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Determination of additional factors in assessing the reliability of heat supply systems

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Annotation. As a result of the research, additional factors that significantly influenced the reliability of the consumers' heat supply were assessed, an assessment of the influence of these factors on the reliability of the operation of the heat network was made. The influence of additional factors is taken into account when developing a new methodology and algorithm for calculating the reliability of consumers' heat supply; a program for calculating the reliability of consumers' heat supply was developed.

Determination of factors unaccounted for in the existing methodology

To determine the reliability of heat supply to consumers, the initial data: failure rate and average recovery time of heat pipelines and equipment should be taken into account [1–8].

The actual level of reliability of the heating system should be assessed on the basis of statistical data on failures of the system components.

To assess the reliability of existing and newly developed schemes of heat networks, a technique described in [9,10] is developed, which allows to determine the availability and probability of failure of the heat network on the basis of such initial data as the length, diameter and duration of operation of the pipeline system sections.

The disadvantage of this approach is that the calculations do not take into account a number of factors that directly affect the reliability of the heating system.

The aim of the study was to identify and take into account additional factors, as well as the development of a new method of calculating reliability indicators.

Research problems are the following:

- Determination of additional factors affecting the reliability of heat supply to consumers;
- Assessment of the impact of these factors on the reliability of the heat network;
- Taking into account the influence of these factors in the development of a new method of calculating the reliability of heat supply to consumers;
- Development of the program of reliability indicators calculation for consumer heat supply on

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the basis of the new methodology.

It was assumed that the failure rate of the elements of the heat network (in addition to the service life) is influenced by the following factors: the residual thickness of the metal of the pipeline, the previous gusts, the corrosion activity of the soil, the presence of the channel flooding, the material of the pipeline, the presence of intersections with communications, the percentage of failure of the pipeline [7,11–21]

In order to solve the issue of including factors in the new methodology, the analysis of statistical data on gusts in different parts of the heat network of the city of Kazan was carried out [10].

Information on gusts was grouped by a set of factors. The influence on the failure rate of the elements of the heat network was revealed for the following factors: the residual thickness of the metal walls of the pipeline (K1), the presence of previous gusts (K2), the corrosion activity of the soil (K3), the presence of the channel flooding (K4), the presence of intersections with communications (K5). The influence of these factors on the reliability of heat supply of consumers was evaluated [10].

To take into account the factors identified in the existing methodology was introduced the coefficient of additional factors:

$$\mathrm{K}i = f\,(\mathrm{K1;K2;K3;K4;K5}) \tag{1}$$

With the calculated values of the coefficient Ki it is possible to estimate the effect of additional factors on the failure rate of the heat network sections.

The linear dependence of the coefficient of additional factors Ki on the residual wall thickness of the pipeline metal was revealed during the comparison of the parameters (figure 1):

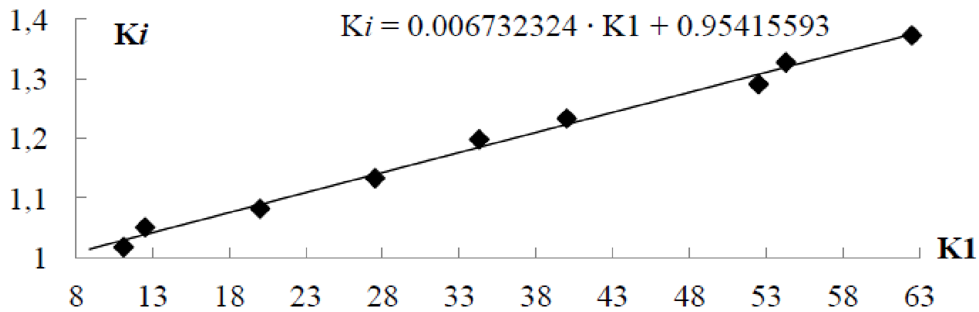

Figure 1. Influence of residual wall thickness of the pipeline metal on the coefficient of additional factors Ki

The next stage was the failure analysis, which includes two additional factors-the thickness of the pipeline metal and the corrosion activity of the soil (figure 2).

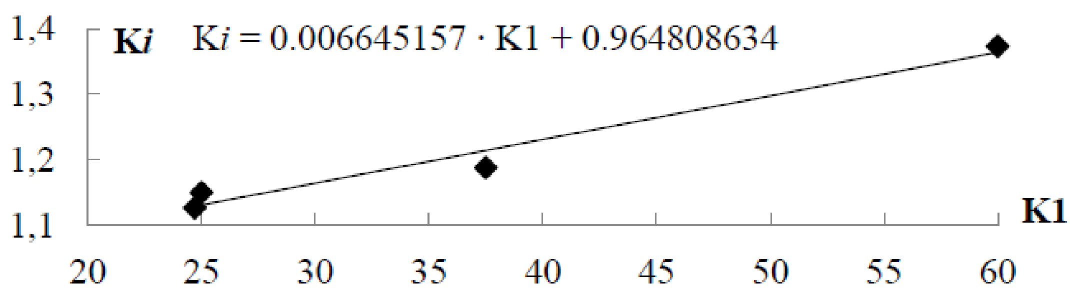

Figure 2. The influence of parameters K1 and K3 on a coefficient by accounting additional factors Ki

Next analysis was performed, which includes two additional factors-the thickness of the pipeline metal and the presence of the channel flooding (figure 3).

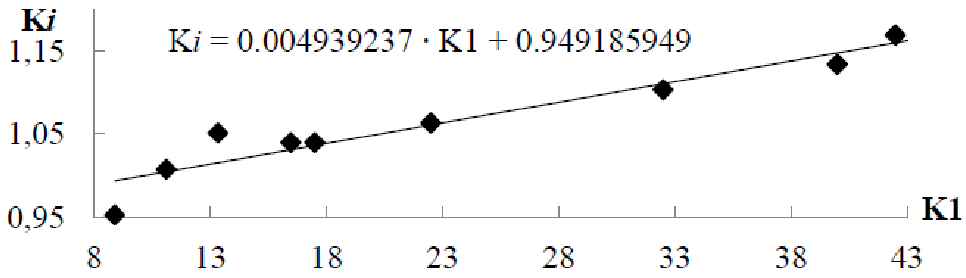

Figure 3. The influence of parameters K1 and K4 on the coefficient by accounting additional factors Ki

The next sample included parameters-the thickness of the pipeline metal and the presence of intersections with communications.

The functional dependence of the coefficient Ki on the parameters K1 and K5 is shown in figure 4.

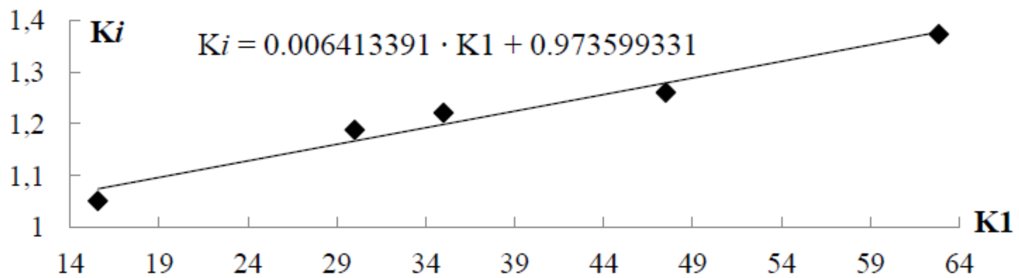

Figure 4. The influence of parameters K1 and K5 on the coefficient by accounting additional factors Ki

The final analysis of failures was combined with five parameters – the thickness of the pipeline metal, the presence of previous gusts at the site, the corrosion activity of the soil, the presence of the channel flooding and the presence of intersections with communications.

The functional dependence of the coefficient Ki on the parameters K1, K2, K3, K4 and K5 is shown in figure 5.

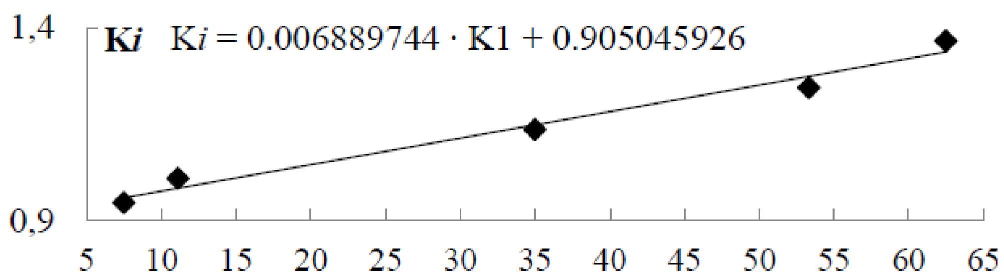

Figure 5. The influence of parameters K1, K2, K3, K4 and K5 on the coefficient by accounting additional factors Ki

Consideration of the influence of parameters not included in the analysis

The remaining isolated cases of refusal of sections of heating networks (for example, the combination of K1-K2, K1-K3,-K5, etc.) that were not included in the analysis were taken into account using a General functional dependency is built according to the values of the coefficient Ki (figure 6).

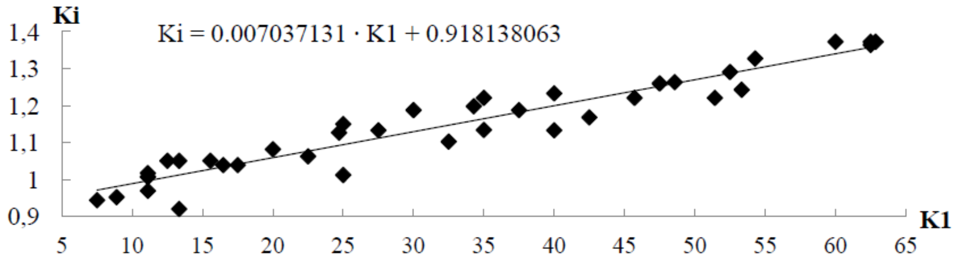

Figure 6. General functional dependence in all cases bounce sections of a heating system

Based on the functional dependencies presented in table 1, the theoretical values of the coefficient Ki were calculated.

Table 1. Functions of influence of additional parameters

№	The presence of the factors	Functional dependence
1	K1	Ki = 0.00673·K1+0.954
2	K1, K3	Ki = 0.00664·K1+0.964
3	K1, K4	Ki = 0.00494·K1+0.949
4	K1, K5	Ki = 0.00641·K1+0.973
5	K1, K2, K3, K4, K5	Ki = 0.00689·K1+0.905
6	A combination of factors different from options 1-5	Ki = 0.00704·K1+0.918

Figure 7 compares the theoretical and experimental values of the coefficient of additional factors Ki.

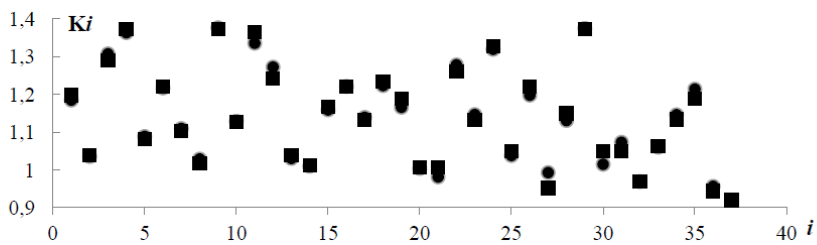

Figure 7. Theoretical and experimental values of the coefficients taking into account additional factors Ki

Conclusion

As can be seen from the graph, the deviation of theoretical values from the experimental data is not so significant – the average error does not exceed 1.13%. Therefore, the obtained functional dependences can be used to calculate the reliability of heat supply to consumers.

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References

[1] Gorshkov A and Murgul V 2018 Calculation of Heat Energy Consumption by a Typical Historical Building with a Courtyard *Adv. Intell. Syst. Comput.* **692** 577–91
[2] Kostenko V A, Gafiyatullina N M, Semchuk A A and Kukolev M I 2016 Geothermal heat pump in the passive house concept *Mag. Civ. Eng.* **68** 18–25
[3] Nefedova A, Bykova J, Kosov S and Petrichenko M 2015 Selection of individual automatic heat supply unit of ecomatic LLC vol 117(Elsevier Ltd)pp 1102–11
[4] Borodinecs A, Zemitis J, Sorokins J, Baranova D V and Sovetnikov D O 2016 Renovation need for apartment buildings in Latvia *Mag. Civ. Eng.* **68** 58–64
[5] Akhmetova I, Chichirova N and Derevianko O 2017 Revisiting heat losses calculation at district heating network *Int. J. Civ. Eng. Technol.* **8** 694–702
[6] Murgul V 2016 Assessment of the Energy - Efficient Modernization of Residential Historical Buildings in Kiev vol 73(EDP Sciences)
[7] Strogonov K, Fedyukhin A, Stepanova T and Derevianko O 2018 Estimation of Practical Significance for Application of Composite Pipes in Comparison with Metal and Polymer Materials *Adv. Intell. Syst. Comput.* **692** 1024–35
[8] Soldatenko V S, Smagin V A, Gusenitsa Y N, Gera V I and Soldatenko T N 2017 The method of calculation for the period of checking utility systems *Mag. Civ. Eng.* **70** 72–83
[9] Akhmetova I G and Mukhametova L R 2017 Innovative development of the regional economy *Innovative clusters in the digital economy: theory and practice Proc. of the Scientific and practical conference with international participation* (Saint Petersburg, May 17-22)
[10] Akhmetova I G and Chichirova N D 2016 Evalution of Thernal Insulation Type Impact on the Value of Regulatory Heat Losses in Heat and Power Systems *J. Eng. Appl. Sci.* **11** 2946–9
[11] Kiselev V G 1999 *Information and engineering support of pipeline electrochemical protection* (Saint Petersburg: SPbGUVK)
[12] Turichin G, Kuznetsov M, Sokolov M and Salminen A 2015 Hybrid Laser Arc Welding of X80 Steel: Influence of Welding Speed and Preheating on the Microstructure and Mechanical Properties vol 78(Elsevier B.V.)pp 35–44
[13] Muravyeva L and Vatin N 2016 Elaboration of the Method for Safety Assessment of Subsea Pipeline with Longitudinal Buckling *Adv. Civ. Eng.* **2016**
[14] Silva C C, De Assis J T, Philippov S and Farias J P 2016 Residual stress, microstructure and hardness of thin-walled low-carbon steel pipes welded manually *Mater. Res.* **19** 1215–25
[15] Kondrat'ev S Y and Shvetsov O V 2018 Technological and Operational Features of Drill Pipes from Aluminum Alloys 2024 and 1953 *Met. Sci. Heat Treat.* 1–7
[16] Davydov V V, Myazin N S, Logunov S E and Fadeenko V B 2018 A Contactless Method for Testing Inner Walls of Pipelines *Russ. J. Nondestruct. Test.* **54** 213–21
[17] Gritskevich M S and Garbaruk A V 2017 Influence of upstream pipe bends on the turbulent heat and mass transfer in T-junctions vol 891(Institute of Physics Publishing)
[18] Muravyeva L V 2017 Simulation modeling in pipeline safety assessment (CRC Press/Balkema) pp 213–8
[19] Loktionova E A and Miftakhova D R 2017 Fluid filtration in the clogged pressure pipelines *Mag. Civ. Eng.* **76** 214–24
[20] Kitanin É L, Smirnov Y A and Lebedev M E 2016 Development of Flow and Heat Transfer During Filling a Pipeline with Water at the Pipe Wall Temperature Below the Freezing Point *J. Eng. Phys. Thermophys.* **89** 808–14
[21] Vasilyev A, Rudskoy A, Kolbasnikov N, Sokolov S and Sokolov D 2012 Physical and mathematical modeling of austenite microstructure evolution processes developing in line-pipe steels under hot rolling **706–709** 2836–41