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THE RESULTS OF MODELING OF THE PROCESS OF RESTRUCTURING OF LOW PRESSURE GAS SUPPLY SYSTEMS

Statement of the problem. Restructuring is a complicated and daunting task, due to the change in the number, wiring diagrams and mechanism of interaction of the structure forming elements of the hydraulic network system. The city's low pressure gas supply system, transporting natural gas domestic and small utility consumers, limiting or completely will stop gas supply as a result of natural disasters, terrorist attacks, deep (planned) for reconstruction. The restoration of this competitiveness of the system is possible as a result of its restructuring.
Results. The work describes and analyzes the results of the mathematical simulation of and restoration, the exclusion of a group of sites in the street of the distribution of the gas supply system low pressure stage, which gives an opportunity to overcome the consequences of natural hazards and deep re-design of the system. The most simplified staged part of the task of restructuring is presented.
Conclusions. Important encouraging result is a relatively weak dependence of the process of sustainable combustion gas from the restructuring, which allows a possible implementation of this model in theory and practice in the solution of operational problems.

Keywords: gas supply, restructuring, restructuring, hydraulic mode, matrix of intsidention, gas consumption mode.

Introduction

Deep reconstruction will be defined as part of a complex restructuring of a hydraulic network system as opposed to a switch-off of individual regions under repairs, abandonment and (or) regeneration of whole new customers, sources, links, network fragments as well as unloaded reservation [1—6].

The urban system of low pressure gas supply that transports the natural gas to home and community users curbs or prevents the gas supply as a result of natural disasters, terrorist attacks, deep (planned) reconstruction. Resuming the operation of the examined system is possible as a result of its restructuring which is a continuous regeneration of new and rejection of old (failed) elements. In the present, more simple concept restructuring of these elements are regions joined (rejected) to a functioning street system which are not restructured (Fig.).

Restructuring is also known as submodelling of flow distributions while rejecting a set of regions using computer-controlled throttle centre for water supply and distribution systems [1—7]. However, direct modelling apart from the reverse one (the regeneration of new regions) shows a limited reconstruction region. Regeneration of a part of a system using throttle centres cannot be seen as part of the reverse submodelling.

All the regions of the system should be divided into four groups: 1 are unchangeable ones (D_i = const, S_i = const); 2 are recyclable (excluding) real (D_i = var, S_i = var); 3 are recyclable (excluding) fictional (S_i^f = var); 4 are unchangeable fictional (S_i^f = const). Groups 3, 4 includes the region that equalizes the community and private (intershop) infrastructure networks (Fig.), carrying network selections and path loads.

1. Linear mathematical model of restructuring

A developed turbulent natural gas supply in low pressure gas pipes is known to be adequately described based on the hydraulic smoothness:

$$\Delta P_i = S_i \cdot Q_i^{\alpha}, \tag{1}$$

where $$S_i = \frac{a \cdot Q_i^{\alpha}}{D_i^{\beta}};$$

a is a constant coefficient that depends on the properties of gas; Q_i is a design consumption in the region i, m^3/h; D_i is an interior diameter of the region i; α = 1.75 and β = 4.75 are indices of the degree that are determined by the mode of flow and roughness of the pipes; ΔP_i are gas pressure losses in the region i.

The below linear model is more informative as part of a complex model of flow distribution of restructuring:

$$\left\|\begin{array}{c} C_{n1\times P} \\ \hline C_{n2\times P} \\ \hline C_{n3\times P} \\ \hline C_{n4\times P} \end{array}\right\|^T \left\{ \left\|\begin{array}{c|c|c|c} \alpha\Delta P_{n1} & 0 & 0 & 0 \\ \hline 0 & \alpha\Delta P_{n2} & 0 & 0 \\ \hline 0 & 0 & \alpha\Delta P_{n3} & 0 \\ \hline 0 & 0 & 0 & \alpha\Delta P_{n4} \end{array}\right\| \left\|\begin{array}{c} \delta\overline{Q}_{n1\times1} \\ \hline \delta\overline{Q}_{n2\times1} \\ \hline \delta\overline{Q}_{n3\times1} \\ \hline \delta\overline{Q}_{n4\times1} \end{array}\right\| + \right.$$
$$\left. + \left\|\begin{array}{c|c|c|c} \Delta P_{n1} & 0 & 0 & 0 \\ \hline 0 & \Delta P_{n2} & 0 & 0 \\ \hline 0 & 0 & \Delta P_{n3} & 0 \\ \hline 0 & 0 & 0 & \Delta P_{n4} \end{array}\right\| \left\|\begin{array}{c} 0 \\ \hline \delta\overline{S}_{n2\times1} \\ \hline \delta\overline{S}_{n3\times1} \\ \hline 0 \end{array}\right\| \right\} = \|0\|; \tag{2}$$

$$\left\|\begin{array}{c} K_{n1r\times r} \\ \hline 0_{n2\times r} \\ \hline 0_{n3\times r} \\ \hline 0_{n4\times r} \end{array}\right\|^T \left\|\begin{array}{c|c|c|c} \alpha\Delta P_{n1} & 0 & 0 & 0 \\ \hline 0 & \alpha\Delta P_{n2} & 0 & 0 \\ \hline 0 & 0 & \alpha\Delta P_{n3} & 0 \\ \hline 0 & 0 & 0 & \alpha\Delta P_{n4} \end{array}\right\| \left\|\begin{array}{c} \delta\overline{Q}_{n1r\times1} \\ \hline \delta\overline{Q}_{n2\times1} \\ \hline \delta\overline{Q}_{n3\times1} \\ \hline \delta\overline{Q}_{n4\times1} \end{array}\right\| = \|0\|; \tag{3}$$

$$\left\|\begin{array}{c} A_{n1\times m} \\ \hline A_{n2\times m} \\ \hline A_{n3\times m} \\ \hline A_{n4\times m} \end{array}\right\|^T \left\|\begin{array}{c|c|c|c} Q_{n1} & 0 & 0 & 0 \\ \hline 0 & Q_{n2} & 0 & 0 \\ \hline 0 & 0 & Q_{n3} & 0 \\ \hline 0 & 0 & 0 & Q_{n4} \end{array}\right\| \left\|\begin{array}{c} \delta\overline{Q}_{n1\times1} \\ \hline \delta\overline{Q}_{n2\times1} \\ \hline \delta\overline{Q}_{n3\times1} \\ \hline \delta\overline{Q}_{n4\times1} \end{array}\right\| = \|0\|; \tag{4}$$

$$\left\|\delta\overline{S}^{\,f}_{n3\times1}\right\| = \left\|\delta\overline{S}^{\,z}_{n2\times1}\right\|, \tag{5}$$

where *C*, *K*, *A* are block matrices of independent nets (routes), contours and nets respectively made up of separate elements; n_1 is a number of actual regions in the system at D_i = const, S_i = const which are not subjects to restructuring (exclusion) according to the statement of the problem; n_2 is a number of actual areas that are renewed (excluded) if D_i = var, S_i = var; n_3 is a number of fictional renewed (excluded) infrastructure regions in the system of community and intrahome (intrashop) networks with S_i^f = var; n_4 is a number of fictional not renewed (not excluded) areas at S_i^f = const; *P, r, m* is a number of independent nets, contours (cyclomatic number), nets (intermediate) with non-specified pressure respectively; $\delta\overline{S}^{\,z}_n$ is a relative deflection of the coefficient *S* of renewed (excluded) regions in the column matrix specified according to the magnitude of a relative deflection of the diameter of the marked regions $\delta\overline{D}^{\,z}_{n2}$; n_1r is a subgroup of the regions in n_1 that make up a system of independent contours.

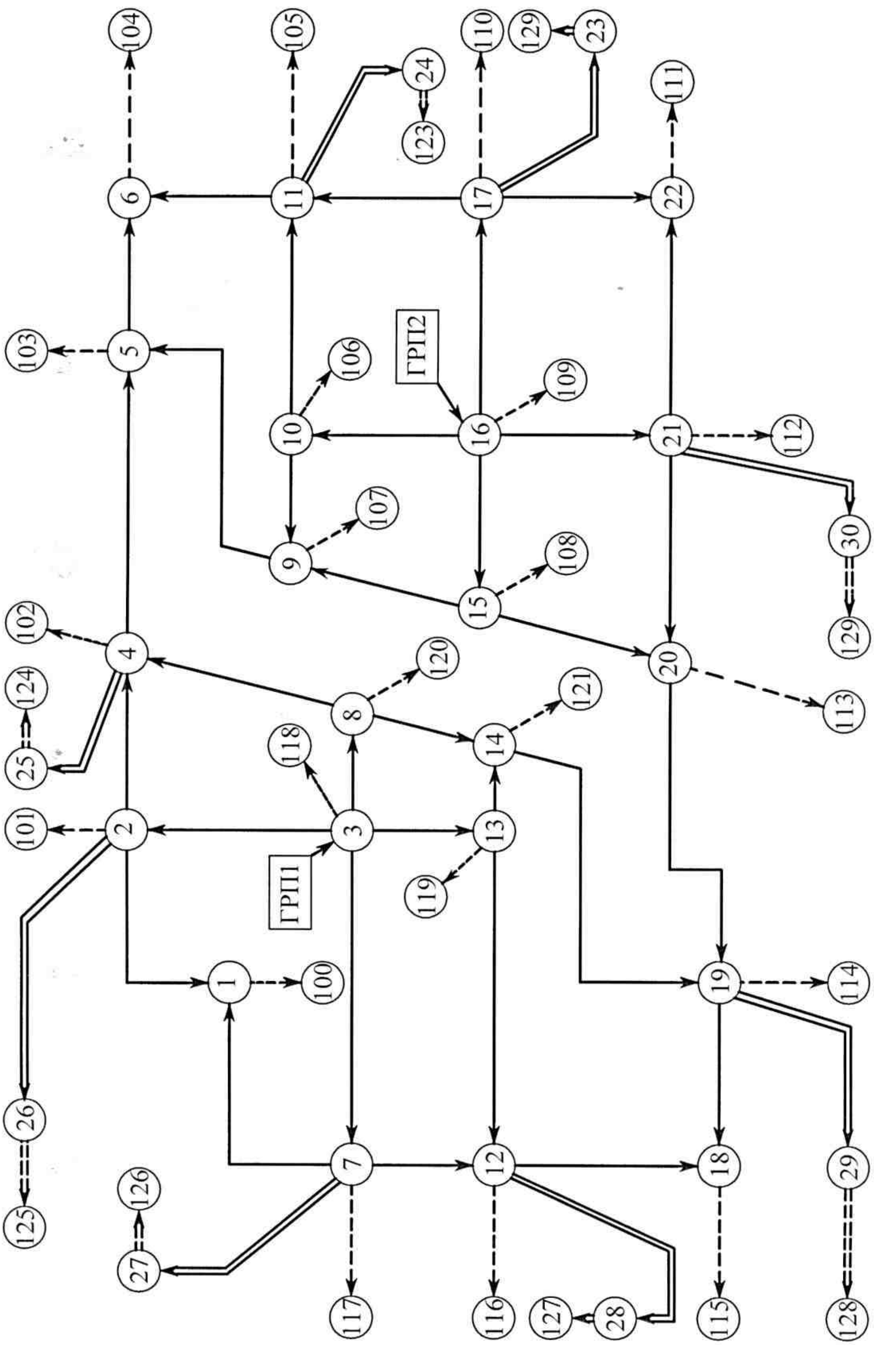

Fig. Binary structure graph of the initial low pressure gas supply system:

2 ⟶ 1 is an actual region in n_1 (D_i = const; S_i = const);

2 ⟹ 26 is a recyclable (excluding) actual region in n_2 (D_i = var, S_i = var);

26 ⇢ 125 is a recyclable (excluding) fictional region in n_3 (S_i^f = var);

2 - - - → 101 is an existing fictional region in n_4 (S_i^f = const); nets ГРП1, ГРП2 are not included

1. Algorithm aspects of the mathematical model of restructuring

(2)—(5) contains linearized subsystems of the equations of independent nets (2), contours (3), net balances (4) and restructuring conditions for fictional infrastructure nets (5). The latter manifests one of the versions which is thought to contribute to maintaining stable gas combustion on the burners of gas consuming aggregates during deep disturbances caused by restructuring.

The magnitudes of the diameters of the pipes of renewed (excluded) regions give the best insight into the process of restructuring. The diameters as such are not included in the initial variables (2)—(5) and can therefore be included into the algorithm and determined (specified) in the current iteration using the conversion formula:

$$\delta\overline{S}_i^{z(k)} = \frac{1}{1+\beta\cdot\delta\overline{D}_i^{z(k)}} - 1, \quad i = 1, 2, \ldots, n_2, \tag{6}$$

after that a system of equations is solved (2)—(5).

The value of $\delta\overline{D}_i^{z(k)}$ was accepted to be $3\cdot 10^{-4}$ cm, $\delta\overline{D}_i^{z(k)}$ = const, $i = 1, 2, \ldots, n_2$.

It is obvious that for renewed regions $\delta\overline{D}_i^{z(k)} > 0$, for excluded ones $\delta D_i^{z(k)} < 0$, for the regions with the specified diameters, $\delta\overline{D}_i^{z(k)} = 0$, $D_i^z = \text{const}$, $S_i^z = \text{const}$.

2. Results of modelling a low-pressure gas supply system of a residential area

The results of modelling restructuring a low-pressure gas supply system are identified in Table 1—8.

3. Analysis of the results of modelling

Table 1 and 5 show a change in flow distribution in actual regions in the group n1 (32 regions) while renewing (see Table 1) and excluding (see Table 5) of the regions. Table 2 and 6 show a change in flow distribution in regions in the group n4 (22 regions). It is to be noted that the group n4 includes the consumption in the burner5s of gas consuming aggregates that are a subject to a rigid control. Table 3 and 7 shows the renewal (Table 3) and exclusion (Table 7) of actual regions in the group n2. Table 4 and 8 show the renewal (Table 4) and exclusion (Table 8) in fictional infrastructure regions in the group n3.

Table 1

Results of modelling a flow distribution in restructuring a gas supply system while renewing the group n_2 and n_3 of the regions (see Fig.)

Number of the region	Prior to restructuring							Following restructuring	
	STP	Other conditions	*L*, m	$D_н \times \delta$, mm	$D_{вн}$, cm	*Q*, m^3/h	ΔP, dPa	*Q*, m^3/h	ΔP, dPa
1	2	1	540	108×3.5	10.1	120.2	92.455	123.303	96.672
2	2	4	490	108×3.5	10.1	96.2	55.814	105.204	65.275
3	3	2	460	219×5.0	20.9	477.8	27.545	519.741	31.915
4	7	1	460	89×3.0	8.3	73.0	83.088	66.225	70.066
5	8	4	490	108×3.5	10.1	97.4	57.104	108.471	68.943
6	3	8	320	219×5.0	20.9	567.8	26.256	592.021	28.247
7	3	13	450	219×5.0	20.9	571.6	37.398	600.094	40.721
8	3	7	550	219×5.0	20.9	508.5	36.913	661.692	58.52
9	7	12	450	127×3.5	12.0	179.3	68.682	173.348	64.742
10	13	12	550	127×3.5	12.0	160	68.197	178.442	82.542
11	8	14	480	159×4.0	15.1	244.1	41.616	257.978	45.844
12	13	14	150	127×3.5	12.0	209.8	30.474	220.973	33.37
13	4	5	400	76×3.0	7.0	21.6	18.497	15.246	10.054
14	12	18	550	127×3.5	12.0	67.4	14.406	68.999	15.009
15	19	18	280	108×3.5	10.1	32.2	4.502	26.539	3.21

End of Table 1

Number of the region	Prior to restructuring							Following restructuring	
	STP	Other conditions	L, m	$D_н$×δ, mm	$D_{вн}$, cm	Q, m³/h	ΔP, dPa	Q, m³/h	ΔP, dPa
16	20	19	490	108×3.5	10.1	53.7	19.648	63.049	26.02
17	14	19	900	159×4.0	15.1	185.5	47.626	213.62	60.97
18	5	6	150	89×3.0	8.3	58.5	18.144	61.89	20.024
19	9	5	770	159×4.0	15.1	198.2	45.906	206.152	49.177
20	10	9	100	127×3.5	12.0	211.3	20.564	214.04	21.033
21	10	11	450	127×3.5	12.0	167.9	60.863	180.235	68.902
22	11	6	450	127×3.5	12.0	99.6	23.751	93.67	21.332
23	16	10	450	219×5.0	20.9	554.6	35.386	569.196	37.032
24	16	15	260	219×5.0	20.9	554.7	20.435	568.6	21.34
25	16	17	470	219×5.0	20.9	537.5	34.903	625.73	45.538
26	16	21	500	219×5.0	20.9	441.4	25.917	601.084	44.49
27	21	22	480	89×3.0	8.3	76.4	94.083	72.403	85.639
28	17	22	500	108×3.5	10.1	119.8	85.098	119.392	84.591
29	15	20	520	108×3.5	10.1	109.8	75.415	119.691	87.702
30	17	11	450	127×3.5	12.0	168.6	61.346	167.103	60.396
31	21	20	450	108×3.5	10.1	114.1	69.933	108.998	64.552
32	15	9	480	159×4.0	15.1	223.8	35.515	228.127	36.725

Table 2

Results of modelling a flow distribution in restructuring a gas supply system while renewing the group n_2 and n_3 of the regions

Number of the region	Prior to restructuring					Following restructuring		
	STP	Other condit di-tions	Q, m^3/h	ΔP, dPa	S, dPa/(m^3/h)$^{1.75}$	Q, m^3/h	ΔP, dPa	S, dPa/(m^3/h)$^{1.75}$
33	1	100	193.2	260	0.0259693	189.528	251.413	0.0259693
34	2	101	261.4	352.45	0.0207405	259.543	348.085	0.0207405
35	3	118	312.3	380.0	0.0163788	312.3	380.0	0.0163785
36	4	102	172	296.64	0.0363125	167.371	282.811	0.0363125
37	5	103	161.3	278.14	0.0380955	159.508	272.757	0.0380985
38	6	104	158.1	260	0.0368844	155.56	252.734	0.0368844
39	7	117	256.2	343.09	0.0209118	246.85	321.479	0.0209118
40	8	120	226.3	353.74	0.0267911	225.571	351.753	0.0267911
41	9	107	336.9	324.05	0.0226529	236.015	321.935	0.0226529
42	10	106	175.4	344.61	0.0407044	174.92	342.968	0.0407644
43	11	105	236.9	283.75	0.0198357	232.245	274.065	0.0198357
44	12	110	271.9	274.41	0.0150722	261.754	256.738	0.0150722
45	13	119	201.8	342.6	0.0317086	200.679	339.279	0.0317080
46	14	121	268.4	312.13	0.0175373	265.33	305.908	0.0175373
47	15	108	221.1	359.56	0.0283627	220.782	358.66	0.0283627

End of Table 2

Number of the region	Prior to restructuring					Following restructuring		
	STP	Other conditions	Q, m^3/h	ΔP, dPa	S, $dPa/(m^3/h)^{1.75}$	Q, m^3/h	ΔP, dPa	S, $dPa/(m^3/h)^{1.75}$
48	16	109	294.7	380.0	0.0181288	294.7	380.0	0.0181288
49	17	110	249.1	345.1	0.0220946	244.684	334.462	0.0220946
50	18	115	99.6	260	0.0827979	95.538	241.729	0.0827979
51	19	114	207	264.5	0.0234143	198.107	244.938	0.0234143
52	20	113	170.2	284.15	0.0354298	165.639	270.958	0.0354298
53	21	112	250.9	354.08	0.0223861	243.293	335.51	0.0223861
54	22	111	196.2	260	0.0252784	191.795	249.871	0.0252784

Table 3

Results of modelling a flow distribution in restructuring a gas supply system while renewing the group n_2 and n_3 of the regions

Number of the region	Prior to restructuring (0th iteration)							Following restructuring				
	STP	Other conditions	L, m	$Q^{(0)}$, m^3/h	$\Delta P^{(0)}$, dPa	$D_{BH}^{(0)}$ cm	$S^{(0)}$, $dPa/(m^3/h)^{1.75}$	$Q^{(\kappa)}$, m^3/h	$\Delta P^{(\kappa)}$, dPa	$D_{BH}^{(\kappa)}$ cm	$S^{(\kappa)}$, $dPa/(m^3/h)^{1.75}$	$D_н \times \delta$, mm
55	2	26	500	0.00429	92.48	0.3	$1.284 \cdot 10^6$	31.695	89.752	8.05	0.212	88.5×4
56	4	25	450	0.00429	36.67	0.3	$0.51 \cdot 10^6$	31.063	34.361	8.05	0.08407	88.5×4
57	11	24	420	0.00429	23.73	0.3	$0.33 \cdot 10^6$	21.428	22.541	7.0	0.105626	76×3

End of Table 3

Number of the region	Prior to restructuring (0^{th} iteration)							Following restructuring				
	STP	Other conditions	L, m	$Q^{(0)}$, m^3/h	$\Delta P^{(0)}$, dPa	$D_{BH}^{(0)}$ cm	$S^{(0)}$, dPa / (m^3/h)$^{1.75}$	$Q^{(\kappa)}$, m^3/h	$\Delta P^{(\kappa)}$, dPa	$D_{BH}^{(\kappa)}$ cm	$S^{(\kappa)}$, dPa / (m^3/h)$^{1.75}$	$D_н$×δ, mm
58	17	23	430	0.00429	85.07	0.3	$1.18 \cdot 10^6$	95.555	80.85	12.1	0.0282	132×5.5
59	21	30	400	0.00429	94.06	0.3	$1.306 \cdot 10^6$	176.394	87.29	15.3	0.010224	165×6
60	19	29	320	0.00429	5.005	0.3	$0.07 \cdot 10^6$	52.028	4.35	9.8	0.004514	108×5
61	12	28	550	0.00429	14.38	0.3	$0.2 \cdot 10^6$	21.042	13.233	7.0	0.064016	76×3
62	7	27	440	0.00429	80.04	0.3	$1.113 \cdot 10^6$	175.272	73.45	15.3	0.0087	165×6

Table 4

Results of modelling of restructuring a gas supply system

while renewing a group of n_3 regions

Number of regions	Prior to restructuring (0^{th} iteration)					Following restructuring		
	STP	Other condi-tions	$Q^{(0)}$, m^3/h	$\Delta P^{(0)}$ dPa	$S^{(0)}$, dPa/(m^3/h)$^{1.75}$	$Q^{(\kappa)}$, m^3/h	$\Delta P^{(\kappa)}$, dPa	$S^{(\kappa)}$, dPa/(m^3/h)$^{1.75}$
63	26	125	0.00429	260	$3.615 \cdot 10^6$	31.695	258.33	0.610157
64	25	124	0.00429	260	$3.615 \cdot 10^6$	31.063	248.45	0.607873

End of Table 4

Number of regions	Prior to restructuring (0 th iteration)					Following restructuring		
	STP	Other conditions	$Q^{(0)}$, m³/h	$\Delta P^{(0)}$ dPa	$S^{(0)}$, dPa/(m³/h)$^{1.75}$	$Q^{(\kappa)}$, m³/h	$\Delta P^{(\kappa)}$, dPa	$S^{(\kappa)}$, dPa/(m³/h)$^{1.75}$
65	24	123	0.00429	260	$3.615 \cdot 10^6$	21.428	251.52	1.178568
66	23	122	0.00429	260	$3.615 \cdot 10^6$	94.555	253.61	0.088454
67	30	129	0.00429	260	$3.615 \cdot 10^6$	174.39	248.22	0.0296602
68	29	128	0.00429	260	$3.615 \cdot 10^6$	52.028	240.38	0.238561
69	28	127	0.00429	260	$3.615 \cdot 10^6$	21.04	243.5	1.178064
70	27	126	0.00429	260	$3.615 \cdot 10^6$	175.27	248.02	0.0293764

Table 5

Results of modelling a flow distribution while restructuring a gas supply excluding a group of n_2 and n_3 regions

Number of the region	Prior to restructuring								Following restructuring		
	STP	Other conditions	L, m	D_{BH}, cm	$D_н \times \delta$, mm	Q, m³/h	ΔP, dPa	S, dPa/ (m³/h)$^{1.75}$	Q, m³/h	ΔP, dPa	S, dPa/ (m³/h)$^{1.75}$
1	2	1	540	10.1	108×3.5	123.303	96.668	0.021188	119.986	92.167	0.021188
2	2	4	490	10.1	108×3.5	105.204	65.276	0.018888	106.75	66.96	0.018888
3	3	2	460	20.9	219×5	519.74	31.912	0.000564	487.706	28.55	0.000564
4	7	1	460	8.3	89×3	66.225	70.077	0.045575	72.908	82.9	0.045575
5	8	4	490	10.1	108×3.5	108.47	68.942	0.01891	107.867	68.27	0.01891
6	3	8	320	20.9	219×5	592.02	28.247	0.000398	579.91	27.24	0.000398

Table 5 (continuous)

Number of the region	Prior to restructuring								Following restructuring		
	STP	Other conditions	L, m	D_{BH}, cm	$D_н \times \delta$, mm	Q, m^3/h	ΔP, dPa	S, dPa/ (m^3/h)$^{1.75}$	Q, m^3/h	ΔP, dPa	S, dPa/ (m^3/h)$^{1.75}$
7	3	13	450	20.9	219×5	600.09	40.72	0.00056	580.25	38.39	0.00056
8	3	7	550	20.9	219×5	661.69	58.505	0.000678	515.58	37.82	0.000678
9	7	12	450	12	127×3.5	173.35	64.75	0.007818	186.86	73.83	0.007818
10	13	12	550	12	127×3.5	178.44	82.534	0.009474	166.67	73.25	0.009474
11	8	14	480	15.1	159×4	257.98	45.841	0.002761	246.1	42.21	0.002761
12	13	14	150	12	127×3.5	220.97	33.368	0.002635	212.11	31.06	0.002635
13	4	5	400	7	76×3	15.24	10.054	0.085469	15.516	10.368	0.085469
14	12	18	550	12	127×3.5	68.99	15.008	0.009086	63.502	12.98	0.009086
15	19	18	280	10.1	108×3.5	26.54	3.211	0.010343	35.081	5.23	0.010343
16	20	19	490	10.1	108×3.5	63.03	26.013	0.018444	49.737	17.18	0.018444
17	14	19	900	15.1	159×4	213.6	60.96	0.005108	190.59	49.93	0.005108
18	5	6	150	8.3	89×3	61.89	20.023	0.014663	59.98	18.95	0.014663
19	9	5	770	15.1	159×4	206.15	49.177	0.004385	204.43	48.46	0.004385
20	10	9	100	12	127×3.5	214.04	21.033	0.001756	213.51	20.94	0.001756
21	10	11	450	12	127×3.5	180.23	68.9	0.007772	175.73	65.92	0.007772
22	11	6	450	12	127×3.5	93.67	21.333	0.007564	96.42	22.44	0.007564
23	16	10	450	20.9	219×5	569.19	37.031	0.000558	564.32	36.48	0.000558

End of Table 5

Number of the region	Prior to restructuring								Following restructuring		
	STP	Other conditions	L, m	D_{BH}, cm	$D_н$×δ, mm	Q, m³/h	ΔP, dPa	S, dPa / (m³/h)^1.75	Q, m³/h	ΔP, dPa	S, dPa / (m³/h)^1.75
24	16	15	260	20.9	219×5	568.59	21.339	0.000322	562.71	20.95	0.000322
25	16	17	470	20.9	219×5	625.67	45.53	0.000582	548.05	36.11	0.000582
26	16	21	500	20.9	219×5	601.08	44.49	0.00061	594.08	43.59	0.00061
27	21	22	480	8.3	89×3	72.4	85.64	0.047654	70.59	81.92	0.047654
28	17	22	500	10.1	108×3.5	119.39	84.59	0.019616	123.22	89.4	0.019616
29	15	20	520	10.1	108×3.5	119.69	87.7	0.020249	114.58	81.26	0.020249
30	17	11	450	12	127×3.5	167.11	60.4	0.007777	176.23	66.29	0.007777
31	21	20	450	10.1	108×3.5	108.99	64.548	0.017556	103.16	58.63	0.017556
32	15	9	480	15.1	159×4	228.12	36.725	0.002743	227.2	36.47	0.002743

Table 6

Results of modelling a flow distribution

while restructuring a gas supply system excluding a group of n_2 and n_3 regions

Number of the region	Prior to restructuring					Following restructuring		
	STP	Oth-er condi di-tions	Q, m³/h	ΔP, dPa	S, dPa/(m³/h)^1.75	Q, m³/h	ΔP, dPa	S, dPa/(m³/h)^1.75
33	1	100	189.53	251.413	0.025969	192.894	259.2806	0.025969
34	2	101	259.54	348.085	0.02074	260.973	351.448	0.02074
35	3	118	312.3	380	0.016379	312.3	380	0.016379

End of Table 6

Number of the region	Prior to restructuring					Following restructuring		
	STP	Other conditions	Q, m^3/h	ΔP, dPa	S, dPa/(m^3/h)$^{1.75}$	Q, m^3/h	ΔP, dPa	S, dPa/(m^3/h)$^{1.75}$
36	4	102	167.371	282.811	0.036313	167.937	284.486	0.036313
37	5	103	159.508	272.76	0.038099	159.962	274.117	0.038099
38	6	104	155.56	252.73	0.036884	156.412	255.161	0.036884
39	7	117	246.85	321.479	0.020912	255.815	342.184	0.020912
40	8	120	225.57	351.753	0.026791	225.939	352.756	0.026791
41	9	107	236.015	321.935	0.022653	236.285	322.58	0.022653
42	10	106	174.921	342.968	0.040764	175.082	343.521	0.040764
43	11	105	232.245	274.065	0.019836	233.953	277.602	0.019836
44	12	116	261.754	256.738	0.015072	268.457	268.355	0.015072
45	13	119	200.679	339.279	0.031709	201.465	341.606	0.031709
46	14	121	265.33	305.908	0.017537	267.62	310.542	0.017537
47	15	108	220.78	358.66	0.028363	220.918	359.046	0.028363
48	16	109	294.7	380	0.018129	294.7	380	0.018129
49	17	110	244.684	334.462	0.022095	248.6	343.89	0.022095
50	18	115	95.538	241.729	0.082798	98.583	255.375	0.082798
51	19	114	198.107	244.938	0.023414	205.252	260.605	0.023414
52	20	113	165.639	270.958	0.03543	168.011	277.786	0.03543
53	21	112	243.293	335.51	0.022386	243.667	336.414	0.022386
54	22	111	191.795	249.871	0.025278	193.814	254.492	0.025278

Table 7

Results of modelling restructuring a gas supply system excluding a group of n_2 areas

Number of the region	Prior to restructuring (0^{th} iteration)							Following restructuring			
	STP	Other conditions	L, m	$Q^{(0)}$, m^3/h	$\Delta P^{(0)}$, dPa	$D_{BH}^{(0)}$, cm	$S^{(0)}$, dPa/(m^3/h)$^{1.75}$	$Q^{(\kappa)}$, m^3/h	$\Delta P^{(\kappa)}$, dPa	$D_{BH}^{(\kappa)}$ cm	$S^{(\kappa)}$, dPa / (m^3/h)$^{1.75}$
55	2	26	500	31.695	89.75	8.05	0.212	0.00138	88.852	0.2	$8.989691 \cdot 10^6$
56	4	25	450	31.063	34.36	8.05	0.08407	31.168	34.565	8.05	0.08407
57	11	24	420	21.428	22.541	7.0	0.105626	21.585	22.832	7.0	0.105626
58	17	23	430	95.555	80.85	12.1	0.0282	0.001374	81.333	0.2	$8.292513 \cdot 10^6$
59	21	30	400	176.394	87.29	15.3	0.01022	176.665	87.525	15.3	0.010224
60	19	29	320	52.028	4.35	9.8	0.00451	0.001368	4.742	0.2	$0.487181 \cdot 10^6$
61	12	28	550	21.042	13.233	7.0	0.064016	21.5805	13.832	7.0	0.064016
62	7	27	440	175.272	73.45	15.3	0.0087	0.001373	76.4	0.2	$7.803111 \cdot 10^6$

Table 8

Results of modelling restructuring a gas supply system excluding a group of n_3 regions

Number of the region	Prior to restructuring (0th iteration)					Following restructuring		
	STP	Other conditions	$Q^{(0)}$, m³/h	$\Delta P^{(0)}$, dPa	$S^{(0)}$, dPa/(m³/h)$^{1.75}$	$Q^{(\kappa)}$, m³/h	$\Delta P^{(\kappa)}$, dPa	$S^{(\kappa)}$, dPa/(m³/h)$^{1.75}$
63	26	125	31.695	258.33	0.610157	0.00138	262.595	$26.57844 \cdot 10^6$
64	25	124	31.063	248.45	0.607873	31.168	249.921	0.607873
65	24	123	21.428	251.52	1.178568	21.585	254.77	1.178642
66	23	122	95.555	253.61	0.088454	0.001374	262.56	$26.778174 \cdot 10^6$
67	30	129	176.394	248.22	0.0296602	176.665	248.89	0.029073
68	29	128	52.028	240.38	0.238561	0.001368	255.86	$26.296 \cdot 10^6$
69	28	127	21.042	243.5	1.178064	21.5805	254.52	1.177916
70	27	126	175.272	248.05	0.0293764	0.001373	265.78	$27.13979 \cdot 10^6$

As a result of disturbances caused by the renewal and exclusion of the regions of the group n_2, n_3, there are natural changes in a flow distribution and the major (basic) net system which is not under reconstruction. Change in the consumption in the regions of the group n_4 reflects a change in the consumption in the burners of functioning gas consuming aggregates (gas stoves, gas-flow and capacitive water heaters, local heating boilers, etc.) which are not equipped with combustion stabilizers. If the above change occurs in a wide range, there might be negative changes in the quality of gas combustion and environmentally unfriendly substances in the combustion products (nitrogen oxide, carbon oxide, 3, 4-benzopyran, etc.). There might be flames in the separation and breakthrough region accompanied by leaks and flammable concentrations. It is therefore necessary to control the quality of gas combustion while restructuring a gas supply system. Indirect control is possible in a range of gas consumption change in the regions in the group n_4.

As a result of modelling the conclusion is made that the above consumption does not see a significant change (Table 2, 6), in the range of 4—5 % ($\Delta Q_{max} \leq 10$ m^3/h) and this kind of restructuring is moderate. This is because burners of domestic gas appliances according to [7—9] allow for a 2-fold or more change in the consumption or a 4-fold change in pressure deflections providing for a stable gas combustion. However, there can be more fundamental changes in the consumption (pressure deflections) on the burners of gas-consuming aggregates, particularly if the basic gas supply system is under reconstruction. In this case it is necessary to introduce a so-called unloaded reservation [10, 11] which enables the renewal (stabilization) of a high-quality gas combustion on the burners. Unloaded reservation can be modelled using the above restructuring model by renewing reserve regions of the system with possible intermediate control of the efficiency of this type of reservation [11]. The similar solutions can be acquired for medium (high)-pressure gas supply systems as well.

Conclusions

1. A mathematical model of restructuring a low-pressure gas supply system was suggested that enables changes in the configuration, joining scheme and interaction of the structural elements of a hydraulic network system.

2. The results of modelling suggest there can be intermediate control of the parameters of the system, indirect analysis of the quality of gas combustion, back-up of the system while choosing (based on the intermediate control) an optimum structure of back-up lines, dealing with natural disasters and deep reconstruction.

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