as well as taking into account other flow modes [8], pressure losses can be taken as

$$\Delta P_i = P_{нi}^\gamma - P_{кi}^\gamma .$$

When calculating a branched (including radiant) network, each section has two unknown dimensions: d_i and pressure loss on the site. If the number of dead ends is r, then the number of unknowns is 2r, which are included in R of equations (A). To ensure a given equal pressure drop ΔP in each niche of the I sections that start from the food point and end at the dead end point, you must complete

$$\sum_{i=1}^{k} \Delta P_i - \Delta P_p = 0. \qquad (C)$$

If there are such points k, then an equation of type (C) is composed in the number ΔP_i . In this case, the equation has the form (B) or (B'). Let's assume that the supply and take-off pressure points are set. Then the uniqueness of the solution of systems (A), (B) and (C) is ensured by the fact that only those equations in which the known nodal pressure is not configured are included in the system from group (C). The only requirement for solving the pressure problem is to reduce the nodal pressures in the direction of gas movement. When calculating a ring network, such a condition cannot be imposed, since an infinite number of flow distribution options can be outlined [2]. This is due to the fact that, unlike a distributed network, in a ring network, precinct expenses are also unknown Q_i.. In other words, each section of the ring network is characterized by three unknowns.

Application of the first Kirchhoff law with regard to precinct districts ($Q_{i,j}$)costs and intensity of selection and/or paging (Q_i) [2]

$$\sum Q_{i,j} + Q_j = 0$$

for each j-th node, make the first group of m-1 equations (m is the number of nodes in the network graph, to eliminate the linear relationship between the equations, remove one equation).

According to the second Kirchhoff's law in each fundamental contour the algebraic sum of the pressure drops on the contour sections must be zero

$$\sum_{по\ контуру} \Delta P_i = 0.$$

The number of such dependencies is equal to n-the number of fundamental contours.

Using the two Kirchhoff laws gives a total of r equations, i.e. by the number of sections in the network. To these we add (B) and (B¢) (total r equations). If we take into account k equations of type (C), we still do not have enough r-k equations to optimize the diameters. It follows that it is not possible to find an economically optimal solution to the problem taking into account the diameters of the ring network

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pipeline [2]. In this regard, it is proposed to select diameters based on the average specific pressure drop $\Delta P_i / l_i$, which gives a close to optimal solution of the problem.

For known diameter values, the section in the problem is closed: the number of unknowns is equal to the number of equations. Recall that if there are more than two nodes, then more than one corresponding number of equation nodes are removed from the group of equations of the first Kirchhoff law.

Thus, for the automation of scientific research on the design and management of vehicles, as a tool for optimal selection of the topology of pipeline networks, it is compiled in the form of software called "Graf" (Fig. 4).

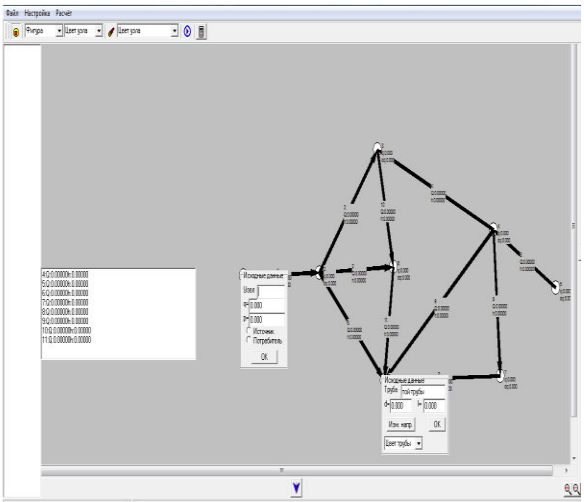

Fig. 4. window for building a redundant gas pipeline network

In the process of creating a program first describes all of the objects together with their inherent properties and characteristics. Then you define procedures and functions that describe in detail all possible operations on objects from the area of external interactions with the environment, as well as internal interactions of objects with each other.

After setting specific values for each of the properties of the obtained objects, we create a description of the real gas network. The objects in it will be interconnected with each other, and the methods developed for them allow you to perform the required network processing with the specified input information.

The proposed ideas and concepts formed the basis for the developed system for automating the design and management of vehicles.

As a rule, the choice of network scheme is performed approximately. The uneven distribution of loads, the specific weight of the load of each consumer is taken into account only intuitively.

As a result, the quality of the network scheme selection depends on the experience of the designer, and in complex cases, other solutions that may differ from the optimal ones are quite possible.

The task is set in such a way that in the original redundant scheme, we select the optimal subnet in the form of a tree that corresponds to the most profitable trace of a branched network [9].

The program is a system in which all operations for calculating the projected gas networks are performed in a certain sequence continuously based on one initial information with the output of both intermediate and final results.

Since the redundant scheme corresponds to a multi-contour non-planar network, finding its best tree corresponds to solving the problem of the most profitable flow distribution. Such a tree is a directed graph without cycles.

The source data for the task is:

1. locations of sources and consumers;
2. consumer loads and source performance;

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3. redundant scheme connecting them, set by the designer;
4. all necessary technical and economic characteristics of the network (Fig. 5);

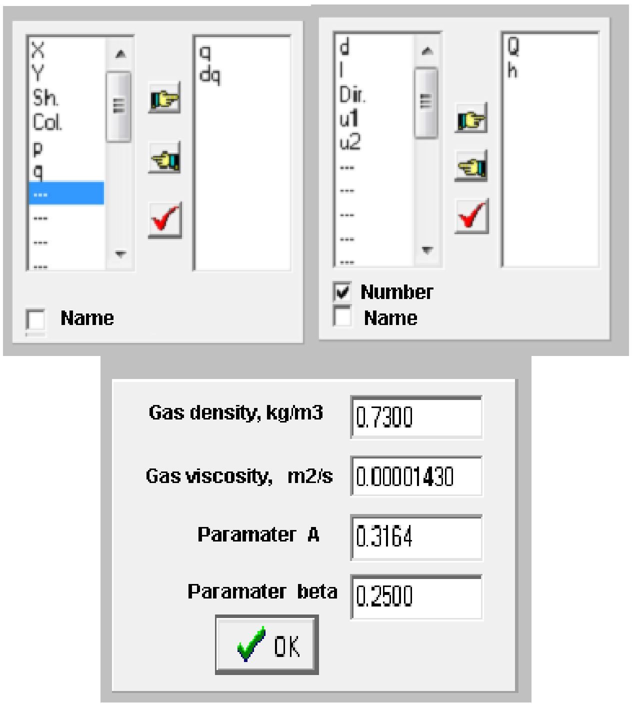

Fig. 5. Technical and economic characteristics of the gas network (node and pipe labels and corresponding coefficients)

The software product based on the proposed conceptual model and algorithm is certified By the Agency for intellectual property of the Republic of Uzbekistan.

5.The results of the calculations. As an example, the gas distribution network of the village "Geologist" of the regional administration "Samarkand gas" is considered [10].

The following production technical and technological data used in the calculations are presented in table 2. [6]. The initial pressure at the entrance to the gas distribution network was assumed to be 300 mm of water. column's.

Table 2. Technological data of the GDS of the village " Geologist"

Start node	End node	lenght, m	diametr, mm	Start node	End node	lenght, m	diametr, mm
1	2	20	50	12	14	85	50
1	7	65	80	12	16	65	50
2	3	35	50	14	15	45	50
2	4	55	50	16	17	60	50
4	5	20	50	16	18	40	50
4	6	45	50	19	1	5	80
7	8	120	50	19	20	70	50
7	9	55	70	20	21	60	50
9	10	30	50	20	25	25	50
9	11	30	50	21	22	45	50
9	12	60	70	21	24	50	50
12	13	60	50	22	23	60	50

The results of calculations based on pressure indicators and optimal gas flow rates for network sections obtained by the steepest descent method are presented in table 3.

Table 3.Technological data of the GDS of the village "Geologist", obtained on the basis of a computational experiment

Start node	End node	Pressure, mm water. St.	Gas consumption, m3 / h	Start node	End node	Pressure, mm water. St.	Gas consumption, m3 / h
1	2	293,6	144,9	12	14	276,3	103,4
1	7	294,9	152,4	12	16	283,8	112,4
2	3	290,3	128,4	14	15	274,8	92,7
2	4	285,5	119,0	16	17	280,3	95,4
4	5	283,0	104,7	16	18	282,3	101,1
4	6	283,0	104,7	19	1	295,0	155,7
7	8	244,3	90,0	19	20	277,2	117,8
7	9	294,5	147,1	20	21	272,8	99,2
9	10	292,0	132,56	20	25	276,4	110,1
9	11	292,0	132,5	21	22	271,5	89,3
9	12	294,2	141,6	21	24	271,2	88,2
12	13	285,4	114,7	22	23	270,0	78,6

Table 4. Technological data of the GDS of the village "Geologist", obtained on the

basis of a computational experiment using the" Graf " program

Calculation result for laminar mode by sections

№ region's	Flow direction		Diameter of the pipeline section	Gas consumption by area	The estimated pressure drop
	start	end			
1	1	2	50	144,9	0,0005586738341184
2	1	7	50	152,4	0,0019096697725248
3	2	3	50	128,4	0,0008663492789952
4	2	4	50	119	0,001261739214736
5	4	5	50	104,7	0,0004036794370752
6	4	6	50	104,7	0,0009082787334192
7	7	8	50	90	0,00208201428864
8	7	9	50	147,1	0,0015596793150224
9	9	10	50	132,56	0,00076664392806144
10	9	11	50	132,5	0,00076629692568
11	9	12	50	141,6	0,0016378512403968
12	12	13	50	114,7	0,0013267057717056
13	12	14	50	103,4	0,0016943355169312
14	12	16	50	112,4	0,0014084441104448
15	14	15	50	92,7	0,0008041780189872
16	16	17	50	95,4	0,0011034675729792
17	16	18	50	101,1	0,0007795986836352
18	19	1	50	155,7	0,0001500785299728
19	19	20	50	117,8	0,0015896564651968
20	20	21	50	99,2	0,0011474212079616
21	20	25	50	110,1	0,000530624474952
22	21	22	50	89,3	0,0007746828165648
23	21	24	50	88,2	0,000850155834528
24	22	23	50	78,6	0,0009091462393728
Total				2756,46	

The calculated pressure drop of the results obtained is on average equal to 1.0292*10-3, which undoubtedly allows us to judge the practical acceptability of this method. The analysis of table 4 shows the minimum gas losses in the network sections and, accordingly, the savings in its consumption. At the same time, due to optimization and the required level of system reliability, certain material resources were saved, including savings in daily and annual gas consumption.

6. Conclusion. Thus, the developed computational algorithm and calculation program can be used to optimize the functioning of gas pipeline networks in other sparsely populated areas, when the network has a complex radiant and multi-ring structure.

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