INTEGRATION OF TECHNOLOGY IN THE MECHATRON MODULE OF LIQUID DOSING

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Abstract. *The influence of individual parameters on the accuracy of product dose formation was determined during physical and mathematical modeling. We have found ways to ensure the necessary distribution of compressed air pressure, subject to compliance with the specified performance of the dispenser. Research results make it possible to improve the operation of dosing systems for liquid products with high dosing accuracy. The control system is formed on the basis of electro-pneumatic complexes. The control model with dosing operating modes is substantiated. It was established that the consumption of compressed air will depend on the value of the input main pressure P (0.05... 0.4 MPa).*

The consumption of the product was in the range of 1 ml to 50 ml with a feeder volume of 2.25 l. A mathematical model of the dosing process of liquid products (non-carbonated drinking water, milk, juice) has been developed. Boundary conditions took into account the influence on the formation of the product dose from the programmed current values in mA (with an accuracy of 0.001 mA) in relation to the standard scale Imin, Imax=4..20 mA.

An analytical description of individual stages of the dosing process with further analysis of individual stages and accepted assumptions was formed. Tests of the experimental sample of the dispenser showed the accuracy of the repetitions of the dose extrusion (limits ± 0.035% and 0.8%) from the set value of the dose mass up to 50 ml during the change and the initial liquid level in the reservoir of the dispenser feeder.

Keywords: *dosing, air lift system, excess pressure, feedback, dosing accuracy.*

I. INTRODUCTION

A number of small and medium-sized enterprises are now engaged in the production and packaging of liquid products in containers. In this regard, the problem of creating inexpensive and compact import-substitutable dosing and packaging equipment, taking into account the specific working conditions for small productions, becomes extremely urgent [10-27].

The systems of dosing and packaging modules for liquid products in containers, in the conditions of small productions, have specific requirements: high operational reliability, a wide range and high accuracy of dosing in combination with the possibility of rapid reconfiguration of the equipment for different types of liquids and dosing ranges; the possibility of smooth adjustment of the dose in a wide range; the possibility of prompt flushing or replacement of the product line; the possibility of installing the dispenser in the conveyor line; construction of multi-channel dosing systems; absence of intraoperative drop formation; compactness, simplicity and safety of maintenance; fire and explosion safety, etc.

Therefore, the tasks of developing valveless airlift systems for dosing and packaging of liquid products are relevant.

II. LITURATURE ANALYSIS

The processes of food, chemical, textile, perfumery and many other industries are based on operations of metered supply of liquid products. For example, in work [1-27], the costs of the product, which are established by the technological regulations, are investigated. The authors describe a process control system based only on the contours of the automatic adjustment of one dosing parameter. The issues of development and implementation of aerial mechatronic dosing systems with tracking circuits for two or more technological parameters remain unresolved. Critical analysis of liquid food product dosing systems is based on electropneumatic systems and is complicated by the lack of ready-made industrial executive modules. In particular, in [2] dosing devices for small dose ranges. The analysis of the task of automating technological processes of aerial dosing, in work [3], describes the design of servo-pneumovalves. This description is even more complicated because the control object has an inertial delay and parametric non-stationarity. The results given in [4] can be a solution to overcome the relevant difficulties. In this case, a high-quality organization of dosing processes is possible only when closed systems of automatic regulation are used. Such tasks require the development of universal automatic dosing systems, which are functionally adapted to perform both batch and continuous dosing operations. [5,6] Complex tasks for the formation of multicomponent emulsions, as the authors note, are a relevant direction in the development of synergy of water purification systems with elements of dosing systems. The issue of dosage accuracy is also relevant. Despite the fact that in the work [7-9], the authors described the data of the analysis of pure water and impurities added to it, but the results do not give recommendations for the design of the dispenser.

The text of the source [10-11] describes data on the dosing process with an analysis of the reliability parameters of technological elements. Pneumatic valves and product line connection systems are described, but the results are not complete. The dosing principle, described in [12], is time-oriented with the condition of ensuring a constant flow of liquid. Unfortunately, the results of the conducted experimental studies do not describe the energy consumption of the dosing system [13-17]. Therefore, there are reasons to assert the expediency of conducting a study devoted to the construction and testing of liquid product dosing systems based on electropneumatic complexes.

And also, according to the method of empirical research, to obtain results for the analysis of the process of forming the dose of the product for the airlift dispenser system and the study of further dosing accuracy.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of the research is an in-house developed manipulator-dispenser of the airfoil type for liquid food products. The subject of the research is the processes of formation and release of the product dose in the airlift type system.

The purpose of the research is mathematical and physical modeling for the process of aerial dosing of liquid food products. For this, the search for initial conditions and assumptions is proposed. This provides calculations for the further development of a functional airlift dosing module without dose shut-off valves and piping fittings.

The research objectives are as follows. Investigate the process of formation and subsequent extrusion of the dose of the product from the dosing receiver. Analytical description of individual stages of the dosing process and further analysis of individual stages and accepted assumptions. Determining the influence of individual parameters on the accuracy of product dose formation, as well as finding ways to ensure the necessary distribution of compressed air pressure under the conditions of compliance with the specified performance of the dispenser. Development of a stand for the study of a functional dosing module with software-set modes of product dose formation and displacement.

Research methods. The experimental theoretical studies performed were based on the application of fundamental laws for the hydrodynamics of liquid media and viscous fluid media, the general theory of solving ordinary differential equations, the theory of 3D modeling, and the mathematical statistical theory of experimental data processing.

The research is based on the static and dynamic characteristics of the control system of the dosing device with the analysis of the choice of design parameters of the equipment, which is aimed at improving the metrological characteristics of the automated airlift dosing system.

Schematic diagrams of universal dosing devices and dosing control algorithms were developed to prepare experiments that ensure the implementation of various laws of product dose formation. The assessment of systematic errors was carried out in the Excel package for the proposed method of batch dosing. The batch system of automated dosing, based on the principles of the airlift system and works [3, 5, 8, 11-26], is described by the mathematical model of the description of the dosing process, the scheme of the experimental setup and is described below.

Experimental studies of processes of precessional dosing of liquid products based on electropneumatic complexes, carried out taking into account numerical methods; hydrogas dynamics; copyrights.

IV. RESULTS

4.1. Experimental stand

The installation diagram of a valveless electropneumatic dosing device with a control module is shown in Fig. 1. The diagram in Fig. 1 contains a pneumatic control system (CP) 4 for processing pressure signals about PP (pi) and DE (p) in a programmable logic controller (PLC). Control signals are generated on the executive pneumovalves of the dispenser -5, 6, 7 and 8. In fig. 1, a valveless electropneumatic dosing device for an airlift type of dosing tank system is given. The solution refers to pressure-type dosing systems. The feeder tank (PP) 1 has a liquid level sensor 2, formed with a system for pushing out the product into the dosing receiver (DE) - 3.

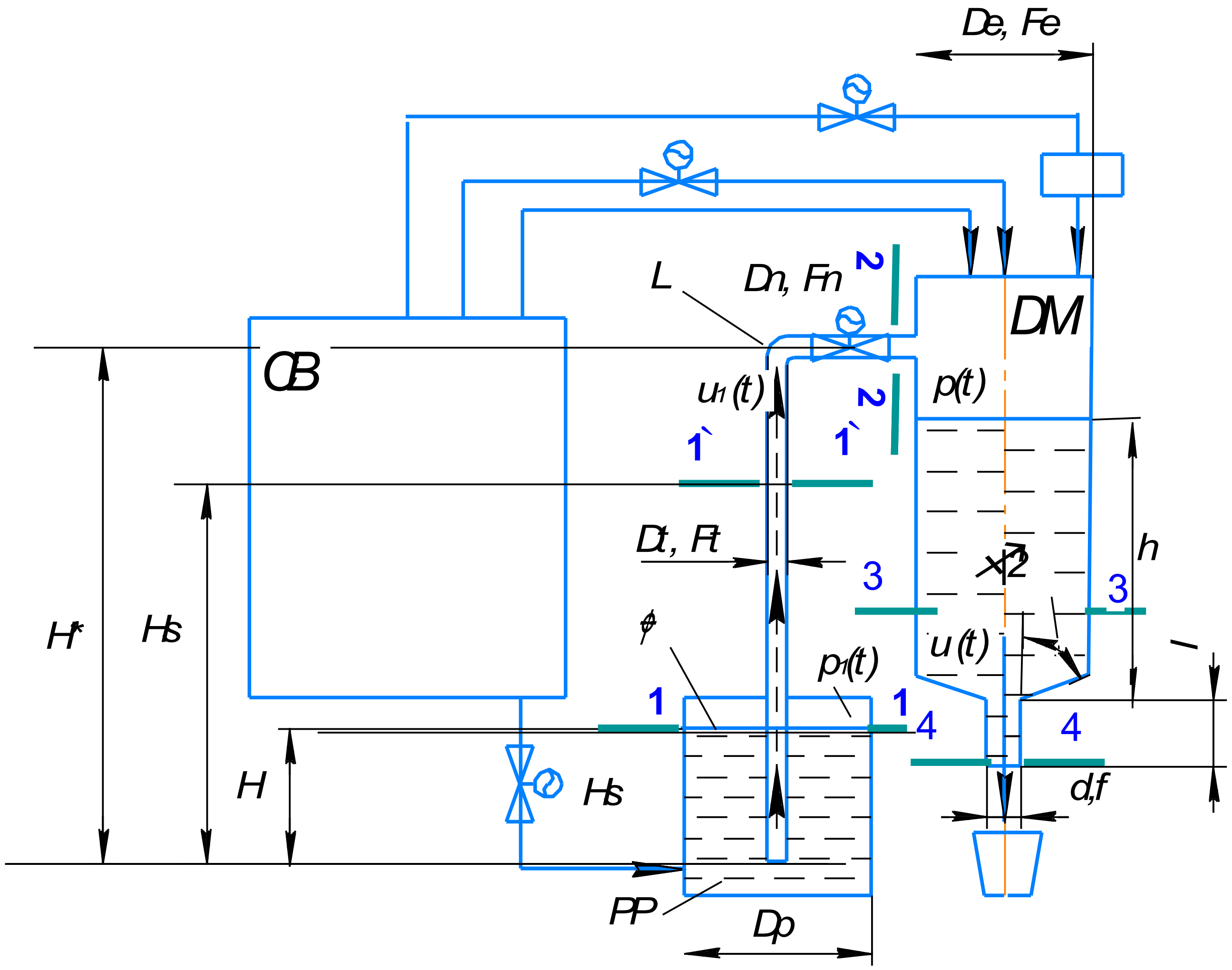


Fig. 1. Installation diagram for a valveless electropneumatic dosing device of an airlift type system with a control module: 1 - loading hopper, 2 - product supply area by auger, 3 - vertical transport channel; 4 - product, 5 - compressed air; 6 - gas suspension (air, fine-grained product), 7 - electropneumatic control unit; P - main pressure of compressed air (MPa), 2P - double the pressure at the booster outlet; 1.1., 1.2. - reed switches; l1, l2 - length of the acceleration section and stabilization section (m)

PP with a level sensor, DE and executive pneumatic valves of the DU are the basis for the OU control object. The pressure control system for pushing out the dose in the dosing receiver works on a combination of the control system with feedback (current loop format 4..20 mA). The control signal can also be adjusted according to the current on the solenoid of the distributor by supplying compressed air to the remote control with a range of 0..5s.

The principle of operation of the dispenser is based on the software control of the pressure supply to the system of the dosing receiver from PP with the DE mounted above it at a height of H*y. The dose of the product is formed through the drain pipe 9 (DE) due to the change in pressure in the DU system and with the help of an ejector.

The dosing process is controlled within the limits of the pressure P in a closed gas medium of variable volume, and is accordingly ensured in the process of product outflow. At the beginning of the operation of the dosing module, the DE is connected to the channel 10 of the power source through the open valve 7. At the same time, blowing with compressed air for the drain pipe 9, the inlet pipe 11 and the connecting pipe 12 is turned on. Such actions maintain the cleanliness of the product line of the dispenser until the start of the next dosing cycle.

DU the remote control is in the dosing mode, and at this time, the command-programmed pressure change in the control device from the PLC is carried out

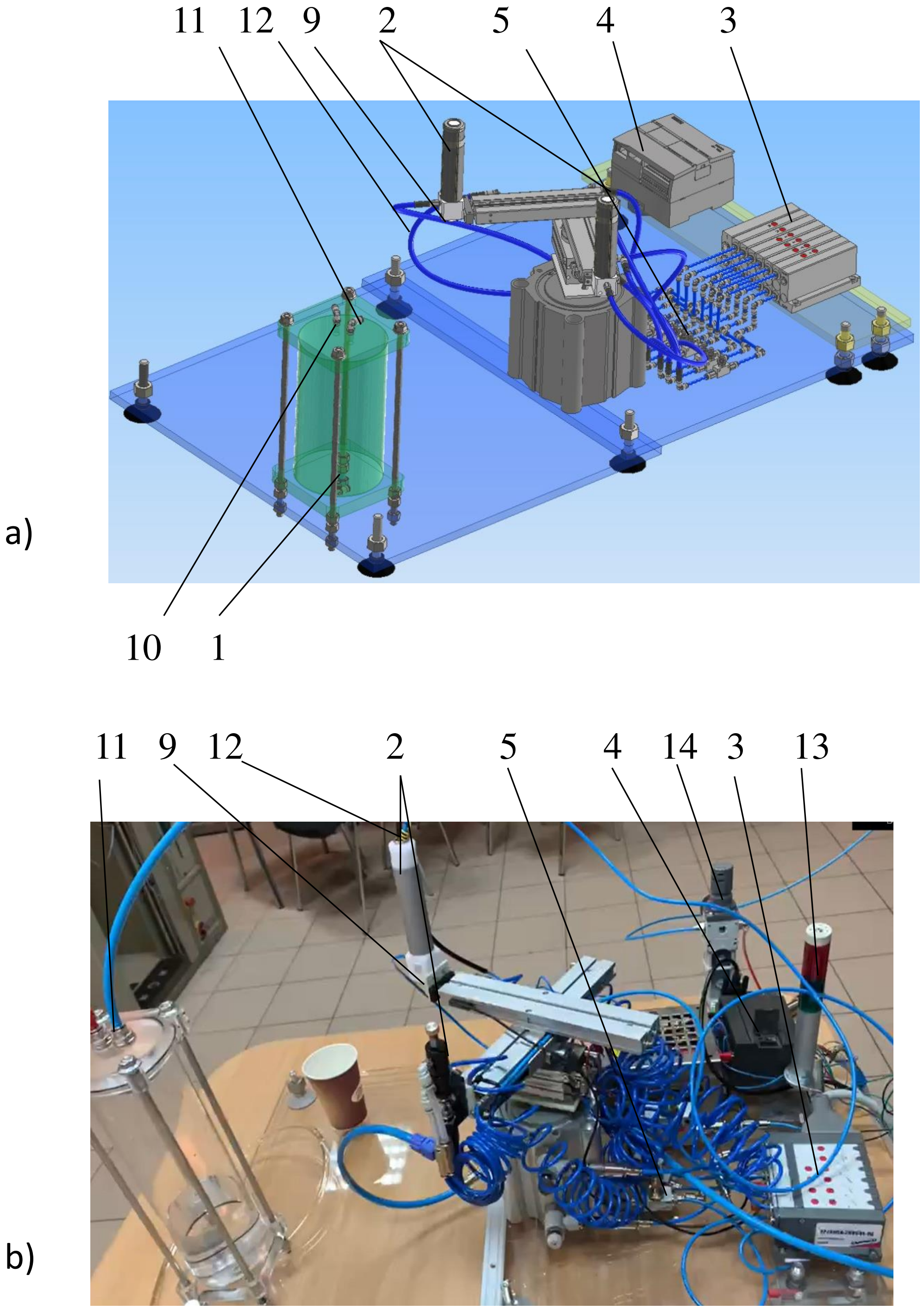


Fig. 2. Type of the experimental stand for the study of the airlift system for dosing liquid products: a) – general view of the experimental stand 3D; b) – general view of the dosing manipulator module after installation; 1 – waste tank; 2 – dosing and packaging module of the membrane type; 3 – a pneumatic island with a set of executive control valves (electromagnetic distributors 3/2NO, 5/3, 5/2) with a pneumatic signal;

4 – control system (PLC); 5 – executive pneumovalves of the doztor; 6 – module for linear movement of dispensers (2 tandem cylinders with anti-rotation platform; 7 – rotary cylinder; 8 – module for vertical movement of the manipulator (linear cylinder is equipped with sensors and reed switches); 9 – drain nozzle; 10 – power source channel with ejector; 11 – inlet nozzle 12 – connecting pipeline); 13 – signal lamp; 14 – compressed air control and preparation unit

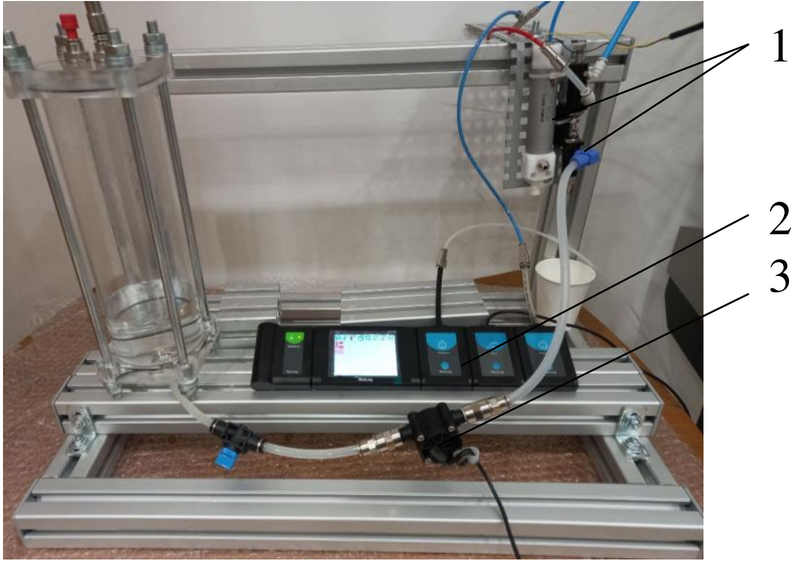


Fig. 3. Elements of the control system: 1 – dispenser; 2 - analog-digital measuring complex (flow sensor, pressure sensor, signal processing system); 3 – flow-mirror type

The dosing cycle is based on the stages of product filling of the pipeline 12, partial filling of the DE and displacement of the product, with the setting of the UE purging mode. The operation of the DU involves fixed values of the design parameters: nozzle and outlet cross-section of the nozzle, through-sections of the product line, the length of the compressed air supply pipeline and the full volume of the DE, the height H* for the installation of the DE. Therefore, the time constant PZ and pressure for the power source 10 and the size of the dose volume Vd will be a function of the pressure formed for the ru dispenser and for the initial filling level of PP – H0. We also obtained a function with the condition of a constant H0 value to ensure the working tare characteristics of the dosing module. The function describes the error for fixed values of py during the change of the initial filling level of PP. On the basis of the conducted experimental research, the error values are set within the limits of ±1%.

To analyze the conditions for ensuring the accuracy of dosing, the design of the experimental stand of DU was developed (Fig. 3). We will consider the flow of the product in the connecting pipeline (from RR to DE) with the analysis of movement through the drain nozzle of DE in the system of unsteady one-dimensional turbulent motion of a Newtonian fluid. The impact of various factors on dosing accuracy was evaluated with accepted assumptions. The comparison of different stages of dosing during the operation of the DU was carried out under the condition of a constant pressure value, which is programmed for the Ru doser.

4.2. Mathematical model

At the stage of filling the connecting pipeline, we will describe a system that contains two equations for the variables s (t) and H (t), where s (t) is the current level of the liquid in the pipeline, H (t) is the current level of the liquid in the PP.

The equation of motion for the free surface of the test liquid in the connecting pipeline, according to the Bernoulli equation for unsteady motion for section 1 - 1, which coincides with the position of the liquid level in the RR, and section 1'- 1', and coincides with the liquid level in the assembled pipeline at a distance s from the inlet edge for the pipeline:

$$s(d^2s/dt^2)+\frac{\lambda_T}{2D}s(ds/dt)^2+\frac{1+\xi_T}{2}(ds/dt)^2+gH_s(s)=\frac{p_1(t)}{\rho}+gH(t). \tag{1}$$

During the simulation, there are additional assumptions: Hs(s) is the height of the section 1' - 1' as a function of the parameter s, which depends on the configuration of the connecting product line; DT is the diameter of the connecting pipeline;

$$p_1(t)\cong p_{1,3}(t)=P(1-e^{-t/\tau_0}),\,\text{—} \tag{2}$$

$p_1(t)$ – the actual pressure in the RR as a function of time t under the condition of the ideality of the programmable RD pressure regulator; *$p_{1,3}(t)$* $p_{1,3}(t)$ – set value of the adjustment parameter; *P=const* – supply pressure of pneumatic elements of UU; τ_0 – the software time constant, which depends on the conditions of the surrounding environment; ρ - product density; g = *const* – acceleration of gravity; ξ_T = *const* – coefficient of local resistance at the entrance to the product line, which depends on the configuration of the entrance edge of the pipeline; λ_T – the coefficient of friction in the pipeline depends on the Reynolds number $Re_T = \rho D_T(ds/dt)/\mu$, is calculated by the Blasius formula:

$$\lambda_T=\frac{0,316}{(\mathrm{Re}_T)^{1/4}}=\frac{0,316}{(\rho D_T(ds/dt)/\mu)^{1/4}}, \tag{3}$$

coefficients $\alpha_{1\text{-}1}$; $\alpha_{1'\text{-}1'}$ take into account the non-uniformity of the distribution of velocities in the sections 1- 1; 1'-1', we take as equal 1; μ - dynamic viscosity of the product, which depends on temperature. During the formulation of equation (1), a number of assumptions were made: from equation (1), we neglect (insignificant values) the product velocity coefficient in the RR and take the cross-sectional area of the RR and the connecting product pipeline: $\Omega = \pi D^2_p/4$; $F_T = \pi D^2_T/4$ – area of RR cross-sections and connecting pipeline.

The balance equation of fluid flow from RR is as follows:

$$-\Omega(dH/dt)=F_T(ds/dt).. \tag{4}$$

The system of equations (1) and (4) is solved according to the initial conditions: s*(0) = s_0 = H_0, (ds/dt)(0)=(ds/dt)$_0$=0; H(0) = H_0.* The result of solving this system is the value of the function *s(t)* provided the time is determined τ_T product filling of the connecting nozzle and initial speed $u_{1,0}$ introduction of the product in DE. Provided the value is known *s(t)* parameters τ_T, $u_{1,0}$ are defined as:

$$s(\tau_T)=L;\ u_{1,0}=\left(ds/dt\right)|_{t=tT},, \tag{5}$$

L – pipeline length.

The stage of filling the DE drain pipe determines the initial conditions of the next stages of the dosing process - the outflow of the product in the outlet section. Given the small size of the nozzle, in particular its length *l* and the empirical value of the optimal ratio of the inlet pipe diameters D_n for DE and nozzle *(d)* - $D_n/d \geq 1{,}7$ we accept the condition that the inflow of the product into the DE at each moment of time exceeds the consumption through the section of the nozzle with the following conditions:

$$\begin{gathered} u_1(0) = u_{1,0}; H(0) = H_0^* = H_0 - F_T L; p(0) = p_0 \cong 0; h(0) = h_o \cong 0; \\ v(0) = v_0 \cong 0; u(0) = u_0 = \sqrt{2gl}\ ; p_1(0) = p_{1,0} = P(1 - e^{-\tau/\tau_0}), \end{gathered} \tag{6}$$

where $u_1(t)$ – speed of movement in the product pipeline, $H(t)$ – the current value of the product level in RR; $p(t)$ – pressure in the DE gas space during filling; $h(t)$ – product level in DE; $v(t)$ – the volume of the filled part of the DE without the volume of the drain nozzle; $u(t)$ – the flow rate of the product through the nozzle.

Note that the outflow of the product is carried out through the section of the nozzle and is described by conditions (6). The equation of motion of the product in the connecting pipeline is represented by the Bernoulli equation for unsteady motion, according to constraints 1–1; 2–2, taking into account the condition of the equality of the diameters of the product line and the DE inlet pipe $(D_T=D_P=D,\ F_T=F_P=F)$ will look like:

$$\frac{p_1(t)}{\rho g} + H = \frac{p(t)}{\rho g} + H^* + (1 + \xi_T + \lambda_T \frac{L}{D}) \frac{u_1^2}{2g} + \frac{L}{g} \frac{du_1}{dt}, \tag{7}$$

$$p_1(t) \cong p_{1,з}(t) = P\left(1 - e^{-(t+\tau_T)/\tau_0}\right), \tag{8}$$

the pressure in the RR is a function of time t under the condition of ideality of the software pressure regulator of the RD; λ_T – coefficient of friction in the pipeline, which depends on the Reynolds number $\mathrm{Re}_T = \rho D u_1 / \mu$, which is calculated by the Blasius formula:

$$\lambda_T = 0{,}316 / (\mathrm{Re}_T)^{\frac{1}{4}} = 0{,}316 / (\rho D u_1 / \mu)^{\frac{1}{4}}. \tag{9}$$

Similarly to equation (1), in equation (7) coefficients $\alpha_{1\text{–}1}$ та $\alpha_{2\text{–}2}$, take into account the unevenness of the speed distribution in sections 1–1 and 2–2. The specified coefficients are assumed to be constant and equal to 1. Also, we ignore the equal component $\alpha_{1-1}(F/\Omega)^2(u_1)^2/2$, which takes into account the pressure velocity in RR.

Accordingly, for periods 3–3 and 4–4, the product flow equation is also based on the Bernoulli equation:

$$\frac{p(t)}{\rho g} + l + h + \frac{(\frac{dh}{dt})^2}{2g} = \left(1 + \xi_n + \lambda_n \frac{l}{d}\right) \frac{u^2}{2g} + \frac{l}{g} \frac{du}{dt}, \tag{10}$$

λ_n – coefficient of friction inside the nozzle; ξ_n – nozzle inlet resistance coefficient, $\alpha_{3\text{-}3}$ та $\alpha_{4\text{-}4}$ – speed distribution coefficients in these sections are equal to 1. Then, the cost balance equation in DE:

$$\frac{dv}{dt} = u_1 F - u \cdot f, \tag{11}$$

$v=v(t)$ – fluid volume in DE. Consider the equation of the gas state in DE:

$$v = V_0 p / (P_a + p), \tag{12}$$

V_0 – DE volume, taking into account the volume of connecting channels, except for the drain nozzle, P_a – atmospheric pressure. Equation (12) corresponds to the isothermal compression of gas in the DE system, subject to the inequality: $P_a \square\ p_0 \cong 0$. p_0 – excess air pressure in DE at a moment in time t=0, this is the period of completion of product filling of the cross-section of the DE drain nozzle.

The equation of the balance of product costs in DE will look like this:

$$-\Omega\left(\frac{dH}{dt}\right) = u_1 F. \tag{13}$$

The equation of the relationship between the volume and the level of the product in DE:

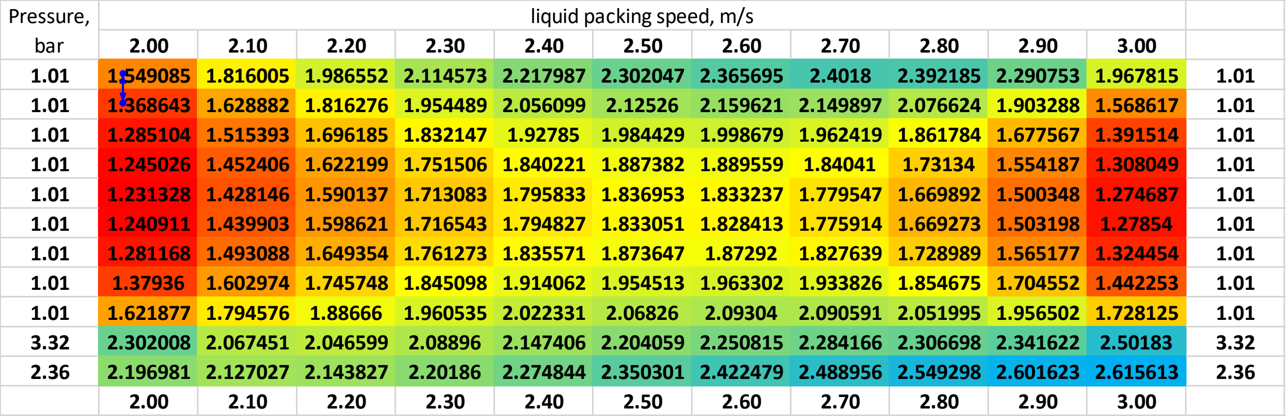
$$v = \left(\frac{1}{3}\right)\alpha_1 h_3 + \left(\frac{1}{2}\right)\alpha_2 h^2 + fh \text{ provided } h \le h_k, \tag{14}$$

$$\mathrm{P}\, v = \left(\frac{1}{3}\right)\alpha_1 h_3 + \left(\frac{1}{2}\right)\alpha_2 h^2 + fh \text{ provided } h \le h_k, \tag{15}$$

in accordance $\alpha_1 = \pi tg^2\left(\frac{\varphi}{2}\right)$, $\alpha_2 = \pi dtg\left(\frac{\varphi}{2}\right)$, h_k – height of the lower conical part of DE; $F_e = \pi \frac{D_e^2}{4}$ - the area of the cylindrical section DE. Ejection of the dose of the product and the subsequent process of switching to the purging mode using the ejector occurs according to the established algorithm and is achieved by bringing the pressure to the programmed value p_y. The process is accompanied by the opening of valves 5 and 7; at the same time, the pressure in DE increases from the value p_y to a value equal to the supply pressure R. A pressure p_1 in RR decreases from p_{1vd}, (moment of dose cut-off) to zero. Under the action of pressure P, the DE is completely emptied. After the end of the process, the pressure p in the DE is reduced due to the removal of air into the atmosphere through the drain nozzle. Considering the small volume of DE - V_o and nozzle length – *l*, its complete emptying occurs significantly earlier than in the connected pipeline, as well as before the pressure drops to zero p_1 in PP.

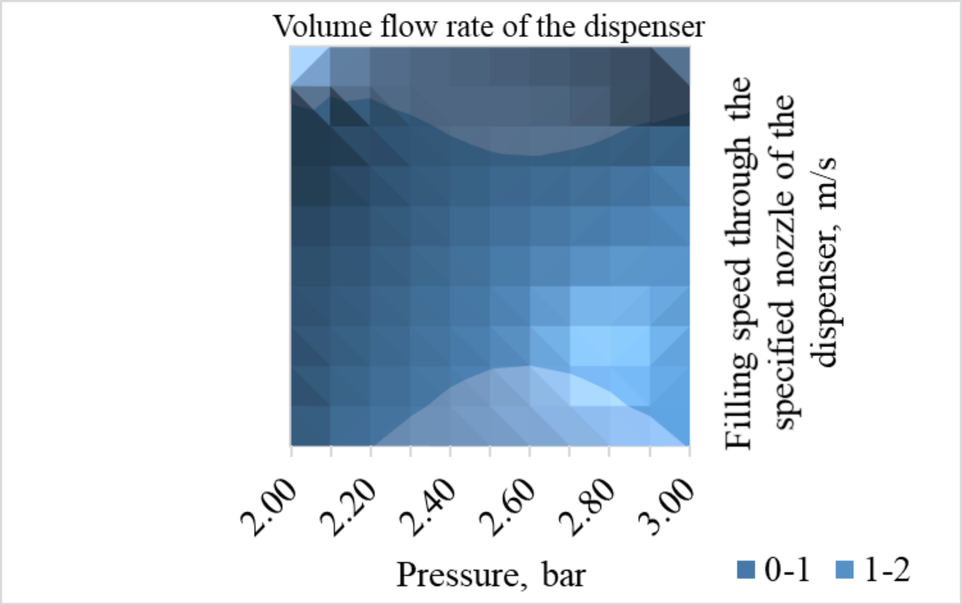
4.3. Study of a precision dosing system for liquid products based on electropneumatic control systems.

In fig. 3 shows the results of the conducted experiment according to the algorithm for changing the pressure in the feeder tank of the dispenser from excess to vacuum pressure, in accordance with the developed plan of the drinking water dosing experiment. After summarizing the results of the conducted experiment in Excel, the results in Fig. 3 are obtained:



Pressure, bar	liquid packing speed, m/s										
	2.00	2.10	2.20	2.30	2.40	2.50	2.60	2.70	2.80	2.90	3.00	
1.01	1.549085	1.816005	1.986552	2.114573	2.217987	2.302047	2.365695	2.4018	2.392185	2.290753	1.967815	1.01
1.01	1.368643	1.628882	1.816276	1.954489	2.056099	2.12526	2.159621	2.149897	2.076624	1.903288	1.568617	1.01
1.01	1.285104	1.515393	1.696185	1.832147	1.92785	1.984429	1.998679	1.962419	1.861784	1.677567	1.391514	1.01
1.01	1.245026	1.452406	1.622199	1.751506	1.840221	1.887382	1.889559	1.84041	1.73134	1.554187	1.308049	1.01
1.01	1.231328	1.428146	1.590137	1.713083	1.795833	1.836953	1.833237	1.779547	1.669892	1.500348	1.274687	1.01
1.01	1.240911	1.439903	1.598621	1.716543	1.794827	1.833051	1.828413	1.775914	1.669273	1.503198	1.27854	1.01
1.01	1.281168	1.493088	1.649354	1.761273	1.835571	1.873647	1.87292	1.827639	1.728989	1.565177	1.324454	1.01
1.01	1.37936	1.602974	1.745748	1.845098	1.914062	1.954513	1.963302	1.933826	1.854675	1.704552	1.442253	1.01
1.01	1.621877	1.794576	1.88666	1.960535	2.022331	2.06826	2.09304	2.090591	2.051995	1.956502	1.728125	1.01
3.32	2.302008	2.067451	2.046599	2.08896	2.147406	2.204059	2.250815	2.284166	2.306698	2.341622	2.50183	3.32
2.36	2.196981	2.127027	2.143827	2.20186	2.274844	2.350301	2.422479	2.488956	2.549298	2.601623	2.615613	2.36
	2.00	2.10	2.20	2.30	2.40	2.50	2.60	2.70	2.80	2.90	3.00	

a

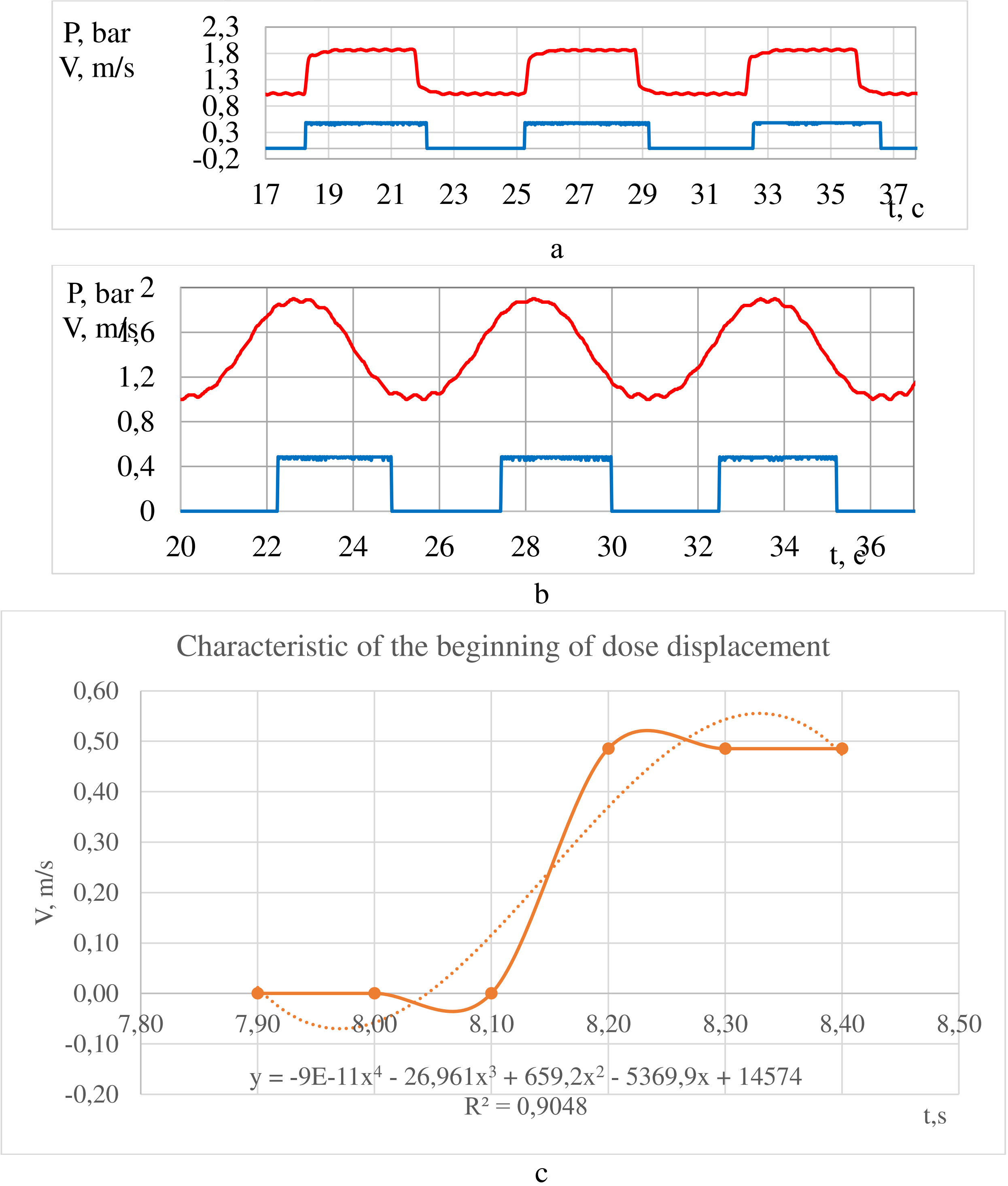


b

Fig. 3. Characterization of changes in the main parameters of dosing and pressure control in the airlift functional mechatronic dosing module system under the condition: a) according to tabulated average data of dosing experiments; b) change in pressure in accordance with the change in flow rate in the vector field with determination of extrema

Stationary mode is determined by air speed and pressure, which remain constant during the operation of the installation, taking into account the mode of transportation. Air speed and pressure at the inlet are the main conditions for the start of the product dose selection (extrusion) stage. The first stage of Fig. 3, a, b shows the output of the installation to the stationary mode of product extrusion when compressed air is supplied to the system within the software-defined range of pressure changes in the range from 0.99 to 1.81.

4.4. Characterization of the laws of controlling the parameters of the functional mechatronic module of aerial dosing with a change in pressure in the product line. The range of pressure change was chosen by the method of sorting, based on the main monitoring of the change in the flow rate in the system (0.5 m/s) and the accuracy of the allocated dose (50 ml): As the compressed air accumulates in the supply receiver, the speed and pressure stabilize, the dosing accuracy increases by 2 % (Fig. 4, a, b). (Addition A) The second stage of research, the results of which are shown in Fig. 4, is related to the monitoring of the working zone of changes in the parameters of the speed of movement of the dosed product in the pipeline. Acceleration is determined by a time interval of 0.1... 0.3 s and depends on the established compressed air supply control modes. Measurements were carried out using a turbine-type digital flow meter. In fig. 5, b clearly shows the distribution of the linear speed of the movement of the fine-artificial product when moving in the channel of the product pipeline under pressure. This confirms the results of modeling [7], regarding the influence of local resistances on the increase of specific pressure losses.



a

b

c

Fig.4. Characterization of the laws of controlling the parameters of the functional mechatronic module of airlift dosing with a change in pressure in the product pipeline under the condition: a – change in pressure and flow rate in the output product pipeline

during the influence of the control signal according to the step law; b – change in pressure and flow rate in the output product line during the influence of the control signal according to the sinusoidal law; c – the results of the experimental data are worked out in Excel by a polynomial of the 4th degree

As a result of working out the experimental measurements, the data characterizing the dosing and packaging process was obtained within the specified error of up to 2%. The value of the approximation reliability coefficient is 0.9.

V. CONCLUSIONS

The obtained results are explained, first of all, by the fact that the shape of the working channel of the product line and the diametrical cross-section of the working channel for the supplied and squeezed product from the dosing receiver are taken into account. As the time of the dosing process increases, the compressed air in the product line stabilizes and the accuracy of the product dose improves significantly.

Stationary mode is determined by air speed and pressure, which remain constant during the operation of the installation, taking into account the mode of transportation. Air speed and pressure at the inlet are the main conditions for the beginning of the stage of selection (extrusion) of the product dose. The results of the pressure change at the inlet and outlet of the product line are shown in (Fig. 3–4), due to internal pressure fluctuations of 20 Hz for 1 cycle of pressure supply. This mode of air supply is organized by the driver. Taking into account the purpose of the conducted research, which also takes into account the physical modeling of the airlift dosing process of liquid and low-viscosity food products. the initial conditions for further development and research of the operation of the functional mechatronic module of airlift dosing without dose cut-off valves and elements of pipeline fittings are defined. So, in particular, the error of dosing accuracy when using the step law of controlling the change in pressure in the dosing receiver system is 0.8% of the set dose of 50 ml; and when using the step law, the pressure change control in the dosing receiver system is 0.3%. The obtained modeling results allow, through physical modeling, to obtain initial parameters for mathematical studies, to describe the dependence of the main kinematic parameters of product dosing and to predict the drop and compensation of pressure in the dispenser system. The following parameters were introduced as limitations of the research results. current control value, relative to the standard scale, Imax..Imin = 4.1..19.9 mA, the frequency of compressed air pulses in the product line - 0.1... 7 s. Previously, the value of the control signal formed the maximum pressure in the pipe of 0.1... 0.5 bar. This confirms the results of the work [20, 22] and determines the optimal dosing regimen of the product under study. The limitations of the conducted studies can be considered that they were conducted only for liquid products from the group of Newtonian media. The lack of complete experimental data for other types made it impossible to carry out a more detailed analysis of the effectiveness of the developed design of the functional mechatronic module of airlift propulsion and its calculation methodology. Especially, this would be relevant for mixing products (suspensions, emulsions) with particles of different diameters (up to 1 mm or more), for which the curvature of the working channel in the diametrical cross-section of the product line can become a condition for influencing the accuracy of dosing.

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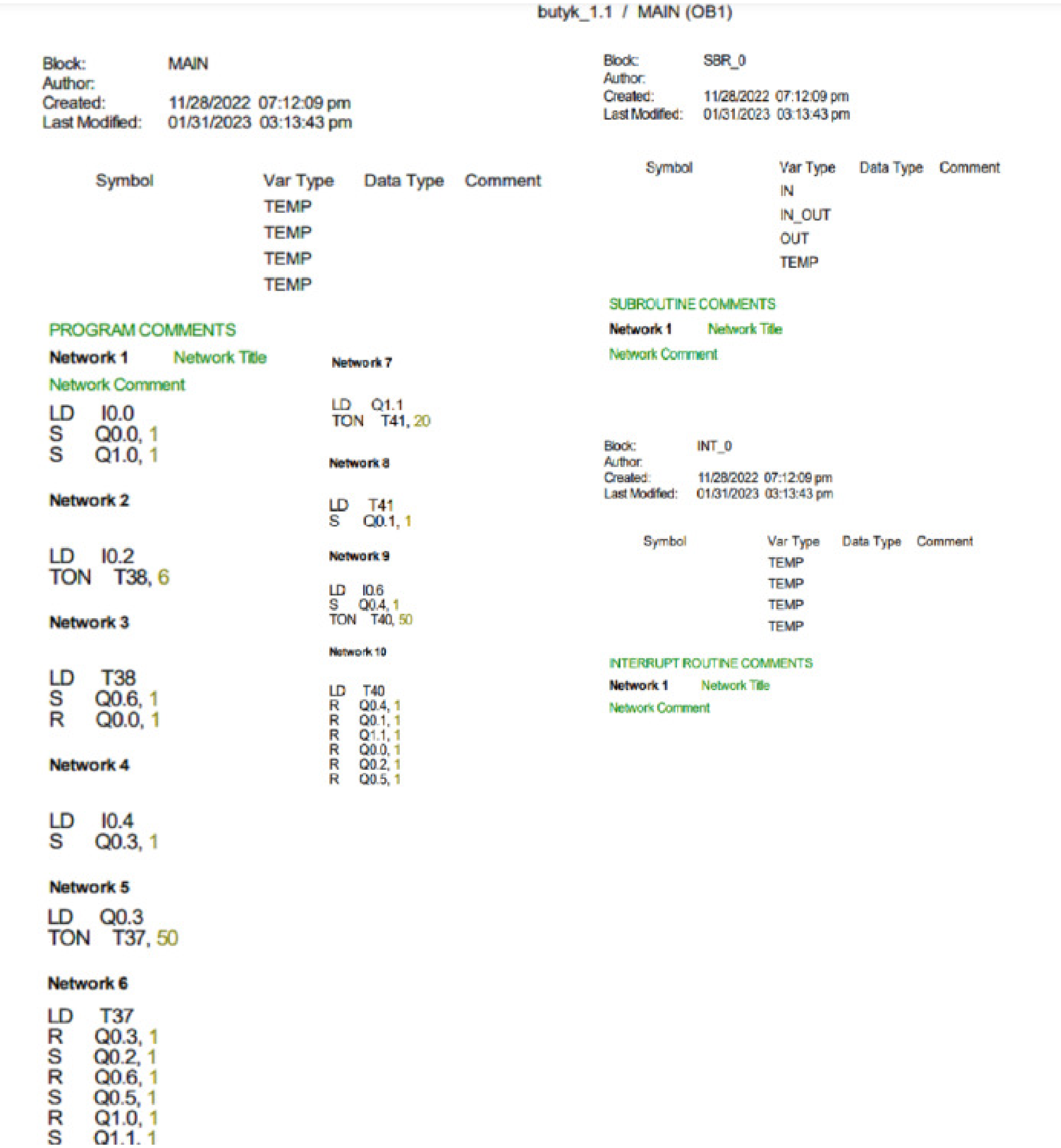
Addition A



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Last Modified:  01/31/2023  03:13:43 pm

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                          TEMP
                          TEMP
                          TEMP

PROGRAM COMMENTS
Network 1        Network Title
Network Comment
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S     Q1.0, 1

Network 2

LD    I0.2
TON    T38, 6

Network 3

LD    T38
S     Q0.6, 1
R     Q0.0, 1

Network 4

LD    I0.4
S     Q0.3, 1

Network 5
LD    Q0.3
TON    T37, 50

Network 6
LD    T37
R     Q0.3, 1
S     Q0.2, 1
R     Q0.6, 1
S     Q0.5, 1
R     Q1.0, 1
S     Q1.1, 1

Network 7

LD    Q1.1
TON    T41, 20

Network 8

LD    T41
S     Q0.1, 1

Network 9

LD    I0.6
S     Q0.4, 1
TON   T40, 50

Network 10

LD    T40
R     Q0.4, 1
R     Q0.1, 1
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R     Q0.0, 1
R     Q0.2, 1
R     Q0.5, 1
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                          IN_OUT
                          OUT
                          TEMP

SUBROUTINE COMMENTS
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Network Comment


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Created:        11/28/2022  07:12:09 pm
Last Modified:  01/31/2023  03:13:43 pm

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                          TEMP
                          TEMP
                          TEMP

INTERRUPT ROUTINE COMMENTS
Network 1        Network Title
Network Comment
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