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MODELING A PROCESS OF REPAIRS OF INTRAHOUSE GAS EQUIPMENT

Statement of the problem. Improving the quality of technical services and repairs of the equipment is an important problem faced by gas supply. In the context of the problems discussed it is necessary that applied research is undertaken of technical services and repairs of the equipment in order to improve the quality and reliability of gas supply. This paper has sought to study the technical services and repairs of the equipment in order to improve its technological reliability.

Results. A model of applying for a repair of the equipment based on the mass service theory has been developed. The dependencies of the average time of requests remaining in queue from the intensity of a stream of repairing the equipment applications have been calculated. A model of repairing the equipment that calls for using imitational modeling in *MatLab — Simulink* package has been developed. Statistical dependencies of the characteristics of the system of mass service of dealing with application for the repairs from the key parameters have been obtained.

Conclusions. Implementation of the results obtained in industrial practice allows one to estimate and increase the effectiveness of repair units.

Keywords: intrahouse gas equipment, repair organization.

Introduction

There has been a growing number of gas accidents in block of flats. The major causes were the wear of the gas supply equipment and failed technical maintenance and repair of intrahouse gas supply equipment.

The provision of uninterrupted and accident-free gas supply of the components of the city's infrastructure, population and industrial enterprises is governed by the Law of the Russian Federation "On Gas Supply in the Russian Federation" and "Safety Guidelines of Gas Distribution and Gas Supply Systems".

Intrahouse gas supply equipment comprises:

– joined gas network with external and internal gas pipes and reinforcement;

– household gas supply equipment;

– gas analyzers with gas contamination control systems;

– gas meters;

– group compressed gas cylinders.

Gas distribution organizations are in charge of the state and proper operation of the gas supply equipment. The major services provided are technical maintenance and repairs consumers need to register for.

Improving the quality of technical maintenance is an important issue that is now addressed by gas supply specialists. In the context of the problems being addressed, it is necessary that the research of technical maintenance and repairs is carried out to improve the quality and reliability of gas supply.

This paper attempts to make a study of technical maintenance and repairs by means of the method of mathematical modelling to improve its technological reliability.

1. Analysis of the equipment of the equipment

The analysis of the equipment was performed using the example of "Voronzgas" Ltd. [3, 4, 5, 13, 15, 17]. The distribution of the equipment according to when it started being used in pipes is identified in Table 1. The data on the overall growth of the operated equipment is Fig. 2.

According to for how long they have been operated, the following groups can be distinguished, %:

- up to10 — 62.6;
- from 11 to 20 — 15.2;
- from 21 to 30 — 10.4;
- from 31 to 40 — 8.2;
- from 41 yeas 50 — 3.3;
- over 50 — 0.2.

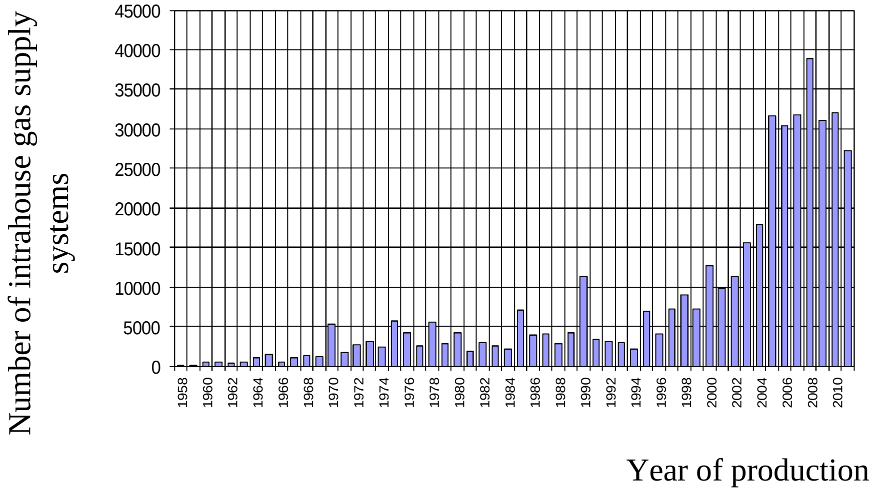

Fig. 1. Equipment distribution according to when it started being used: intrahouse gas supply

Over the last decade there has been a greater number of equipment (from 6.4 to13.5 % a year). From 2002 to 2011 the number of the equipment has gone up by 150 %. All of the above caused the growth of the number of repair registrations and increasing workloads for companies responsible for the maintenance.

Fig. 3—4 shows the distribution of the total maintenance requests in each month in the whole organization and in its particular departments. There is a 50 % growth of maintenance requests in February-March and September-November. In all the departments apart from the emergency services, requests are distributed over the months of the year in a similar way as in the whole organization.

Fig. 5—6 indicate the distribution of the total equipment maintenance requests over the days of the week in the whole gas distribution organization and particular departments. There is an average 6.6 % reduction per day in the number of maintenance requests from Monday to Friday. Over the weekend only a few maintenance requests are accepted by the emergency services.

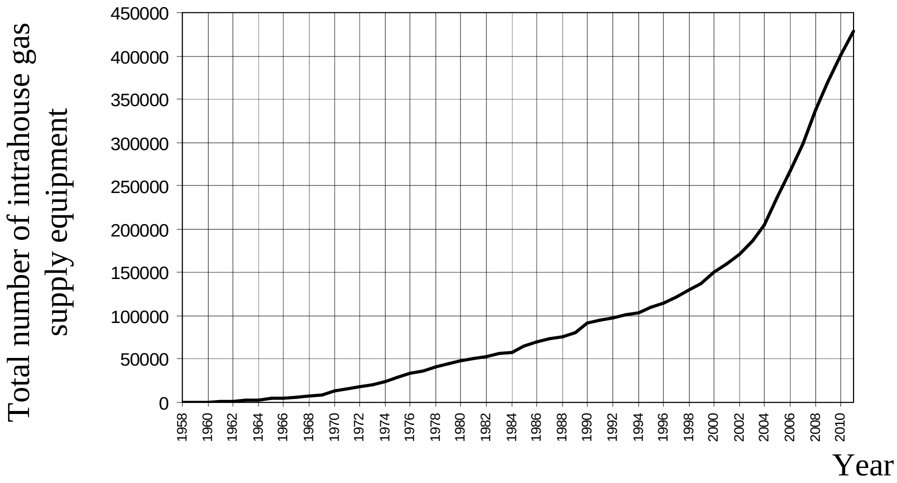

Fig. 2. Growth of the total number of the operated equipment

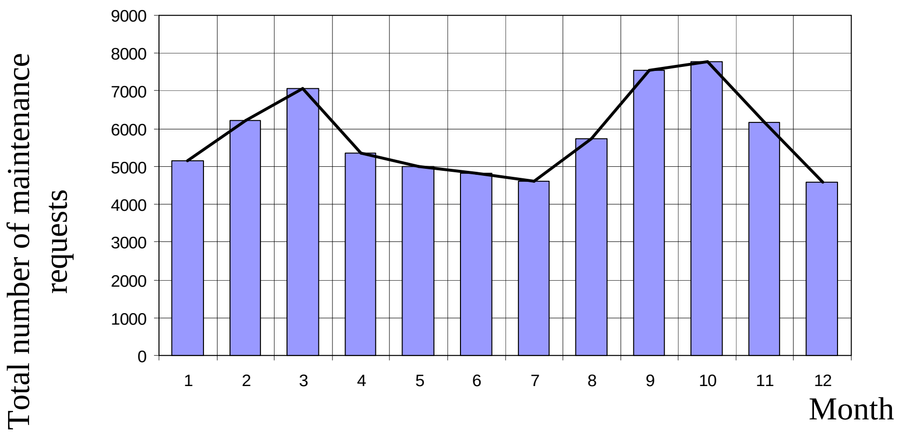

Fig. 3. Distribution of the total equipment maintenance requests over the months of the year

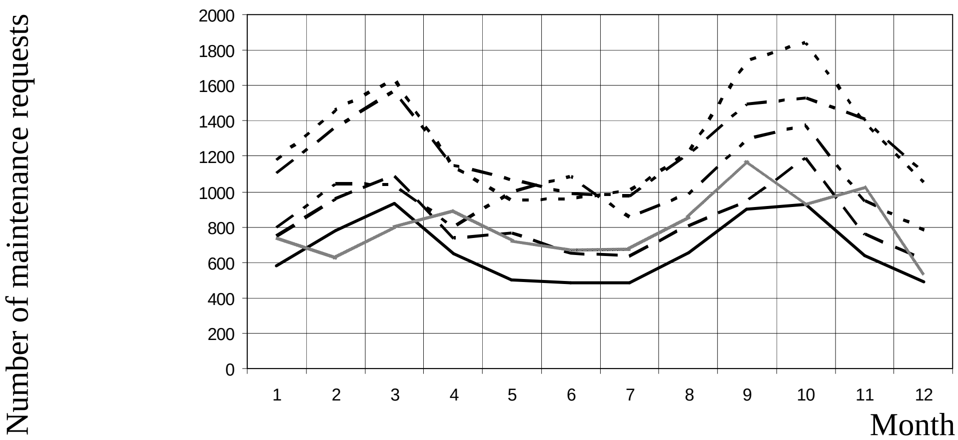

Fig. 4. Distribution of the total maintenance requests filed in the months: r — department № 1; ▬ . — department № 2; ...... — department № 3; ▬ . — department № 4; ▬ . . — department № 5; ...... — emergency service

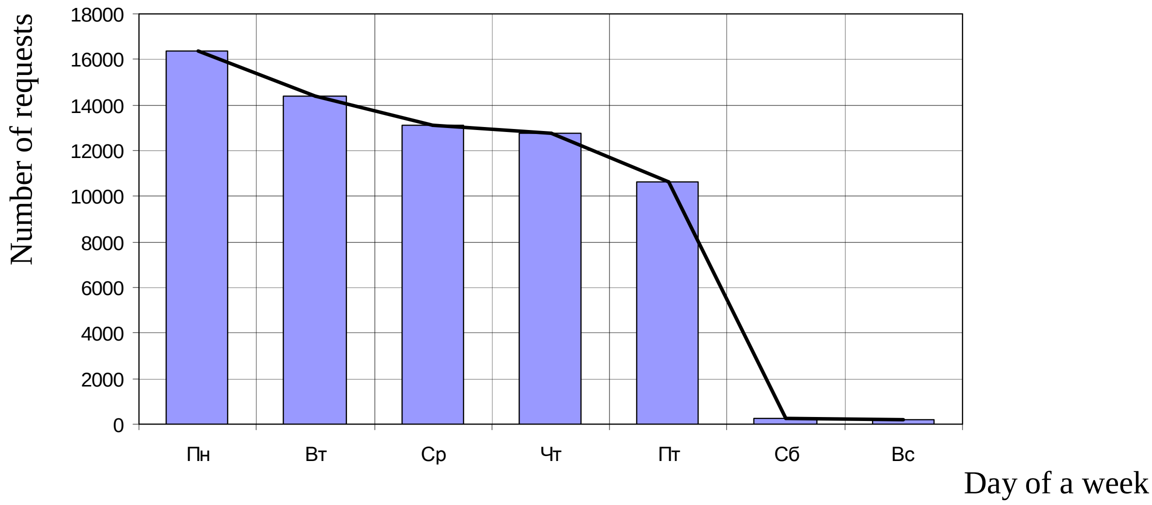

Fig. 5. Distribution of the total equipment maintenance requests over the days of the week

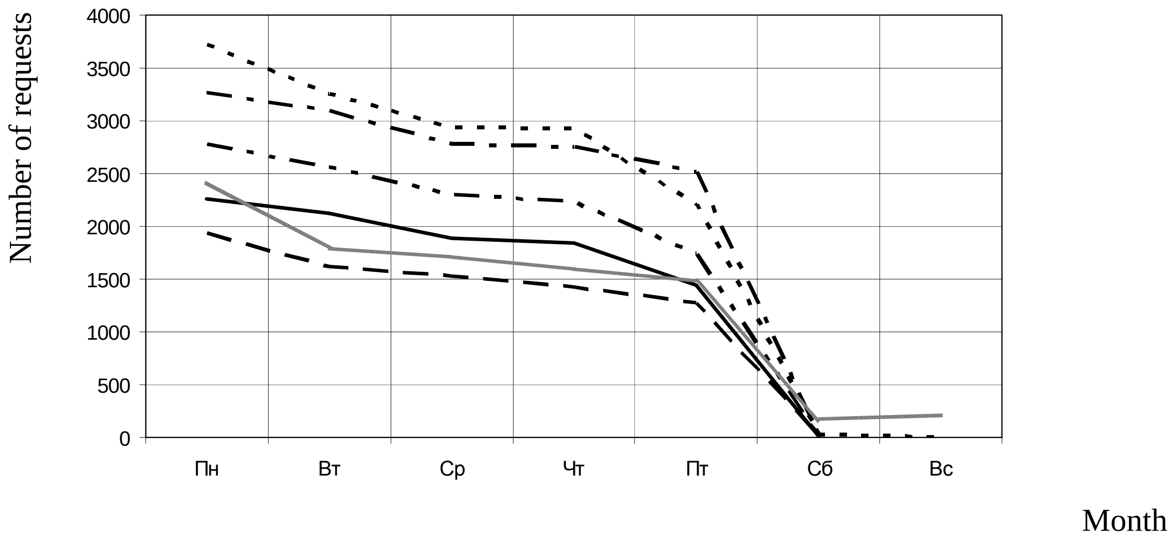

Fig. 6. Distribution of the total equipment maintenance requests filed over the week: ▬▬ — department № 1; ▬ ▪ — department № 2; ...... — department № 3; ▬ ▪ — department № 4; ▬ ▪ ▪ — department № 5; ▬▬ — emergency service

2. Model of filing equipment maintenance requests based on the mass service theory

In order to work out ways to improve the quality of maintenance works of gas distribution organizations, let us analyze their work using the mass service theory [1, 2, 10, 12, 14].

A workload characteristics of the mass service system:

$$\rho = П_з \,/\, П_в\,, \tag{1}$$

where $П_з$ is the intensity of maintenance requests, requests/min; $П_в$ is the intensity of the accomplished maintenance requests, requests/min.

Workload characteristics per one staff person:

$$\alpha = \rho \,/\, n\,, \tag{2}$$

where n is the number of staff members responsible for maintenance requests.

The likelihood of all the staff members being free to take on a request:

$$p_0 = \left(\sum_{k=0}^{n} \frac{n^k}{k!} \alpha^k + \frac{n^n}{n!} \frac{\alpha^{n+1}}{1-\alpha} \right)^{-1}. \tag{3}$$

An average number of requests waiting to be processed:

$$\overline{N}_{оч} = \frac{n^n}{n!} \frac{\alpha^{n+1}}{(1-\alpha)^2}\, p_0\,. \tag{4}$$

An average number of requests waiting to be processed and served:

$$\overline{N}_{оч,обсл} = n\alpha + \frac{n^k}{n!} \frac{\alpha^{n+1}}{(1-\alpha)^2}\, p_0\,. \tag{5}$$

An average request waiting time:

$$\overline{T}_{оч} = \frac{n^k}{П_з n!} \frac{\alpha^{n+1}}{(1-\alpha)^2}\, p_0\,. \tag{6}$$

An average time of the requests waiting to be processed and served:

$$\overline{T}_{оч,обсл} = \frac{n}{П_з}\alpha + \frac{n^k}{П_з n!} \frac{\alpha^{n+1}}{(1-\alpha)^2}\, p_0\,. \tag{7}$$

The calculations of the work of gas distribution services using the example of the Voronezh-gas branch Ltd. Voronezhoblgas were performed by means of the above dependencies.

Fig. 7 and 8 shows the dependence of an average time of the request waiting to be processed and served on the intensity of maintenance requests with the staff of 140 members working a 8-hour shift 5 days a week and the intensity of maintenance requests $П_з$ = 0.134 requests/min.

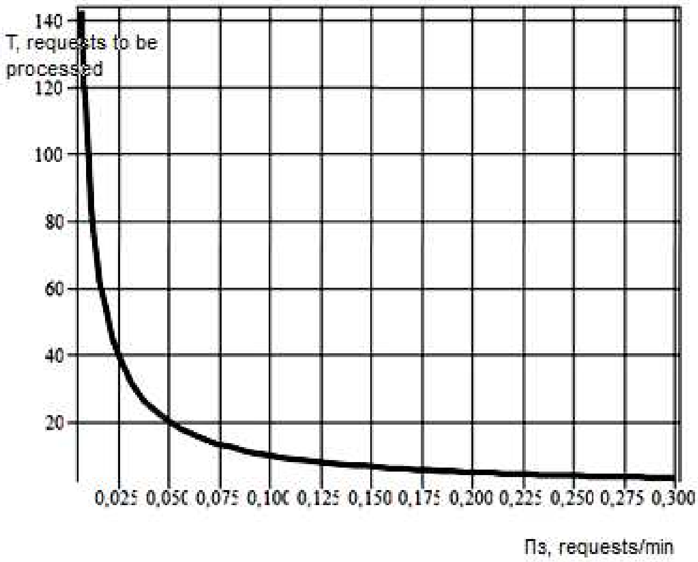

Fig. 7. Dependence of an average time of the request waiting to be processed on the intensity of maintenance requests

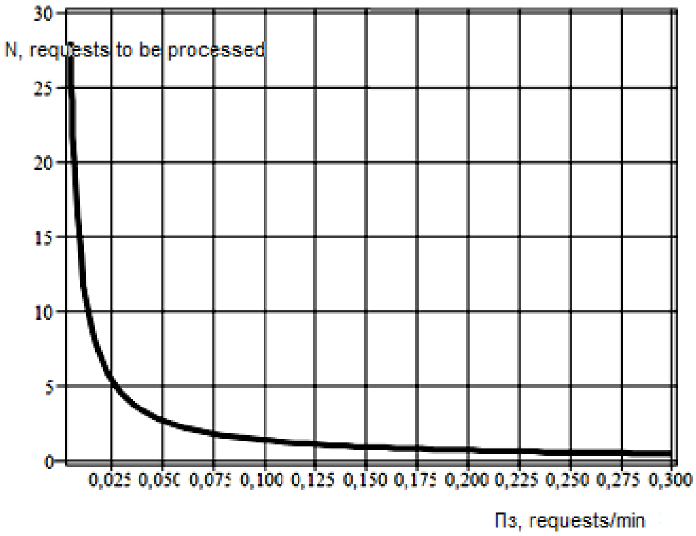

Fig. 8. Dependence of an average number of requests waiting to be processed and served on the intensity of maintenance requests being served

The results identified in Fig. 7 and 8 reflect the major characteristics of the work of a gas distribution organization. However, the downside of analytical methods of analyzing the work of a mass service system is that a flow of maintenance requests and their service are taken to be the simplest.

The process of the functioning of a mass service system is regarded as a stationary one and the obtained dependencies can only be accepted for a fixed operation mode [6—9, 16]. In the process of its actual operation maintenance services of gas distribution organizations show transient periods and the number of requests coming in and their service are not the simplest but changes according to complex laws. There are also season, weekly and daily changes in maintenance requests coming in.

The parameters of emergency requests coming in are random values and only their distribution laws and numerical characteristics of their distribution can be known in the process of their modelling and therefore the analysis of functioning of maintenance services is statical.

For the reasons above, in order to model the work of maintenance services of gas distribution, the method of imitation modelling is used.

3. Imitation modelling of the service of equipment maintenance requests

In order to model the work of maintenance services, the following data was specified:

1) the description of the work of maintenance services of gas distribution services as a multi-channel waiting mass service system;
2) law of maintenance works coming in was specified according to the actual data on the work of a gas distribution organization;
3) law of the waiting time for maintenance requests was specified according to the actual data on the work of a gas distribution organization.

Modelling of the work of maintenance services takes the following stages:

1) a continuous model time is specified;
2) time of maintenance requests coming in from the actual request database was specified;

3) time of the service of maintenance requests from the actual request database was specified;

4) time of the following happening is determined:

a) a maintenance request filed to be served,

b) a maintenance requests filed to be served by a staff member,

c) a maintenance requests coming in to be processed,

d) a maintenance request waiting to be processed,

e) the service of a maintenance request coming to an end.

The overall service of maintenance requests is modelled and statistical data on the process is collected. The characteristics of the quality of maintenance services are identified by processing the modelling results using the methods of mathematical statistics.

In order to study the work of maintenance services of a gas distribution organization with an actual request flow, a mathematical model of serving maintenance requests was implemented on a PC as a *MatLab — Simulink* package [11, 15, 18—20]. Fig. 9 indicates a fragment of the structural scheme of the model of services of equipment maintenance request, in Fig. 10 is the composition of the model of service of equipment maintenance requests.

Fig. 11 presents a window with the work schedule of the staff members in charge of serving maintenance requests obtained in the process of modelling. Fig. 12 shows the dependence of an average number of requests waiting to be processed and served on an average intensity of a flow of served requests. Due to a stochastic nature of the modelling process, the solution was obtained in the range of possible values.

As a result of the modelling, all the characteristics of the work of actual maintenance services of a gas distribution organization in its handling of actual maintenance requests. The estimate of the sensitivity of each of the characteristics to a change in the intensity of a flow of maintenance requests and their services was obtained. This permitted to reveal disadvantages of the performance of the maintenance departments and determine possible ways for the improvement.

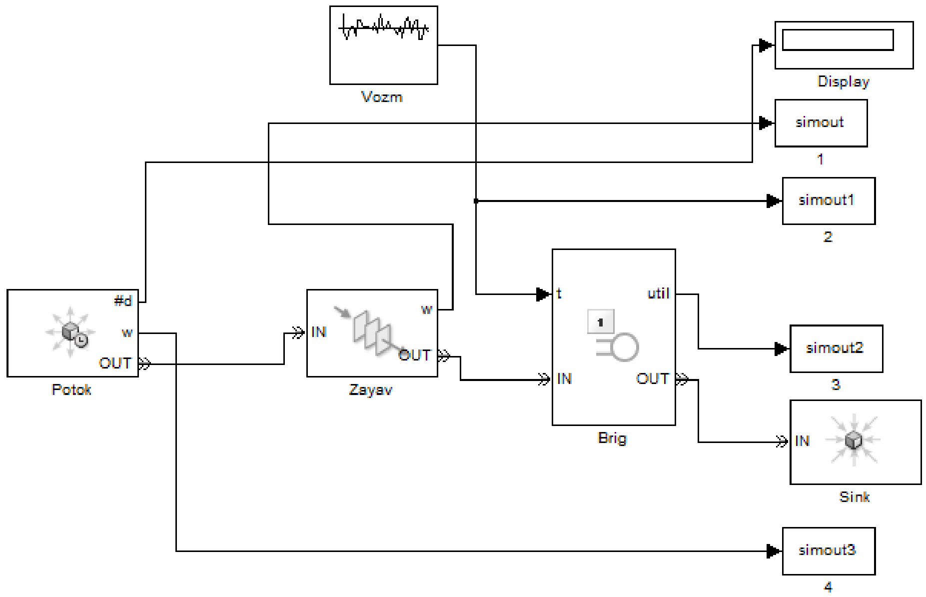

Fig. 9. Fragment of a structural scheme of the model of the service of the network equipment maintenance requests in *MatLab* — *Simulink* environment

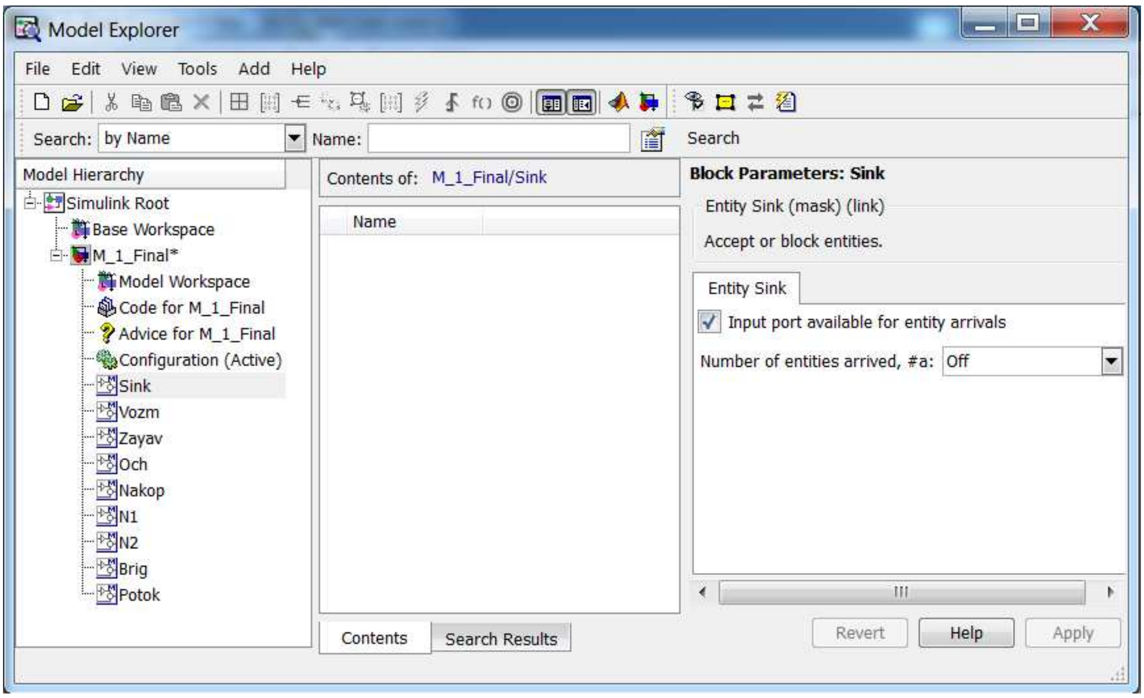

Fig. 10. Composition of the model of the service of equipment maintenance requests in *MatLab* — *Simulink* environment

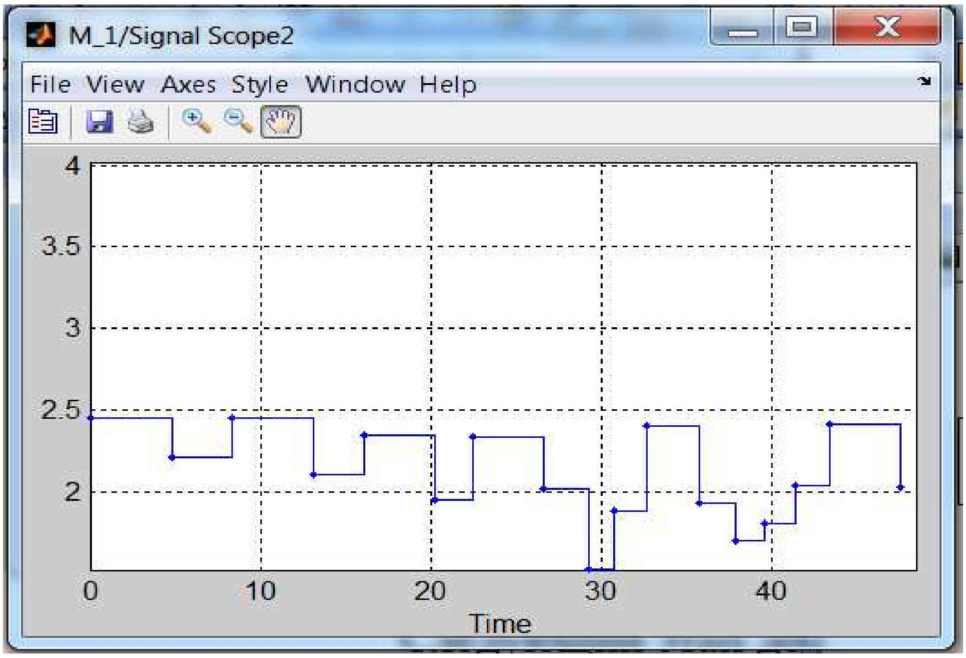

Fig. 11. Window with the work schedule of the staff members in charge of maintenance requests obtained as a result of modelling

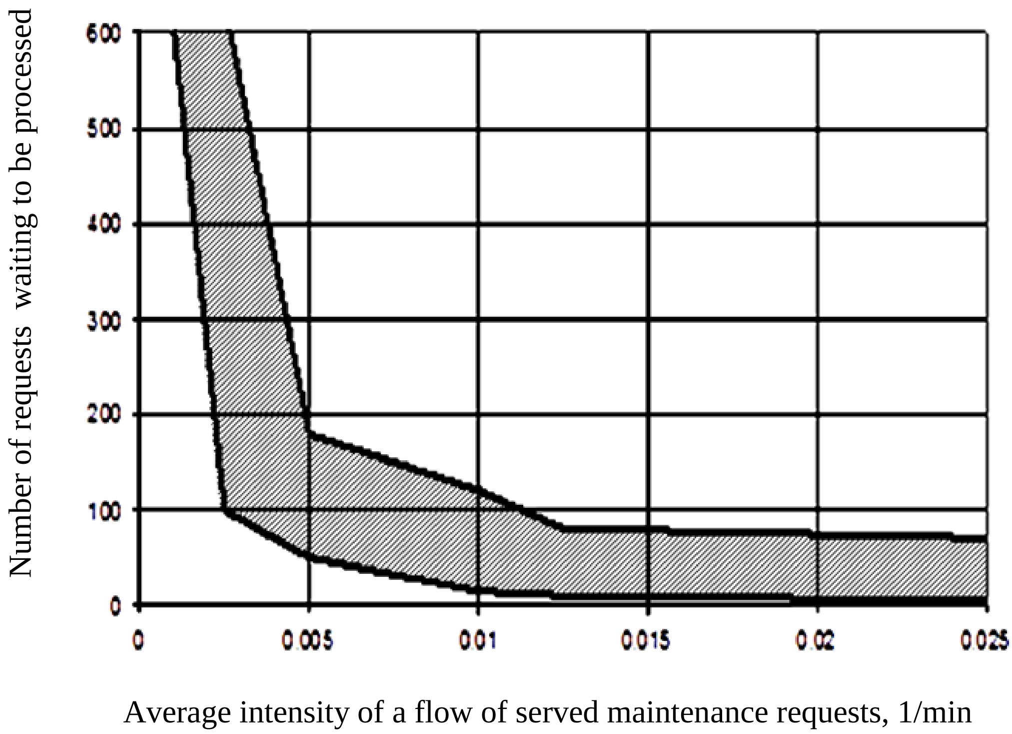

Fig. 12. Dependence of an average number of requests waiting to be processed and served on an average intensity of a flow of served maintenance requests

Conclusions

1. The analysis was carried out of an intrahouse gas supply equipment. The distribution of the total equipment according to the operation period. The distribution of the total maintenance requests in the departments over the months and weeks was determined. The growth of the amount of the equipment resulted in more maintenance requests and workload of the service departments.

2. The model of serving maintenance requests was developed based on the mass service theory. The dependencies were found of an average time of a requests waiting to be processed and the time of it waiting to be served on the intensity of a flow of maintenance requests.

3. The model of the service of equipment maintenance requests was developed based on the imitation modelling in *MatLab — Simulink* environment. The dependencies of the characteristics of the mass service system of equipment maintenance requests on the crucial parameters were established.

4. The introduction of the obtained results into the industrial practices enhances the performance of the maintenance departments of a gas distribution organization.

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