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OPTIMIZATION OF VERIFICATION AND REPAIR PROCESSES OF MEASUREMENTS USED IN CONTROL OF HAZARDOUS AND NOXIOUS PRODUCTION FACTORS AT FOOD INDUSTRY ENTERPRISES OF TURKESTAN REGION USING MATHEMATICAL METHODS AND SOFTWARE ALGORITHMS

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ABSTRACT

The article discusses the processes of metrological support in the field of labor protection and safety at food industry enterprises, in terms of verification and repair of measuring instruments in operation and used to control hazardous and harmful production factors to create new methods and algorithms for solving problems of organizing and planning metrological support combining modern mathematical approaches and software tools into a single whole, taking into account the needs in metrological services of industrial enterprises.

Keywords: labor protection and safety, metrological support, measurements, hazardous and harmful production factors, error, measuring instruments, control, industrial enterprises, food industry, mathematical methods of process modeling, operations research, optimization, software tools, algorithm, stages, economic efficiency, on-site metrological services.

INTRODUCTION

Metrological support in the field of occupational safety and health (MS) is a complex of organizational and technical measures, rules and regulations, technical means aimed at ensuring the uniformity and required accuracy of measurements performed to control the parameters of hazardous and harmful production factors at workplaces when determining the safety of production equipment and technological processes [1].

Metrological support in the field of occupational safety and health is carried out in accordance with the requirements of the standards of the State System for Ensuring the Uniformity of Measurements (SSM), the System of Occupational Safety Standards (SOSS), rules and regulations approved by various state bodies of state control and supervision, sanitary and epidemiological services and other normative and technical documentation (NTD).

The main tasks of metrological support in the field of occupational health and safety of food industry enterprises include:

- organization and carrying out of a systematic analysis of the state of measurements of parameters of hazardous and harmful production factors and the development on its basis of measures to improve this work;
- rganization of work on the creation and implementation of modern methods and measuring instruments for monitoring the parameters of hazardous and harmful production factors;
- development and implementation of labor safety system standards and other regulatory and technical documentation in accordance with the tasks approved in the prescribed manner;
- organization of metrological examination of draft labor safety standards containing safety requirements for design, technological and other normative and technical documentation for metrological support in the field of labor safety;
- organization of metrological certification of newly developed and operating measuring instruments and methods for measuring parameters of hazardous and harmful production factors;
- organization of verification and control over the production, condition, use and repair of measuring instruments;
- introduction of international quality management systems, including in the field of occupational health and safety.

One of the main processes in the system of metrological support in the field of labor protection and safety are the processes of verification and control over the production, condition, use and repair of measuring instruments in operation.

In the Republic of Kazakhstan, verification activities are regulated by the state standard ST RK 2.4 - 2017 State system for ensuring the uniformity of measurements of the Republic of Kazakhstan. Verification of measuring instruments. Organization and procedure [2].

Verification activity belongs to the sphere of state metrological control, since measuring instruments that fall into the sphere of state metrological control must be subject to mandatory verification when measuring instruments are released from production or repair, their

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operation and import by import. During the verification period, measuring instruments must go through the procedure of their type approval or metrological certification in KazInMetr and register in the register of the state system for ensuring the uniformity of measurements of the Republic of Kazakhstan. According to the law of the Republic of Kazakhstan "On ensuring the uniformity of measurements", verification must be carried out by the state metrological service or the metrological service of legal entities that have an accreditation certificate for this type of activity [3]. All measuring instruments used in ensuring labor safety and environmental protection are subject to mandatory verification [4]. The MI verification algorithm is shown in Figure-1.

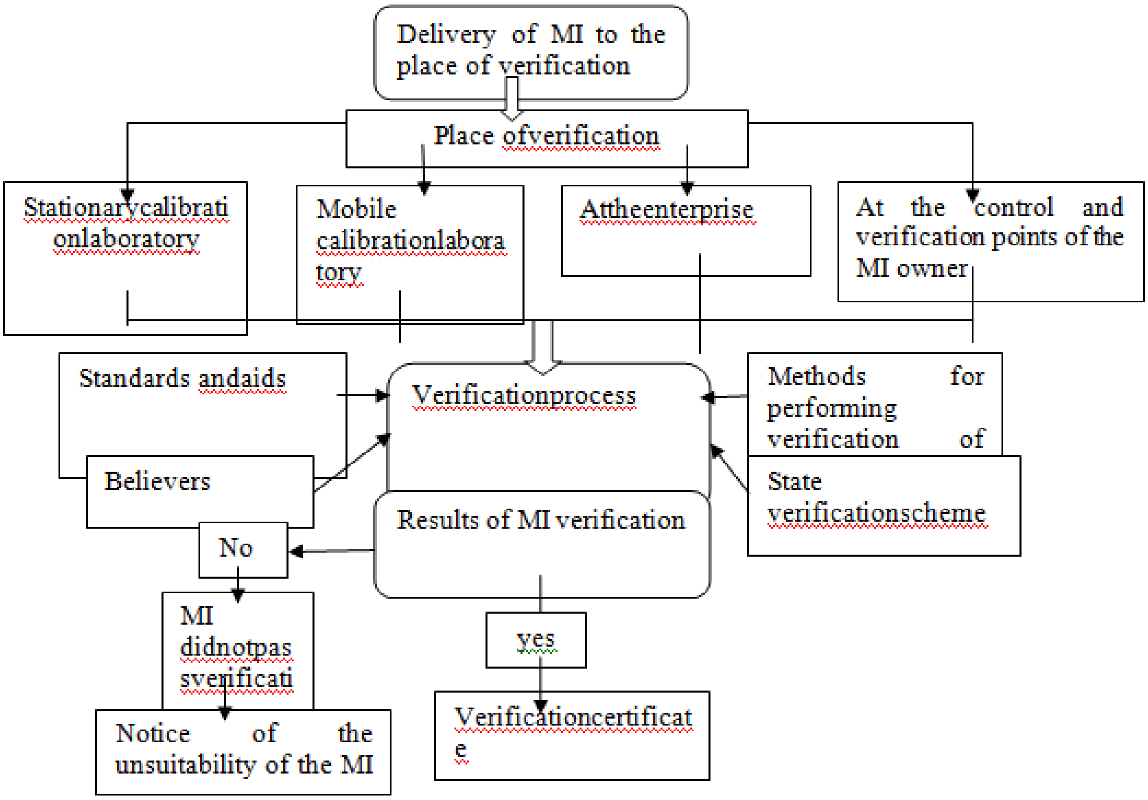

Figure-1. Algorithm for organizing the verification of measuring instruments.

Stages of carrying out

a) The place of verification of measuring instruments is determined, in accordance with the requirements of ST RK 2.4 [1]

b) The measuring instrument is delivered to the place of verification. In necessary cases, storage of measuring instruments is provided, on which the seal of the verification organization is installed.

c) Carrying out verification. The verification process is provided with the necessary standards, an approved methodology for performing verification of a specific measuring instrument. Verification is carried out by verifiers who have a verification certificate for this type of measuring instrument. Verification is carried out in accordance with the state verification scheme.

d) After the verification, the verification results are drawn up. If the measuring instrument has not passed the verification according to the declared metrological characteristics, a "Notice of the unsuitability of the measuring instrument for use" is issued (Appendix B ST RK 2.4). If the measuring instrument has confirmed all its verified characteristics during verification, a “Certificate of verification” is issued in the prescribed form (Appendix A ST RK 2.4).

e) Regardless of the results of the verification, the owner of the measuring instrument pays in full all the costs of verification.

f) A measuring instrument that has not passed verification must be removed from the balance sheet of the enterprise and must be written off.

Strengthening the role of metrological assurance in improving the quality of food products with the development of market relations is becoming increasingly important. This is primarily due to the growth of requirements for the quantity and reliability of measurements, as the creation and production of high-quality products depends on this.

One of the urgent tasks of metrological support, among others, is work on maintaining technical means, which include measuring instruments, test equipment, control devices in a metrologically sound condition, the list of which at food industry enterprises is tens and hundreds of copies.

One of the most important activities for an enterprise is the verification of its measuring instruments, which fall under state metrological control. The transition of all metrological services to contractual relations at the same time poses a task for enterprises so that verification is carried out with minimal expenditure of material resources and ensures the maximum reliability of the conclusion on the validity or unsuitability of measuring instruments for use, since the quality of products largely depends on the quality of verification of measuring instruments.

Also, an important role is played by the economic component of the process of verification of measuring instruments, since at present the state is creating conditions when it becomes more profitable for a manufacturer of products to maintain a metrological service and pay for metrological services in order to avoid large fines and an obvious threat of termination of production activities, as is customary in the world. practice. So, in August 2012, significant amendments were made to the law on metrology and the Code "On Administrative Violations" of the Republic of Kazakhstan, in terms of increasing liability for violations of metrological norms and rules and a significant increase in the amount of fines [5].

Studies have shown that in the context of the development of market relations, there has been a significant reorganization of the country's metrological service. From a centralized structure, which was completely regulated by state documentation on the state of measuring instruments, it is being transformed into a system that meets the specific needs of the manufacturer and consumer in accordance with the development of the market.

The adoption of the law on the protection of consumers' rights, the Law on Metrology, testifies to the fact that their influence on the various interests of society on the part of the state is given close attention. State control in the field of labor protection, environmental protection, quality and safety of products will always be socially necessary and important, which preserves the centralized planning of their metrological support within the metrological service of the enterprise.

In a market economy, it turned out that the problems of efficient use of production capacities of metrological services are relevant, since metrological services have been developing for a long time without economic analysis of management decisions, by simple administration.

The transition of all metrological services to contractual relations posed serious tasks for the theory and practice of the metrological support system to develop new methods for substantiating management decisions, both on the scale of one metrological service of enterprises, and the region and the state as a whole.

The imperfection of the methodological base, calculations of the amount of financing for metrological services, carried out on the basis of scientifically grounded methods on the part of enterprises and their budget, practically leads to the elimination of their metrological support, and this, in turn, worsens the level of measurements in technological processes and therefore affects the quality of products.

Our studies have shown that the low level of economic efficiency and quality of work on metrological support is explained not only by objective factors: the complication of economic relations, an increase in the scale of production, which, accordingly, increases the volume of processed management information, but one of the main reasons for this phenomenon is also the lack of , methodology of criteria for assessing the improvement of these processes.

One of the directions of improving metrological support is the development of a model for optimizing the metrological activity of industrial enterprises in the food industry, based on the use of mathematical methods for modeling the processes of metrological support.

The main content of work on the verification of measuring instruments is the processes associated with the accuracy of measurements, i.e. related to the identification and assessment of the influence of various factors that determine the measurement error [4]. Errors of means and measurement results are the main quantitative characteristic of their quality. Since the causes of errors in measuring instruments and measurement results, the nature of their manifestation are very diverse, they are classified according to various criteria. In practice, a number of classifications of errors are used, which have been studied in sufficient detail and sanctified in various literary sources, we will take only three main components of the measurement process - a measuring instrument, a selected measurement method, as well as some algorithm for processing the received measurement information, which ultimately determine, the measurement error as a whole. This allows you to determine the initial data for mathematical modeling methods in order to optimize the processes of verification of measuring instruments.

EXPERIMENTAL PART

Mathematical methods of structural modeling - a process that uses mathematical and formal constructive methods of changing the elements of the set of the system and the relationship between the elements [6, 7, 8, 9].

In the process of solving a specific optimization problem, first of all, you need to choose a mathematical method that leads to the final results with the least cost of computation or makes it possible to obtain a larger amount of information about the required initial solution. The choice of the method is determined primarily by the formulation of the optimal problem and the mathematical model of the optimization object used. Table 1 shows the

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main methods currently used to solve optimal problems [10, 11].

Table-1. Mathematical methods in structural modeling

Methodname	Application area
Methods for studying the functions of classical analysis	For solving simple optimal tasks. Application area - problems with a well-known analytical expression of the optimality criterion, which allows you to find an analytical expression for the derivatives. A system of finite nonlinear equations is solved using numerical methods similar to those of nonlinear programming
Methods based on the use of indefinite Lagrange multipliers	The solution of problems of a class of complexity, as when using conventional methods for studying functions, but with constraints such as equalities on independent variables. To the possibility of obtaining analytical expressions for the derivatives of the optimality criterion, a similar requirement is added regarding the analytical form of the equations of constraints
Calculus of variations	Solving problems in static optimization of processes with distributed parameters or dynamic optimization in which the optimality criteria are represented in the form of functionals and solutions of unknown functions. The solution to the optimal problem is reduced to the integration of a system of Euler differential equations, each of which is a second-order nonlinear differential equation with boundary conditions specified at both ends of the integration interval. In this case, the number of equations of this system is equal to the number of unknown functions determined when solving the optimal problem. Each function is found by integrating the resulting system
Dynamic programming techniques	Solutions of optimization problems for discrete multistage processes, in which the optimality criterion is specified as an additive function of the optimality criteria for individual stages. It is an algorithm for determining the optimal control strategy at all stages of the process. At each stage, a solution to particular optimization problems is found sequentially using methods for studying the functions of classical analysis or methods of nonlinear programming. Solution results are obtained in the form of tables
Maximum principle	Solving optimization problems for processes described by systems of differential equations. Defined as discontinuous functions
Linear programming	Mathematical apparatus for solving optimal problems with linear expressions for the optimality criterion and linear constraints on the range of variables. They are used in solving the issues of optimal production planning with a limited amount of resources, in determining the optimal transportation plan (transport tasks), etc.
Non-linear programming	Solving optimal problems with nonlinear target functions. The independent variables are constrained in the form of nonlinear relations in the form of equalities or inequalities. The methods are used if none of the above methods allows any progress in solving the optimal problem. Methods are also called Direct Optimal Problem Solving Methods.

Table-2 provides a comparative assessment of the merits of each method in solving various types and types of optimal problems. The classification of tasks during optimization is carried out according to such characteristics as:

a) The kind of mathematical method for describing one of the processes of the system;

b) Type of constraints on process variables in the process of solving problems;

c) The number of variables in the equations.

In the process of solving the optimal problem for the selected processes, which are described by systems of certain finite equations, a set of values of control actions on the processes is established, i.e., the static optimization of processes with lumped parameters, in the case when the processes are described by systems of ordinary differential equations, the necessary control actions are determined functions of time, which include dynamic optimization of processes with lumped parameters or static optimization of processes with distributed parameters, i.e. spatial variables. This classification allows you to display real problems that arise when performing tasks with a three-time excess of dimension.

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Table-2. Comparative assessment of the areas of application of optimization methods.

A kind of mathematical method for describing one of the process of the system		**Latest Equations**						**Differential Equations**					
Type of constraints on process variables in the process of solving problems		No (-)		Equality (=)		Inequalities (>, <)		No (-)		Equality (=)		Inequalities (>,<)	
The number of variables n in the equations		?3	>3	?3	>3	?3	>3	?3	>3	?3	>3	?3	>3
Type	MCA	1	2	4	4	4	4	3	4	4	4	4	4
	Lagrangemultipliers	-	-	1	2	-	-	-	-	2	3	-	-
	VI	-	-	-	-	-	-	2	3	2; 7	3; 7	-	-
	DP	1; 5	3; 5	1;5;7	3; 5; 7	1; 5	3; 5	2	3	3	3	3	3
	VC	2; 5	1; 5	2; 5	2; 5	2; 5	2; 5	1	1	2	2	2	2
	LP	-	-	-	2; 6	2; 6	1; 6	-	-	-	-	-	-
	MNP	2	1	2	.1	2	1	4	4	4	4	4	4
	GP	2; 8	2; 8	-	-	2; 8	2; 8	-	-	-	-	-	-

Notes:
1. Maximum efficiency of the method
2. Applies
3. Ability to use
4. Used as a helper method
5. Processes proceeding in many stages
6. Equations with linear optimality criteria and constraints
7. Lagrange multipliers are applied.
8. Equations in the form of posynomials using criteria and constraints

In our studies, when optimizing metrological support processes, we used methods based on indefinite Lagrange multipliers [10]. The Lagrange differential equation is as follows.

$$y = \varphi\left(y'\right)x + \psi\left(y'\right) \tag{1}$$

When solving the required problem, it is necessary to perform calculations in a parametric form and assume that the values of x, y, as well as the derivative y ′ will be functions of the parameter t.

Operations research. Operations Research, translated from English Operations Research is engaged in the development and application of optimal solutions based on methods of mathematical and statistical modeling for solving problems in various fields of human activity [12].

When using the concept of operations research, quantitative mathematical methods are used to make informed management decisions. The use of one or another mathematical apparatus gives rise to the use of this concept. The conceptual apparatus of the concept of operations research includes the fundamental term operation, by which it is necessary to understand a system of actions and measures united by a single concept and aimed at achieving some goal [13].

Since an operation always depends on the actions of a person and is controlled by him, then the choice of parameters that characterize its organization depends on the decisions made by him. The decision made, regardless of whether it is successful or unsuccessful, reasonable or unreasonable, is the desired parameter depending on the person.

A solution that is preferable for one reason or another is called optimal. Thus, the purpose of operations research is a preliminary quantitative substantiation of the adopted optimal decisions, taking into account the efficiency indicator.

The elements of the solution include such parameters, the combination of which makes it possible to show the solution itself, that is, certain numbers, vectors, functions, physical signs, etc. be violated, e.g. temperature, measuring range, etc. These conditions include material, technical and human resources that a person has the right to dispose of, and other restrictions imposed on the solution. The set of possible solutions forms the totality of these tools.

A feature of the concept of operations research is a systematic approach, as its main methodological

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principle to the problem posed and its analysis. This principle is based on the following proposition: the problem that is being solved and which can be any must be solved from such a point of view, when its influence on the criteria for the functioning of the system is determined as a whole.

For the application of the operation research method, the main characteristic is that in the process of solving each problematic issue, new problems may arise in it. The most characteristic feature of the operations research method is the desire to find the most optimal solution to the investigated one, which is called the principle of optimality. However, finding an ideal solution in practice is impossible for several reasons:

a) The optimal solution to the problem on a global scale cannot be found due to the lack of such methods.

b) The implementation of accurate optimization methods is limited by existing resources, for example, limited time for verification of measuring instruments.

In this case, it is only necessary to search for sufficiently good, practical solutions, which allows you to find an average between the effectiveness of solutions and the cost of finding them. The operations research method provides a mechanism for finding such trade-offs.

The OR method has a close methodological relationship with control theory, systems analysis, mathematical programming, game theory, optimal decision theory, etc.

This method is currently used by large Western companies in solving production planning problems, such as managing logistics, marketing and other complex tasks. The application of the OR method allows you to reduce ineffective costs or, as economists say, to increase the productivity and efficiency of any enterprise. The OR method is actively used in the military industry to solve complex complex tasks of increasing the combat readiness of the army.

The solution of various complex problems of special status is carried out by IO methods using modern software systems on powerful computers, and using simpler programs for small small enterprises using a PC.

Figure-2 shows an algorithm for constructing a mathematical model for describing process operations using the IO method, and a description of each stage is given in Table-3.

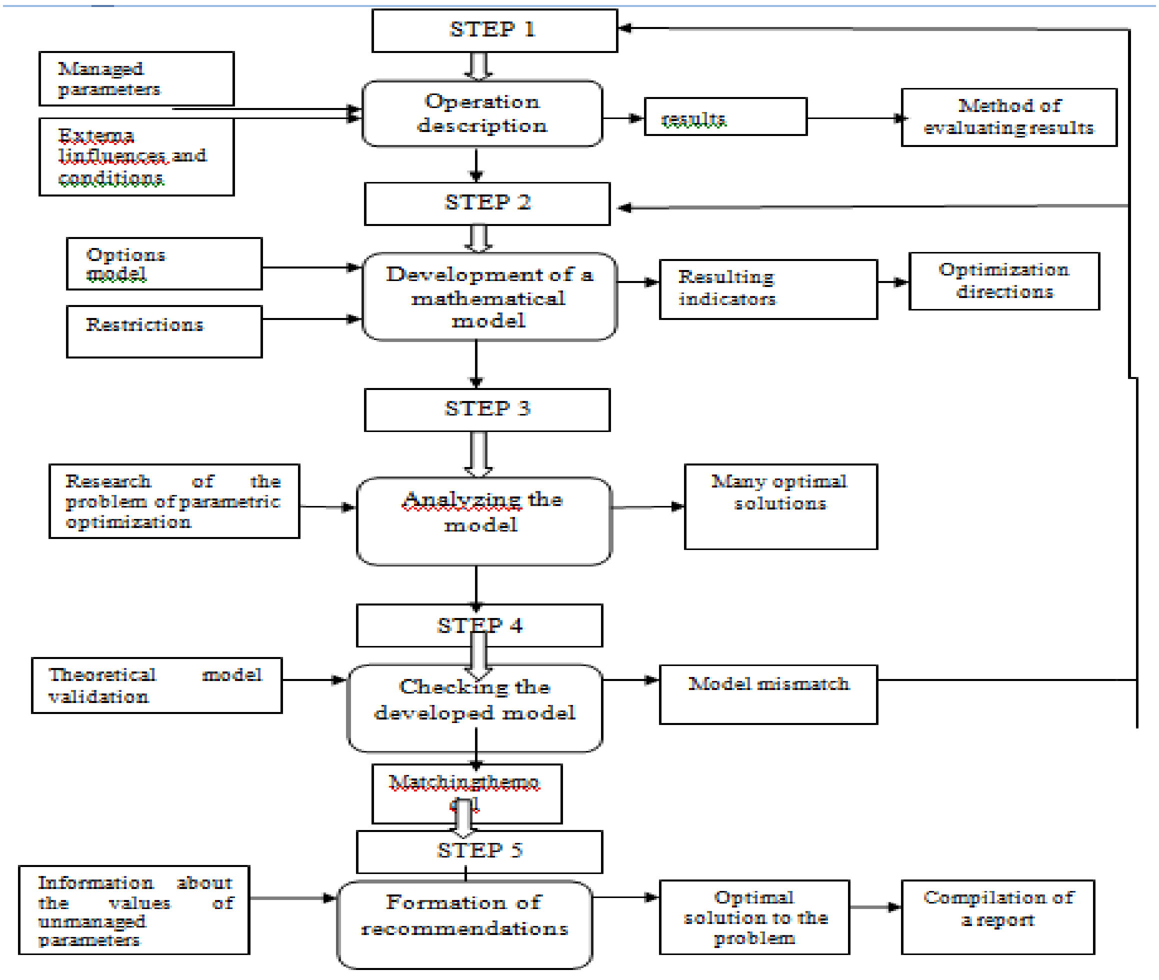

Figure-2. Algorithm for constructing a mathematical model for describing process operations.

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Table-3. Characteristics of the stages, construction of a mathematical model of the process operation.

No step	Name of the step	Description	Results
Step1	Operation description	Formulation of the objectives of the operation and the list of controlled parameters. Method of evaluating the result	Formation of essential properties of the operation and the object as a whole.
Step 2	Development of a mathematical model	Controlled parameters are assigned variables, the values of which the model must determine. External conditions and influences, parameters of the model, output parameters, resulting indicators. Constraints are set that describe the sets of values of variables, model parameters and resulting indicators (inequalities and equations (algebraic, differential, etc.)	Optimization directions minimization or maximization of control parameters F (x, a) → max for x ∈D (a) (optimization formula)
Step 3	Model analysis	Investigation of the parametric optimization problem P (a) for a ∈A. Finding the set A0 ⊆A of those values of the external parameters for which the problem P (a) has a solution, find the necessary and / or sufficient conditions for its solvability. For each, a ∈A0, the solutions of the optimization formula form the set of optimal solutions (optimal designs) X ∗ (a).	Algorithm for solving the problem for all values of a∈A0.
Step 4	Checking the developed model	The absence in the model of conflicting data on theoretical concepts and empirical data	Confirmation that the operation cannot be performed for those values of a for which the problem (optimization formula) is undecidable, and whether the operation is really theoretically realizable for all a ∈A0.
Step 5	Formation of recommendations	Collecting information about the values of uncontrollable parameters, fixing the vector a0 and solving the problem P (a0): finding the optimal solution or establishing the insolvability of the problem	Description of all stages of the study, including: -the hypotheses put in the basis of the model, and their rationale; mathematical model of the operation and its main properties; principles and results of checking the adequacy of the model; the actual recommendation indicating that how they are derived from the model.

RESULTS AND DISCUSSIONS

To use the listed methods for optimizing the metrological support of production, it is necessary to select several industrial enterprises in the Turkestan region and conduct an analysis (formulation of research tasks) on the main task of metrological support - verification and repair of measuring instruments used at these enterprises. Table-4 provides a list of MI used at food industry enterprises in the region [14].

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Table-4. List of measuring instruments used at the enterprises of the region.

Name of the enterprise	Number of MI	MI by type			
		Radio Measuring Devices	Electrical measuring instruments	electrical shield	CT & verification method
JSC «Shymkentmai»	730	236	105	210	179
LLP «Foodmaster-Shymkent»	2300	536	734	480	600
LLP «Visit»	257	87	56	61	53

The results of the analysis showed the following tasks that can be used to develop mathematical models and organize the verification and repair of measuring instruments:

a) MI are withdrawn from service for a long time;

b) Organization of delivery of measuring instruments for verification;

c) The organization of work of the SOP is carried out empirically;

d) Lack of automation of the process of distribution of the serviced enterprises between the bodies for the verification and repair of measuring instruments;

e) There is no mechanism for the cost and time optimization of the work of the bodies for the verification and repair of measuring instruments.

Ways to improve medical equipment:

a) Automation of processes of organizing metrological support;

b) Changes to the guidelines;

c) Optimization of the production activities of bodies for the verification and repair of measuring instruments.

Statement of the research problem for the optimization of MO: 1. To develop an algorithm for the distribution of the serviced enterprises between the bodies for the verification and repair of MI2. To develop an algorithm for optimizing the work of bodies for the verification and repair of MI3. To develop a methodology for performing calculations to optimize the work of bodies for the verification and repair of measuring instruments.

Algorithm for the distribution of the serviced enterprises between the bodies for the verification and repair of measuring instruments. Figure-3 shows the distribution of the serviced enterprises during the calibration and repair of measuring instruments:

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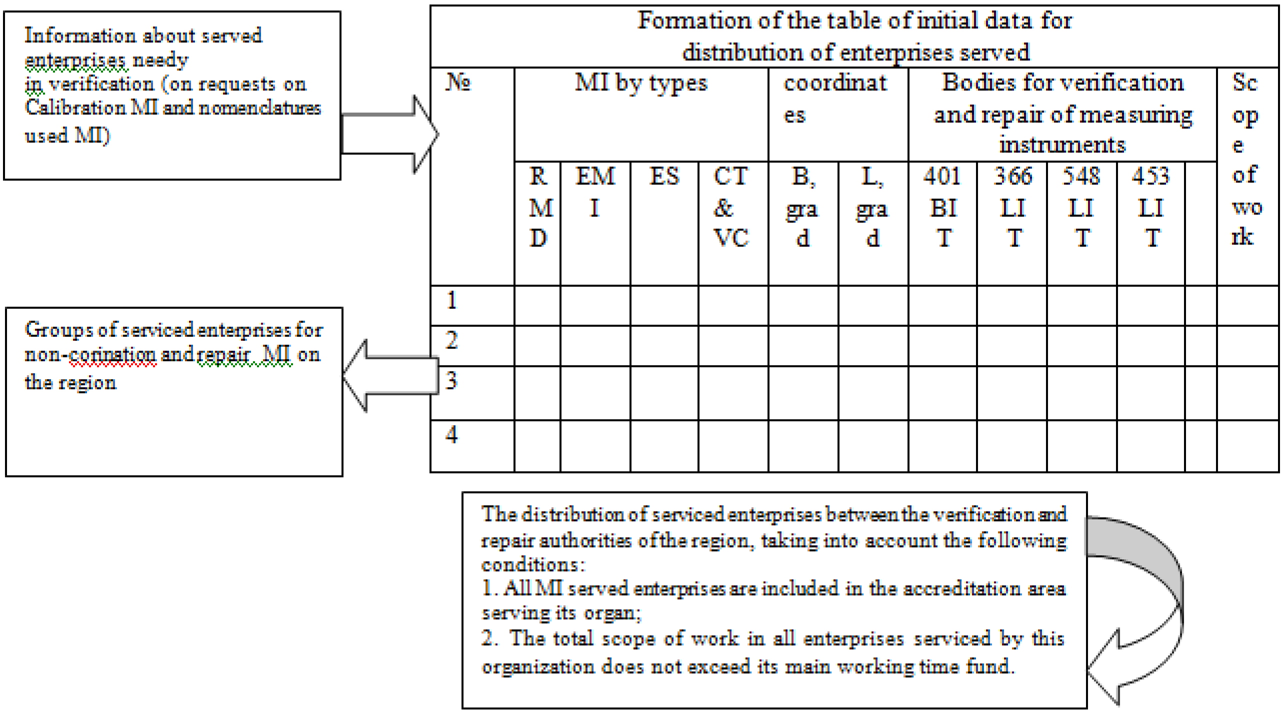

Figure-3. Distribution of serviced enterprises when carrying out calibration and repair

In the course of the study, data were collected on 4 enterprises, according to the table of initial data, to build an algorithm for the distribution of serviced enterprises during the verification and repair of measuring instruments. An example of the algorithm is shown in Figure-4. Thus, the developed algorithm for the distribution of serviced enterprises during the verification and repair of measuring instruments makes it possible to optimize one of the types of MOS - verification and repair of measuring instruments of several enterprises under study by numerical and analytical methods.

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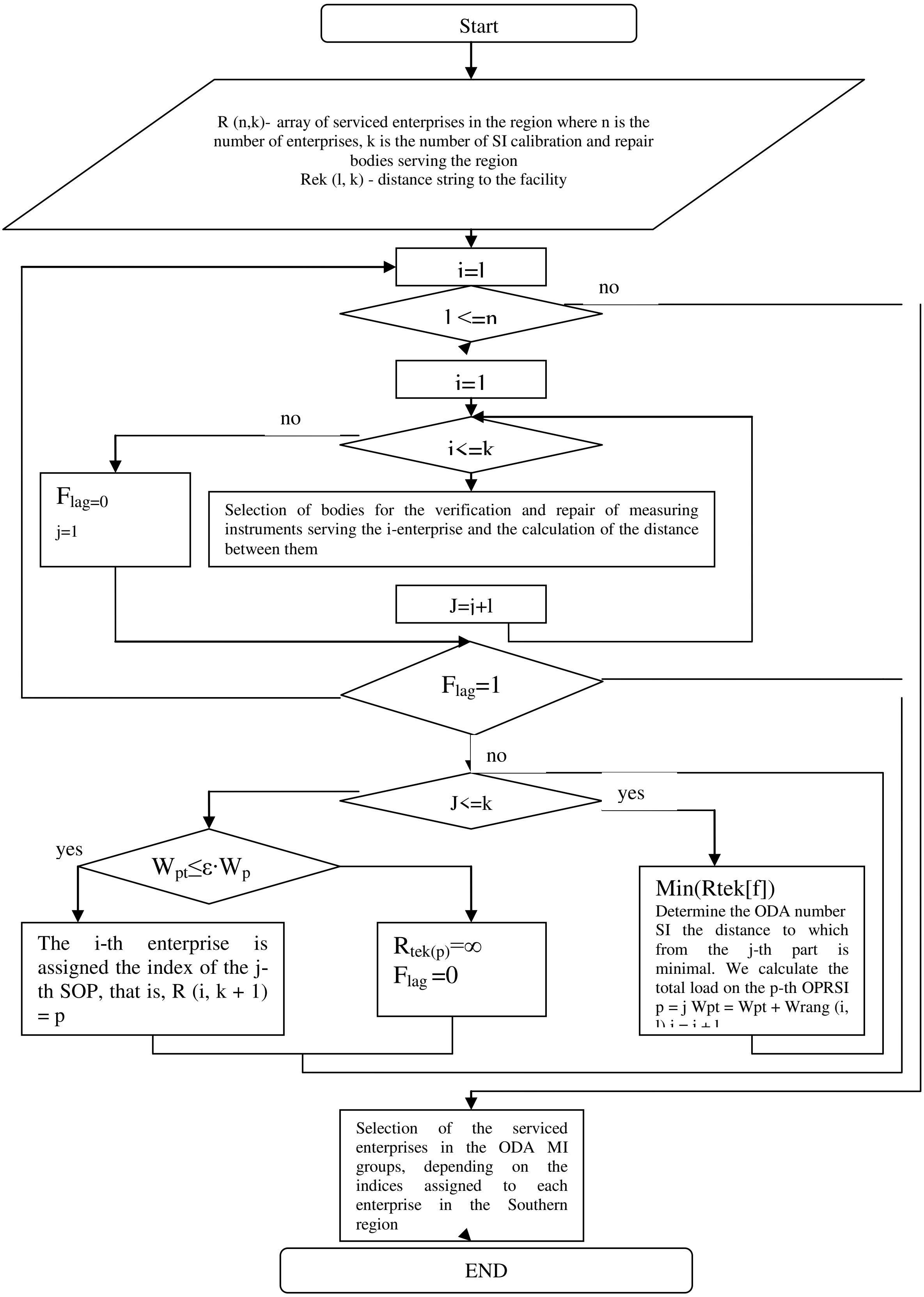

Figure-4. Algorithm for the distribution of the serviced enterprises during the verification and repair of measuring instruments.

Calculation methodology to optimize the work of bodies for the verification and repair of measuring instruments. Optimization of the composition of visiting metrological groups. One of the problems in the verification of measuring instruments is that the measuring instruments are withdrawn from operation for a long time, since enterprises often do not have a replacement fund of measuring instruments that allows one or another measuring instrument to be removed from the production or operation process for its maintenance and verification. There is a need for metrological support of measuring instruments at the places of their operation, that is, at enterprises. To perform work on metrological maintenance of measuring instruments (MI) at the places of their operation, we propose to create field metrological groups (FMG) [15]. The function of the FMG is the verification and repair of measuring instruments at the enterprise using mobile laboratories of measuring equipment (MLME) and transfer standards. The work of FMG on the basis of automobile MLMEs is organized by a sequential detour of all serviced enterprises. In this case, the measuring instruments are withdrawn from operation only for the duration of the verification work. As a result, the verification period is significantly reduced, since transportation to the metrological body, acceptance and temporary storage are excluded. Thus, the urgent task is to increase the efficiency of the functioning of the FMG, which requires the optimization of their work.

In optimizing the operation of the FMG, in particular, the following subtasks can be distinguished:

- finding the optimal bypass route for all serviced enterprises;
- optimization of the composition of the visiting metrological group.

In this study, the optimization of the composition of the field metrological groups is considered.

Let us formulate this problem as follows: At this stage, we follow the optimal route, visiting all serviced objects, in each of which it is necessary to perform a certain amount of work corresponding to the number of verified measuring instruments. Data on the number of verified measuring instruments are summarized in Table-5.

Table-5. The need for verification of serviced objects.

No	The name of the facility of the enterprise	RMI	EMI	ES	CT&VC	serv.
1	LLP«Shymkentmai»	75	95	250	75	25
2	LLP «Carlskrona»	40	35	130	20	0
3	LLP "Standardcement"	20	30	90	10	0
4	LLP "Golden Cammel"	30	60	120	150	10
5	Shymkent kus LLP	10	20	40	12	10
6	Kayipata LLP	10	10	13	15	20
7	Shymkentcement LLP	90	147	230	0	43
8	LLP "Barys 2007"	25	70	180	120	0
9	LLP "Visit"	10	20	40	15	10
10	LLP "Asia cold"	9	27	53	18	5
11	LLP "Reaktivsnab"	70	120	210	100	40
12	Rauan LLP	20	60	150	120	10
13	LLP "Balmuzdak"	70	100	220	180	30
14	Bolashak 7 LLP	10	20	60	40	15
15	Nik1 LLP	20	50	150	120	10
16	LLP "As Dinar"	20	40	100	100	30
17	Borte Milta LLP	70	120	210	80	30

Verified measuring instruments are divided by type of measurement and include:

- radio measuring devices (RMD);
- electrical measuring instruments (EMI);
- electrical shield (ES);
- CT and verification code (CT and VC);
- service devices (Serv).

Let us consider two variants of the problem of optimizing the composition of the FMG:

a) Service time is minimized, while restrictions are imposed on the monetary costs of servicing all objects;
b) Monetary costs are minimized, while restrictions are imposed on the time of service of all objects.

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Consider optimization while limiting the cost of servicing all objects. In this case, the problem is formulated as follows.

Let it be possible to change the number of specialists, for example, by sending them from the BIT to the i-th point and returning them back to the BIT by public transport. Let the route be fixed by the result of solving Problem 1.

Then you can set a task, for example, to minimize time under cost constraints (travel costs, daily allowances for business travelers).

The expression for the execution time takes the form:

$$T_{\Sigma} = \sum_{i=1}^{N+1} \frac{l_i}{v_i} + \sum_{i=1}^{n} \frac{W_i}{(m_c+\overline{m}+m_i)} \rightarrow min, \quad (2)$$

where m_i - the number of additional specialists sent to the i-th point.

Price

$$Q_{\Sigma} = \{\widetilde{T_{\Sigma}}(m_c + \overline{m}) + \sum_{i=1}^{N} m_i \widetilde{T_i}\} g_{сут} + \sum_{i=1}^{N} 2m_i\, l_{iB} S(l_i) \leq S_{max}, \quad (3)$$

where $\widetilde{T_i} = \frac{W_i}{(m_c+\overline{m}+m_i)}\frac{1}{t_p}$ working time at the i-th point in days.

$S(l_i)$ – the cost of traveling from BIT to the i-th point or vice versa. Calculated either by tariffs or by the formula $S(l_i) = l_i\overline{s_i}$, где $\overline{s_i}$ - the average cost of transportation of 1 person per 1 km of track.

S_{max}- restrictions on expenses.

It is also necessary to introduce a limitation on the number of seconded specialists:

$$m_c + \overline{m} + m_i \leq m_{max}, \; i = \overline{1, N} \quad (4)$$

where m_{max} - the maximum number of specialists who can simultaneously be on a business trip.

When solving this problem, consider two possible cases:

a) The structure of the FMG includes only highly qualified specialists that is, having the right to verify all types of measuring instruments.

b) The structure of the FMG includes specialists who have the right to verify only one type of measuring instrument.

In the case of servicing by highly qualified specialists, the entire volume of devices is verified by the entire staff of the field metrological group without dividing into types of measurements.

Thus, according to table 5 and the norms of time for the verification of measuring instruments, we obtain the time required to service this enterprise in working hours.

$$W_{M[i]} = W_{M[i]\mathrm{RMI}} + W_{M[i]\mathrm{EMI}} + W_{M[i]\mathrm{ES}} + W_{M[i]CT\&VC} + W_{M[i]SERV}, \quad (5)$$

$$W_{M[i]\mathrm{RMI}} = n_{RMIM[i]} \cdot \tau_{RMI},$$

$$W_{M[i]\mathrm{EMI}} = n_{EMIM[i]} \cdot \tau_{EMI},$$

$$W_{M[i]ES} = n_{ESM[i]} \cdot \tau_{ES},$$

$$W_{M[i]\mathrm{CT}\&VC} = n_{CT\&VCM[i]} \cdot \tau_{\mathrm{CT\&VC}},$$

$$W_{M[i]\mathrm{serv}} = n_{\mathrm{servM}[i]} \cdot \tau_{\mathrm{Serv}},$$

where $n_{\mathrm{RMIM}[i]}$,$n_{\mathrm{EMIM}[i]}$, $n_{\mathrm{ESM}[i]}$, $n_{\mathrm{CT\&VCM}[i]}$, $n_{\mathrm{ServM}[i]}$ – the number of measuring instruments by type at the i-th point of the route;

$\tau_{RIM}, \tau_{EMI}, \tau_{ES}, \tau_{CT\&VC}, \tau_{Serv}$ - the time required for verification of measuring instruments of the corresponding type.

The standards of time for verification for each type of measuring instrument are determined by regulatory documents.

Suppose that a travel set of verification equipment is moved on a vehicle PLATE, while 2 FMG specialists move on the PLATE, and the rest of the specialists move by public transport. Thus, material costs will be calculated using the following expressions:

$$\mathrm{S} = \mathrm{S}_{PLATE} + \mathrm{S}_{whole} + \mathrm{S}_{day},$$

$$\mathrm{S}_{PLATE} = \mathrm{L}_{\mathrm{M[i-1]M[i]}} \cdot \mathrm{s}_{plate}, \quad (6)$$

$$\mathrm{S}_{\mathrm{whole}} = \mathrm{L}_{\mathrm{M[i-1]M[i]}} \cdot \mathrm{s}_{\mathrm{whole}} \cdot (k-2),$$

$$\mathrm{S}_{day} = \mathrm{T} \cdot \mathrm{k} \cdot \mathrm{s}_{day},$$

where T – The time of finding a personnel on a business trip;

s_{plate}, s_{whole} - The cost of moving one kilometer on the plates or public transport, respectively;

$\mathrm{L}_{\mathrm{M[i-1]M[i]}}$ – the distance between the I-1 and I point of the fixed shortest path;

k – Number of specialists in FMG.

Time is calculated by the following expressions in the days:

$$T = T_{mov} + T_{cal}$$

$T_{mov} = {}^{\mathrm{L}_{\mathrm{M[i-1]M[i]}}}\!\big/_{(\mathrm{V}_{\partial в} \cdot 24)}$ – Time to move between (i-1) -th and i-th route items (7)

$T_{cal} = {}^{W_{M[i]}}\!\big/_{(k \cdot \tau_p)}$- time on the calibration of measuring instruments of the i object,

where $\tau_p = 8 -$ duration of working days in hour.

In this case, it is necessary to minimize the value for T, subject to the limitation of material costs. This task is solved by the method of extinguishing all possible options for the composition of the NMG for all enterprises, then the total maintenance costs of all enterprises in the region are assessed. By changing the limitations of the maximum number of specialists in the VMG values of 6,8, 10, 12, 14. Restrictions on material

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costs are determined by the values from 240,000 to 570000 tenge with an interval of 30,000, we obtain the following calculation results. Calculations are made by the method of extinguishing [8, 12].

Figure-5 along the abscissa axis, limitations are postponed for maintenance for maintenance, along the ordinate axis time spent on maintenance.

High6, High8, High10, High12, High14 – Restrictions on the maximum number of exit metrological groups are equal, respectively, 6,8,10,12,14.

According to this nomogram, it is possible to determine, for example, the period for which the exit group of 6.8.10,12,14 specialists will serve all objects if the number of financial resources is limited to the amount of 360,000 tenge. According to the nomogram, it can be seen that when limiteding funds in 360000 FMGs, consisting of 6 specialists will fulfill the maintenance of all enterprises in 170 days, 8 specialists - for 140, 10 - for 130, 12 - for 127, 14 - for 124 days. In the same way, the number of funds needed to serve all enterprises in the region, as well as the number of Navy for service for servicing for service.

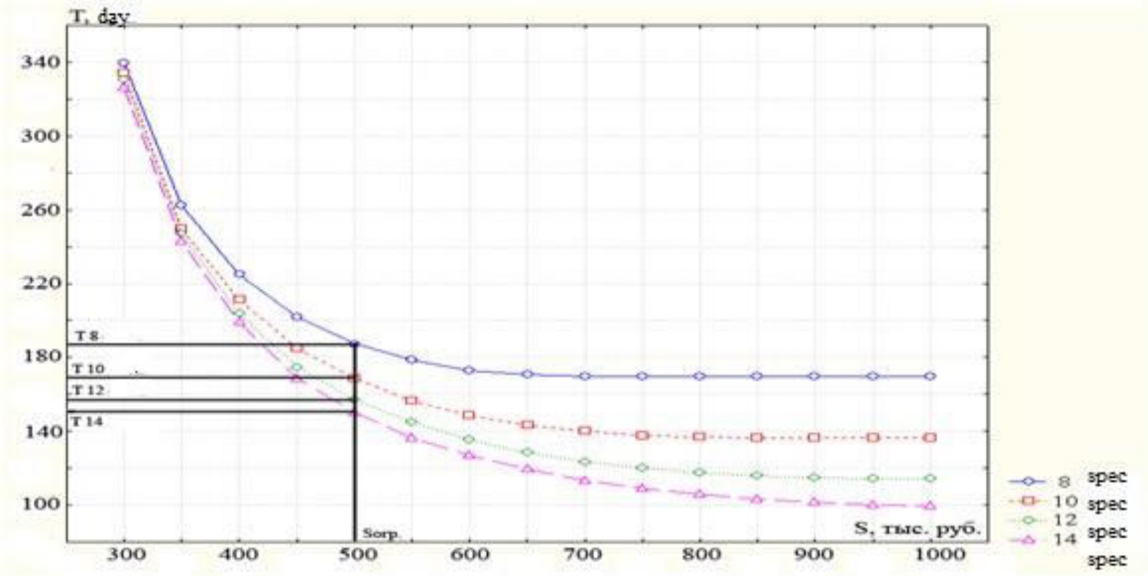

Figure-5. The dependence of the service time from limiting material tools, with various restrictions on the number of FMG (qualified specialists).

We now consider cases of specialists who have permission to verify only one type of MI. In this case, experts are added to the number of FMG sequentially for each type of work. The time spent on the calibration of each type of MI will be calculated depending on the number of specialists in this type of MI, and the number of this species. The total cost of servicing the enterprise will be determined by the greatest time of verification of one or another MI type at this enterprise.

$$T_{cal} = Min[T_{RMI}, T_{EMI}, \mathrm{T}_{CT\&VM}, \mathrm{T}_{Serv}], \quad (8)$$

where $T_{RMI} = {W_{rmi}}/{(\tau_{wor} \cdot k_{RMI})}$,

$$T_{EMI} = {(W_{EMI} + W_{ES})}/{(\tau_{wor} \cdot k_{EMI})},$$

$$T_{RMI} = {W_{CT\&VM}}/{(\tau_{wor} \cdot k_{CT\&VM})},$$

$$T_{serv} = {W_{serv}}/{(\tau_{wor} \cdot k_{serv})},$$

where T_{cal}- service time of one enterprise;

$T_{rmi}, T_{emi}, T_{CT\&VM}, T_{serv.}$ – time spent on the calibration of RMI, EMI, CT&VM and Serv, respectively;

$k_{RMI}, k_{EMI}, k_{CT\&VM}, k_{Serv}$ – The number of experts in the verification of RMI, EMI, CT&VM and Serv, respectively.

τ_{wor}- The number of working hours in the days.

The results of calculations in this case are shown in Figure-6.

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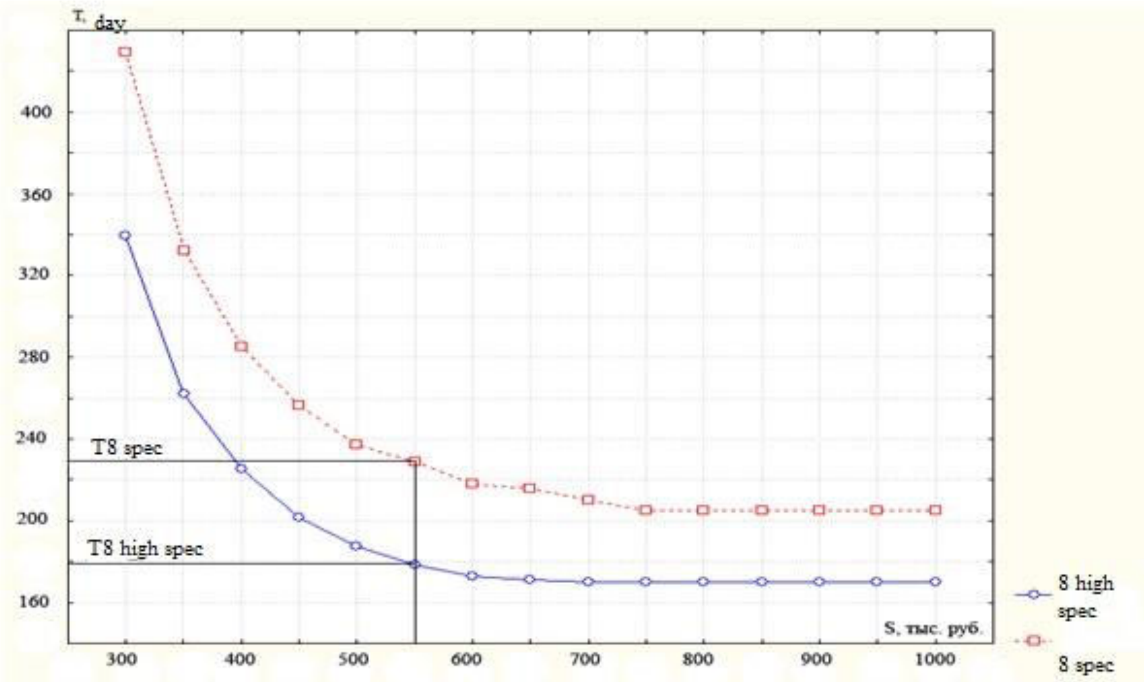

Figure-6. Dependence of the service time from limiting material means, with various restrictions on the number of FMG specialists of low qualifications).

In Figure-7, the designations are similar to the designations of Figure-5. For this nomogram, it can be seen that when limiteding funds in 360000 FMGs, the maintenance of all enterprises in 230 days, 8 specialists - for 200, 10 - for 190, 12 - for 187, 14 - for 186 days.

To analyze the impact of the level of training of specialists belonging to the FMG, during the service of enterprises, we will apply on one plane of dependency graphics for the same number of specialists of different preparations (Figure 4). On this schedule, dependations are constructed for the number of specialists equal to 8.

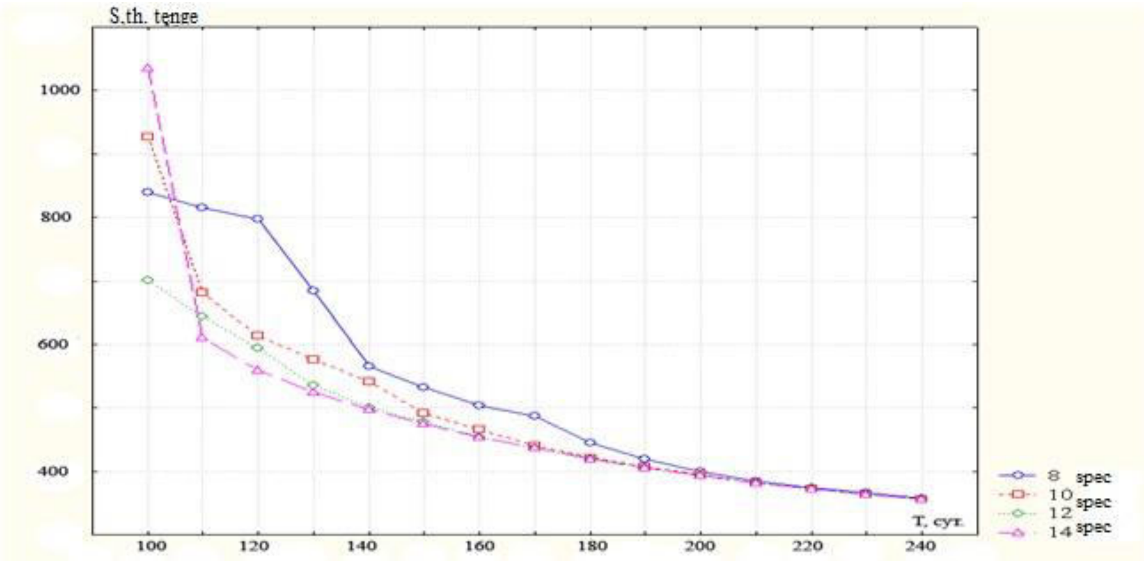

Figure-7. The impact of the level of training of specialists, At the time of servicing enterprises in the region.

According to this nomogram, it can be seen that one volume of work limits, for example, in 330,000 tenge, qualified specialists are performed in 150 days, and experts with low qualifications for 225 days

Thus, the analysis of the above graphs allows to determine the minimum necessary number of the outbound metrological group for servicing enterprises with specified material costs, as well as the time necessary to serve all enterprises in the presence of certain material resources.

The previous task can be considered in another formulation: minimize costs during time constraints.

$Q_\Sigma \rightarrow \min$

With restrictions

$T_\Sigma \leq T_{\max}$

where T_Σ and Q_Σ Defined by formulas (1) and (2), respectively. Restrictions (3) must also be introduced, for the maximum number of VMG specialists.

According to both nomograms, we can identify the necessary funds for metrological support of enterprises in the region if there is a restriction on service time.

According to the results obtained, the following conclusions can be drawn:

a) As a result of the performance of work, a methodology for calculating the optimal composition of exit metrological groups, depending on the restrictions placed during the time or the cost of execution of work.

b) The impact of the level of training of personnel, which is part of the exit metrological groups, for the total time to perform work and material costs for them.

CONCLUSIONS

All works related to calibration, both for enterprises and calibration laboratories, must be carried out at minimal costs and ensure maximum reliability of the conclusion about the shelf life or unsuitability of measuring instruments, since the quality of the products of the products produced largely depends on the quality of the calibration of measurements.

For this purpose, it is necessary to optimize work on the metrological provision of industries. For this, international practice uses mathematical methods for modeling various processes, which were taken as a basis for research on the optimization of the metrological activities of the food industry enterprises of the Turkestan region, in terms of repair and verification of measuring instruments in these enterprises. Modern mathematical approaches were applied to planning and organizing metrological activities, for more efficient use of available resources. An analysis was conducted and the main problems of metrological support of industrial enterprises were revealed, in terms of the organization of control over the production, condition, application and repair of measuring instruments. Studies of mathematical methods of modeling - structural modeling, research of operations, numerical optimization for improving the processes of metrological support, in terms of verification and repair of measuring instruments. Theoretical studies of the properties of selected mathematical methods for modeling and optimizing metrological support are carried out. An analysis and selection of modern software tools was carried out in order to ensure optimal opportunities for the implementation of algorithms and methods for optimizing the methods of metrological support of industrial enterprises. These studies made it possible to develop recommendations for pouring the processes of repair and verification of measuring instruments based on structural modeling methods, research of operations and numerical optimization, mathematical models and methods of organization and verification of measurement tools. A methodology for calculating the optimal composition of exit metrological groups is developed, depending on the restrictions placed during the time or the cost of execution of work.

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