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## Section 1. Engineering

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### ALGORITHMIZATION OF THE PROCESS OF DESIGNING UNIFORM MACHINES

**Abstract.** This article devotes to the formation of the layout of aggregate machines by compiling the process algorithm design.

**Keywords:** aggregate machine, layout, block diagrams, elementary technological operations, elementary operations.

Algorithmization of this task will consist in formalizing the method and presenting it in a convenient form for programming. The first step of the algorithmization process is the compilation of the generalized flowchart of entire task, including separate logical complete particular algorithms. Private algorithms in turn, are developed into flowcharts.

In general, the whole task of forming the structures of an aggregate machine (AM) is expediently divided into three stages. The first stage involves the formation of elementary structures of the AM, i.e. structures implementing elementary technological operations. The meaning and content of elementary operations will be shown by example.

Consider the implementation of the operation of drilling three-step holes, three combinations of surfaces, combined into a set. The implementation of these holes can be done by multi-spindle processing, and, as a combination of tools and simple tools. The third option eliminates the use of multiple

spindle machining and is carried out sequentially by one combined tool. The fourth option involves the processing of simple tools for which it is necessary to perform three transitions with one tool and three subsequent ones with another.

So, all of four options for constructing the process are considered set of the surfaces are elementary operations. Technological transitions that make up these elementary operations, depending on the method of combination, differ in the following types:

- junction-surface -technological transition performed by processing elementary surface with a simple tool;
- transfer-combination-technological transition performed by the combination tool or tool kit;
- transfer-technological transition, performed by multi-spindle processing with the simple or combined tools.

In accordance with these types of transitions in the considered example, in the first embodiment, the

elementary technological operation is implemented by one transition-aggregate using a combined tool; the second version a combined-transition by using a simple tool, at third by using three a combination-transition and at fourth by using six transition surfaces.

Thus, an elementary technological operation will be the union of the same type of transitions necessary to perform a combination or combination of surfaces, as well as a separate image intensifier.

Different versions of the construction of elementary technological operations determine the different composition and structure of the AM, necessary for their implementation.

Figure 1 shows the enlarged algorithm for the formation of the elementary structure of the AS, which constitutes as a whole the first stage of this task.

The second stage of the formation of AM structures considers the possibility and feasibility of enlarging technological operations by combining the same type of elementary operations and forming for their joint execution more complex processing systems combining separate processing units.

Enlarged elementary operations can be constructed as according to the principle of process differentiation, i.e. sequential execution of each transition in the operation, and a different way of combining transitions. Consider the issues of integration of technological operations and the choice of options for the structures of the AM for their implementation on the example of drilling process of the two sets of surfaces.

As a version of the structure of the AM in the case of sequential processing of each hole of the combined sets, in principle, will consist of the options for the separate implementation of each set. In the case when their processing in transitional aggregates is possible, i.e. with the use of multi-spindle process, in specific cases there are many situations, depending on which the end results are far from the same.

The analysis of the conditions determining these or other versions of structures, by various types of surface combinations and by the various processing methods, led to the conclusion that these principles apply to

other types of aggregates, as well as combinations and individual surfaces that can be represented as special cases aggregate. Such a fundamental aspect allows us to switch to a formalized basis for solving this problem.

The contents of the concept of the algorithm can be represented as a graph – of “tree”. Such a presentation of the algorithm allows, firstly, to reveal the essence of the solution of the task in a brazen form and, secondly, to trace the logical interconnection of all the links that determine the choice of one or another solution. The analysis of the conditions and directions of paths presented in this form, which determine the possible variants of the AM, showed that, on the basis of these conditions, it is possible to carry out not just the choice of the variant, but also its formation (synthesis).

Step-by-step verification of each condition, which bears in itself certain information about the structural and technological features available on the part, makes it possible to take private decisions first and on the basis of them to form the structure of the AM necessary for these conditions (in one or several versions).

It is this principal aspect that forms the basis of the flowchart of the algorithm for forming the structure of the AM for implementation on a computer.

The third stage of the formation of structures of the AM provides for the further integration of operations by combining various methods and types of processing to implement them in one AM.

It is possible to combine various methods and types of processing in one speaker in the following ways:

1. Through the use of a combined tool (drill-countersink, countersink scanner, etc.) or a set of tools (boring bar with rough and finishing cutters);
2. Due to the revolving process and use of machines of the type “machin center”;
3. Due to multi-point processing.

At this stage, the specific detail reveals first the need for processing by various methods, highlighting the options that make it possible to combine them in one operation, checking the conditions for their applicability.

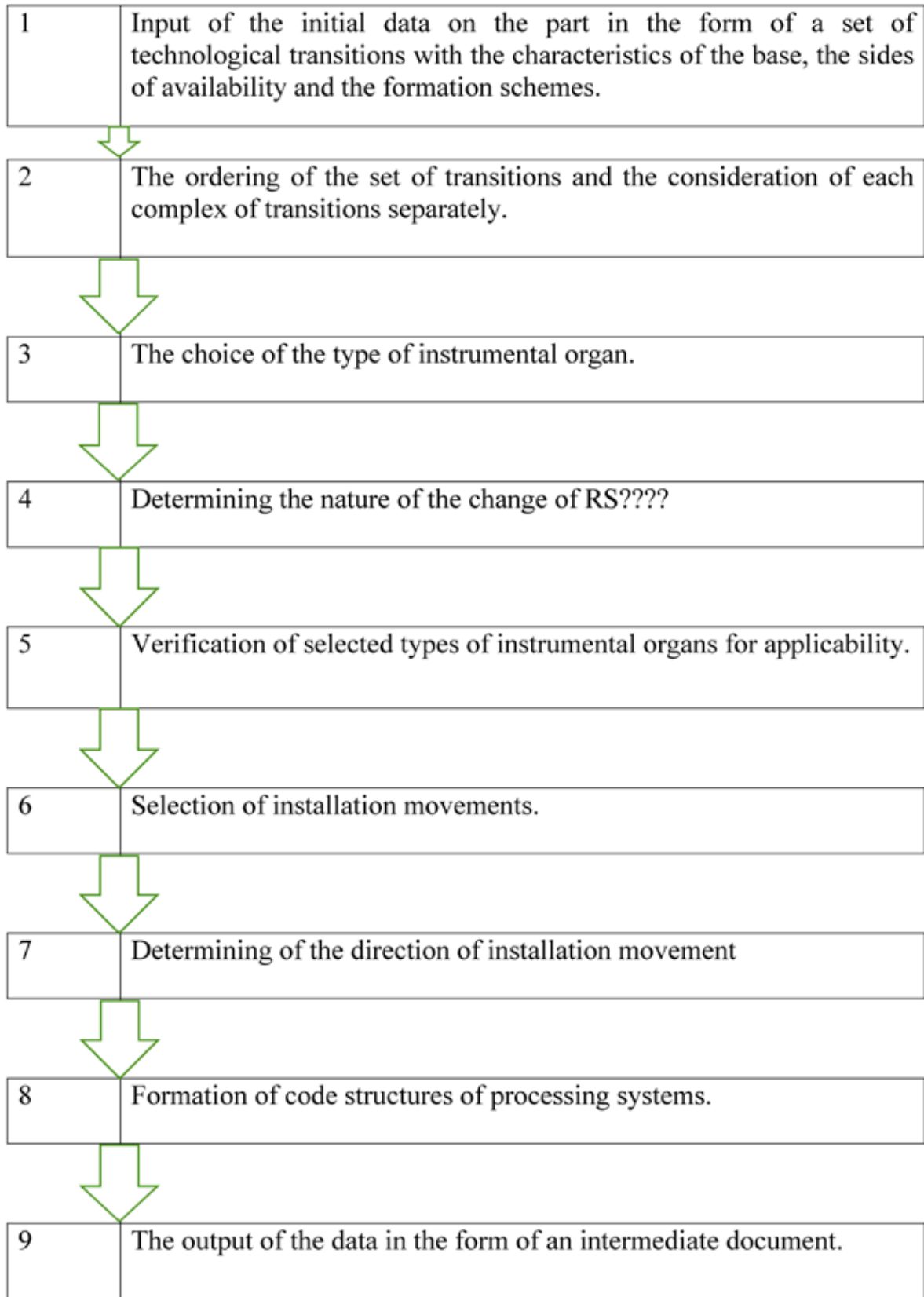


Figure 1. Integrated algorithm of formation elementary structures of the AM

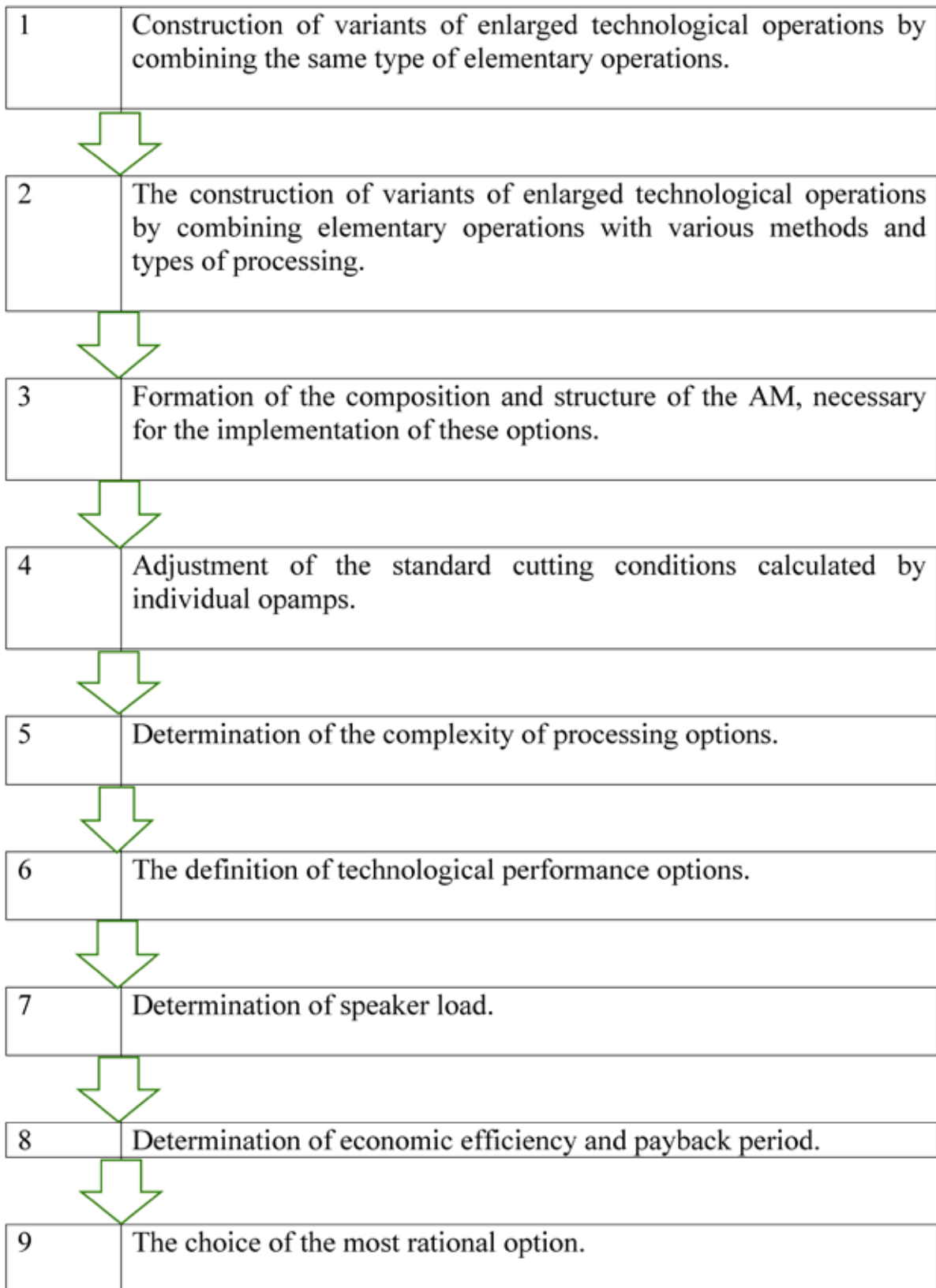


Figure 2. Integrated algorithm for the formation and evaluation of variants of the structures of the AM

According to the above methods of combining various processing methods into a single speaker, there are certain limitations, testing of which in specific cases gives an answer about the acceptability of the option. For example, machining one surface (hole) with a combination tool (drill-countersink) is possible for a smooth open surface (through). Moreover, this method of combining different methods applies to the same surface that requires sequential processing.

In the second method of combining various processing methods that implement an essentially automatic scheme of the tool, besides the sequential processing of the same surfaces, it is already possible to process other surfaces located on one side.

Multi-item processing, in contrast to these methods, allows to combine in time (perform simultaneously) various processing methods, both from one and from several sides.

The enlarged algorithm that combines the second and third stages of the formation of versions of the structure of the AM, as well as the assessment and selection of the most rational option is presented in (Fig. 2).

The formed structures of the NPP, being its functional and technological side, can be implemented both in the existing types and configurations of equipment, and can be a circuit basis for the development of special equipment.

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## Section 2. Food processing industry

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### INFLUENCE OF THE PULSED IR-RADIATION ON THERMO-PHYSICAL CHARACTERISTICS OF FRUITS

**Abstract.** The development of unconventional production methods for processing and drying fruits requires additional studies of characteristics that can have a big impact on the drying process and the properties of fruits. This article discusses the hygroscopic characteristics, moisture binding energy, and pore distribution for apricot drying.

**Keywords:** desorption; infra-red irradiation processing; moisture content; moisture bond.

The evaporation of the moisture from solids we call desorption. The character of the isotherms of sorption and desorption depends on the type of the moisture bond with the material. The moisture bond depends on the material structure and its characteristics. We report on the influence of electromagnetic

field processing on changes to the cellular structure of apricot. In this study, desorption isotherms were investigated after IR-irradiation processing for apricots in syrup with sugar concentrations of 50, 60 and 70% at various air temperatures (25–60 °C) and humidity between 10–70%.

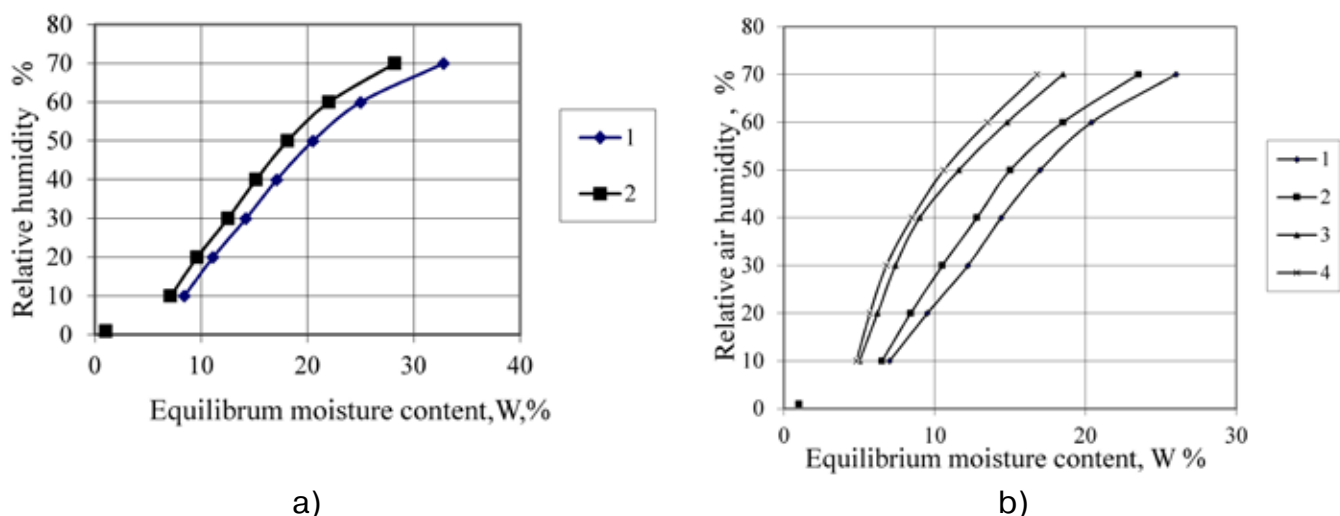


Figure 1. Desorption isotherms of apricot: a) immersed in sugar syrup: (1) at  $t=25\text{ }^{\circ}\text{C}$ , (2) at  $t=60\text{ }^{\circ}\text{C}$ ; b) (1) at  $t=25\text{ }^{\circ}\text{C}$ , (2) at  $t=25\text{ }^{\circ}\text{C}$  and IR-irradiation processing (3) at  $t=60\text{ }^{\circ}\text{C}$ , (4) at  $t=60\text{ }^{\circ}\text{C}$  and IR-irradiation processing



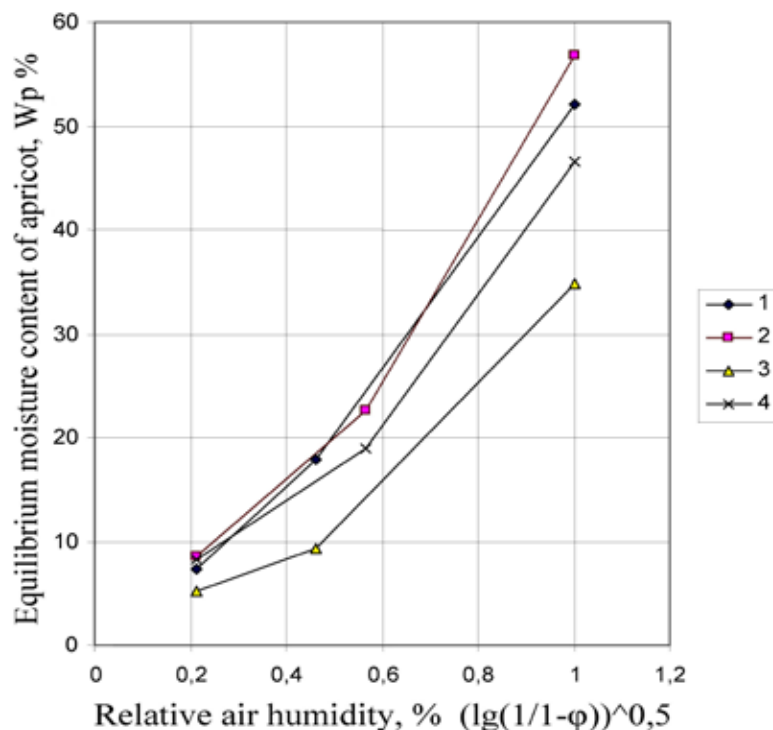


Figure 2. Rectilinear modification of the averaged apricot desorption isotherm before and after thermal processing at different temperatures: 1) at 25 °C; 2) after IR irradiation processing and immersing in 70% sugar syrup at 25 °C; 3) at 60 °C; 4) after IR irradiation processing and immersing in 70% sugar syrup at 60 °C

The analytical way to find the dependence of apricot equilibrium moisture content on relative air humidity and temperature for different kinds of apricot does not exist yet. Therefore formula for calculating desorption isotherms was developed on the basis of experimental data.

Experimental results of apricot desorption isotherms are shown on (Fig. 2) as a graphical dependence  $W = f(\lg(1/1-\phi))$ . As shown on the (Fig. 2) modified broken lines of the apricot desorption isotherms have characteristic points which divide them on three zones (Table 1).

Table 1. – Rectilinear modification of the averaged apricot desorption isotherm before and after thermal processing at different temperatures

Apricot processing method	at 25 °C		at 60 °C	
	$\phi$ .%	$W_e$ %	$\phi$ .%	$W_e$ %
Without any processing	0–10	0–7.4	0–10	0–5.2
	10–40	7.4–17.8	10–40	5.2–9.3
	40–90	17.8–52	40–90	9.3–34.8
After IR-irradiation processing	0–10	0–7.3	0–10	0–4.5
	10–42	7.3–16.2	10–42	4.5–8.0
	42–90	16.2–48	42–90	8.0–31.5
After IR-irradiation processing and immersing in sugar syrup	0–10	0–8.5	0–10	0–8.2
	10–52	8.5–22.6	10–52	8.2–18.9
	52–90	22.6–56.8	52–90	18.9–46.5

The aim of the dividing of the desorption isotherm to zones is to define the type of the moisture content in the apricot. According to classification of A. V. Lykov and Lengmure first zone is related to adsorption monomolecular layer with relative air humidity  $0 < \varphi < 10\%$  where equilibrium moisture content in apricot without processing is  $0 < W_e < 7.4\%$  and  $0 < W_e < 8.5\%$  in apricot after IR-irradiation processing and immersing in sugar syrup.

The middle zone is related to poly molecular adsorption where at  $10 < \varphi < 40\%$  equilibrium moisture content in apricot without processing is  $7.4 < W_e < 17.8\%$ , at  $10 < \varphi < 52\%$  equilibrium moisture content in apricot after immersing in sugar syrup is  $8.5 < W_e < 22.6\%$ .

Third zone characterises the moisture content in micro capillaries. At relative air humidity  $40 < \varphi < 90\%$  equilibrium moisture content in apricot after immersing in sugar syrup is  $17.8 < W_e < 52\%$ , at  $52 < \varphi < 90\%$  it is  $22.6 < W_e < 56.8\%$ . After IR-irradiation and immersing apricot in 70% sugar syrup the volume of pores is increased and equilibrium moisture content is increased up to 1.15 times at 25 °C and moisture content 60–70%.

An empirical formula for calculating the equilibrium moisture content of apricots as a function of humidity and temperature was developed, based on the experimental data:

$$WW_e^c = A + B(t) + C(t)(\lg(1/1-\varphi))^{1/2} \quad (1)$$

where  $\varphi$  – relative air humidity, %  $\varphi = P_p/P_s$ ;  $W_e^c$  – equilibrium moisture content in apricot during desorption, %;  $P_p$  – vapour partial pressure, kPa;  $P_s$  – saturated vapour partial pressure, kPa;  $A, B, C$  – coef-

ficients which have been defined for the each of characteristic zones.

So, the formula of equilibrium moisture content in the apricot after IR-irradiation and immersing in 70% sugar syrup at relative air humidity 10–70% and temperature 25–60 °C is next:

$$W_p = 6.47 - 0.265t + 18.17^{0.25} \left( \log \times \frac{1}{1-\varphi} \right)^{0.5} \quad (2)$$

For the third zone:

$$W_p = 41.5 - 0.78 \times t - 15.54^{0.25} \left( \log \times \frac{1}{1-\varphi} \right)^{0.5} \quad (3)$$

For the defining the effective pores diameter and apricot porosity authors used the method described by A. Ginzburg and E. Savina [3].

The specific surface of the distant film of water which forms in the beginning of the capillary condensation section is:

$$S = \frac{1}{G_u} \int_{U_n}^{U_s} \Delta r \times du \quad (4)$$

where  $G$  – a liquid surface tension, N/m;  $U_s$  – moisture content in material, Mol/kg;  $U_n$  – moisture content in the beginning of the capillary condensation section, Mol/kg;  $L_i$  – bond energy or differential work during product dehydration, kJ/moist kg

$$L = -RT \ln \varphi \quad (5)$$

where  $R$  – universal gas constant, J/K Mol%.

So the effective diameter of pores is:

$$d = 4GV_m / RT \ln(P_n / P_s) \quad (6)$$

where  $G$  – surface tension of the apricot juice which depend on sugar content, mN/m;  $V_m$  – molar volum of the water, m<sup>3</sup>/Mol and can be defined from next equation:

$$V = U \cdot V_m \quad (7)$$

Calculations of the effective diameter of pores are showed in (Table 2 and Table 3).

Table 2. Calculations of the effective diameter of pores

Air humidity in chamber	Apricot desorption at temperature 25 °C without processing				Apricot desorption at temperature 60 °C after IR-irradiation				
	$W_p$ , kg/kg	$U$ , mol/kg	$L$ J/mol	$D \cdot 10^{-9}$ m	$W_p$ , kg/kg	$U$ , mol/kg	$L$ J/mol	$D \cdot 10^{-9}$ m	
$\varphi$ , %	1	2	3	4	5	6	7	8	9
90	0.52	28.9	260.1	20.5	0.348	19.33	290.7	17.85	

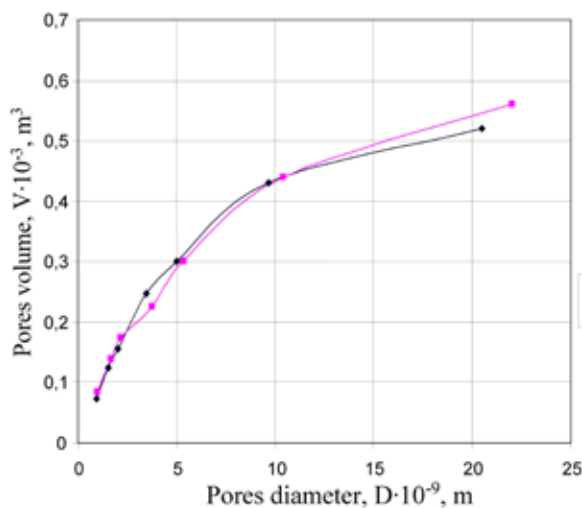
1	2	3	4	5	6	7	8	9
80	0.43	23.8	552.0	9.66	0.225	12.5	617.4	8.4
65	0.30	16.7	1068	4.99	0.16	8.8	1193	4.35
54	0.248	13.6	1526	3.49	0.12	6.8	1705	3.04
35	0.155	8.61	2602	2.05	0.075	4.16	2907	1.78
25	0.125	6.94	3434	1.55	0.055	3.05	3837	1.35
10	0.074	4.11	5698	0.93	0.052	2.88	6368	0.815

Table 3. Calculations of the effective diameter of pores

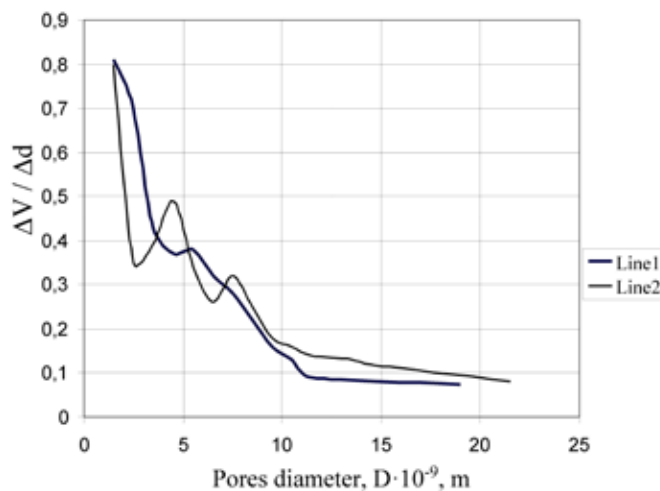
Air humidity in chamber	Apricot desorption after IR-irradiation and immersing in sugar syrup, 25°C				Apricot desorption after IR-irradiation and immersing in sugar syrup, 60°C			
	$W_p$ , kg/kg	U, Mol/kg	L J/Mol	$D \cdot 10^{-9}$ m	$W_p$ , kg/kg	U, Mol/kg	L J/Mol	$D \cdot 10^{-9}$ m
90	0.56	31.1	260.1	22.0	0.465	25.8	290.7	19.7
80	0.44	24.4	552.0	10.4	0.34	18.8	617.4	9.28
65	0.32	16.9	1068	5.36	0.245	13.6	1193	4.8
54	0.25	14.5	1526	3.75	0.18	10.0	1705	3.36
35	0.175	9.72	2602	2.2	0.14	7.77	2907	1.97
25	0.14	7.77	3434	1.67	0.12	6.66	3837	1.49
10	0.085	4.72	5698	1.01	0.082	4.55	6368	0.9

As we can see the moisture bond energy of the apricot has shown that it increases from 280 to 1200 J/mol with moisture content reducing from 56% to 25%, and steps from 1200 up to 1700 J/mol with moisture con-

tent reducing from 25% to 18%. In this connection at calculation of the expense of heat on drying of an apricot with up to 25% moisture the specific heat of evaporation will be increased by 4.0%-5.0%.



a)



b)

Figure 3. a) Dependence of the moisture volume on pores diameter; b) Curve of the pores volume distribution by effective diameters

The graphical dependence of the moisture volume on pores diameter is shown on the Fig. 3. As it

shown on the graph the maximum point is  $6 \cdot 10^{-11}$  m. On desorption isotherm the beginning of the curve

bend correlate with value  $P_n/P_h = 0,05$ . It means that the most part of pores in apricot cells have a diameter, therefore they can be related to micro pores. It is the characteristics of the colloid capillary-porous matters. So, for the calculation of the apricot drying process we can use general kinetic methods for the drying of colloid capillary-porous matters.

Analysis of a desorption isotherm of an apricot after IR-irradiation processing shows that the moisture in poly molecular section decreases by 1.15 times, and after immersing in a sugar syrup and IR-irradiation processing increases by 1.4 times. So, during IR-irradiation influence on an apricot its cellular structure partially collapses,

and when immersed in a sugar syrup the moisture holding ability of cells due to penetration of the sugar increases.

The results of the study can be used to improve drying process efficiency through:

- defining conditions of storage and need to consider critical points of the apricot moisture content at various temperatures and relative humidity of air in calculations of drying process;
- correlating moisture bond energy with a product;
- defining thermodynamic parameters;
- by calculating porosity and the sizes of pores of the fruit.

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## Section 3. Agricultural sciences

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### COMPARISON OF THE EFFECTIVENESS OF THREE INSECTICIDES WITH *GRANULOVIRUS*, *INDOXACARB* AND *DIFLUBENZURON* ACTIV INGREDIENT IN INTEGRATED MANAGEMENT OF COODLING MOTH FOR 2017

**Abstract.** The tendency to increasing the area cultivated with apples, increasing production and introducing new varieties has led to the addition of a number of problems that apple farmers and growers in the Korça region has faced on a daily basis. Among these problems one of the most important is the management of pests and diseases, where one of the most important pests is the **Coodling Moth**. In addition to these problems it is the low reliability of the effectiveness of the preparations that are applied to the control and management of this pest.

**Keywords:** coodling moth, variety, effectiveness, credibility, infection percentage, F factic dhe teoric.

#### 1. Introduction

Apples production is one of the sectors that occupies the most important fruit crop site in Albania, with the Korça region being one of the largest regions in the country with apple trees planted areas. In Korca region there are three main apple cultivation districts, the districts of Korça, Devoll and Kolonja where there has always been a tendency of growing the surfaces planted with apples in both ways, with traditional and intensive blocks [1].

This increasing trend of surface and cultivated trees where the number reaches up to 3 million trees has also led to an increase in the quantity and quality

of production where today can be ensured a production of 90.000 tonnes per year.

Regarding the varietal structure of apples that are mostly produced in the Korça region, the main two are Red Delicious (Red Chief and Starking) derivatives, both of which are locally referred as «Starking», which make up 52% of the fruit trees, and Golden Delicious making up 42%. Other apple varieties make up 6% of other fruit trees. Here are included other non – traditional varieties grown in the region, such as Gala (which is an early variety), Mutsu (a derivative of Golden Delicious), and Granny Smith [2].

All this tendency to increasing the area cultivated with apples, increasing production and introducing new varieties has led to the addition of a number of problems that apple farmers and growers in the Korça region has faced on a daily basis. Among these problems one of the most important is the management of pests and diseases, where one of the most important pests is the **Coodling Moth**.

The main damage in the fruit is caused by the larva which opens a gallery towards the fruit seeds, the affected fruits are distinguished from healthy fruits as they are smaller and intense in color, these fruits usually fall prematurely on the ground. Depending on the area, the coodling moth can show from 1 to 3 generations [3].

Referring to the above facts about pest risk as well as the low reliability of growers for the effectiveness of the preparations that they use for the management of this pest, it is necessary to conduct a number of studies and experiments to assist in this direction.

Therefore, during 2017, an experiment was conducted to compare the effectiveness of the three most widespread preparations on the market for coodling moth control such as *a.i. granulosevirus, cpv*, *a.i. indoxacarb*, *a.i. diflubenzuron*, with predetermined dose and amount of solution used. The effectiveness of the insecticides used was determined by infection percentage for the Golden Delicious and Star King test varieties compared with the untreated control varieties [4].

## 2. Materials and methods

The setting up of the study experiment was carried out during 2017 within a 5 ha plot of apple cultivated in Dvoran village of Korça region. Dominant in this experimental plot were the two main varieties **Golden Delicious** and **Star King**, both separated in rows which in themselves represented variants **a1** and **a2**. To conduct the experiment, a small parcel area of 100 m<sup>2</sup> with 240 apple trees was selected. Each replicate for each variant was represented by 10 apple trees, whereby the first and tenth trees were labeled as P1 a1 b2 to make them more dis-

tinct. Then, according to the forecast – signalisation system by monitoring attractive pheromone traps, the moment of application of chemical preparations was determined and the insecticides were tested with active ingredients: *a.i. granulosevirus, cpv*, *a.i. indoxacarb* and *a.i. diflubenzuron* which constituted in themselves the variants **b1**, **b2** and **b3**. Their application for the first generation was made at the end of May, while for the second generation it was carried out in the third week of July. The parcel that served as a witness (control block) was not treated with any kind of pesticide.

To determine the infection rate at the beginning of July for the first generation and at the end of August for the second generation on ten apple trees labeled for each variety, ten fruit per tree were analyzed in total 100 fruits. The rate of infection and the percentage of infection indicated the number of fruits, in percentage, affected per 100 fruits analyzed. Apple fruit completely infected by the pest was considered complete when the pest had penetrated deep into the fruit. (to the seeds). All these comparisons were made with untreated control cultivars at the same time and the effectiveness of chemical preparations (insecticides) used for pest protection was determined [5].

## 3. Results and discussion

Data on the percentage (%) of fruit infection for each variant for all three replicants in both Golden Delicious and Star King cultivars for both generations studied for 2017 are presented in (tables 1, 2).

From the table data we see that:

The percentage (%) of fruit infection for each variant for all three replicants in both Golden Delicious and Star King cultivars for both generations studied for 2017 indicates that in both variants where were treated with *a.i. indoxacarb*, *a.i. diflubenzuron* and *a.i. granulovirus* percentage (%) of fruit infection in Golden Delicious cultivar was 0%, 0.3% and 1.6% in first generation. Compared to Star King cultivar where infection was 2% when treatment with *a.i. indoxacarb*, 1.3% treated with *a.i. diflubenzuron* and 2.6% in the treatment where was

used a.i. granulovirus in first generation. Regarding the second generation in both variants where was treated with the active ingredients a.i. indoxacarb and a.i. diflubenzuron, the percentage (%) of fruit infection in Golden Delicious cultivar was 0% while in treatments with active ingredient a.i. granulovirus the percentage (%) of infection was 7.6%. While in

Star King cultivar the percentage (%) of infection for the second generation in the variants treated with a.i. indoxacarb, a.i. diflubenzuron and a.i. granulovirus was respectively 2.6%, 1% and 10.3%. In comparison with the control plot where the percentage (%) of infection was 8 times higher in the first generation and more than 20 times in the second generation.

Table 1. – Data on percentage (%) of infection in fruit for each variant for all three replicant in both Golden Delicious and Star King cultivars for both generations studied for 2017

Year	Gener	Preparation	Golden delicious a <sub>1</sub>					Star king a <sub>2</sub>				
			P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Σ	Avar	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	Σ	Avar
2017	I	<i>A.i. granulosevirus</i>	3	1	1	5	1.6 b	4	2	2	8	2.6 ab
		<i>A.i. indoxacarb</i>	0	0	0	0	0 b	2	1	3	6	2 b
		<i>A.i. diflubenzuron</i>	0	1	0	1	0.3 b	1	3	0	4	1.3 ab
		<b>Control</b>	4	9	10	23	7.6 a	10	13	9	32	10.6 a
		<b>Sum</b>	7	11	11	29	9.5	17	19	14	50	16.5
		<b>Avarage</b>	1.75	2.75	2.75	7.25	2.375	4.25	4.75	3.5	12.5	4.125
		<b>LSD</b>	Lsd = 2.87966 for @ 0.05 according to the test Dunnett's									
	II	<i>A.i. granulosevirus</i>	10	5	7	23	7.6 ab	13	9	9	31	10.3a
		<i>A.i. indoxacarb</i>	0	0	0	0	0 b	2	3	3	8	2.6 a
		<i>A.i. diflubenzuron</i>	0	0	0	0	0 ab	2	1	0	3	1 a
		<b>Control</b>	32	31	38	101	33.6 a	37	33	33	103	34.3 a
		<b>Sum</b>	42	36	45	124	41.2	54	46	45	145	48.2
		<b>Avarage</b>	10.5	9	11.3	31	10.3	13.5	11.5	11.25	36.25	12.05
		<b>LSD</b>	Lsd = 2.87966 for @ 0.05 according to the test Dunnett's									

Note: **a** the highest level of authenticity for Lsd = 2.87966 for @ 0.05 dhe **ab**= the lowest level of authenticity for Lsd = 2.87966 for @ 0.05 according to the test Dunnett's

In (Table 2) are presented the results of One – way ANOVA analysis of variance (One – way ANOVA) on the percentage (%) of fruit infection for each variant for all three replicants in both Golden Delicious and Star King cultivars for both generations studied for 2017.

This is verified by the F – factic values tah are 10.77\*\* in the first generation in Golden cultivar and 23.14\*\* in Star King cultivar and in the second generation 149.24\*\* for the Golden cultivar and 359.81\*\* in Star King cultivar verified for levels of P 0.05 and P 0.01 of the probability which is greater than the theoretical F values that are 4.75 and 9.779 (Table 2).

Comparison between the F – factic values of the replicantns with those of the tables shows that the replicantns do not give statistically significant differences for both levels of P = 0.05 and P = 0.01 because the F – factic values are smaller than; F – teoric which shows that our experiment is set up in the correct conditions and allows us to continue the data analysis.

The comparisons of percentage (%) of infection according to the replicants for all three variants in the study for the year 2017 according to the Dunetts test (Lsd = 2.87966 for @ 0.05 according to Dunnett's test) shows the presence of confirmed differences between the variants taken for the study (Table 2).

Table 2. – One – way ANOVA analysis of variance for the infection percentage% in apple fruit according replicants for all three variants in the study year 2017

Gener.	Culti- vars	Anova						
		Sources of variation	Quadratic sum	Freedom Degrees	Quadratic mean	F factic	F teoric	
							95%	
1	Golden del	Variants	114.9167	3	38.30556	10.77 **	4.75	9.78
		Replicant	2.666667	2	1.333333	0.375 ns	5.14	10.9
		Mistake	21.33333	6	3.555556			
		Total of error	138.9167	11				
1	Star king	Variants	171.6667	3	57.22222	23.14 **	4.75	9.78
		Replicant	3.166667	2	1.583333	0.640 ns	5.14	10.9
		Mistake	14.83333	6	2.472222			
		Total of error	189.6667	11				
2	Golden del	Variants	2300.917	3	766.9722	149.24**	4.75	9.78
		Replicant	10.5	2	5.25	1.021 ns	5.14	10.9
		Mistake	30.83333	6	5.138889			
		Total of error	2342.25	11				
2	Star king	Variants	2128.917	3	709.6389	359.81**	4.75	9.78
		Replicant	12.16667	2	6.083333	3.084 ns	5.14	10.9
		Mistake	11.83333	6	1.972222			
		Total of error	2152.917	11				

Note: \*\*: Verified for the level of probability 1% ( $p < 0.01$ ); \*: Verified for the level of probability 5% ( $0.01 < p < 0.05$ ); ns: Without verified probability ( $p > 0.05$ )

Verified differences between the variants taken for the study when comparing them according to Dunetts test (Lsd = 2.87966 for @ 0.05 according to Dunnett's test for @ 0.05) sorts the variants into different classes (Table 2).

Thus for the Control variant is signed with the letter **a** for both generations of pests which are statistically verified for Lsd = 2.87966 for @ 0.05 according to Dunnett's test; For the variant treated insecticide a.i. indoxacarb and a.i. diflubenzuron are signed with the letters **b** and **ab** for the first generation of the codling moth and signed with the letters **a**, **b** and **ab** for the second generation of the codling moth. Thus or the variant treated insecticide a.i. granoloseviru for Lsd = 2.87966 for @ 0.05 according to Dunnett's are signed with the letters **b** and **ab** for both generations of pests.

#### 4. Conclusions

Based on the statistical refinements reflected in the preceding paragraph resulted in some conclusions presented as follows:

- The percentage (%) of fruit infection for the 2017 data on the Golden Delicios variety was lower compared to the Star king variety and 8 to 10 times lower than for both varieties when compared to the percentage (%) of infection to the control for both generations of codling moth;
- In the second generation of apple worm it results that the percentage (%) of infection is higher than in the first generation in both Golden delicious and Star King varieties even when all three preparations *a.i. indoxacarb*,



- a.i. diflubenzuron* and *a.i. granulosevirus, cpv* have been used;
- Analysis of variance results in the presence of confirmed differences between variants over the infection percentage% for both generations and in both cultivars, confirmed by F- factic of 10.77\*\* in the first generation in Golden cultivar and 23.14\*\* for Star King cultivar as well as 149.24\*\* for the second generation in Golden cultivar and 359.81\*\* for Star King cultivar;
  - Better results on the effectiveness on codling moth protection was provided by chemical preparations *a.i. indoxacarb* and *a.i. diflubenzuron* for both generations of pest;
  - When applying *a.i. granulosevirus, cpv* had a slightly higher percentage (%) of codling moth infection in both generations and therefore it's effectiveness in pest control was somewhat lower compared with two other preparations;
  - In the plot left for control it results that the percentage (%) of infection and damage in fruit caused by codling moth is many times higher than in cases where codling moth is managed with chemical preparations;
  - To have better pest control and to have a lower infection rate resulting in a guaranteed quantity and quality of production requires the application of chemical preparations.

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## Section 4. Technical sciences

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### **INVESTIGATION OF THERMOPHYSICAL PROPERTIES AND CHARACTERISTICS OF DISPERSED MATERIALS BASED ON EXPERIMENT PLANNING METHODS**

**Abstract.** Thermal physical characteristics of dispersed materials are studied on the basis of experiment planning methods, their thermal conductivity, thermal diffusivity, heat capacity, thermal absorption, which are thermal characteristics and mass transfer characteristics: moisture conductivity, thermal conductivity, mass capacity, etc., have been determined. Thermal processes of materials as well as the structure of the material as a quasi-homogeneous body have been studied.

**Keywords:** heatphysical characteristic, disperse materials, thermal process, experiment, planning of an experiment.

Thermophysical characteristics are usually of great interest. They represent a set of parameters that characterize simultaneously the reaction of the material to the processes of heat and mass transfer. The latter includes, first of all, thermal characteristics:

- coefficient of thermal conductivity  $\lambda$ ,
  - coefficient of thermal diffusivity  $k$ ,
  - volumetric heat capacity  $C$ ,
  - heat absorption  $b = \sqrt{\lambda C}$ ,
- as well as mass transfer characteristics:
- coefficient of moisture permeability  $K$ ,

- coefficient of thermal and moisture permeability  $\delta_T$ ,

- coefficient of mass intensity  $\delta_M$ , etc.

In this work, the main emphasis is placed on a comprehensive study of only the complex of thermal characteristics of  $\lambda$ ,  $k$ ,  $C$  and  $b$ .

The research was motivated by the following assumptions. On the one hand, the authors had studied, in addition to typical dispersed materials, also complex solid non-metallic structures. In such objects, as a rule, there is no mass transfer. On the other

hand, dispersed systems are characterized by the simultaneous flow of organically interrelated processes of heat and moisture exchange.

The study of thermal processes in such materials is carried out in two key directions.

1. Based on data gathering, solving and analyzing a unified system of equations of heat and mass transfer. It is necessary to know the thermal and mass transfer characteristics of the material. This alternative finds more and more applications; however, its practical implementation at present is associated with considerable difficulties: the need to take into account a large number of characteristics that vary widely depending on the structure of the material and the conditions of experience.

Currently, rather complex nature of these dependencies is far from being fully understood. Otherwise, when precise quantitative relationships are established between the complex of thermal characteristics and the properties and structure of the material, complications arise in solving non-linear heat conduction problems. As a rule, to bring the solution to a productive end, it is necessary to take the thermal characteristics of the substance within certain limits constant.

2. Based on the representation of the structure of the material as a quasi-homogeneous body. In this case, the task of finding the temperature field is reduced to solving one heat conduction equation, complicated by the action of internal sources and, first of all, by the presence of variable thermal characteristics. With this approach, it is necessary to take into account only the thermal characteristics of the material such as  $\lambda$ ,  $k$ ,  $b$  and  $C$ .

In this case, the characteristics are not taken as constant ones: they reflect mutual impact of all possible processes in the material, in addition to thermal conductivity, such as convection, radiation and, above all, mass transfer. Therefore, it is rather unjustified to call them thermal characteristics and the term thermophysical characteristics is proper to describe them. We emphasize that such a narrowing of the

problems solved on the basis of the second principle as compared with the first one is undoubtedly a disadvantage, since it is not possible to simultaneously find the humidity and temperature fields.

However, other obvious advantages of the second principle: its relative simplicity, a significantly smaller number of necessary parameters, the ability to bring solutions up to the operational view – all of the above allow recommending it in a significant number of engineering-type tasks.

This technique is especially effective when it is necessary to jointly evaluate heat and mass transfer, if boundaries are set within which it ends and the boundaries of the temperature and humidity under study are precisely defined, as well as the structural features of the material under study are noted.

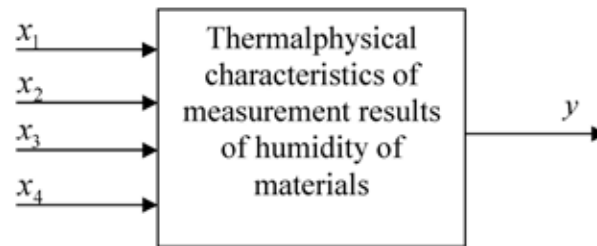
Thus, we believe that in order to assess the thermal properties of dispersed materials and to understand the basic thermal processes occurring in them under the most different modes and conditions, it is necessary and sufficient knowledge of four parameters  $\lambda$ ,  $k$ ,  $b$  and  $C$ , and reflected as effective characteristics of the entire set of heat exchange and mass transfer processes occurring in the material. The choice of the first or second option is not an alternative. On the contrary, they should complement each other.

To facilitate the selection, we put forward a factor that distinguishes the extremum-type tasks. The task is extreme if its goal is to search for the extremum of a certain function. To establish which of the two problems is extreme, one must turn to their formulations and find out where the requirements of extremality are satisfied. In task 1, it is required to establish a relationship between the moisture content of the material and three factors. It is not determined here what thermal conductivity is optimal, and it is not required to optimize it.

In task 2, it is necessary to increase the reliability of the device. The very formulation of the problem indicates that the existing reliability does not satisfy the experimenter and requires the search for such

conditions under which its values will increase. Tasks of type 1 will be called interpolational, and of type 2 – extremal.

To describe the object of study, it is convenient to use the concept of a cybernetic system, which is



$x_1$  - humidity;  $x_2$  - gaseous phase;  $x_3$  - solid phase;  $x_4$  - temperature

Figure 1. “Black box” schematic

For experiments, one must be able to influence the behavior of the “black box”. All methods of such exposure, we denote by letter “x” and call them factors. In solving the problem, we will use mathematical models of the object, i.e. the equation relating the interrelation between optimization parameter and the factors. This equation in general form can be written as follows:

$$y = \phi(x_1, x_2, \dots, x_k), \quad (1)$$

where  $(\phi)$ , means: «as a function of».

Such a function is called a *response function*. Later we will look at how this function can be selected and built. Now we can comprehend how the conditions for conducting experiments are obtained in the experiment that we are going to conduct.

Each factor in the experience can take one of several values. Such values will be called levels. It may turn out that the factor is capable of taking infinitely many values (continuous series). However, in practice, the accuracy with which a certain value is established is not infinite.

Therefore, we can assume that every factor has a certain number of discrete levels. This assumption greatly facilitates the construction and analysis of the “black box” and experiment, and also simplifies the assessment of their complexity.

A fixed set of levels of factors determines one of the possible states of the “black box”. At the same time, this is the essence of the conditions for con-

ducting one of the possible experiments. If we enumerate all possible sets of states, then we get a complete set of various experiments.

schematically shown in Fig. 1. Sometimes such a system is called a “black box”. The arrows on the right depict the numerical characteristics of the research objectives. We denote them by the letter “y” and call them optimization parameters.

ducting one of the possible experiments. If we enumerate all possible sets of states, then we get a complete set of various experiments.

To find out the number of different states, the number of levels of factors (if it is the same for all factors) is enough to raise to the power of the number of factors  $k$ :  $p^k$ , where  $p$  is the number of levels. In addition, it is obvious that the real objects that we encounter every day, have significant complexity. So, at first glance, a simple system with four factors on four levels is very complex.

In these conditions, it is necessary to abandon such experiments, which include all possible experiments: the search is too large. The question arises: how many and what kind of experiments should be included in the experiment to solve the problem? This is where experiment planning comes to the rescue.

However, it should be borne in mind that when planning an experiment, it does not matter what properties the object of a study has. We indicate two basic requirements that have to be considered.

First of all, it is important whether the experimental results are reproduced on the object. We will select some levels for all factors and in these conditions we will conduct an experiment. Then we repeat it several times at unequal intervals and compare the values of the optimization parameter.

The scatter of these values characterizes the reproducibility of the results. If it does not exceed a certain predetermined value (our requirements for the accuracy of the experiment), then the object satisfies the requirement of reproducible results, and if it exceeds, it does not satisfy this requirement. We will consider only those objects for which the requirement of reproducibility is satisfied.

Planning an experiment implies active intervention in the process and the possibility of choosing in each experience the levels of factors that are of interest. Therefore, this experiment is called active. The object on which an active experiment is possible is called a managed one. This is the second requirement for the object of study.

In practice, there are no absolutely controllable objects. A real object is usually affected by both controlled and unmanaged factors. Uncontrollable factors affect the reproducibility of the experiment and cause its violation. If the requirement of reproducibility is not met, one must turn to the active – passive experiment.

Perhaps poor reproducibility is explained by the action of a factor that is systematically changing (drifting) in time. Then you need to refer to a special method of planning. Experiment, finally, it is possible that all factors are uncontrollable. In this case, the problem arises of establishing a connection between the optimization parameter and the factors from the results of observations of the object's behavior, or, as they say, from the results of a passive experiment (7). We will not consider these cases. Our goal is to present the methods of planning an extreme experiment for reproducible controlled static objects.

Planning an extreme experiment is a method of choosing the quantity and conditions for conducting experiments that are minimally necessary for finding the optimal conditions, that is, for solving the problem posed.

Starting to get acquainted with the planning of an extreme experiment, one must keep in mind that when optimizing, the so-called deterministic

approach is widespread, especially widely used in chemistry. In this case, it is proposed to build a physical model of the process based on a thorough study of the mechanism of the phenomena (for example, kinetics, hydrodynamics), which makes it possible to obtain a mathematical model of the object in the form of a system of differential equations.

Undoubtedly, the deterministic and static (associated with the planning of the experiment) approaches should reasonably complement each other, and not be contrasted.

The use of all possible experiments to obtain a model leads to absurdly large experiments. The task of choosing the experiments necessary for the experiment, methods of mathematical processing of their results and decision-making – this is the task of planning an experiment. A special case of this task is the planning of an extreme experiment, that is, an experiment designed to find the optimal conditions for the functioning of an object.

Using the principles of regression and correlation analysis in the processing of experimental data, it is possible to find a relationship between the variables and optimum conditions. In both cases, the mathematical model is the response function, which relates the optimization parameter characterizing the results of the experiment, with the variable parameters with which the experimenter varies during the experiments:

$$y = \phi(x_1, x_2, \dots, x_k). \quad (2)$$

It is customary to call independent variables as  $x_1, x_2, \dots, x_k$  factors, the coordinate space with the coordinates  $x_1, x_2, \dots, x_k$  – the factor space, and the geometric image of the response function in the factor space – the response surface.

This surface can be represented as a contour diagram (Fig. 1), reflecting, for example, the dependence of the reaction yield (in%) on temperature and concentration. In this case, the optimal output is concentrated in a small area of the surface. If the experiments and their processing were carried out by the traditional method (when only one variable

changes, and all the others are kept constant) there is a high probability of falling into a false optimum.

When using statistical methods, the mathematical model is represented as a polynomial – a segment of the Taylor series into which the unknown relation (2) decomposes:

$$y = \beta_0 + \sum_{j=1}^k \beta_j x_j + \sum_{u,j=1;u \neq j}^k \beta_{uj} x_u x_j + \sum_{j=1}^k \beta_{jj} x_j^2 + \dots, (3)$$

where  $\beta_j = \frac{\partial \phi}{\partial x_j} \Big|_{\bar{x}=0}$      $\beta_{uk} = \frac{\partial^2 \phi}{\partial x_u \partial x_k} \Big|_{\bar{x}=0}$      $\beta_{jj} = \frac{\partial^2 \phi}{\partial x_j^2} \Big|_{\bar{x}=0}$ .

Due to the fact that in a real process there are always uncontrollable and uncontrollable variables, the change in magnitude is random. Therefore, when processing the experimental data, so-called sample regression coefficients  $b_0, b_j, b_{uj}, b_{jj}$  are obtained, which are estimates of theoretical coefficients  $\beta_0, \beta_j, \beta_{uj}, \beta_{jj}$ .

The regression equation derived from the experience will be written as follows:

$$y = b_0 + \sum_{j=1}^k b_j x_j + \sum_{u,j=1}^k b_{uj} x_u x_j + \sum_{j=1}^k b_{jj} x_j^2 + \dots (4)$$

The coefficient  $b_0$  is called the free term of the regression equation; the coefficients  $b_j$  are linear effects; the coefficients  $b_{jj}$  are quadratic effects; coefficients  $b_{uj}$  – interaction effects.

The coefficients of equation (4) are determined by the least squares method from the condition:

$$\varphi = \sum_{i=1}^N (y_i - y_i)^2 = \min. (5)$$

Here:  $N$  – the sample size from the entire set of values of the parameters studied. The difference between the sample size  $N$  and the number of links imposed on this sample  $l$  is called the number of degrees of freedom of the sample  $f$ :

$$f = N - l (6)$$

When finding a regression equation, the number of links is equal to the number of coefficients to be determined.

When studying the dependence on one variable parameter, it is useful to determine the type of regression equation by constructing an empirical regression line. For this, the entire range of variation

on the correlation field (Fig. 2) is divided into different intervals  $v$ . All points in this interval  $\Delta x_j$  belong to its middle  $x_j$ . To do this, calculate the private average for each interval  $\bar{y}_j$ :

$$\bar{y}_j = \frac{\sum_{i=1}^{n_j} x_{ji}}{n_j} (7)$$

Here:  $n_j$  – number of points in interval  $\Delta x_j$ .

$$\sum_{j=1}^k n_j = N (8)$$

where  $k$  – number of intervals of division;  $N$  – selection volume.

Then the points  $(x_j, \bar{y}_j)$  are connected in series with straight line segments. The resulting broken line is called an empirical regression line of  $y$  by  $x$ . By the form of the empirical regression line, you can choose a regression equation  $y = f(x)$ .

The task of determining the parameters of the regression equation is reduced practically to the determination of the minimum of the function of several variables. If a

$$y = f(x, b_0, b_1, b_2, \dots) (9)$$

there is a function that is differentiable and requires  $b_0, b_1, b_2, \dots$  to choose so that

$$\varphi = \sum_{i=1}^N [y_i - f(x_i, b_0, b_1, b_2, \dots)]^2 = \min. (10)$$

A necessary condition for the minimum  $\varphi(b_0, b_1, b_2, \dots)$  is the fulfillment of equations:

$$\frac{\partial \varphi}{\partial b_0} = 0, \frac{\partial \varphi}{\partial b_1} = 0, \frac{\partial \varphi}{\partial b_2} = 0 \dots (11)$$

or

$$\left. \begin{aligned} \sum_{i=1}^N 2[y_i - f(x_i, b_0, b_1, b_2, \dots)] \frac{\partial f(x_i)}{\partial b_0} &= 0 \\ \sum_{i=1}^N 2[y_i - f(x_i, b_0, b_1, b_2, \dots)] \frac{\partial f(x_i)}{\partial b_1} &= 0 \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \end{aligned} \right\} (12)$$

Thereafter we receive:

$$\left. \begin{aligned} \sum_{i=1}^N y_i \frac{df(x_i)}{db_0} - \sum_{i=1}^N f(x_i, b_0, b_1, b_2, \dots) \frac{df(x_i)}{db_0} &= 0 \\ \sum_{i=1}^N y_i \frac{df(x_i)}{db_1} - \sum_{i=1}^N f(x_i, b_0, b_1, b_2, \dots) \frac{df(x_i)}{db_1} &= 0 \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \end{aligned} \right\} (13)$$

The system of equations (13) contains as many equations as the unknown coefficients  $b_0, b_1, b_2, \dots$  enters the regression equation and is called in mathematical statistics the system of normal equations.

The value  $\Phi \geq 0$  for any  $b_0, b_1, b_2, \dots$ ; therefore, it must necessarily have at least one minimum. There-

fore, if the system of normal equations has a unique solution, then it is the minimum for the quantity  $\Phi$ . It is impossible to solve the system (12) in general. To do this, you need to specify a specific form of the function  $f$ .

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## APPLICATION OF ROTOR-FILTER DUSTY GAS CLEANER IN INDUSTRY AND IDENTIFYING ITS EFFICIENCY

**Abstract.** In the article, given description about experiments on rotor – filter’s cleaning efficiency which operates in wet method in order to clean manufacturing toxic gases. Apparatus is used for cleaning dusty gases which are emitted in manufacturing of superphosphate minerals from three stages mixing reactors and drum drier granulator. Rotor-filter gas cleaner is used in aspiration department.

For experimenting different parameters were selected: hole in the filter material has different diameters  $d_f = 2, 3, 4$  mm; rotation numbers of rotor are 15, 25, 35 rotation/min; velocity of gas in the apparatus  $v_g = 7.67 \div 34.4$  m/s (The velocity range is close to the speed range imposed on dust-cleaning devices in industry-wide wet methods); the diameters of the fluid strainer hole are  $d_{st} = 1; 2; 3$  mm. The experiments were conducted in air and water systems at a temperature of  $20 \pm 2$  °C.

To absorb secondary hydrogen-fluoride (2HF) gas, the absorbents were selected and the wastewater neutrality increased from 5 Ph to 9.6 Ph by absorbing it into the absorbent fluid.

When applying fertilizer dust from drum granulator-dryer, it is found that the efficiency of cleaning is 4.6% higher than the existing wet method, and 2.5 times less water consumption per 1 m<sup>3</sup>.

Acceptable values were selected based on the results of the experiment.

**Keywords:** rotor filter, secondary gas, mixing reactor, filter material, wastewater, absorbent, scrubber, superphosphate.

### **Research purpose:**

Learn construction and scientific research of preferences and limitations of apparatus which operates cleaning process in wet method. By analyzing of that searched scientific information rotor filter apparatus’s new construction was designed [1; 2; 3; 4].

In experimental model of rotor filter dusty cleaner main factors which impact to cleaning process were identified (1 figure).

Hydraulic loss, gas velocity, gas flow, liquid flow and resistances in apparatus were determined by experiments. Different materials were chosen for apparatus. Initial requirements and technical tasks for apparatus were devised by the result of theoretical and real experiments.





Figure 1. Total view of rotor-filter dusty gas cleaner's laboratory model

### Research object

Experiments identifying of dusty gas cleaning efficiency in apparatus were held in both the department of technological machines and equipment in Ferghana polytechnic institute and in "Farg'onaazot" JS plat's super phosphate mineral fertilizers manufacturing shop.

Firstly, dusty gas cleaner connected to the secondary line of dusty gases which were emitted in phosphate mineral fertilizers manufacturing shop and then to the line of dusty gases which were emitted from the drum drier (figure 2).

### Research method

Experiments in terms of defining cleaning efficiency of rotor filter apparatus which were held on basis of different intervals of parameters and working factors.

1. Admissible gas velocity for the model of apparatus is  $7.67 \div 34.4$  m/s.
2. Revolution of rotors per minute  $n = 15 \div 45$ .
3. Liquid flow  $68.1 \div 178.2$  liters /h.

In defining cleaning efficiency of apparatus, АСНЕРАТОР M-822 mark gaz analyser (operating temperature- $10 \div 35$  °C, absorbing flow of air by filter  $31$  m<sup>3</sup>/h? admissible resistance coefficient  $3 \pm$

$\pm 0.15$  kPa ( $300 \pm 15$  mm. column of water)) and sequence formule were used [5; 6].

$$\eta = \frac{G_1 - G_2}{G_1} 100\% \quad (1)$$

where:  $\eta$  – apparatus's cleaning efficiency;  $G_1$  – amount of dust in influent air compound to apparatus;  $G_2$  – amount dust in effluent air compound from the apparatus.

Two stages of experiments were held in order to identify the dust in air composition and cleaning of toxic gas.

**Stage 1:** Studies on the absorption of secondary toxic gases ( $2\text{HF}$  and  $\text{CO}_2$ ) from the three-stage mixing reactors into the absorbent fluid in the rotor filter apparatus and the determination of acid neutrality in waste water; The diameter of the filtration net material  $d_f = 3$  mm, rotor rotation  $n = 25$  rotation/min, fluid dispersion hole diameter  $d_{sh} = 3$  mm, gas velocity  $v_g = 7.67 \div 34.4$  m/s and ambient temperature  $20 \pm 2$  °C. have been reached.

According to the technological regulations the laboratory analysis of the absorbance of the toxic gases formed by the reaction of sulfuric acid and phosphorite in the mixing reactors mounted on lig-

nin and the neutrality of the acid in the wastewater. The substances for the absorption were selected according to <sup>1</sup>SSR12.1.005–88, <sup>1</sup>SSR17.2.4.08–90. According to it, taking into account the absorption of secondary toxic gas and rapid adaptation to the active environment, a solution of calcium technical soda, sodium carbonate soda and 10.20.30% water

technical shampoo was prepared. The experiments on each selected absorbents were conducted depending on the gas velocity entering the rotor-filter apparatus. The duration of each experiment was 30 minutes. The laboratory tests to determine the neutrality of the gas absorbed by the absorptive liquid medium are presented in (table 1).

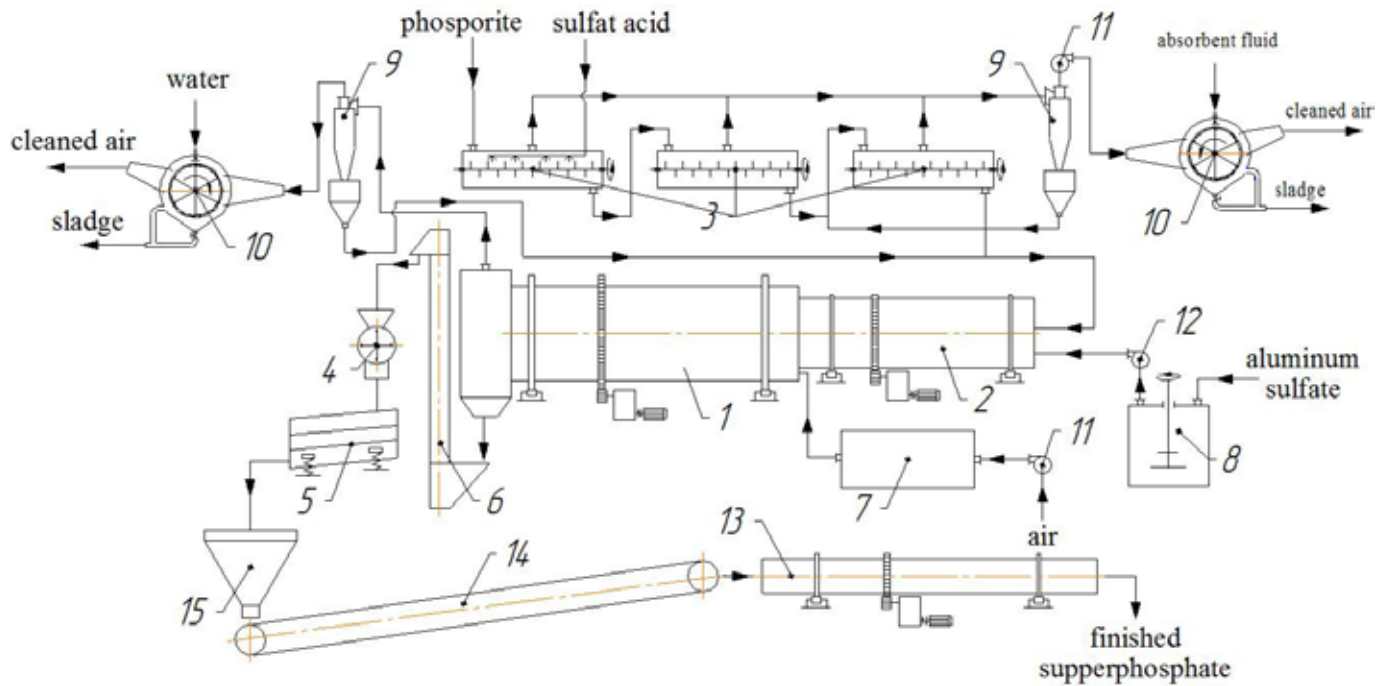


Figure 2. Technological scheme manufacturing of super phosphate: 1 – drum drier; 2 – drum granulator; 3 – horizontal reactor with mixer; 4 – hammer mill; 5 – bolting machine; 6 – bucket elevator; 7 – calorifer; 8 – vertical reactor with mixer; 9 – cyclone НЮОГАЗ; 10 – rotor filter gas cleaner; 11 – fan; 12 – centrifugal pump; 13; 14 – conveyor; 15 – feeder

Table 1.

10% solution			
№	Technical white soda ash	Calcium-carbonate soda	Technical shampoo
1	2	3	4
0°	6.5	6.14	5.8
30°	6.1	5.9	5.61
45°	5.85	5.67	5.12
60°	5.34	5.1	4.83
90°	5.1	4.79	4.42
20% solution			
№	Technical soda ash (white)	Calcium-carbonate soda	Technical shampoo
0°	7.9	7.1	6.8
30°	7.4	6.4	6.1
45°	7.15	6.2	5.8

1	2	3	4
60°	6.8	6.1	5.4
90°	6.3	6.0	5.0
30% solution			
Nº	Technical white soda ash	Calcium-carbonate soda	Technical shampoo
0°	9.46	8.7	8.1
30°	9.15	8.45	7.6
45°	8.73	8.1	7.19
60°	8.4	7.78	6.84
90°	8.12	7.4	6.5

When the acid content of the waste water required by technology is greater than 7Ph, the waste water is considered to be alkaline and can be reused in industry. The scrubber currently used in the manufacturing process is  $3.5 \div 5.0\text{Ph}$ .

Table 1 shows that the absorption of toxic gas into the absorbent liquid and the increase in wastewater depend on the rate of gas entering the unit.

The following results were obtained in the experiments to determine the effective absorption of toxic gas into the absorbent liquid.

#### **Absorbent added as 10% solution to the water.**

1. In the technical soda ash – interval velocity of gas is  $7.67 \div 34.4$  m/s and  $51 \div 65\%$  poisonous gas is absorbed in liquid.

2. In the calcium-carbonate soda- interval velocity of gas is  $7.67 \div 34.4$  m/s and  $47.9 \div 61.4\%$  poisonous gas is absorbed in liquid.

3. In the technical shampoo- interval velocity of gas is  $7.67 \div 34.4$  m/s and  $44.2 \div 58\%$  poisonous gas is absorbed in liquid.

#### **In the added absorbent as 20% solution to the water.**

1. In the technical soda ash – interval velocity of gas is  $0.31 \div 34.47.67 \div 34.4$  m/s and  $63 \div 79\%$  poisonous gas is absorbed in liquid.

2. In the calcium-carbonate soda- interval velocity of gas is  $7.67 \div 34.4$  m/s and  $60 \div 71\%$  poisonous gas is absorbed in liquid.

3. In the technical shampoo- interval velocity of gas is  $7.67 \div 34.4$  m/s and  $50 \div 68\%$  poisonous gas is absorbed in liquid.

#### **In the added absorbent as 30% solution to the water.**

1. In the technical soda ash – interval velocity of gas is  $7.67 \div 34.4$  m/s and  $81.2 \div 94.6\%$  poisonous gas is absorbed in liquid.

2. In the calcium-carbonate soda- interval velocity of gas is  $7.67 \div 34.4$  m/s and  $74 \div 87\%$  poisonous gas is absorbed in liquid.

3. In the technical shampoo- interval velocity of gas is  $7.67 \div 34.4$  m/s and  $65 \div 81\%$  poisonous gas is absorbed in liquid.

Based on the results of the experiment, a graph of dependence of the shear degree on the ventilator of the absorption efficiency (Figure 3) was made.

The choice of the optimal value of hydraulic resistance in the exhaust gas exhaust pipe was analyzed according to the above graphic. It was found that the efficiency of cleaning at a gas velocity of  $23.8$  m/s was higher than the technical requirements and that the hydraulic resistance of the smoke pipe was at optimum value.

#### **STAGE 2: cleaning of dusty gas which flows from the drum drier-granulator in the manufacturing mineral fertilizers was experimented.**

For the experiment, filter material with diameter  $d_{\phi} = 3$  mm, revolution of rotor per minute  $n = 25$ , diameter of the connecting pipe hole  $d_{uu} = 1,2,3$  mm, gas velocity at apparatus  $v_g = 7.67 \div 34.4$  m/s, fluid flow rate is  $0.072 \div 0.178$  m<sup>3</sup>/h, ambient temperature is  $20 \pm 2$  °C, dust temperature is  $80-120$  °C.

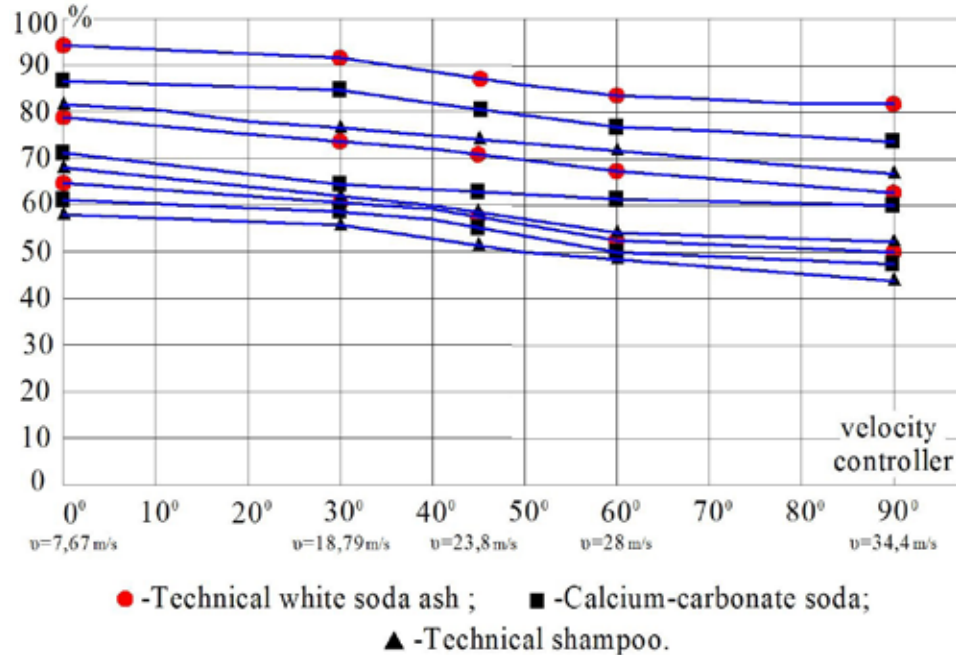


Figure 3. Influence of the degree of sheber installed on the ventilator on cleaning efficiency: 1 – 30% liquid solution prepared; 2–20% liquid solution prepared; 3–10% liquid solution prepared;

The efficiency of the cleaning was determined experimentally, depending on the rate of gas entering the rotor-filter apparatus and the change in fluid flow.

The multicomponent gas analyzer ANKT-410–410 was used to determine the degree of purification. The results of the experiment are presented in (Table 2).

Table 2.

connecting pipe hole's diameter $d=1\text{ mm}$					
No	$v_{1\text{ sheber } 90}^0$	$v_{2\text{ sheber } 60}^0$	$v_{3\text{ sheber } 45}^0$	$v_{4\text{ sheber } 30}^0$	$v_{5\text{ sheber } 0}^0$
<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
	34.4	28	23.8	18.79	7.67
0	79.8	81.4	82.4	83.8	84.7
10	89.7	92.9	93.5	94.7	95.6
20	90.8	93.7	94.8	95.9	95.1
30	92.3	94.5	95.1	96.4	96.9
connecting pipe hole's diameter $d=2\text{ mm}$					
No	$v_{1\text{ sheber } 90}^0$	$v_{2\text{ sheber } 60}^0$	$v_{3\text{ sheber } 45}^0$	$v_{4\text{ sheber } 30}^0$	$v_{5\text{ sheber } 0}^0$
	34.4	28	23.8	18.79	7.67
0	81	82.3	83	84.2	85.4
10	90.4	93.6	94.7	95.3	96
20	91.8	94.2	95.2	96.4	96.9
30	93.2	95.1	95.6	96.9	97.1
40(36)	93.6	95.8	96.4	97	98.2
connecting pipe hole's diameter $d=3\text{ mm}$					
No	$v_{1\text{ sheber } 90}^0$	$v_{2\text{ sheber } 60}^0$	$v_{3\text{ sheber } 45}^0$	$v_{4\text{ sheber } 30}^0$	$v_{5\text{ sheber } 0}^0$
	34.4	28	23.8	18.79	7.67

<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
0	84	84.7	85.3	87.1	88.2
10	93.6	95.2	95.9	96.7	97.8
20	94	95.7	96.2	97.1	98.3
30	94.3	96	96.9	97.8	98.5
40(42)	94.8	96.5	97.6	98	98.9

Based on the experimental results, a histogram of the efficiency of cleaning of the fluid consumption and gas velocity was constructed. The colored

growth lines in the histogram represent the amount of fluid determined by the fluorescence scale readings of the device.

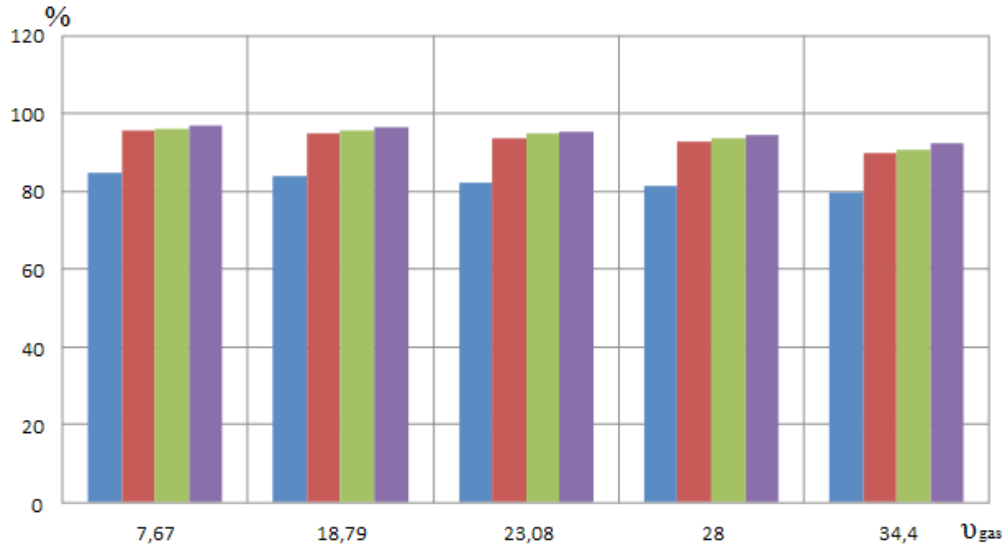


Figure 4. Rotor filter apparatus's nipple diameter is 1mm, dynamics of cleaning efficiency change depending on gas velocity and liquid flow: ■ → liquid flow 68.1 l/hour; ■ → liquid flow 85.3 l/hour; ■ → liquid flow 124.7 l/hour; ■ → liquid flow 141.7 l/hour

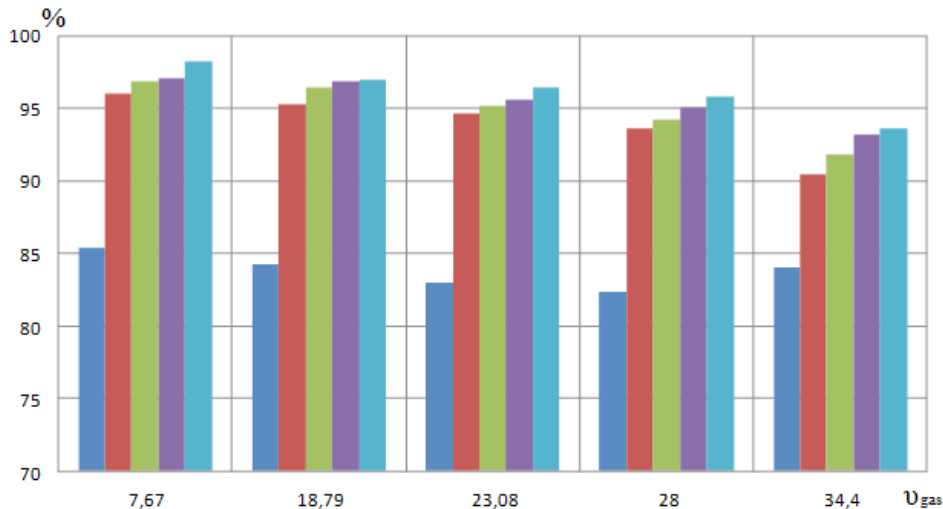


Figure 5. Rotor filter apparatus's nipple diameter is 2mm, dynamics of cleaning efficiency change depending on gas velocity and liquid flow: ■ → liquid flow 71 l/hour; ■ → liquid flow 86.95 l/hour; ■ → liquid flow 130.45 l/hour; ■ → liquid flow 147.54 l/hour; ■ → liquid flow 168.2 l/hour

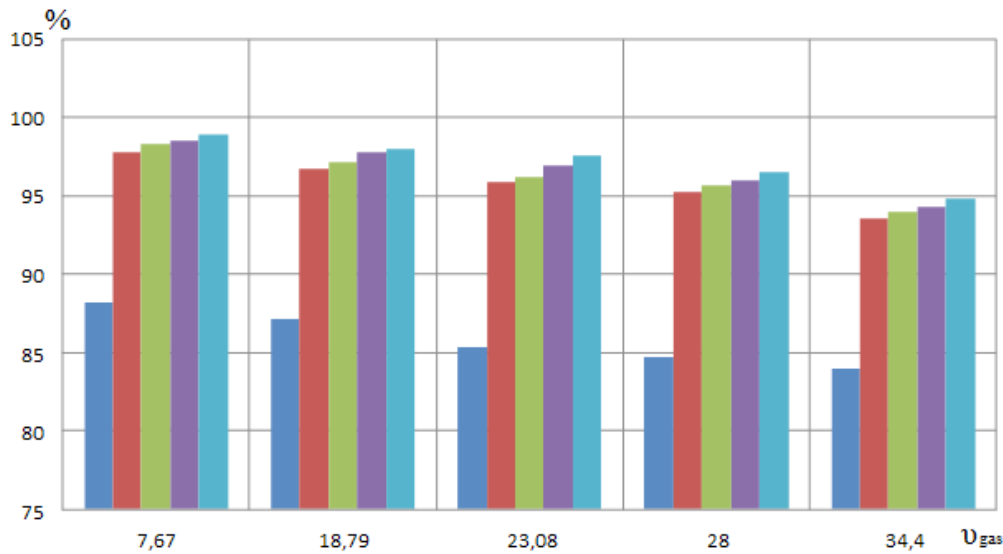


Figure 6. Rotor filter apparatus's nipple diameter is 3mm, dynamics of cleaning efficiency change depending on gas velocity and liquid flow: ■ → liquid flow 72 l/hour; ■ → liquid flow 89.55 l/hour; ■ → liquid flow 135.33 l/hour; ■ → liquid flow 152.5 l/hour; ■ → liquid flow 178.2 l/hour

### Chose optimal working parameters

The choice of the optimal value of hydraulic resistance in the exhaust pipe for exhaust gas was analyzed according to the graph above (see Figure 3). It was found that the efficiency of cleaning at a gas velocity of 23.8 m/s was higher than the technical requirements and that the hydraulic resistance of the smoke pipe was at optimum value.

The choice of the optimal value of dust suppressors and hydraulic resistance in the smoke pipe was analyzed in (Table 2) above. It was found that when the gas entering the device was 18.79 m/s, the efficiency of the treatment was higher than the technical requirements and that the hydraulic resistance in the exhaust pipe was of optimum value.

The rotor-filter apparatus has been compared with existing devices which works in wet methos.

### Conclusion

1. Experimental results obtained when using rotor-filter apparatus for purification of hydrogen-fluoride gas and phosphorite dust from the mixing

reactors in the process of producing superphosphate, as well as in the wet method of purification with a wet cleaning method. 4.6% higher, 1m<sup>3</sup> air purification was 2.5 times less, and wastewater discharge (Ph)  $\alpha$  increased from 5 to 9.6, which is 1.8 times higher.

The choice of the optimal value of dust suppressors and hydraulic resistance in the smoke pipe was analyzed in (Table 2) above. It was found that when the gas entering the device was 18.79 m/s, the efficiency of the treatment was higher than the technical requirements and that the hydraulic resistance in the exhaust pipe was of optimum value.

Based on the experience we can draw the following conclusion.

1. Rotor-filtering apparatus can be used to purify the dusty air produced during the production of sulfate.
2. The liquid supplied to the rotor-filter apparatus can be used in the process of purification of toxic gases by adding absorbents to the liquid.

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**NOTE:**

<sup>1</sup>See also: State standart requirement.

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## **HYDRODYNAMICS OF NON SINKING DISPERSE PHASE HOLDING FILTER IN BUBBLING EXTRACTOR**

**Abstract.** In the article, hydrodynamics of a fiberglass fitted with L–L–G system to prevent leakage of supercooled droplets in the mixing phase of the solid phase with inert gas in the mixing zones was studied.

Theoretical studies have suggested a formula for determining the rate of fluid leakage. With this formula, if the resistance coefficient is known, the rate of fluid flowing through the surface of the filter and its associated flow can be determined. As a result, the flow of fluids in the mixing zones of the apparatus was supplied.

To determine the resistance coefficient of the filter, a pilot study was performed on the experimental device of the apparatus. The fibers were selected for the filter and the fibers' sizes were defined. As a result of the research, a formula for determining the contact surfaces, depending on the mass of the glass fibers, which retains the droplets of small particles of heavy fluid, was proposed.

The filter resistance coefficients were determined based on the relative contact surfaces of the fibers mounted on three different base racks and the fluids with three types of surface tension values. Depending on the results of the experiment, the empirical formulas for calculating the resistance coefficient of fiberglass filters installed on the base racks were recommended.

**Keywords:** bubble extractor, filter, contact surface, glass fiber, base set, external stirring zone, dispersing phase, drop, resistance coefficient, heavy liquid.

### **Introduction**

The use of pneumatic mixing extractors in fluid extraction processes involves less metallic wastewater than the mechanical mixing extractors, smaller than the production area, and has a simplicity and reliability. Such pneumatic mixing extractors are known as barbatal extractors in literature and are among the extraction apparatus in the fluid-liquid system and can be used in chemical, petrochemical, hydrometallurgical, pharmaceutical, biotechnology and food industries [1].

The construction of the paddle-forming bladed extractor [1] is made by us and its constructional structure allows the drainage zone formed in the lower part of the outer mixing zone to escape to the top of the apparatus without falling into small particles of heavy particles. To eliminate this, a floppy fiber was installed on the patrol booth that formed the outer stirrup.

**The principle of extruder performance is as follows.**

Lightweight fluid (ES) is a part of the gas distribution gear 5. The same pipe flows through heavy



holes (OS) through the holes 8 of the tube 7. In the Patrol 3, the mixture of fluid mixture from bottom to top is mixed intensely by means of a rectifying inert gas through the holes 6 in the gas dispenser. This part of the gas collects the liquids and accumulates in the gas chamber 2.

At the same time, the rest of the inert gas is pumped through the hole 13 through the gas pipe 12 to the annular channels between the 3 and 4 patrol boards. This part of the inert gas, moving from the top to the bottom in transverse channels, passes through the flow of the mixture from the top to the bottom of the fluid. In this process, it mixes the fluid flow and accumulates in the gas heater under the set.

When the light fluid passes through the holes 14 and the adjacent glass fiber filters 15 at the bottom of the patrol 4, the particles of small particles that are mixed with it are sealed in the filter and, as a result of their interconnection, turn into large droplets and undergo gravity and inertial forces begins to sink. Light-weight fluid light fluid continues to move higher. Heavy liquid drops stop at the bottom of the canal made by 3 and 4 ports and flow through the slots 16 at the bottom of the post 4 and form a coat layer over the set 2.

The mounting position of the Patrol 4 allows the maximum utilization of the annular channel, allowing the light fluid to pass through the hole 14 and the fibrous fibrous filters 15. The bottom hinges 16 provide only heavy liquids.

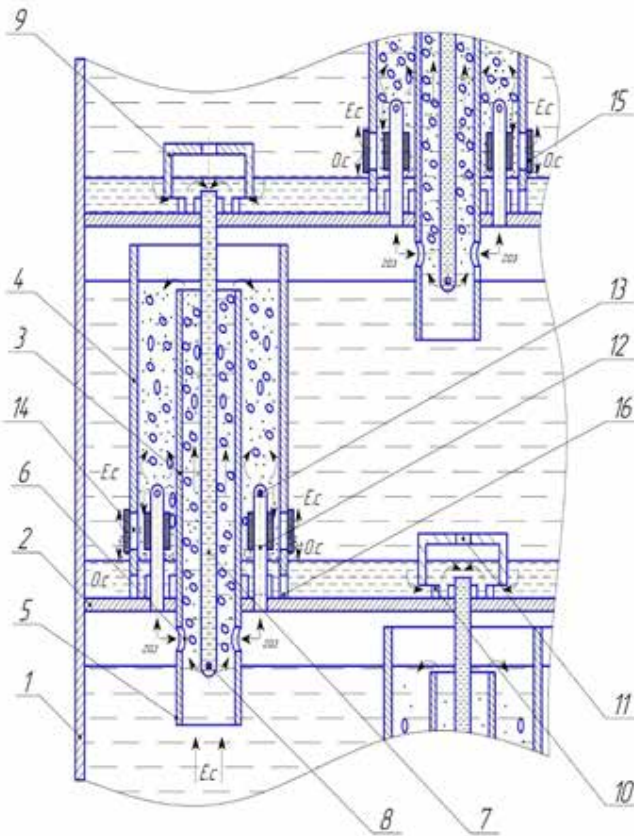


Figure 1. Internal part of bubble extractor      Figure 2. Overall view of experimental apparatus

The heavy liquid stopping at block 2 moves through pipes 7 through the hole 9 of the hood 9 and goes down the hole 8 through the bottom. The size of the hole 14 formed by the dimensions of

the Patrol 4 and the fibrous filament fibers 15 attached to the base plate are determined by ensuring that the light fluid has a moderate leak rate. The dimensions of the slots 16, which provide heavy

fluid flow through the annular channel formed at the bottom of the Patrol 4, are determined by the condition of leakage, regardless of the heavy liquor consumption.

With an external stirring zone of the apparatus the curing zone is in the form of a container, and the fluid flow passes through the filter. The filter resistance should be selected so that the fluid flows from the outside to the mixing zone. Otherwise, the hydrodynamic mode of the unit will be broken. This,

in turn, depends on the surface of the filter hinges, the size of the fiberglass filter beds and the specific contact surfaces of the glass fiber filter.

#### Research object and method.

The filter fluid speed depends on the total resistance of the filter. Theoretical and experimental research was carried out to determine these magnitude. The calculation scheme of the filter inserted into the outer mixing zone of the apparatus is shown in (Figure 3).

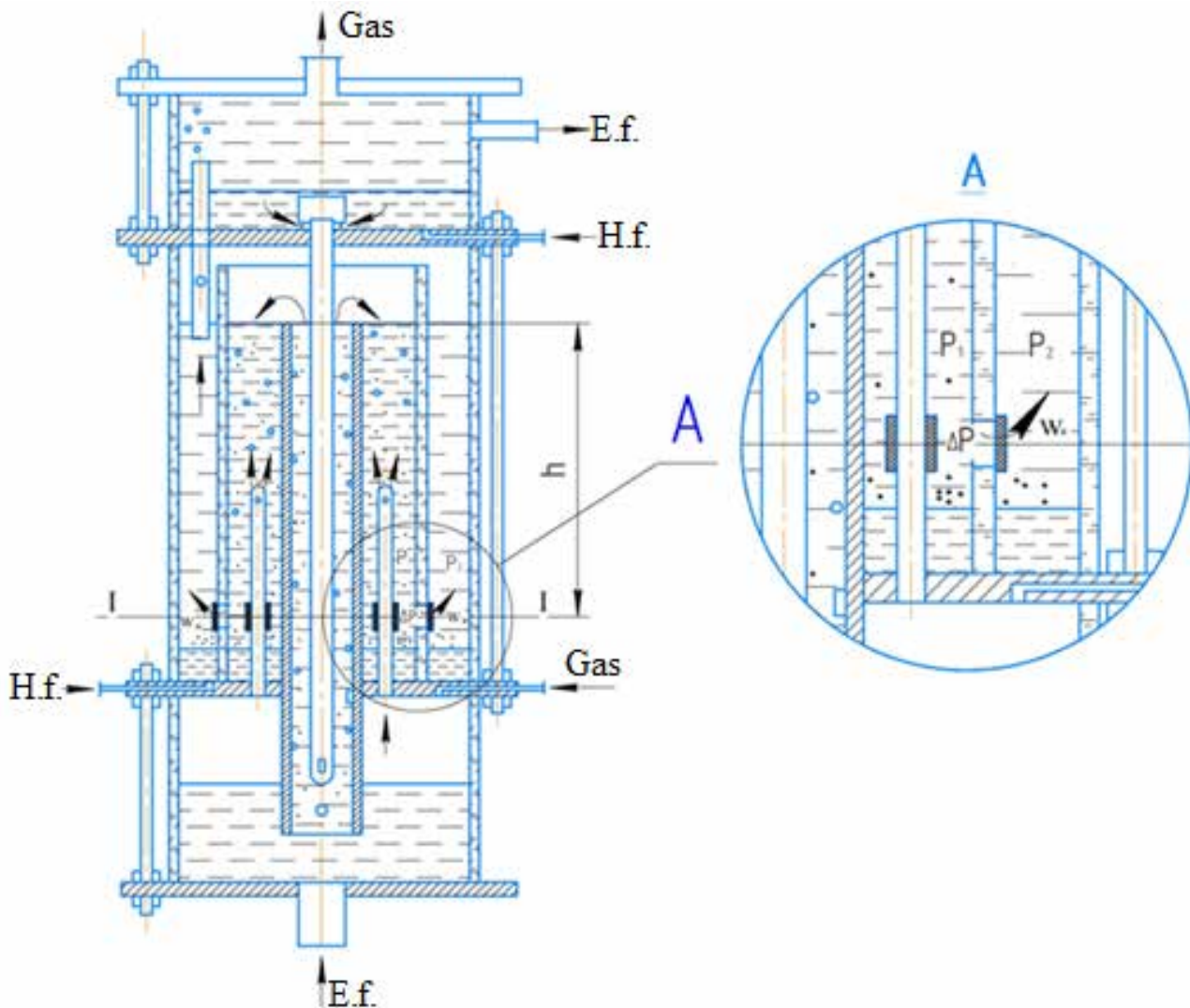


Figure 3. Filter's scheme for calculation

The center of the filter 1-1 is affected by the geometric pressure  $P_1$  on the annular channel of the device, the pressure  $P_2$  from the outside, and the hydrodynamic pressure of the fluid flowing through

the filter. Then the total pressure is calculated as follows

$$\Delta P + P_1 + P_2, \text{ Pa} \quad (1)$$

It is well known that the hydrodynamic pressure is determined as follows.

$$\Delta P = \xi_{\phi} \frac{\omega_c^2 \cdot \rho_{ap}}{2}, \text{ Па} \quad (2)$$

Where:  $\xi_{\phi}$  – filter resistance coefficient determined by experiences;  $\omega_c$  – fluid flow rate through filter, m/s;  $\rho_{ap}$  – density of the liquid mixture, kg/m<sup>3</sup>;

The geometric pressure is determined by the following formula:

$$P_1 = \rho_{ap} g h (1 - \varphi), \text{ Па} \quad (3)$$

Where:  $h$  – is the level of the fluid flowing down in to the center of the filter, mm;  $\varphi$  – value of gas in outer blending zone [2; 3].

External pressure to the center of the filter is defined as  $P_2$ .

$$P_2 = \rho g h, \text{ Па} \quad (4)$$

Where:  $\rho$  – density of dispersion phase, kg/m<sup>3</sup>.

If results of formula (2) (3) and (4) are placed to formula (1) it appears as follows.

$$\xi_{\phi} \frac{\omega_c^2 \cdot \rho_{ap}}{2} + \rho_{ap} g h (1 - \varphi) + \rho g h, \text{ Па} \quad (5)$$

(5) If  $\omega_c$  – is found by doing the necessary mathematical operations in equation (5) it will look as follows.

$$\omega_c = \sqrt{\frac{2 g h (\rho_{ap} (1 - \varphi) - \rho)}{\xi_{\phi} \rho_{ap}}}, \text{ м/с} \quad (6)$$

Since the external mixing zone of the device and the sedimentation zone are in the form of adjacent vessels, the pressure created by volume of gas  $\phi$  pressures equally. Then equation 6 will look as follows.

$$\omega_c = \sqrt{\frac{2 g h (\rho_{ap} - \rho) (1 - \varphi)}{\xi_{\phi} \rho_{ap}}}, \text{ м/с} \quad (7)$$

The internal and external mixing zones of the device are designed according to the volume of extraction fluid [4; 5]. Determining the rate of fluid leakage from the filter by using formula 6, depending on this rate, the difference between the amount of fluid flowed from the filter and the fluid flowing to the apparatus can be determined. This, in turn, requires the correct filter resistance of the filter to allow the fluid to flow smoothly when designing.

The object of the research is to use the experimental copy of the sampled extractor set up at the Fargonaazot JSC acetic acid regeneration shop for selecting fibrous filament material and detecting its resistance coefficient with the addition of non-depleting dispersed droplets to the gaseous phase of the apparatus (Fig. 2).

In Uzbekistan glass fiber is produced and that material was chose as a filter. Glass fiber is produced in the following marks ГОCT10499–95. ISO 9001:15.

Glass fiber measured through electronic balance and follow rates were obtained  $m=0.15$ ;  $0.25$ ;  $0.35$ ;  $0.45$  (figure 4).



Figure 4. Total view of glass fiber filter:  $m = 0.15$  gr;  $m = 0.25$  gr;  $m = 0.35$  gr;  $m = 0.45$  gr

Glass fibers were magnified 400 times in microscope **CM001-CYANS** and the pictures were taken in DSM camera (figure 5).

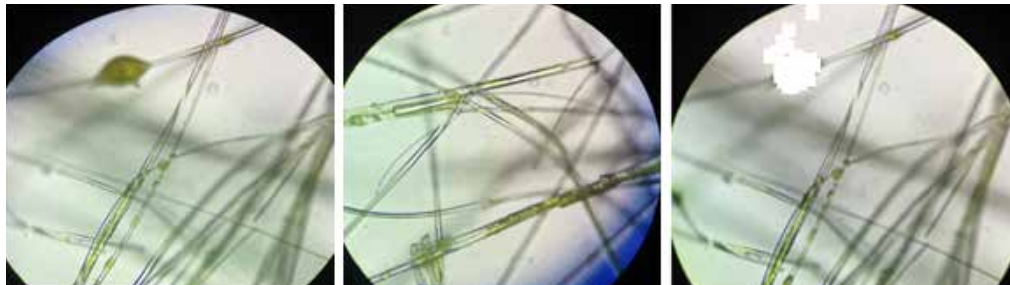


Figure 5. View of glass fibers in microscope



Average diameter of 400 times magnified view of glass fiber equals  $d_{ap} = 3092 \text{ m/km}$

If it divides to zoom

$$d = \frac{d_{ap}}{m} = \frac{3092}{400} = 8 \text{ m/km};$$

in order to determine the specific contact surface of glass fiber density determination formula is used

$$\rho = \frac{m}{V} \text{ kg/m}^3 \quad (8)$$

Where  $m$  – glass fiber’s mass, kg;  $V$  – glass fiber’s volume which is found as follow,  $\text{m}^3$ ;

$$V = \pi R^2 \cdot l \quad (9)$$

Where  $R$  – glass fiber’s radius, m;  $l$  – glass fiber’s length, m;

In order to find glass fiber’s length 8 formula is put to 7<sup>th</sup> formula

$$l_{mind} = \frac{m}{\pi R^2 \cdot \rho} \quad (10)$$

By using of 9<sup>th</sup> formula lengths of glass fiber were determined

1. If mass of glass fiber  $m = 0.15 \text{ gr}$ ,  $l = 1350 \text{ m}$ ;
2.  $m = 0.25 \text{ gr}$ ,  $l = 2261 \text{ m}$ ;
3. If mass of glass fiber  $m = 0.25 \text{ gr}$ ,  $l = 3166 \text{ m}$ ;
4.  $m = 0.25 \text{ gr}$   $l = 4071 \text{ m}$ .

In order to determine the specific contact surface of glass fiber its circle length needs to be found

$$l_a = 2\pi R \quad (11)$$

Total length of glass fiber is produced to its circle length, specific contact surface can be found as follows

$$S = l \cdot l_a \quad (12)$$

By putting of 9<sup>th</sup> and 10<sup>th</sup> formulas’ values to the 11<sup>th</sup> formula glass fiber’s specific contact surface can be found

$$S_\phi = \frac{m}{\pi R^2 \cdot \rho} \cdot 2\pi R = \frac{2m}{R \cdot \rho}, \text{ m}^2; \quad (13)$$

density of glass fiber  $\rho = 2200 \text{ kg/m}^3$ ; glass fiber radius  $R = 0.00004 \text{ m}$ ;

density of glass fiber  $\rho = 2200 \text{ kg/m}^3$ ; by using 6<sup>th</sup> formula glass fiber’s contact surface can be found.

1. If mass of glass fiber  $m = 0.15 \text{ gr}$ , surface is  $S_\phi = 0.034 \text{ m}^2$ ;

2. If mass of glass fiber  $m = 0.25 \text{ gr}$ , surface is  $S_\phi = 0.0565 \text{ m}^2$ ;

3. If mass of glass fiber  $m = 0.35 \text{ gr}$ , surface is  $S_\phi = 0.0791 \text{ m}^2$ ;

4. If mass of glass fiber  $m = 0.45 \text{ gr}$ , surface is  $S_\phi = 0.1 \text{ m}^2$ .



Figure 5. Filter installed nozzle and filter’s view

Apparatus nozzle which is replaced filter was made X18H10T mark metallic material. By its circle in per  $120^\circ$  3 holes with sizes  $B^*l = 15^*45$  mm were made. Per hole's surface is  $S_m = 0.00066 \text{ m}^2$ , filtr's will be established to it (figure 5).

In order to establish of glass fiber to nozzle's holes, metallic net was made X18H10T steel is used. The sizes of square holes are  $a = 0.25; 0.8; 1.2$  mm and thicknesses of the net are  $\delta = 0.08; 0.2; 0.25$  mm.

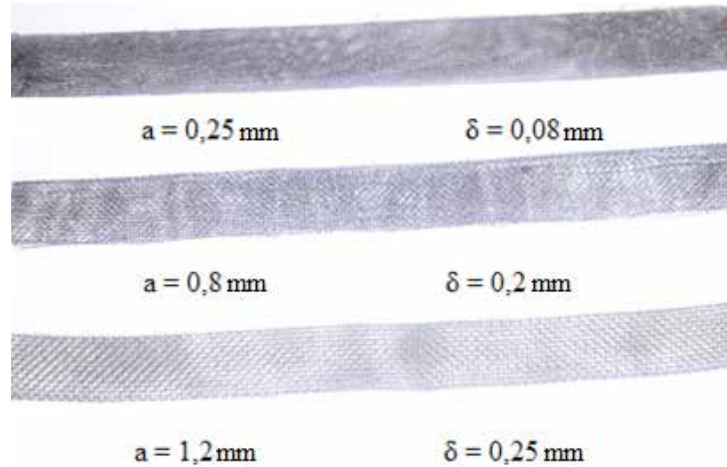


Figure 6. Views of the based nets

### Obtained results

Experiments were hold in the following sequences. Firstly, holes of the settling nozzles were shut and mixing zone of apparatus was filled with liquid. Internal diameter of the glass tube which forms mixing zone is  $d_1 = 56$  mm, value is  $V = 0.001 \text{ m}^3$ . On of the holes was opened and liquid's stream time was determined. This experimenting process was held iteratively a lot. Videos of experiment were taken by Canon EOS700D mark camera.

The resulting image was slowed down by the EDIUS (grass valley) program and the actual flow velocity was determined. At the next stages of the experiment,  $a = 0.25; 0.8$ ; Each of the 1.2 mm base brackets is fitted to the self-contained and base rings with respect to the specific bonding fibers of the glass fiber  $S = 0.034; 0.0565; 0.0791$ ; It was determined that the flow of liquids was determined in serial numbers at  $0,1 \text{ m}^2$ . Resistance coefficients were determined on the basis of the selected base supports

They were cut off according to the installation location of the apparatus and used as a base for holding both wrapped glass fibers (figure. 6). The height of the fluid level of the mixing zone in the filter hole is about 400 mm (figure 2). Different densities and surface tension fluids were used to determine the filter resistance ratios. Water,  $\rho = 1000 \text{ kg/m}^3$ ,  $\sigma = 0.073 \text{ N/m}$ ; antacid,  $\rho = 1198 \text{ kg/m}^3$ ,  $\sigma = 0.038 \text{ N/m}$ ; butyl acetate,  $\rho = 888 \text{ kg/m}^3$ ,  $\sigma = 0.0248 \text{ N/m}$ .

and the relative contact surfaces of the glass fibers placed on the filament hole for the leakage time. The experimental sequences were recorded separately for each of the selected liquids.

Based on the experimental researches, research was carried out to produce an empirical formula for determining the coefficient of resistance of the fibrous filament.

The resistivity coefficient is the reference surface of the glass fibers fixed to base sets  $S_\phi$ , the filtered hole surface  $S_T$ , and the correction coefficient to the ratio of multiplicity of  $\Delta K$ . That is,

$$\zeta = \frac{S_\phi}{\Delta K S_T} \quad (14)$$

The correction coefficient is defined as follows.

$$\Delta K = \frac{\xi}{\xi_T} \quad (15)$$

Here, the resistivity coefficients in the form given in formula 13,  $\xi$  – correction coefficients 1,  $\xi_T$  – resistance coefficients determined by experiments.

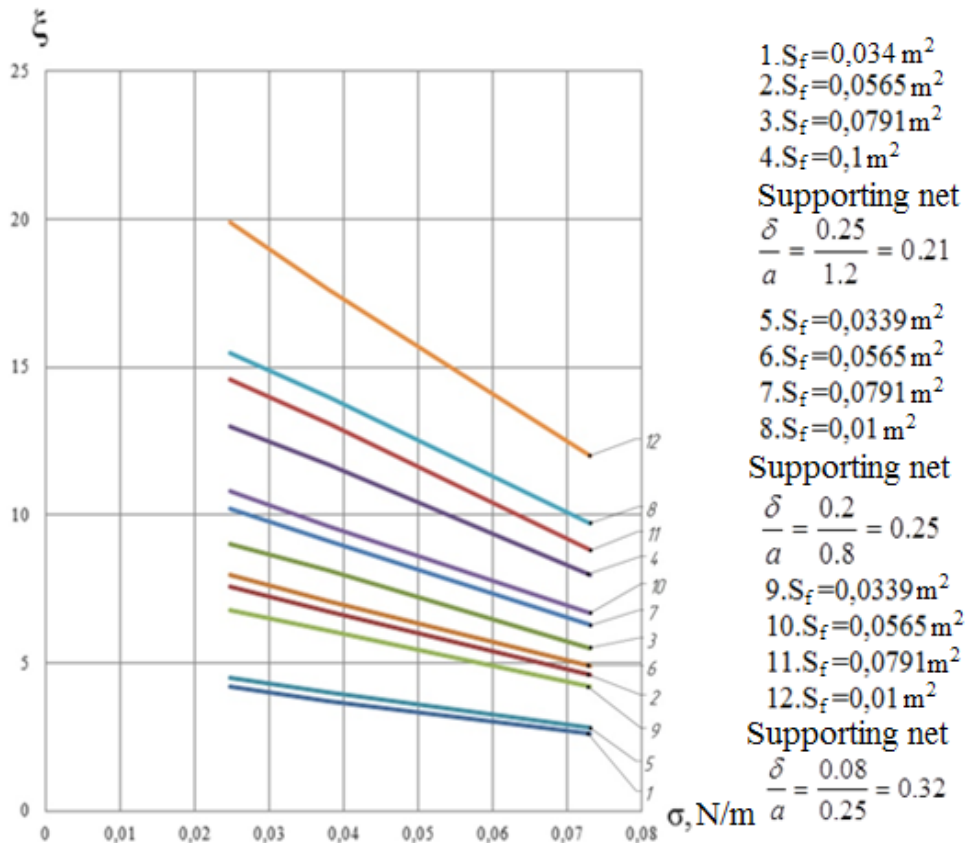


Figure 7. The graph shows changes of resistance coefficient, depending on the fluidity of the surface tension

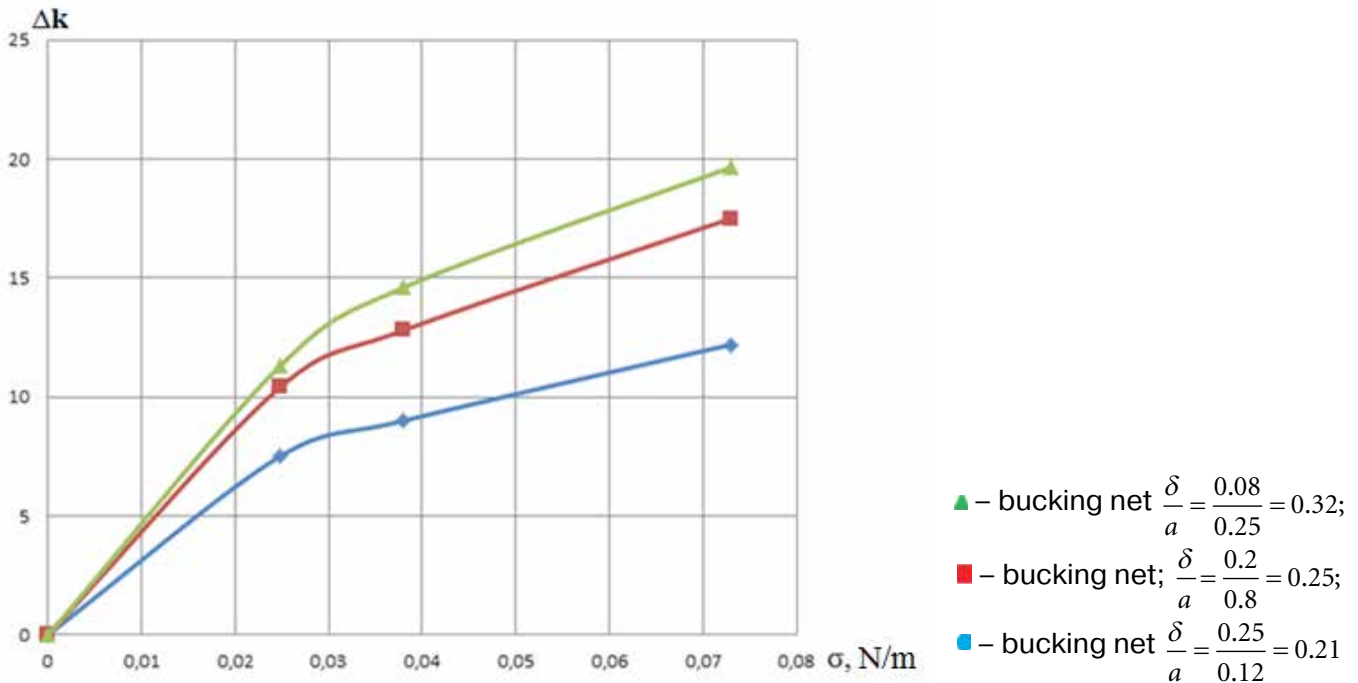


Figure 8. The graph shows changing correction coefficient according to the liquid's surface tension:

The resistivity coefficient  $\xi$  was determined by formula 13, depending on the specific contact surfaces of the glass fibers identified by formula 12 and the filter hole surface ( $S_m = 0.00066 \text{ m}^2$ ).

Depending on the values of the experimentally determined resistor coefficients, the correction factors were correlated with Formula 14.

The 13-empirical formula is recommended for calculating the resistance coefficients depending on the size of stand sets and the specific bonding areas of the glass fibers.

The main function of the selected set is to hold the fibers of the glass and serve as a base. Theoretical values of resistance coefficients were compared with the experimental values using the recommended empirical formula. The error between them was  $\Delta = \pm 4\%$ .

Based on the experimental results, it is recommended to measure the size of the base hole by taking into account the size of the fiberglass diameter  $a = 1 \div 1.2 \text{ mm}$ . Because, if larger sizes are selected,

the resistance factor can be reduced, but the glass fiber is removed from the hole and the filter can change stability. The results of the experimental researches have been based on exponential graphics of processing of the computer (Figures 7, 8).

### Conclusion

Theoretical and experimental studies have suggested a formula for detecting specific surfaces, depending on the mass of the glass fibers, which holds the small particulate drops of heavy liquids. Resistance coefficients were determined based on the specific fibers of glass fibers at different values and the different surface tension of the fluids. The empirical formula for the resistance coefficient was recommended depending on the results obtained from the experiment. With these recommended formulas, the basic parameters of the filter to be installed on the apparatus will be projected. Because the filter's ability to hold fluids and hold down heavy particles of heavy particles, which are not buried, will depend on its resistance coefficients

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## TESTABLE LOGICAL CIRCUIT OF A BINARY NONRESTORING ARRAY DIVIDER

**Abstract.** In the information processing systems LSI with regular structure (adders, subtractors, array multipliers, array dividers and so on) perform increasable part. A testable functional-logical circuit of a binary nonrestoring array divider has been elaborated. The circuit being represented possesses a fault detection test of the length of three and a small hardware complexity.

**Keywords:** logical circuits with regular structure, stuck-at fault, fault detection test.

It is easier to design testable digital integrated circuits with a regular structure, including adders, multipliers, subtractors, dividers, and various memory circuits, than integrated circuits with an irregular structure. The article [1] presents a testable functional-logical circuit of a binary nonrestoring array divider with a fault detection test with a sequence length 4 or 5 for single stuck-at faults. However, its implementation requires a significant amount of hardware resources, which is a major flaw. This article proposes a testable functional-logical circuit of a binary nonrestoring array divider with a fault detection test with a sequence length 3 of the same fault class and with less hardware complexity.

Layers of 1-bit adders combined within each layer into parallel adder with sequential carry are the basis of this circuit. At the same time, the construction of a testable 1-bit adder circuit that underlies the multi-bit adder of each layer is based on the representation of the sum  $S$  and carry  $P$  functions of a full 1-bit adder as polynomials dual to the Zhegalkin polynomials [2, P. 24] (since the sum  $S$  and carry  $P$  functions are self-dual) and also on the fact that these polynomials for sum  $S$  and carry  $P$  functions of a 1-bit adder are simple:

$$\begin{aligned} P &= (a \vee b) \odot (a \vee p) \odot (b \vee p), \\ S &= a \odot b \odot p, \end{aligned} \quad (1)$$

where  $a$  and  $b$  are the values of the original 1-bit operands;  $p$  and  $P$  are the values of the input and output carry signals, respectively,  $S$  is the value of the sum signal,  $\vee$  is the symbol of the disjunction operation,  $\odot$  is the symbol of the biconditional operation (equivalence).

The formula for the carry function  $P$  from (1) can easily be converted to convenient form:

$$P = (a \vee b) \odot [p \vee (a \odot b)] = \overline{(a \vee b)} \odot \overline{[p \vee (a \odot b)]}. \quad (2)$$

Then the testable logical circuit of the 1-bit adder can be implemented in a logical basis consisting of NOR and EQUIVALENCE two-input gates. This diagram is shown in (Fig. 1). At the same time, a rather simple schematic diagram of EQUIVALENCE gate on MOS transistors, containing only 3 transistors [3, P. 196], is known. This scheme is shown in (Fig. 2). The fault detection test for the 1-bit adder circuits in the selected basis for all single stuck-at faults contains 3 vectors and is described in table shown in (Fig. 1).

The testable  $n$ -bit ( $n$  is a positive integer) circuit of the binary adder of each layer of the nonrestoring array divider is composed of  $n$  testable circuits of a full 1-bit adder connected in a regular manner, i.e. by connecting the carry output of  $i$ -th circuit with the carry input of  $(i+1)$ -th circuit, where  $1 \leq i \leq n-1$ .



This circuit diagram is shown in (Fig. 3). A fault detection test for a testable circuit of n-bit binary adder

for all its single stuck-at faults is conducted by simply iterating the test shown in (Fig. 1).

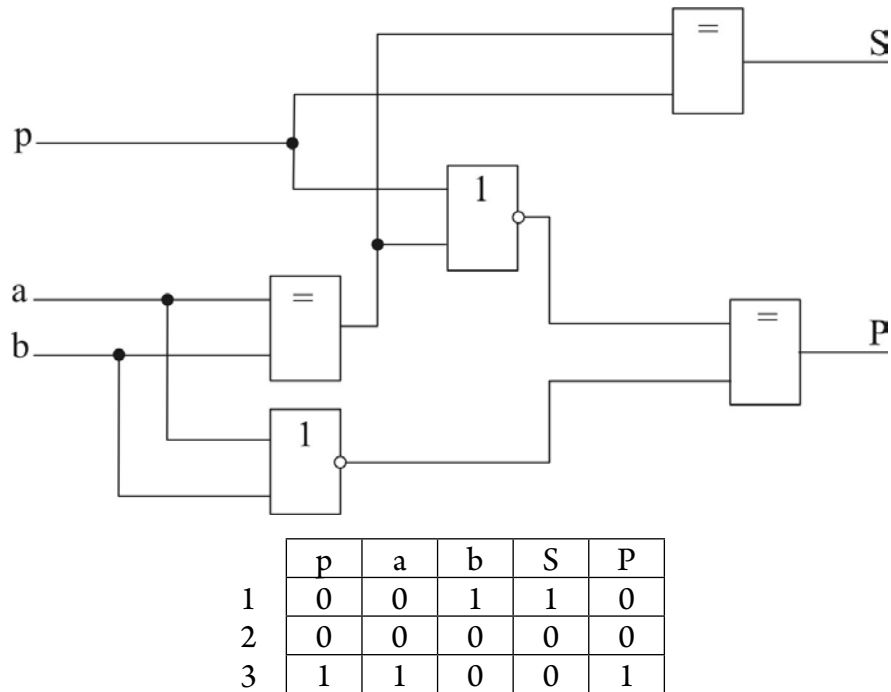


Figure 1. Testable 1-bit adder circuit and its fault detection test

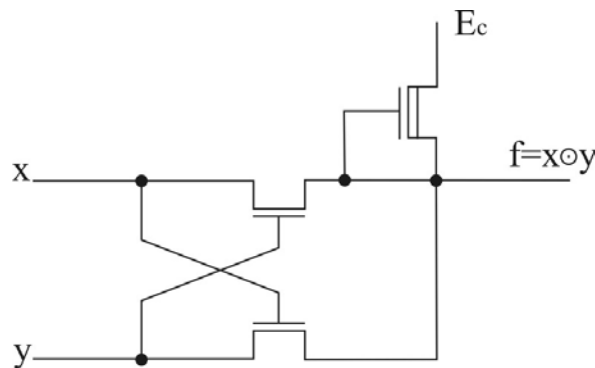
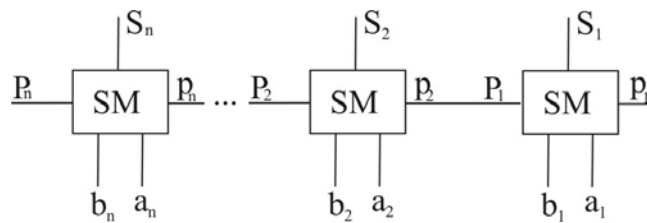
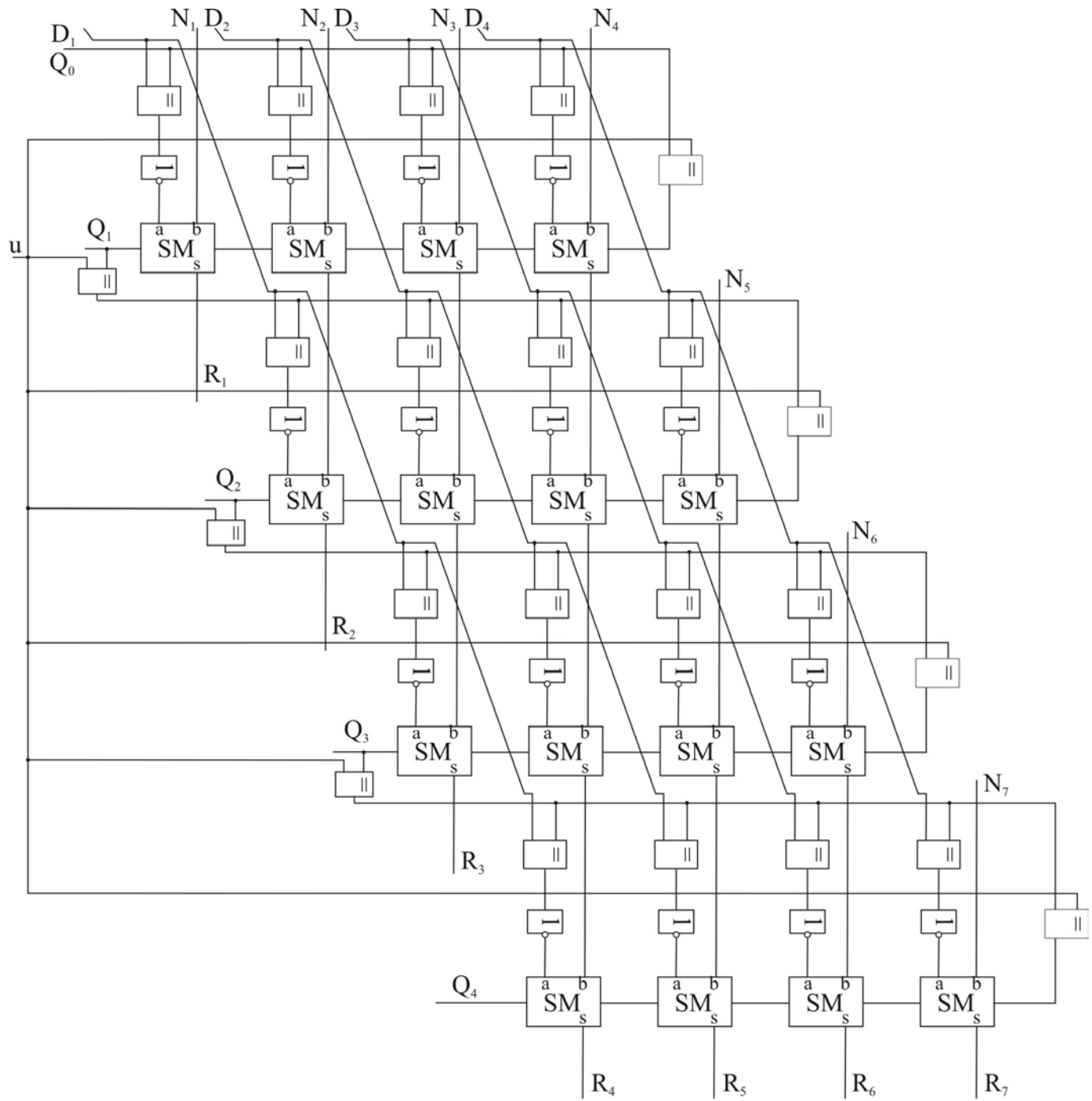


Figure 2. Schematic of EQUIVALENCE gate in MOS transistors



$p_1$	$b_1$	$a_1$	$b_2$	$a_2$	$b_3$	$a_3$	...	$S_1$	$S_2$	$S_3$	...
0	1	0	1	0	1	0	...	1	1	1	...
0	0	0	0	0	0	0	...	0	0	0	...
1	0	1	0	1	0	1	...	0	0	0	...

Figure 3. Testable n-bit adder circuit and its fault detection test



	u	Q <sub>0</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	N <sub>5</sub>	N <sub>6</sub>	N <sub>7</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	R <sub>6</sub>	R <sub>7</sub>
1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1
2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0

Figure 4. Testable circuit of 4 x 4-bit nonrestoring array divider and its fault detection test

The testable functional-logical circuit of the nonrestoring  $n \times n$  bit array divider for array with  $n = 4$  is shown in (Fig. 4). In Fig. 4  $(N_1, N_2, N_3, N_4, N_5, N_6, N_7)$  and  $(D_1, D_2, D_3, D_4)$

represent the dividend and the divisor, respectively.  $N_1$  and  $D_1$  are the respective sign bits.  $(Q_1, Q_2, Q_3, Q_4)$  are the quotient bits.  $(R_1, R_2, R_3, R_4, R_5, R_6, R_7)$  are the remainder bits. The value of  $Q_{i-1}$  determines whether subtraction or addition should be performed in the  $i$ th row. Since the initial subtraction must always be carried out,  $Q_0 = 1$ . The considered circuit contains seven additional two-input EQUIVALENCE gates and one additional input  $u$ . In this case, in the operating mode, the logical (1) signal is fed to the input  $u$ . The fault detection test for all single stuck-at faults of this circuit contains 3 vectors and is described in table shown in (Fig. 4).

The fault-detection test for the general case also contains 3 vectors and is constructed as follows:

- the sequence 1,0,0 ( $j \in \{1, 2, \dots, n\}$ ) is fed to each  $D_j$  input;
- the sequence 1,0,0 ( $i \in \{1, 2, \dots, 2n-1\}$ ) is fed to each  $N_i$  input;
- the sequence 1,0,1 is fed to  $Q_0$  input, and the sequence 0,1,1 is fed to  $u$  input.

It is easily seen that in general the testable  $n \times n$  bit nonrestoring array divider contains  $2n-1$  additional two-input EQUIVALENCE gates. The testable circuit found in [1] requires significantly bigger amount of hardware resources for its implementation than the proposed testable circuit.

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## Section 5. Chemistry

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### **DRESSING MATERIAL FOR THE POLYMER COMPOSITION BASED ON SYNTHETIC POLYMERS**

**Abstract.** It was found that the presence of a dressing composition based on rice starch, PAA and sericin has a positive effect on the process of gelatinization of starch sodium metasilicate and increases the viscosity of the system.

**Keywords:** Modification of polymers, carbamine groups, sulfates and vinyl polymers, dressing with hydroxyethylated starch.

**Purpose.** Development of technology for obtaining a polymer composition based on starch and sericite, the study of their influence on the properties of dressing compositions and the main indicators of dressing cotton yarn.

**Material and methods.** IR–spectroscopy, bacterioscopy, sorption, coloristic and other physical and chemical methods of analysis and research according to the methods set forth in the relevant GOST.

**Results.** The use of the polymer composition allows to simultaneously reduce the starch content in the dressing compositions and improve the most important physical and mechanical characteristics of the coated bases.

**Relevance of the work.** In modern conditions of formation of market relations improvement of quality and competitiveness of production is one of the key tasks in the textile industry solved by creation of the effective resource-saving technologies allowing to reduce considerably consumption of a food product of starch and expensive import, imported chemical materials.

Throughout the history of textile production, starch has played a leading role as the basis of dressing compositions due to its cheapness, availability and adjusted production. Currently, despite the availability of a number of synthetic products for dressing, the situation has not changed fundamentally. The

proportion of starch dressing material for compositions up to about 75%. In the context of the economic crisis, a special place is occupied by the issue of creating polymer composite materials and the search for new types of dressing compositions that reduce the consumption of starch and meet the technological requirements on the world market.

Currently, the traditional starch-based dressing components used have a number of disadvantages, so only modified forms of starch are used abroad. Synthetic dressing preparations are devoid of these disadvantages. However, due to the unreliability of the raw material base and the high cost at present, synthetic dressing agents can not completely replace starch products in the dressing of cotton base.

In this regard, the problem of developing a technology for obtaining a polymer composition based on starch and sericin, providing an improvement in its adhesive ability, increasing the elasticity of the formed films and, accordingly, reducing the consumption of dressing is of great scientific, theoretical and practical interest.

Object and subject of research. The object of the study were starch, sericin-waste silk mills, polyacrylamide (PAA).

The subject of the study was to reduce the resource intensity of weaving production by obtaining high-efficiency dressing polymer compositions based on local raw materials and the involvement of waste silk mills, providing good quality dressing yarn.

The hypothesis of the study is that the composition containing starch and sericin should have an increased efficiency of dressing compared to existing dressing agents.

In the process of dressing can significantly change the physical and mechanical properties of the main yarn, which affects the breakage of the threads on the loom. To reduce breakage in weaving production it is necessary to conduct the dressing process qualitatively.

The essence of the traditional process of dressing is that the main threads from the warping shafts at a given tension is impregnated with a solution of dress-

ing, excess amount of dressing is removed from the threads when pressed in the pressing shafts, drying of the coated threads is carried out in a drying apparatus to a certain humidity, separation of the glued threads and send them to the loom.

In this case, the dressing must meet the following requirements [1–3]:

- be sufficiently adhesive and have a certain viscosity to cover the surface of the main yarn and partially penetrate deep into the thread;
- create an elastic sheath on the threads, resistant to abrasion, does not violate the flexibility of the thread and does not make the yarn brittle and stiff, as well as not to fall off the yarn, both in the process of dressing and when processing the yarn on the loom;
- have a good affinity for fiber, do not destroy the yarn and do not change the color of the thread when dressing colored bases, easy to remove and do not affect the color and finish of fabrics, do not change their properties during use and storage;
- not to spoil the heddle and the reed on the loom, not to promote adhesion of the yarns to the drying drums;
- easy to remove from the surface of the yarn when loosening;
- be cheap enough.

The quality of the dressing is determined by a complex of physical and chemical properties, such as: concentration, viscosity, degree and uniformity of dispersion of the adhesive material, wetting ability, adhesion and cohesion properties.

Substances included in the composition of the dressing, according to its functional purpose can be divided into the following groups: adhesives, splitters, softeners, hygroscopic substances, antiseptics and water.

The main adhesive when dressing cotton threads is a natural polymer-starch (potato, maize, corn, rice). To break down the starch grains into smaller particles that penetrate deep into the thread, splitters are used: sodium hydroxide, sulfuric acid and other acids.

Due to the fact that the textile industry consumes for production needs a large amount of valuable food product – starch, the question of partial or complete replacement of its chemical materials is very relevant. With the development of chemistry and technology of polymers appeared chemical water-soluble adhesives, which in their properties are not inferior to starch products. These are mainly modified natural and synthetic polymers-simple and some cellulose esters, polyvinyl alcohol, polyacrylamide, etc.

The analysis of scientific data shows that in the world practice as dressing agents, the following synthetic polymer compounds are used [4]:

- carbon-chain polymers and their derivatives;
- polyoxy (hydroxy) compounds;
- polyamides;
- various copolymers containing in the chain, along with functional groups such as  $-COOH$ ,  $-COOR$ ,  $-OH$ ,  $-NH_2$ , etc., aromatic radicals and unsaturated bonds.

There are foreign patents describing dressing compositions based on synthetic high molecular weight compounds, in particular, styrene and maleic acid copolymers, polyvinyl alcohol and its copolymers, polyvinylpyrrolidone, acrylic (methacrylic) polymers and copolymers based on them, as well as many others. Note that they were used instead of carboxymethylcellulose, starch, gelatin, because these synthetic dressing compositions had negative properties-a tendency to flaking [5].

Currently, polyacrylamide is successfully used for dressing the bases. When dressing cotton yarn, it has long been used as a partial substitute for food. The dressing was usually introduced 70% starch and only 30% polyacrylamide, which provided good properties of the yarn. In the future, thanks to the conducted developments, numerous compositions based on polyacrylamide, both 8% and 6%, products of its alkaline or oxidative degradation and other copolymers were used [6]. The use of polyacrylamide made it possible to completely eliminate the use of starch.

For dressing, 8–10% polyacrylamide (PAA) or a mixture of it with starch products, gelatin or other adhesives are used. Note that PAA shows sufficient resistance to temperatures up to 400–420°K. Due to the absence of ionogenic groups, when the pH changes from 1 to 10, its viscosity does not change significantly, and this is very important for the dressing process.

In the process of alkaline treatment, part of the amide groups passes into carboxyl and intermolecular bonds of the polymer chains of PAA significantly weaken, thereby increasing solubility and reducing viscosity. The products of alkaline treatment of PAA can be represented as a copolymer of acrylamide, acrylic acid and its sodium salt. It is used for dressing cotton and staple yarn.

The viscosity of the dressing on the basis of PAA can be reduced and as a result of processing it with hydrogen peroxide, that is, carrying out some destruction of the polymer. Products of partial destruction of PAA at low viscosity have satisfactory adhesive ability.

It should be noted that the widespread use of 8% PAA in textile enterprises is associated with some difficulties. Even in the process of synthesis of PAA, under the influence of air oxygen and high temperature, there is a cross-linking between the resulting macromolecules. The process of crosslinking will take place during the storage of PAA.

Given the above circumstances, in particular, for the dressing of linen bases, it was recommended to use 6% PAA obtained by polymerization of 6% acrylamide solution [7].

As noted, in the practice of dressing used and samples of polyvinyl alcohol, and this is due to the fact that PVC provides sufficient adhesion when dressing yarn, especially in the case of a mixture of natural and chemical fibers. PVC is able to form a strong shell with higher structural and mechanical resistance.

In the scientific literature some thermodynamic characteristics of the dressing process are given: these are the thermal effects of limited and

complete dissolution of PVC in water and the integral heat of interaction of the PVC dressing with cellulose [8].

For dressing, as it was established in these works, it is possible to apply PVC with different molecular weight and different number of acetate groups (or degree of saponification). PVC dressing is convenient and easy to prepare, does not require splitters and additives, and its cooking time is 1.5–2 times less than starch dressing. The concentration of PVC in the dressing solution is 2.5–3 times less than starch. In addition, aqueous solutions of PVC are not exposed to bacteria and do not cause corrosion of the equipment, easily regenerated for reuse in the process of dressing.

For preparation of the dressing cotton bases on 1000 l of the finished dressing about 30 kg of PVC is required. The relative viscosity of the dressing is 1.3; the temperature of the dressing in the trough 358K. Glue is 3%. Consumption of PVC per 1 ton of soft yarn brand 18.5-*Tex* is 32 kg.

It is also noted that in its dressing properties, PVC is significantly superior to starch and Na-CMC, due to its good solubility and film-forming properties. The strength and elongation of yarn, oligomannose PVC, above, and breakage in weaving is lower than the yarn, oligomannose starch dressing. The addition of glycerol (3G/l) further reduces 2–2.5 times the stiffness of the lined yarn [9].

The disadvantage of PVC is that it can not be used for hydrophobic fibers, because it does not have sufficient adhesion to the fiber.

In [10] the composition for dressing at a relatively low temperature is recommended. It consists mainly of polyvinyl acetate and starch (or polyvinyl alcohol) in a ratio of 5: 95–70: 30. Further, the us patent is also known. It offers a dressing composition consisting of polyvinyl alcohol and polyacrylic acid molecular weight 25000–100000.

In other sources it is noted [11] that synthetic and artificial dressing products, in comparison with natural polymers, in particular, with starch, have significant advantages, both in terms of equipment performance and quality of dressing. In addition, the conditions for the implementation of the chartering itself will be very simple. In this regard, cellulose esters are more important.

Among the cellulose esters having an adhesive effect, the most suitable for the dressing process is carboxymethylcellulose (CMC) with different degrees of esterification and polymerization. It, indeed, has a number of advantages over starch. It is easier to prepare a dressing from it, since it does not require the addition of other substances (components). CMC dressing is well retained on the yarn, resistant to long-term storage and is easily removed when rinsed in hot water.

The ammonium salt of cellulose-glycolic acid acts similarly to Na-CMC. Its advantage is the possibility of plasticization due to organic amines and polyglycols, which makes it preferable to use it in the process of dressing yarn from synthetic fibers.

The authors report no conflict of interest in the article.

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## SELECTIVE THERMOCATALYTIC SENSOR FOR NATURAL GAS MONITORING

**Abstract.** In the scientific literature and practice, it was traditionally believed that the widely used thermochemical sensors do not provide the selectivity for determining the individual components of a gas mixture. In this work, we developed a sensor for the selective determination of natural gas in the presence of carbon monoxide and hydrogen.

The selectivity of the sensor is ensured using thermosensitive elements with different activity to the components of the gas mixture, differences, the activity of which is ensured by the selection of the composition of the catalyst. In this case, the output signal of the measuring sensor element of the sensor is proportional to the total concentration of the mixture of substances ( $H_2$ , CO and  $CH_4$ ), and the output signal of the comparative sensitive element is proportional to the concentration of the mixture of substances ( $H_2$  and CO) – except for the detected component ( $CH_4$ ), and the signal difference is the first and second elements is proportional to the concentration of the determined component ( $CH_4$ ) in the mixture.

**Keywords:** thermocatalytic sensor, selectivity, sensitivity, silver oxide, iron oxide, nickel oxide, carbon monoxide, sol-gel technology, natural gas.

**Introduction.** Natural gas is one of the most important resources that are actively used in industry and in everyday life. It is almost non-toxic. However, in combination with air at a concentration of from 5.3 to 14.9% they form an explosive mixture [1]. In this regard, the development of sensors for the rapid determination of natural gas is one of the relevant tasks.

The aim of this work is to develop a sensor providing selective determination of natural gas in the presence of CO and  $H_2$ .

It is known that the widely used thermocatalytic sensors (TCS) do not provide selectivity for determining a gas mixture [2]. One of the possible methods for ensuring the selectivity of TCS of combusti-

ble gases is the use of heat-sensitive elements (HSE), which have different sensitivity to the components of the gas mixture [3,4]. In this regard, the main task in the development of selective TCS for natural gas detection is the selection of catalytic systems of HSE.

**Results and discussion.** In the temperature range of 100–250 °C the selectivity of  $\text{In}_2\text{O}_3$ ,  $\text{Ag}_2\text{O}$ ,  $\text{Fe}_3\text{O}_4$  and  $\text{Ni}_2\text{O}_3$  mixture during the oxidation of combustible gases was studied. As a result of these experiments, it was found that the most optimal for the sensing element of the thermocatalytic sensor of natural gas are the catalyst  $0.75\text{In}_2\text{O}_3-0.25\text{Ag}_2\text{O}$ . It is advisable to use  $0.50\text{Fe}_3\text{O}_4-0.50\text{Ni}_2\text{O}_3$  as a catalyst for the comparative element. Taking into account the specifics of the problem being solved and using the above catalysts, sensors were made for the selective

determination of natural gas in the presence of CO and  $\text{H}_2$ . The sensitive elements of the sensor have the form of a miniature ball of  $\gamma$ -oxide aluminum inside which there is a spiral of platinum wire (Fig. 1), which simultaneously serves as a heating element and a resistance thermometer. Given this, the output signal of the measuring sensor element of the sensor is proportional to the total concentration of the mixture of substances ( $\text{H}_2$ , CO and  $\text{CH}_4$ ), and the output signal of the comparative sensitive element is proportional to the concentration of the mixture of substances ( $\text{H}_2$  and CO) – except for the detected component ( $\text{CH}_4$ ), and the signal difference is the first and second elements is proportional to the concentration of the determined component ( $\text{CH}_4$ ) in the mixture.

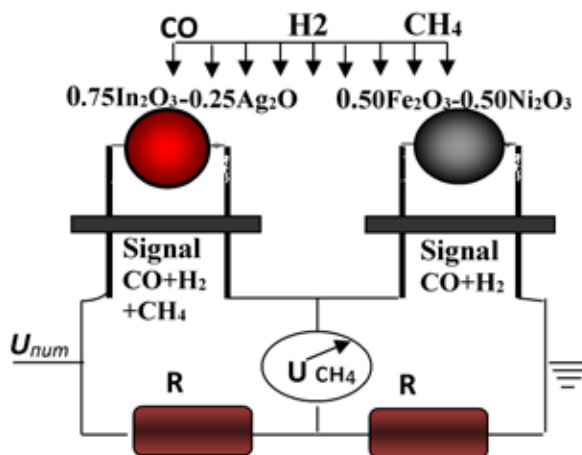


Figure 1. Selective thermocatalytic sensor of natural gas

Tests of the developed sensors included special experiments related to the selection of the supply voltage value, the establishment of calibration characteristics of the sensor, as well as the identification of its degree of selectivity. From the results on the

selection of the optimal supply voltage, it follows that the maximum value of the TCS signal with a catalyst  $0.75\text{In}_2\text{O}_3-0.25\text{Ag}_2\text{O}$  and  $0.50\text{Fe}_3\text{O}_4-0.50\text{Ni}_2\text{O}_3$  when determining natural gas is observed in the range of 2.8–3.0 V.

Table 1. – Sensor signal connection to supply voltage ( $n = 5$ ,  $P = 0.95$ )

No.	Sensor supply voltage, V	Sensor Signal, mV		
		$\bar{x} \pm \Delta X$	S	$\text{Sr} \cdot 10^2$
1.	2.5	$20.6 \pm 0.1$	0.09	1.2
2.	2.8	$27.0 \pm 0.8$	0.15	1.7
3.	3.0	$28.1 \pm 0.4$	0.11	1.4
4.	3.5	$25.9 \pm 0.4$	0.11	1.4

The developed sensor has a response start time ( $t_{0.1}$ ) of 3–4 s, a time constant ( $t_{0.63}$ ) of no more than 9 s, and a readout time ( $t_{0.9}$ ) of 13 s. The dependence of the TCS signal on the concentration of natural gas in the gas mixture in the studied range (from 0.1 to 5.0% vol.) of the gas concentration in the air is straight.

The effect of  $H_2$  and CO content on the determined value of the sensor output signal was studied. As follows from the obtained data, TCS with a measuring and compensation element catalyst are characterized by natural gas selectivities in the presence of  $H_2$  and CO.

Table 2. – Natural gas sensor selectivity results (n=5, P=0.95)

No.	Gas mixture composition,%vol.	Natural gas found, vol%		
		$x \pm \Delta x$	S	$Sr \cdot 10^2$
1.	Natural gas (0.50) + air(res)	0.48 ± 0.06	0.05	1.2
2.	Natural gas (0.50) + CO(1.00) + air(res)	0.52 ± 0.03	0.03	1.6
3.	Natural gas (0.50) + $H_2$ (1.00) + air(res)	0.51 ± 0.03	0.04	1.7

The error of the sensors due to unmeasured components in gas mixtures does not exceed 2.0%.

**Conclusion.** In summary, a highly sensitive sensor has been developed which allows to selectively

detect natural gas from a mixture of combustible substances. The developed sensor is used to measure pre-explosive concentrations of natural gas in atmospheric air.

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## METHODS OF SYNTHESIS OF MALEINIMIDOETHYL ETHER OF ACETIC ACID

**Abstract.** New methods of obtaining N-(2-acetoxyethyl) maleimide using  $\beta$ -hydroxyethyl maleimide, reaction of  $\beta$ -chloroethyl maleimide with acetic acid and its sodium salt have been elaborated. The effect of solvent and temperature on the course of the reaction was determined. The structure of the synthesized substances was analyzed using physico-chemical research methods.

**Keywords:** N-(2-hydroxyethyl-)maleamic acid,  $\beta$ -hydroxyethyl maleimide,  $\beta$ -chloroethyl maleimide, maleic anhydride, N-(2-acetoxyethyl) maleimide.

Maleic acid derivatives are among the compounds with a high practical use. Maleic acid derivatives have been used in various fields. In fact, in the production of different adhesives, the leather paint industry, rubber and polymers are received also, their derivatives are used as sewing agents [1; 2; 3; 4; 5]. Furthermore, maleimide group has been widely used in the pharmaceutical industry [6].

In obtaining copolymers resistant to corrosion, the importance of maleimide monomers is considered to be great in the production of bis-maleimide derivatives, heat-resistant aviation carbon fibers, bis-maleimide derivatives, machine-isolating agents, adhesives for road bitumen, materials [7; 8; 9; 10; 11; 12].

We carried out a scientific investigation by finding new methods of obtaining  $\beta$ -chloroethyl maleimide and N-(2-acetoxyethyl) maleimide. The methods proposed in the work were included reactions that can be carried out under normal laboratory conditions.

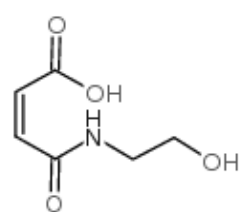
In the literature, homo-polymerization reactions of N-(2-acetoxyethyl) maleimide were synthesized and obtained by microwave irradiation (microwave (MW) irradiation) in acetic acid and dehydrated sodium acetate catalysis [13].

Initially, N-(2-hydroxyethyl-)maleamic acid was synthesized from maleic anhydride and ethanolamine. This reaction was carried out by two methods. At the first the equimolar amounts of maleic anhydride with ethanolamine was carried out. Purified ( $T_{\text{boiling}} = 169-171\text{ }^{\circ}\text{C}$ ) ethanolamine maleic anhydride poured into the cooled state for 30–40 minutes in an ice bath. Then the reaction is carried out by a ring reaction through the decomposition of the reaction mixture. The reaction mixture was heated in a water bath during 1 hour at 55–60  $^{\circ}\text{C}$  stirring. The resulting substance was purified by recrystallizing in 70% ethyl alcohol.

In the second method of obtaining N-(2-hydroxyethyl-)maleamic acid, the reaction was carried out in an acetone as solvent, the yield in this

reaction was 65%. The conditions of obtain ins of N-(2-hydroxyethyl-)maleamic acid are presented in the (table 1).

Table 1.– Conditions of reaction of maleic anhydride with ethanolamine

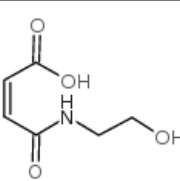
Name and structure of the resulting substance	Temperature, °C	Solvent	Reaction time	Mole ratio Maleic anhydride: monoethanolamine	Yield,%
	20–25: 50–55: 0	–	30–40 min	1:1	53
	0: 50–55: 0	Ethanol	60 min	1:1	55
	0: 50–55: 0	Acetone	150 min	1:1	58
	0: 50–55: 0	Acetone	1 day	1:1	60
	0: 50–55: –12	Acetone	150 min	1:1	65

Based on the results of the conducted experiment, it can be said that with a decrease in temperature, additional reactions decrease, and with high yields, the possibility of taking N-(2-hydroxyethyl-)maleamic acid increases. With an increasing of reaction time, the yield of the product also has increased sharply. The nature of the solvents were used in the reactions also has effect the yield of the product and the course of the reaction [14]. Known polarity values of solvents:

Solvent	Polar Et (30), kcal/mol <sup>-1</sup>
Acetone	0.355
Ethanol	0.654

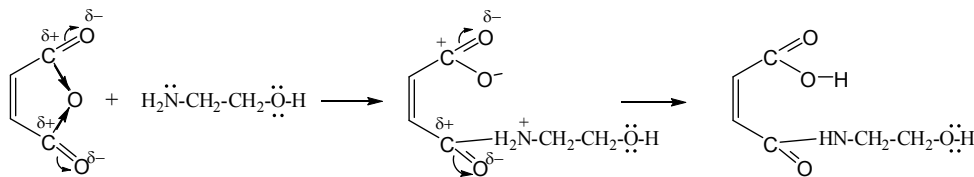
During the synthesis of N-(2-hydroxyethyl-)maleamic acid was carried out in acetone, we saw that the reaction was easy on the low carbohydrate and went with a high yield. The main reason for this was the good melting of the substances obtained for the reaction in this solvent and the room temperature, the for the formed product was melted easy reactions were carried out in polar solvents and yield of reaction was lower, the higher the solubility of the formed product. Data of IR-spectrum of N-(2-hydroxyethyl-)maleamic acid are presented in (table 2).

Table 2.– Areas of self-absorption, cm<sup>-1</sup>

	$\nu(\text{O-H})$ carboxyl	$\nu(\text{C=O})$ carboxyl	$\nu(\text{N-H})$ amide	$\nu(\text{C=O})$ amide	$\nu(\text{CH=CH})$	$\nu(-\text{C-OH})$	$\nu(\text{CH}_2)$
		3309	1736	1539	1647	1628–1646	1174

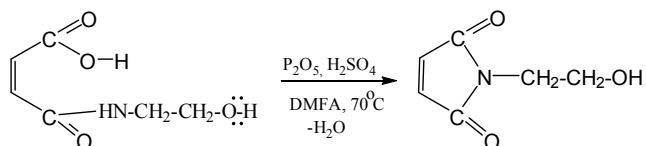
The course of the reaction can be explained using the following scheme. The reaction begins with an attack of amino group with a high nucleophilicity of

ethanolamine to strongly polarized maleic acid with formation of a corresponding N-(2-hydroxyethyl-)maleamic acid:

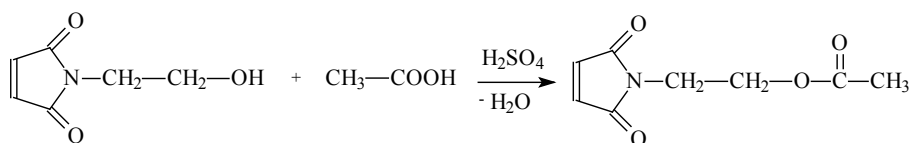


The next stage is the process of dehydration. Dehydration agents were  $\text{P}_2\text{O}_5/\text{H}_2\text{SO}_{4(\text{cons.})}$  and as, sol-

vent DMFA was used, cyclization were carried out temperature of 70 °C:

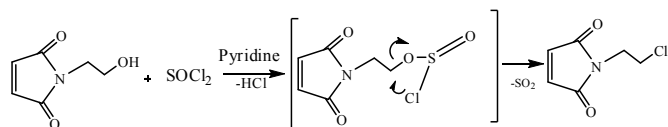


In subsequent reactions,  $\beta$ -chlorethylmaleimide was synthesized from  $\beta$ -hydroxyethylmaleimide. In this method tonyl chloride was used to halogenize alcohols. The hydrophobicity of tonyl chloride and the presence of an active additive of maleimide make the one-side course of the reaction more difficult. The reaction was carried out at temperature of  $0^\circ\text{C}$  at the same time. With a low temperature of the reaction, it is possible to ensure that the double bond in maleimide does not break: the of obtained light yellow sediment was participation with yield 55%:

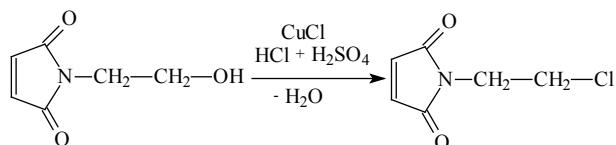


N-(2-acetoxyethyl)maleimide is white crystalline substance,  $T_{\text{liquid}} = 80\text{--}81^\circ\text{C}$ ,  $R_f = 0.47$  (silofol, systema benzene-ethylacetate 3:1). One more method obtaining complex ethers the effect of halogen alkanes on the salts of carbonic acids. With this method, it was possible to obtain ethers of acids, which are difficult to synthesize from space site.

Dipolar aprotic solvents-DMPA, DMSO, GMP-TA, acetone, DMAA and others with anions do not bind hydrogen bonds. The interaction of these solvents with anions occur mainly on account of ion-dipole. The ion-dipole forces are formed from the interaction of anions and solvent molecules. For this reason, the dipolar aprotic solvent solution dissolves small solid anions much weaker than proton solvents. Solvation of anions decreases in solvents of different nature in the following range:  $\text{H}_2\text{O} > \text{CH}_3\text{OH} > \text{C}_2\text{H}_5\text{OH} > \text{HCONH}_2 > \text{CH}_3\text{NO}_2 > \text{CH}_3\text{CN} > \text{DMFA} > \text{DMSO} > \text{GMFTA} > \text{methylpyrrolidine-2}$



$\beta$ -Chlorethylmaleimide can also be obtained in the presence of hydrogen chloride, CuCl and sulfuric acid:



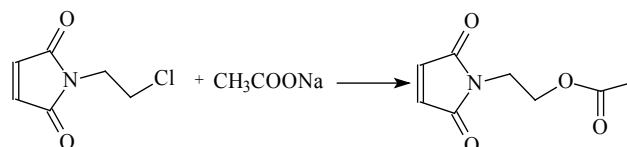
Following specific absorption areas of  $\beta$ -chlorethylmaleimide in IR-spectrum were observed ( $\text{cm}^{-1}$ ,  $\nu$ ): 1660 (C=O), 1423 (imide), 2864 ( $\text{CH}_2$ ), 644 ( $-\text{Cl}$ ).

When the acetic acid reaction of the obtained  $\beta$ -hydroxyethylmaleimide was carried out with the participation of sulfuric acid, the compound ether made up 40% of the yield:

The nucleophilic properties of anions has increased at passage from water or methane to DMSO and GMFTA. If the reaction of acid salt ( $\text{RCOOME}$ ) with halogen alkane is carried out in a solution of GMFTA, the compound ether is dressing with a high was yield.



We were carried out at the reaction of  $\beta$ -chlorethylmaleimide with acetic acid sodium salt in dimethylsulfoxide yield of product was 60%:

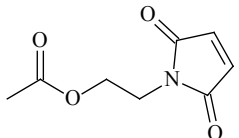


This means that the structure of the carbonic acids obtained for the reaction to the course of the etherification reaction, in which  $\beta$ -chlorethylmaleimide goes with the participation of aliphatic carbonic acid

salts, also affects the nature of the solvent and the temperature of the reaction.

Data of IR-spectrum are presented in (table 3) of maleimidoethyl ether of synthesized acetic acid.

Table 3. – N-(acetoxylethyl)maleimide areas of self-absorption in the IR-spectrum,  $\text{cm}^{-1}$

	$\nu(\text{C}=\text{O})$	$\nu(\text{imide})$	$\nu(\text{CH}_2)$	$\nu(\text{C}(\text{O})\text{OC})$
	1651	1419	2856	1271

In general, the rate of the etherification reaction and the yield of the product have been depended on the nature of carbonic acid and alcohol, and also temperature and nature of catalyst

#### Experimental part:

Infrared Fourier spectrometer "IRTracer-100" (SHIMADZU CORP., Japan 2017) in complete with the prefix broken total internal reflection (NIP) MIRacle-10 c prism diamond/ZnSe (spectral range on the scale of wave numbers-4000÷400  $\text{cm}^{-1}$ ; resolution – 4  $\text{cm}^{-1}$ , sensitivity signal-to-noise ratio-60,000:1; scanning speed-20 spectra per second); PMR<sup>1</sup>H-spectrometer the Unity 400plus (Varian) ICPS AS RUz spectrometer in (CD<sub>3</sub>OD). Have been used purity of obtained compounds was carried out on the was determined on thin-layer chromatography (TLC) with plates (Pre-coated TLC sheets ALUGAM<sup>®</sup> Xtra SIL G/UV<sub>254</sub>), mobile phase-benzene: methanol 3:1.

#### Synthesis of N-(2-hydroxyethyl)-maleamic acid:

A) On a water ice bath tub put 3 g(0.03 mole) of maleic anhydride into the round tube, slowly drip 1.85 g (0.03 mole) of ethanolamine was added. After mixing with the mixture, water vapor was formed as a result of thermal decomposition. Then we heated the formed glue in a water bath, after 30 hours we put 15 ml of ethyl alcohol on the mixture and crystallize again. The purity of the thin layer was determined in chromatography. (silofol, benzene to the system: methanol 3:1, R<sub>f</sub> = 0.38). T<sub>liquid</sub> = 116–117 °C.

B) **Synthesis of N-(2-hydroxyethyl)-maleamic acid:** 9.8 g (0.1 mole) of maleic anhydride and 6.1 g (0.1 mole) of ethanolamine were dissolved in 15 ml of acetone solution. Both solutions were mixed for 2

hours in an ice water bath, drip 1 and 2 drops into the tube. In a colander with a reverse refrigerator, the reaction mixture was heated for 50–55 °C in water bath during 1–1,5 hours. Then, in a low temperature was cooled with ice water and left for 1 day. The fallen white sediment was filtered and dried in a room cart. 10.4 g (65%) of yield. It was recrystallized again in ethanol.

T<sub>liquid</sub> = 116–117 °C. <sup>1</sup>H-NMR (CD<sub>3</sub>OD δ.m.d) 3.24 s (H, OH), 3.54–4.25 t (2H, 2CH<sub>2</sub>), 4.87 s (H, NHCO), 6.19–6.41 d (H, CH=CH), 6.30 s (H, COOH). <sup>13</sup>C-NMR (CD<sub>3</sub>OD-49.00 ppm δ.m.d) 39.7 s (-N-CH<sub>2</sub>-), 63.9 s (-O-CH<sub>2</sub>-), 131.5–130.7 d (-CH=CH-), 167.1–168.6 d (C=O).

**Synthesis of β-hydroxyethylmaleimide:** The mechanical stirrer is furnished with dropper, funnel and reverse cooler. N-(2-hydroxyethyl)-maleamic acid (9.81 g 0.1 mole) was solved in 30 g of DMPA solution and on to its solution 7.4 g of P<sub>2</sub>O<sub>5</sub> and 1 ml of H<sub>2</sub>SO<sub>4</sub> were put and need to mix. The reaction was held for about 8–9 hours at 70 °C. Then the reaction mixture was cooled, the reduced sediment was filtered, the substance was washed several times in cold water. 55% of yield it was cleaned again with ethyl alcohol has been crystallized. Then CaCl<sub>2</sub> was dried on a laid-out extractor. T<sub>liquid</sub> = 71–72 °C <sup>1</sup>H-NMR (DMSO, δ.m.d) 2.87–3.6 m (2H, 2CH<sub>2</sub>), 7.82–7.89 d (2H, -HC=CH-), 5,99 s (H, -OH).

#### Synthesis of β-chlorethylmaleimide:

A) The mechanical stirrer is furnished with dropper, funnel and reverse cooler. 15.9g of β-HEMI were put to three-mouth tuber on 30 ml of pyridine was added. The reaction was carried out in a bath of ice water, in chilled conditions. A reagent mixture was mixed while the dropper was injected into the fun-

nel with tionyl chloride. During the reaction, the extracting  $\text{SO}_2$  and  $\text{HCl}$  gases were lowered into the mining  $\text{KOH}$  solution through a tube connected to the reverse refrigerator, and in every 10 minutia pH value was checked with the indicator paper. The reaction was being lasted for 2 hours. Going to the end of the reaction, the temperature raised to 50–60 °C and to be continued for 30 minutes. Receiving mixture was cooled, poured ice water and separated from the fallen sediment and dried in a room cart. 55% of yield (silofal, benzene to the system: methanol 3:1,  $R_f = 0.27$ ).  $T_{\text{liquid}} = 184\text{--}185$  °C.

**B)** Mechanical stirrer is furnished with dropper, funnel and a reverse cooler. Mechanical 4 g of  $\beta$ -HEMI were put on 10 ml of  $\text{HCl}_{(\text{cons})}$  and 0.5 g of  $\text{CuCl}$  were added. The reaction was carried out in an ice water bath with a cooled solution. At drip funnel 2.5 ml of  $\text{H}_2\text{SO}_4$  (cons.) was initially injected and then 1 ml was added, then the remaining part of the amount was poured into 50–60 °C. It was lasting 2.5 hours. Then the reaction mixture was cooled, put ice water on it, separated by a filter of the fallen white sediment and washed several times in cold water. Dried in the open air. Our reputation was 27%.  $T_{\text{liquid}} = 184\text{--}185$  °C.

Synthesis of N-(2-acetoxyethyl) maleimide ether. A tube equipped with a refrigerator, cooker

and mechanical agitator was added 141 g (0.01 mole),  $\beta$ -hydroxyethylmaleimide and 0.3 g sulfuric acid 1.2 g (0.02 moles) and toluol were collected on top, putting the acid in the iceberg. The reaction was carried out for 3 hours. At the end of the reaction, 10 ml of distilled water was poured into the reaction mixture. The fallen precipitation was filtered out. the substance was washed several times by cold water. Obtained with hydrochloric acid  $\beta$ -hydroxyethylmaleimide of acetic acid 48% of yield

**B)** Tube mixed with magnetic (mixer) into a flat tube, N-(chloroethyl)maleimide (1.5 g, 0.01 mole), 0.82 g crushed sodium acetate and DMSO 15 ml. The reaction lasted 2.5 hours. At the end of the reaction, the reaction mixture was cooled and poured into a container with ice water, the obtained was filtered. The substance was washed several times in cold water. 60% of yield, ethyl acetate re-crystallized purified. Then  $\text{CaCl}_2$  was dried on a laid-out extractor.  $T_{\text{liquid}} = 80\text{--}81$  °C.  $^1\text{H-NMR}$  (DMSO,  $\delta$ .m.d):  $\delta = 7.01$  (s, 2H,  $\text{HC}=\text{CH}$ ), 4.43 (t, 2H,  $-\text{CH}_2-\text{O}-$ ), 3.61 (t, 2H,  $\text{CH}_2-\text{N}-$ ), 1.98 (s, 3H,  $-\text{CH}_3$ ).  $^{13}\text{C-NMR}$  (DMSO,  $\delta$ .m.d):  $\delta = 171.49$  ( $\text{C}=\text{O}$ ), 170.21 ( $\text{O}=\text{C}-\text{O}$ ), 134.87 ( $-\text{CH}=\text{CH}-$ ), 60.12 ( $-\text{O}-\text{CH}_2-$ ), 38.1 ( $\text{N}-\text{CH}_2-$ ), 20.70 ( $-\text{CH}_3$ ).

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## AMPEROMETRIC TITRATION OF MERCURY (II) WITH MPCMDEDTC SOLUTION IN DIMETHYL SULFOXIDE

**Abstract.** The article studies the voltammetric behavior of 4-methoxyphenyl carboxymethyl diethyldithiocarbamate (MPCMDEDTC) in dimethyl sulfoxide (DMSO) on the presence of background electrolytes with different acid-base properties in the anodic polarization region of a platinum microdisk electrode. MPCMDEDTC is oxidized in 0.125 M LiClO<sub>4</sub> solution forming one clearly pronounced anode wave with  $E_{1/2} = 0.85$  V, while the wave height varies in proportion to the concentration of the depolarizer. A procedure has been developed of amperometric titration of mercury (II) with a standard MPCMDEDTC solution in DMSO using two indicator electrodes.

**Keywords:** mercury (II), 4-methoxyphenyl carboxymethyl diethyldithiocarbamate, lithium perchlorate, n-propanol, dimethyl sulfols, microdisk electrode, indicator electrode, potential half-wave, depolarizer, background electrolytes.

### Relevance of the work

Electroanalytical methods, amperometric titration in particular, can be used to determine different elements in broad concentration range and, with an appropriate selection of analysis conditions, they also become highly selective.

Since mercury, which is often found in natural and technological environments in quantities exceeding the permissible exposure limit (PEL), is toxic, monitoring and determination of its content is a relevant issue throughout the world.

Earlier, some features of amperometric titration of a number of cations in glacial acetic acid [1–2] and in N-propanol medium [3–4]. Представляло интерес исследовать возможность амперометрического титрования раствором 4-метoxyphenyl carboxymethyl diethyldithiocarbamate (MPCMDEDTC) in a medium of non-aqueous solvents with acid-base properties.

This work is devoted to studying the possibility of amperometric titration of mercury (II) with two indicator electrodes with a MPCMDEDTC solution

in a medium widely used in electrochemical studies of an aprotic dipolar solvent, dimethyl sulfoxide (DMSO), which exhibits weak basic properties.

The initial 0.002 M mercury (II) nitrate solution was obtained by dissolving a portion of  $\text{Hg}(\text{NO}_3)_2 \cdot \text{H}_2\text{O}$  (chemically pure) в  $\Delta\text{MCO}$  in DMSO and standardized by an aqueous solution of potassium iodide amperometrically [5]. Solutions of lower concentrations were obtained by diluting the original immediately before use. A standard 0.005 M solution of MPCMDEDTC was prepared by accurately weighing the reagent. Stock solutions of background electrolytes (10%  $\text{LiClO}_4$ ; 7.5%  $\text{CH}_3\text{COONa}$  and  $\text{CH}_3\text{COOH}$ ) were prepared by dissolving the corresponding salts in DMSO.

Amperometric titration with two indicator rotating platinum electrodes was carried out according to the setup described in [6]. Titration was carried out with a piston microburette [7] with an accuracy of 0.0005 ml. the final volume of the solution prepared for titration was 10.0 ml.

To obtain the current-voltage curves of MPCMDEDTC, a complex of mercury (II) with MPCMDEDTC and free ions of mercury (II) for the anodic and cathodic polarization of a platinum microdisk electrode ( $l = 1.0$  mm), we used a three-electrode cell and a PPT-1 polarograph, the reference electrode was SCE.

**Results and discussion.** It can be seen from the obtained experimental data that the current-voltage curves of mercury (II) ions in DMSO are restored at  $E_{1/2} = 0.12$  V. The cathode wave of mercury (II) chelating agent is shifted by approximately 0 with respect to the wave of free mercury (II) ions. 2 V towards more negative potentials. MPCMDEDTC anode wave is not clearly expressed due to the partial application of the oxidation current of the solvent itself, which begins to flow at a noticeable rate even at 0.8 V. The mercury (II) chelating agent also oxidizes at the platinum anode at slightly higher potential values ( $E_{1/2} = 0.92$  V), and therefore its wave is expressed even less clearly than the wave of free MPCMDEDTC.

Taking into account the voltammetric behavior of all components of the reaction of formation of mercury (II) chelating agent, it can be concluded that amperometric titration of mercury (II) should be carried out at a half-wave potential in the range of  $E_{1/2} = -0.80$ – $-0.90$  B. Under such conditions, to the point of equivalence, the indicator current will be due to the simultaneous reduction of titrated mercury (II) ions at the cathode and the oxidation of the resulting mercury (II) chelating agent at the anode. Since in this case the concentration of mercury (II) will continuously fall from its initial to almost zero value, and the concentration of mercury (II) chelating agent, on the contrary, will increase, the indicator current will first increase to a certain maximum value, reached at the time of titration of approximately half of all mercury (II), and then fall in this case, a continuously increasing current is observed, due to the reduction of mercury (II) chelating agent at the cathode and the oxidation of free MPCMDEDTC on the anode.

When mercury (II) is titrated against a background of 0.125 M  $\text{LiClO}_4$  a fairly clear titration curve is obtained with a smooth curve in the vicinity of the titration end point, which indicates a slightly lower strength of mercury (II) chelating agent in DMSO compared with its strength in water. The titration endpoint, determined by the generally accepted graphic method, corresponds to the formation of a normal complex of mercury (II) with MPCMDEDTC with a ratio of mercury (II): MPCMDEDTC = 1/1. Unlike solutions containing lithium perchlorate as a background, solutions of mercury (II) nitrate against the background of sodium acetate and acetic acid are titrated much worse: the titration curve is less clear and the equilibrium time sharply increases after each titrant addition. This is explained by the ability of mercury (II) to form very strong complexes with acetate ions.

In order to assess the reproducibility and correctness of the developed method, various amounts of mercury (II) were titrated against a background of 0.1 M lithium perchlorate with a 3-fold repetition of

each determination. The results of titrations of mercury (II) with the standard MPCMDEDTC solution showed that the difference between the taken and found amounts of mercury (II) in all cases does not go beyond the confidence interval, which indicates the absence of systematic errors.

Amperometric titration of mercury (II) with MFKMDEDTK solution can be used in the analysis of certain paints, pharmaceuticals and perfumes containing mercury that are poorly soluble in water.

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