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Data Article

Dataset for assessing the reliability of central heating station based units of buildings

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A B S T R A C T

This article contains data on equipment failures at thirty-six centralized heating stations. In the process of operation of heating stations, the arising failures can lead to a significant decrease in air temperature in heated rooms. Data was obtained through the study of operational logs. When analyzing the data, we used the records of a five-year observation period (2012 to 2017) taking into account the preventive work that carried out annually as part of the preparation of equipment for use in winter conditions. Malfunctions of equipment elements, that arise during the operation of heat supply stations, have different meanings in qualitative and quantitative aspects. Different specialists of the same qualification may not represent the same quality characteristics of the same shortcomings. The presentation of faults in the form of sequences of numbers allows to formalize the analysis and reduce the influence of the subjective factor. Data on observations of equipment failures and restoration are the basis for determining the equipment reliability indicators at heat supply stations. The data can be used for repair planning, emergency services, financial planning and operational

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management focus. The obtained data are related to the research article “Monitoring of heating systems as a factor of energy safety of buildings” [1].

Specifications table

Subject	Safety, Risk, Reliability and Quality
Specific subject area	Evaluation of the reliability of heating units in the points of heat supply of the district heating for buildings
Type of data	Table
How data were acquired	Monitoring of equipment in the points of heat supply
Data format	Raw Analyzed
Parameters for data collection	Operating conditions of heating units of the points of heat supply in the winter period for five years are used.
Description of data collection	Data were collected by examining the operation logs.
Data source location	Peoples' Friendship University of Russia (RUDN University), Moscow, Russian Federation
Data accessibility	With the article
Related research article	[1] Alexander P. Svintsov, Evgenij L. Shchesnyak, Vera V. Galishnikova, Roman S. Fediuk, Monitoring of heating systems as a factor of energy safety of buildings, J. Build. Eng. 31 (2020) 101384. https://doi.org/10.1016/j.jobe.2020.101384.

Value of the data

- This data is useful because it allows to determine the operational reliability of heating units in heating stations of centralized heat supply systems of buildings.
- The benefit from this data can be obtained by companies of designing and manufacturing equipment for centralized heating systems of buildings, as well as companies that operating these systems.
- This data can be used as analogues to put forward new ideas in the field of heat supply of buildings and for further development of experiments.
- This data allows to identify priorities in the preparation of equipment for use in the winter season.
- This data can be used with other sets of similar data to improve models for assessing the reliability of heating units.
- This data can be used for repair planning, emergency services, financial planning and operational management focus.

1. Data Description

These data are the result of monitoring the technical condition of thirty-six heat supply stations in Moscow for the period from 2012 to 2017. Table 1 presents data on the number of inspected equipment in heat supply stations. Table 2 presents data on the number of installed and the number of failed pumps. Data on the number of installed and the number of failed valves are presented in Table 3. Table 4 contains data on the number of installed and the number of failed safety valves. At each heating station, the water heating system pumps are installed with a loaded backup, unloaded backup or without backup. The backup is made by the same type of pumps of the same power and performance. Loaded backup provides for the alternate operation

Table 1
Equipment of water heating systems installed in the points of heat supply.

Name	Quantity (nos.)
Pumps of heating systems	76
Plate heat exchangers	36
Valves	260
Safety valves	76
Control and measuring devices	184
Automatic control and regulation systems	36

Table 2
Quantity of installed and quantity of failed pumps in heating stations.

Object number	Quantity of installed pumps (nos.)	Quantity of failed pumps per year (nos.)					
		2012	2013	2014	2015	2016	2017
1	2	2	1	2	0	0	0
2	2	1	1	1	1	1	0
3	3	1	2	0	1	1	3
4	2	1	1	1	0	0	1
5	2	0	1	0	0	1	0
6	3	0	0	0	3	0	0
7	2	1	1	1	0	0	0
8	2	0	1	0	2	1	2
9	2	1	0	2	0	1	1
10	2	1	2	0	0	0	2
11	2	0	0	0	0	1	0
12	2	1	1	0	1	0	0
13	2	1	0	1	0	0	1
14	2	2	1	1	0	0	0
15	3	1	0	0	2	0	0
16	2	1	2	1	0	2	1
17	2	0	0	0	2	0	0
18	2	1	2	1	0	0	0
19	2	0	0	0	0	0	0
20	2	1	0	2	0	1	0
21	3	2	3	0	1	0	0
22	2	0	2	0	0	0	0
23	2	2	0	2	1	0	0
24	2	1	0	0	0	1	0
25	2	2	1	0	0	0	1
26	2	1	0	0	1	0	1
27	2	0	0	2	0	0	0
28	2	0	2	0	0	1	1
29	2	0	0	1	0	0	0
30	2	1	1	0	0	0	0
31	2	0	1	1	2	1	0
32	2	2	0	0	0	0	1
33	2	1	0	1	0	1	1
34	2	1	1	1	1	1	0
35	2	1	1	0	0	0	0
36	2	1	1	1	0	1	0

of two pumps that circulate the coolant. As an unloaded backup, one pump is installed, which is turned on after failure of the main pump. Pumps without backup function continuously until failure or until the end of the heating period. Units used in the pumping groups: KM-80-50-200, CMNS-80-5, Grundfos TP40-180. The probability of failure-free operation of pumps with a loaded backup is presented in Table 5, with an unloaded backup - in Table 6, without a backup - in Table 7. The data in Tables 5-7 are the result of a joint analysis of the number of installed and the number of failed pumps during the heating season that compile an average of 5000

Table 3
Quantity of installed and quantity of failed valves in heating stations.

Object number	Quantity of installed valves (nos.)	Quantity of failed valves per year (nos.)					
		2012	2013	2014	2015	2016	2017
1	9	1	1	0	0	0	0
2	7	0	1	1	0	0	0
3	7	1	0	1	0	0	0
4	7	0	0	0	0	0	0
5	7	1	1	0	0	0	0
6	9	0	0	0	0	0	0
7	7	0	0	0	0	0	0
8	7	1	0	0	1	1	0
9	7	0	1	0	0	0	0
10	7	0	0	1	0	0	1
11	7	0	0	0	0	0	0
12	7	0	0	0	0	0	0
13	7	0	0	1	1	0	0
14	7	0	0	0	0	0	0
15	9	0	0	0	0	0	0
16	7	1	0	0	0	0	1
17	7	0	0	0	0	0	0
18	7	0	0	0	0	0	0
19	7	1	0	0	0	0	0
20	7	0	0	0	0	0	0
21	9	0	0	0	0	0	0
22	7	0	0	0	0	0	0
23	7	0	0	0	0	0	0
24	7	1	0	0	0	0	0
25	7	0	1	0	0	0	0
26	7	0	0	0	0	0	0
27	7	1	0	0	0	0	0
28	7	0	0	0	0	0	0
29	7	0	0	1	0	0	0
30	7	0	0	0	0	0	0
31	7	0	0	0	0	0	0
32	7	1	0	0	0	0	0
33	7	0	0	1	0	0	1
34	7	0	0	0	0	0	0
35	7	0	0	0	1	0	0
36	7	1	0	0	0	0	0

hours. A model has been developed for assessing the compliance of the reliability of heating units with operational indicators [1]. The model allows you to move from a subjective description of the reliability of equipment to an objective assessment in numerical representation. The most significant factors are: failure-free operation (R), maintainability (E) and equipment cost (C). One of the most important indicators of the reliability of heating units is its failure-free operation. Table 8 presents the failure-free operation of heating units. The equipment of the heating units should not only work without failure during the entire heating period, but also be maintainable (repairable) when eliminating accidents. The maximum duration of the eliminating accident should not exceed 54 hours. In this regard, it is important during operation for how long the equipment failure will be eliminated. The criterion for assessing the effectiveness of eliminating accidents on the heating unit is the maintainability factor. Table 9 presents data on the actual and permissible duration of the elimination of failures and the values of the maintainability factors. Ensuring the reliability of heating units is associated with monetary costs. Failure-free operation and cost of equipment form the basis of a probabilistic model of their adequate ratio. The model allows to assess the adequacy of the choice of heating units in the reliability-efficiency paradigm. The actual data, that form the basis of the mathematical

Table 4
Quantity of installed and quantity of failed safety valves in heating stations.

Object number	Quantity of installed of safety valves (nos.)	Quantity of failed safety valves per year (nos.)					
		2012	2013	2014	2015	2016	2017
1	3	1	0	0	0	0	0
2	2	0	0	0	0	0	0
3	2	0	1	0	0	0	0
4	2	0	0	0	0	0	0
5	2	0	0	0	0	0	0
6	3	0	0	0	0	0	0
7	2	0	0	1	0	0	0
8	2	0	0	0	0	1	0
9	2	0	0	0	0	0	0
10	2	0	0	0	0	0	0
11	2	0	0	0	0	0	1
12	2	0	0	0	0	0	0
13	2	0	0	0	0	0	0
14	2	0	0	0	0	0	0
15	3	0	0	0	0	0	0
16	2	1	0	0	1	0	0
17	2	0	0	0	0	0	0
18	2	0	0	0	0	0	0
19	2	0	0	0	0	0	0
20	2	0	0	0	0	0	0
21	3	0	0	0	0	0	0
22	2	0	0	0	0	0	0
23	2	1	0	0	0	0	0
24	2	0	0	0	0	0	0
25	2	0	0	0	0	0	0
26	2	1	0	0	0	0	0
27	2	0	1	0	0	0	0
28	2	0	0	0	0	0	0
29	2	0	0	0	0	0	0
30	2	1	0	0	0	0	0
31	2	0	0	0	0	0	0
32	2	0	0	0	1	0	0
33	2	0	0	0	0	0	1
34	2	0	0	0	0	0	0
35	2	1	0	0	0	0	0
36	2	0	0	0	0	0	0

Table 5
Probability of failure-free operation of pumps with a loaded backup.

Operating time (hour)	Probability of failure-free operation of pumps $P(t)$		
	$P(t)$ minimum	$P(t)$ maximum	$P(t)$ average
0	1.000	1.000	1.000
500	0.999	1.000	0.999
1000	0.996	0.999	0.999
1500	0.989	0.999	0.997
2000	0.978	0.999	0.995
2500	0.962	0.998	0.990
3000	0.942	0.996	0.985
3500	0.917	0.995	0.978
4000	0.890	0.993	0.969
4500	0.859	0.990	0.959
5000	0.826	0.987	0.947

Table 6
Probability of failure-free operation of pumps with unloaded backup.

Operating time (hour)	Probability of failure-free operation of pumps $P(t)$		
	$P(t)$ minimum	$P(t)$ maximum	$P(t)$ average
0	1.000	1.000	1.000
500	0.994	0.999	0.998
1000	0.977	0.997	0.992
1500	0.953	0.994	0.983
2000	0.923	0.990	0.971
2500	0.888	0.985	0.956
3000	0.850	0.979	0.940
3500	0.811	0.972	0.921
4000	0.771	0.964	0.902
4500	0.730	0.956	0.881
5000	0.689	0.947	0.859

Table 7
Probability of failure-free operation of pumps without backup.

Operating time (hour)	Probability of failure-free operation of pumps $P(t)$		
	$P(t)$ minimum	$P(t)$ maximum	$P(t)$ average
0	1.000	1.000	1.000
500	0.922	0.974	0.954
1000	0.850	0.949	0.910
1500	0.783	0.924	0.868
2000	0.722	0.900	0.829
2500	0.665	0.877	0.791
3000	0.613	0.854	0.754
3500	0.565	0.832	0.720
4000	0.521	0.810	0.687
4500	0.480	0.789	0.655
5000	0.443	0.769	0.625

model, allows to obtain sufficient results with an accuracy for engineering calculations. Table 10 presents data on the actual and designed monetary costs for ensuring the reliability of heating units. A comparison of the equipment failure-free indicators, its maintainability and the costs of ensuring reliability allows revealing the features of the mutual influence of these factors.

2. Experimental Design, Materials, and Methods

The experiments were carried out in thirty-six heating stations of centralized heat supply of buildings in Moscow. Each heat station is connected to a centralized heat supply system and serves one building. The equipment, that installed in the heating station, includes: heating system pipelines; heat exchanger plates; pumping groups; filters; shutoff, regulating and safety valves; blocks of automatic control and adjustment. Monitoring the technical condition of the equipment of heating stations is carried out on the basis of the method of “logical failure layout”. This method allows to quantify the technical condition of the equipment by the malfunctions of the elements that led to the failure of the system. Malfunctions of equipment elements, that arise during the operation of a heating unit, have different meanings in qualitative and quantitative aspects. Qualitative signs of the same malfunctions can be represented not equally by different specialists of the same qualifications. The presentation of malfunctions in the form of sequences of numbers allows us to formalize the analysis and reduce the influence of the subjective factor. The analysis of equipment malfunctions was performed by study-

Table 8
Efficiency of ensuring the reliability of heating units.

Object number	Actual values of failure-free operation coefficients, R_a	Required value of reliability factor, R_f	Reliability factor, R
1	0.970	0.970	1.000
2	0.980	0.970	1.010
3	0.862	0.970	0.875
4	0.844	0.970	0.850
5	0.960	0.970	0.990
6	1.000	0.970	1.030
7	1.000	0.970	1.030
8	0.947	0.970	0.976
9	0.842	0.970	0.848
10	0.893	0.970	0.914
11	1.000	0.970	1.030
12	0.960	0.970	0.990
13	0.874	0.970	0.890
14	1.000	0.970	1.030
15	1.000	0.970	1.030
16	1.000	0.970	1.030
17	1.000	0.970	1.030
18	1.000	0.970	1.030
19	0.920	0.970	0.946
20	1.000	0.970	1.030
21	1.000	0.970	1.030
22	1.000	0.970	0.885
23	1.000	0.970	1.030
24	1.000	0.970	1.030
25	0.910	0.970	0.934
26	1.000	0.970	1.030
27	1.000	0.970	1.030
28	0.940	0.970	0.968
29	1.000	0.970	1.030
30	1.000	0.970	1.030
31	1.000	0.970	1.030
32	1.000	0.970	1.030
33	0.860	0.970	0.872
34	1.000	0.970	1.030
35	1.000	0.970	1.030
36	1.000	0.970	1.030

ing the operation logs. The qualitative characteristics of equipment malfunctions are converted into quantitative failure parameters. Data analysis is performed by methods of probability theory and mathematical statistics. Assessment of reliability indicators of equipment is based on well-known methods of reliability theory. Table 11 presents the qualitative characteristics of the malfunctions and the quantitative values of the failure rates of the equipment that calculated according to the operation data. Based on the deterministic method, functionally significant and system-forming blocks and the weakest elements of the system, are identified. Based on the probabilistic method, the reliability indicators of pumps with various backup layouts are evaluated. A probabilistic mathematical model is proposed for assessing the conformity of the technical condition of heating units to operational indicators. The calculation of the probability of failure-free operation of heating units is based on the hypothesis of an exponential operating time law until the first failure. The authenticity of the assessment of indicators is verified by the Pearson criterion. Testing in accordance with the χ^2 criterion showed the consent of the accepted hypothesis for assessing the probability of failure-free operation of heating units.

Table 9
Efficiency of maintainability of heating units.

Object number	Actual failure recovery time, τ_a (hour)	Allowable failure recovery time, τ_f (hour)	Maintainability factor, E
1	0.0	54.0	0.000
2	0.0	54.0	0.000
3	50.0	54.0	0.926
4	6.0	54.0	0.111
5	0.0	54.0	0.000
6	0.0	54.0	0.000
7	0.0	54.0	0.000
8	60.0	54.0	1.111
9	0.5	54.0	0.009
10	55.0	54.0	1.019
11	0.0	54.0	0.000
12	0.0	54.0	0.000
13	2.0	54.0	0.037
14	0.0	54.0	0.000
15	0.0	54.0	0.000
16	0.0	54.0	0.000
17	0.0	54.0	0.000
18	0.0	54.0	0.000
19	0.0	54.0	0.000
20	0.0	54.0	0.000
21	0.0	54.0	0.000
22	56.0	54.0	1.037
23	0.0	54.0	0.000
24	0.0	54.0	0.000
25	1.0	54.0	0.019
26	0.0	54.0	0.000
27	0.0	54.0	0.000
28	3.0	54.0	0.056
29	0.0	54.0	0.000
30	0.0	54.0	0.000
31	0.0	54.0	0.000
32	0.0	54.0	0.000
33	3.0	54.0	0.056
34	0.0	54.0	0.000
35	0.0	54.0	0.000
36	0.0	54.0	0.000

Table 10
Efficiency of monetary costs for ensuring the reliability of heating units.

Object number	Actual monetary costs, C_a (thousand Russian rubles)	Designed monetary costs, C_f (thousand Russian rubles)	Monetary costs factor, C
1	125.0	120.0	1.04
2	98.0	100.0	0.98
3	100.0	125.0	0.75
4	80.0	88.0	0.90
5	92.0	90.0	1.02
6	240.0	212.0	1.12
7	184.0	180.0	1.02
8	210.0	195.0	1.07
9	172.0	198.0	0.85
10	194.0	182.0	1.06
11	225.0	221.0	1.02
12	210.0	212.0	0.99
13	190.0	224.0	0.82
14	215.0	200.0	1.07
15	191.0	190.0	1.01
16	98.0	90.0	1.08
17	210.0	200.0	1.05
18	270.0	270.0	1.00
19	150.0	153.0	0.98
20	190.0	167.0	1.12
21	210.0	210.0	1.00
22	160.0	175.0	0.91
23	185.0	179.0	1.03
24	215.0	210.0	1.02
25	88.0	92.0	0.95
26	223.0	215.0	1.04
27	195.0	165.0	1.15
28	122.0	145.0	0.81
29	79.0	84.0	0.94
30	122.0	115.0	1.06
31	215.0	198.0	1.08
32	200.0	200.0	1.00
33	151.0	176.0	0.83
34	230.0	210.0	1.09
35	198.0	198.0	1.00
36	92.0	76.0	1.17

Table 11
Qualitative signs of malfunctions and quantitative values of equipment failure rates (according to operation data).

Name of equipment	Qualitative signs of malfunctions	Failure rate (1/h)		
		λ_{min}	λ_{av}	λ_{max}
Pumps	Worn shaft, wear of bearings, crack in housing, wear of mechanical seal, breakdown of motor windings	4.92E-05	8.38E-05	1.38E-04
Heat exchangers	Carbonate deposits on the walls of plates, seal leakage, leaks of end joints	-	-	-
Valves	Damage or wedge wear, stem wear, cracks in the casing, seal leakage	7.72E-07	3.68E-06	8.00E-06
Safety valves	Cracks in housing, failure of a locking element, seal leakage	2.67E-06	6.45E-06	1.71E-05

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dib.2020.105730.

Reference

[1] Alexander P. Svintsov, Evgenij L. Shchesnyak, Vera V. Galishnikova, Roman S. Fediuk, Monitoring of heating systems as a factor of energy safety of buildings, J. Build. Eng. 31 (2020) 101384. https://doi.org/10.1016/j.jobe.2020.101384.