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METHOD OF INTELLIGENT CONTROL OF THE PROCESS OF RECTIFICATION OF MULTICOMPONENT MIXTURES

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Abstract: *An intelligent method of controlling a rectification column, which implements the technological process of separation of multicomponent mixtures by rectification method, is proposed. The advantage of the method is that it uses an advanced process control system (APC-system) and a distributed control system at the same time. The proposed intellectual method of controlling the process of rectification of multicomponent mixtures for the application of APC-systems and a net model of situational control allows to increase the quality of the product coming from the rectification column, and the efficiency of the rectification of the mixture column, to increase the quality of the control of the process of rectification and to obtain energy savings. In the research work, a functional scheme of automation was developed, which serves to implement the control system of the rectification process of multicomponent mixtures. The APC-system, acting as an advanced control system, calculates the values of relevance functions using a virtual analyzer, a fuzzy model of situational control. The fuzzy model of situational control has the ability to calculate the possible situations and transfer them to the decision-maker using the relevance function expressed through linguistic variables. The programmable logic controller and I/O module included in the distributed control system provide timely delivery of measurement information and coordination of control decisions. The decision-making block in the control system allows to evaluate the quality indicators of the product on the basis of fuzzy logic.*

The concentration of the extracted components was selected as a quality indicator of the finished product. Factors affecting concentration are taken as terms, and a model for predicting uncertain situations is obtained. To calculate ambiguous situations, it is proposed to use the software called "Formation of ambiguous standard situations using linguistic variables in the control of the rectification process". In order to check the effectiveness of the proposed intelligent control method, regulation contours with simple PID-controller and fuzzy PID-controller were created using the Matlab application programming package. Descriptions of the transition process were obtained by studying regulation contours. The results show that the fuzzy PID-controller tuning loop has better control quality indicators. The proposed intelligent method of control the process of rectification of mixtures allows to improve the quality of the product and increase the quality of control.

Keywords*: intelligent control, mixtures, rectification, APC-system, fuzzy model, linguistic variable, situational control, membership function, regulator*.

INTRODUCTION. Today, in oil and gas processing, food industry enterprises, separation of multi-component mixtures by rectification method is common, and the quality of the extracted components is evaluated by their concentration. Rectification processes are carried out in columns. Accordingly, the modernity of technological process control systems in organizing the separation process directly affects product quality and energy efficiency. Therefore, regardless of the fact that a large number of scientific researches are being conducted in this field, it is important to improve the control systems of rectification processes, to develop intelligent control systems. Intelligent control systems are systems capable of learning, adapting and adjusting based on the memory and analysis of the information contained in the object's control and reactions to external influences. The characteristics of these systems include the presence of a database, a logical inference engine, systematic knowledge processing, and conceptual systems [1]. Intelligent control systems work based on situational control using knowledge processing information technologies.

In [2], an artificial intelligence-based option for the creation and development of automated control systems for technological processes (ACSTP) was considered. From the point of view of systems theory, the work describes the problems of creating modern and promising ACSTPs, intellectualization methods, observability and controllability properties, their connection with technological parameters, the methodology of ACSTP construction, the influence of the human factor, the place and role of expert and decision-making systems in ACSTP s. considered.

Also, the main methods and principles of mathematical modeling of ACSTP s, construction of simulation test stands and simulator complexes are presented. In his work, the author developed this methodology and proposed a scientifically based strategy for solving the problems of ACSTP and their systematic research. The main results of this work are the transformation of mathematical models of chemical-technological systems with stationary and non-stationary structures into dynamic and logic-dynamic models with average values and distributed parameters. In [3], it was shown that due to the complexity of solving the system of equations of heat and mass transfer, it is necessary to use simplified engineering methods to calculate the main parameters, which in turn causes large calculation errors. Therefore, the author of this work does not recommend using the methods shown in the development of control effects. The way out of such a problematic situation was considered to be in modern artificial intelligence technologies.

The author of the cited dissertation sought solutions to current problems such as minimizing energy and resource consumption, reducing the quality of manufactured products, reducing the productivity of technological processes, based on the development of algorithms for synthesizing the effects of real-time management effects for intelligent-information management systems. [4] based on nonlinear models of the separation process, a control system for optimal static modes of rectification columns was developed. This approach is based on the law of controlling the process based on a generalized model.

The authors of [5, 6, 7], based on fuzzy sets and flexibility theories, showed the existence of methods for solving optimization problems under conditions of uncertainty and suggested the use of a vector optimization approach to obtain more accurate solutions when working with uncertain models. That's why in this work, the output coordinates are kept at the given level due to the use of additional restrictions and generalized models. The analysis of the works presented above shows that there are different approaches to the development of control systems for the separation of multicomponent mixtures. However, none of them mentions the use of APC-systems in combination with distributed control systems.

MATERIAL AND METHODS. We focus on the analysis of several patents received for the development of control methods for the separation of multicomponent mixtures. There is a method of automatic control of the rectification process and a device for its implementation [8]. This method consists in adaptive control of the upper point of the temperature profile by changing the reflux flow rate depending on the magnitude of the current losses of raw materials, compensating for the disturbing effect from the feed mixture, as well as predicting the concentration using a mathematical model of the column top compensator. The disadvantages of the analogue is that it did not take into account the effect of changing the temperature profile in the lower part of the distillation column directly on the temperature profile in the upper part of the column, which adversely affects the dynamics of temperature change in the distillation column along the height of the column.

In addition, there is no correction for the temperature difference between the top of the distillation column and the feed tray, which has the greatest effect on the concentration of the finished product leaving the column. Consequently, the level of product quality control is reduced. The proposed device for implementing the method does not provide for the presence of a programmable logic controller, control is carried out only on the basis of regulators, which does not ensure the joint operation of the regulators. This, in turn, leads to an increase in the dynamic error of the rectification process control.

There is another method for automatically controlling the efficiency of the operation of the distillation process [9], including determining the current temperature profile of the column and calculating the current value of the efficiency of the distillation column, which is set as a task for the feed mixture temperature controller. The reflux flow rate is changed depending on the drift rate of the control criterion. The disadvantages of this method is that the temperature profile of the top of the column is controlled by changing the amount of reflux, taking into account the rate of entrainment of raw materials from the top of the column, which leads to a decrease in the efficiency of the column. Such control can only be used in cases where the amount of light fractions in the feed mixture is very small.

The closest in technical essence is the method of controlling the technological regime of the process of separating oil mixtures by the rectification method [10], including the calculation of product quality indicators based on the calculation of the characteristic points of the curve of the true boiling points of fractions of oil mixtures, as well as the formation of control actions supplied to the regulators of the technological parameters of the distillation columns as corrective. The disadvantages of the closest analogue are that the flow sensors installed at the outlet of the 3 side selections, which reduces the efficiency of the distillation column.

There is no reflux flow in the upper part of the column, which provides vapor-liquid balance and serves to adjust the temperature profile. In this case, it is not possible to control the temperature profile at the top of the column.

Based on the foregoing, the development of a method for intelligent control of the technological process of separation of multicomponent mixtures using the APC-system and a fuzzy situational control model to improve the quality of control with an increase in the separation effect is one of the topical problems.

RESULTS AND DISCUSSION. The problem is solved by providing intelligent control of the process of rectification of multicomponent mixtures, including a distributed control system and an APC-system, by using situational control models to predict changes in the values of the concentration of components, as well as a virtual analyzer when calculating the values of membership functions of indicators when rectification multicomponent mixtures. The functional scheme of the implementation of the method of intelligent control of the rectification of multi-component mixtures is presented in Fig. 1.

The method assumes the presence of a rectification column 1, temperature sensors 2, a dephlegmator 3, a boiler 4, a heater for the initial mixture 5, an interface for input of information and measurement data 6, a distributed control system 14, consisting of a fuzzy programmable logic controller 8 and an input-output device 7, APC-systems 13 (advanced process control systems), which includes a virtual analyzer 9, a decision making unit (DMU) 10, a block for calculating membership functions 11, a block for a fuzzy situational control model 12, and a data output interface 15, decision maker personal (DMP) 16, block for optimization parameters 17. Also used are sensors for the flow rate of the initial mixture FT 1-1, heating steam FT 2-1, liquid level in the lower part of the distillation column LT 3-1, reflux amount FT 4-

1, cooling water flow rate FT 5-1, finished product FT 6- 1, heating steam supplied to the boiler FT 7-1 and bottoms FT 8-1.

The method of intelligent control of the rectification of multicomponent mixtures is carried out in the following order. All measurement information obtained from temperature sensors 2, installed along the height of the column 1, flow sensors of the initial mixture FT 1-1 and heating steam FT 2-1, level sensor LT 3-1, reflux flow sensors FT 4-1, cooling water FT 5-1 and finished products FT 6-1, as well as heating steam FT 7-1 and VAT residue FT 8-1 is transmitted to the input-output unit 7 of the distributed control system 14 through the interface 6.

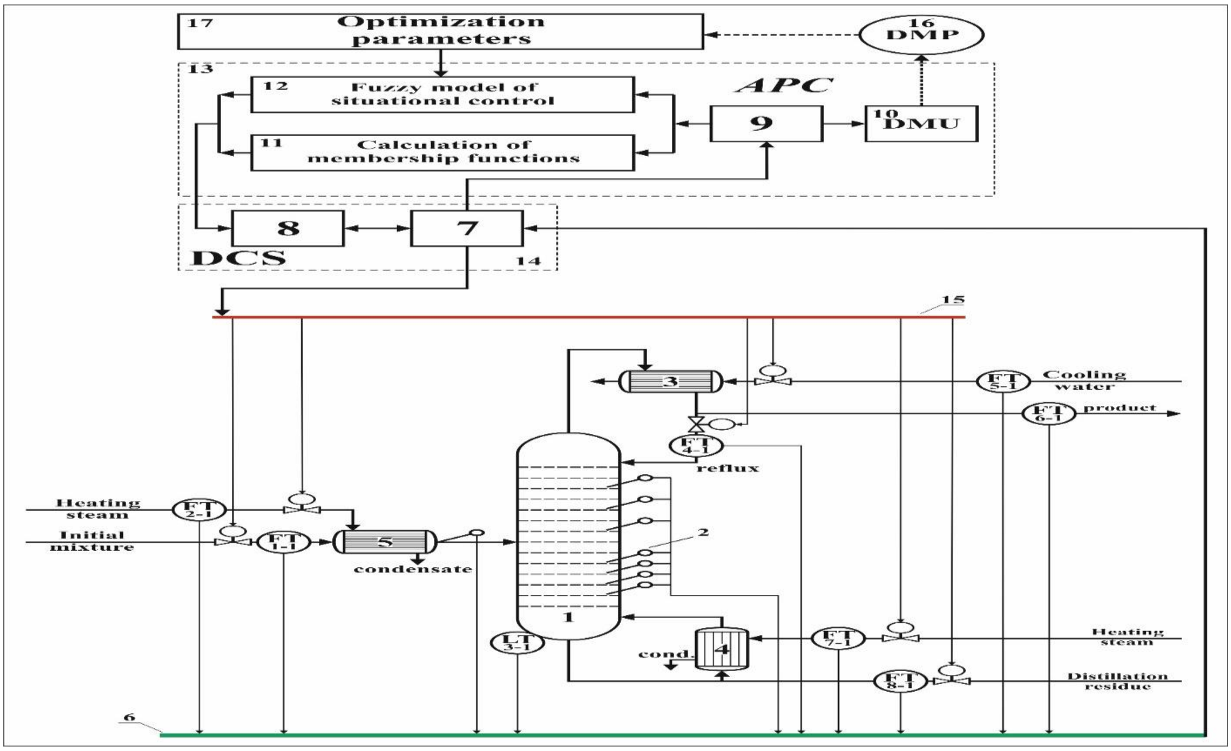

Fig. 1. Functional scheme of the implementation of the method of intelligent control of the rectification of multicomponent mixtures

Further, the signals from the I/O block 7 are transmitted to the programmable logic controller 8 and, after appropriate processing, to the virtual analyzer 9, to process the values of the main technological parameters of the process and transfer them to blocks that serve for intelligent process control: the decision making unit (DMU) 10 and blocks “Computation of membership functions” 11 and “Fuzzy situational control model” 12, which form the basis of the APC-system 13. In DMU 10, a decision is made on the concentration of the finished product based on fuzzy logic. DMP 16 takes into account the decision of the DMU block 10 and, if necessary, corrects the values of the optimization parameters 17. The APC system 13, taking into account the signals received from the virtual analyzer 9, and the corrections made by the decision maker 16 based on the calculated values of the membership function 11 and the fuzzy situational control model 12, sends a signal to the fuzzy programmable logic controller 8, which, in turn, on the basis of the signals received from the APC system 13, generates control signals sent through the input-output device 7 and interface 15 to the actuators on the supply and discharge lines of flows in accordance with the established regulations and software.

Since the finished product obtained by rectification multicomponent mixtures is a distillate, its quality indicator is expressed by concentration. The main block that implements the method of intelligent control of the process of rectification of multicomponent mixtures consists of the APC-system 13, in which in the calculation block of the membership function 11 and the decision block based on fuzzy logic 10 fuzzy values of the output parameter are calculated through the following linguistic variable “Distillate concentration”. Distillate concentration – C», C', X>, where *C* – concentration of finished products; C' = {“concentration is very low”, “concentration is low”, “concentration is normal”}; X = {0; 0.1; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9; 1.0} (deviation of the distillate concentration from the value required by the regulation in % by volume).

The block of the fuzzy model of situational control 12 of the quality of the finished product in the method of intelligent control of the process of rectification of multicomponent mixtures operates on the basis of three main parameters important for intelligent control of the process: the concentration of the initial mixture, the temperature difference and the amount of reflux. When using linguistic variables, a model representing an uncertain situation that occurs at an arbitrary stage of the intelligent control process (for example, at the *i*-th step) is written in the following form [11]: $\bar{S}_i =$ {<< μ_1^1/“ very low”>, < μ_2^1/“low”>, < μ_3^1/“normal”>/“*the concentration of the initial mixture*”>, << μ_1^2/“ very low”>, < μ_2^2/“low”>, < μ_3^2/“normal”>, < μ_4^2/“high”>, < μ_5^2/“very high”> / “*temperature difference*”>, << μ_1^3/“ very low”>, < μ_2^3/“low”>, < μ_3^3/“normal”>, < μ_4^3/“high”>, < μ_5^3/“very high”> / “*amount of reflux*”>.

In block 11 of the intelligent control method, the value of membership functions is calculated. In this case, it is defined as the μ_i^j degree of membership of the *i*-th term of the *j*-th sign. Here “very low”, “low”, “normal”, “high”, “very high” are terms, “concentration of the initial mixture”, “temperature drop”, “amount of reflux” are signs. For example, μ_5^2 of the membership degree corresponds to the 5th term (“very high”) of the 2nd sign (“temperature difference”), that is, a very high value of the temperature difference. Thus, using all the signs and terms, solutions are calculated that are suitable for all possible situations using the embedded software “Formation of fuzzy reference situations using linguistic variables in the management of rectification processes” [12] and presented to the operator for decision making.

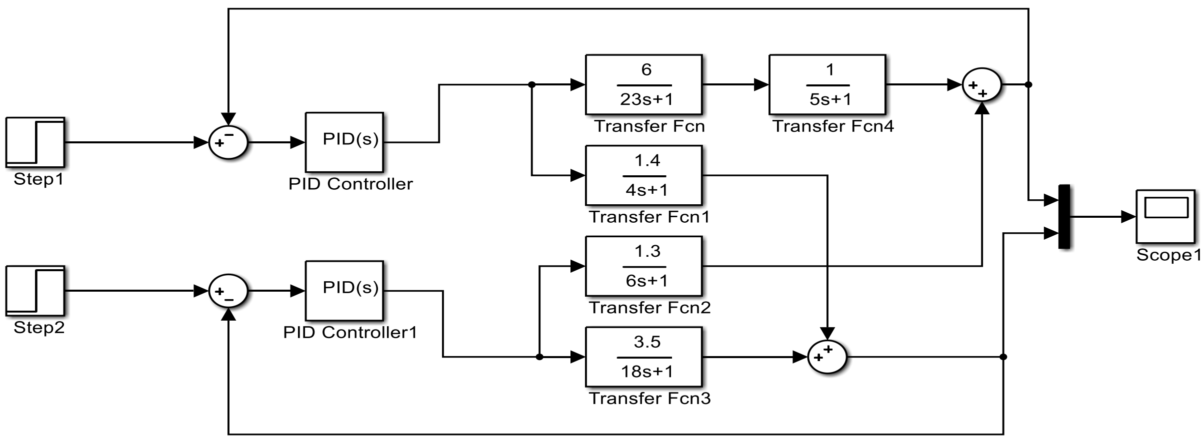

Fig. 2. Structural scheme of the adjustment system with PID-controller.

In order to study the effectiveness as an implementation of the proposed method of intelligent control, simulation modeling of control systems was carried out using the Matlab application programming package. During the simulation, control loops were created using a traditional PID-controller and a PID-Fuzzy Logic Controller (Fig. 2 and Fig. 3).

In the proposed regulation circuit, two PID-controllers and input signals represent the regulation of the temperatures in the upper part of the rectification column and the supply plate (Fig. 2). The temperature difference between the top of the rectification column and the feed plate is the process parameter that has the greatest influence on the concentration of the distillate leaving the top of the column.

Therefore, it is necessary to pay special attention to correcting this temperature difference with the amount of phlegm. When using a fuzzy PID-controller (Fig. 3), due to the presence of an input-output block, this fuzzy PID-controller can perform the function of 2 PID-controllers. Control decisions are also transferred to the corresponding circuits through a single fuzzy PID-controller.

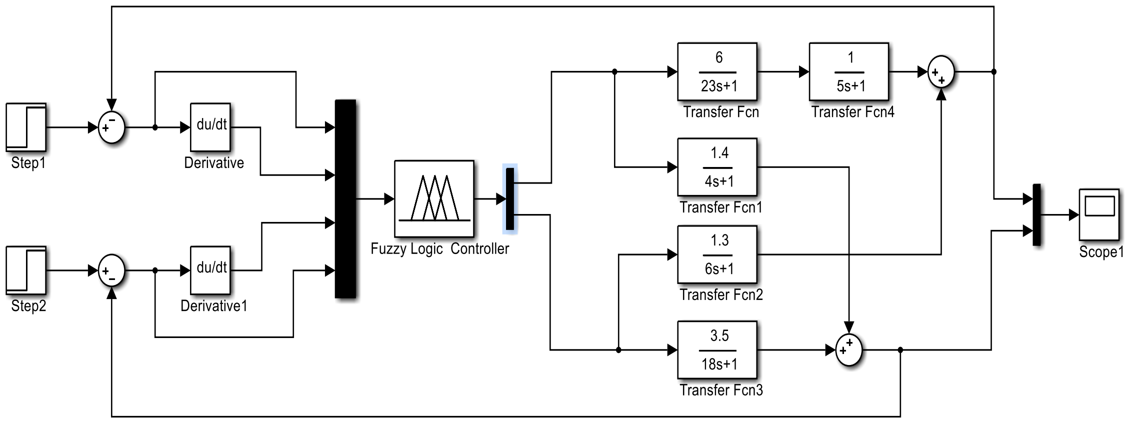

Fig. 3. Structure diagram of the regulation system with fuzzy logic PID-controller.

And also the characteristics of the transient process for the temperatures of the upper part of the column and the feed tray were obtained (Fig. 4).

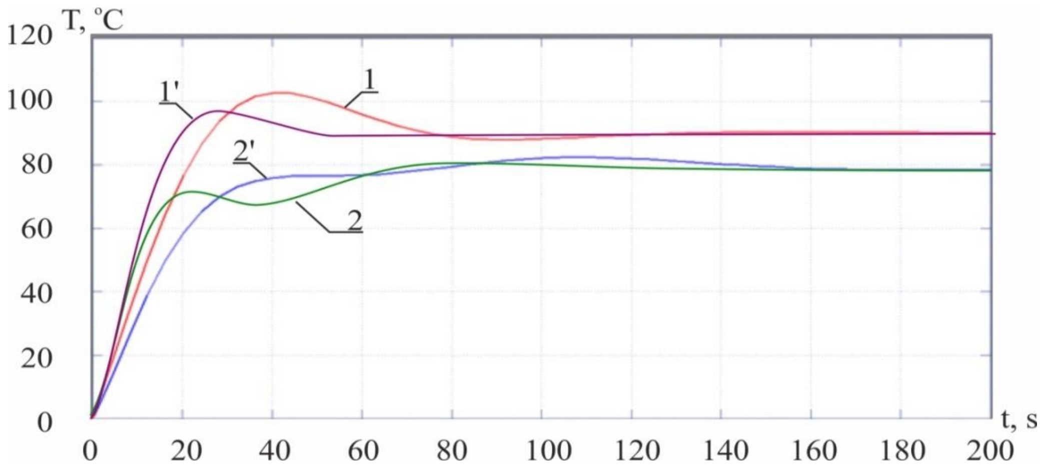

Fig. 4. Descriptions of regulation processes obtained in the development of regulation systems with PID-controller and fuzzy logic PID-controller

By comparing the obtained characteristic transient processes (with traditional PID-controllers: 1- temperature at the plate feed, 2- temperature at the upper of the column; with fuzzy controller: 1' temperature at the plate feed, 2' temperature at the upper of the column) is established, The time of regulation of the system control, realized with an fuzzy controller, is not less than 20 s, even with the system with traditional PID-controllers, which confirms the improvement of the quality of the control process, realized by the proposed method.

CONCLUSION. The proposed intellectual method of controlling the process of separation of multicomponent mixtures for the application of APC-systems and a net model of situational control allows to increase the quality of the product coming from the rectification column, and the efficiency of the separation of the mixture column, to increase the quality of the control of the separation process, and to obtain energy savings.

The proposed intellectual method of managing the rectification process of a multicomponent mixture is distinguished by the fact that it is additionally realized intellectually by regulating the temperature in the upper part of the rectification column, changing the amount of phlegm, the processing of measurable information, the received horse sensors, and the programmable logic controller of the distributed control system and the transfer of results, as for the analysis of the indicators of the quality of the product with the help of a virtual analyzer, and for the development of control solutions and block acceptance solutions of APC-systems, increasing the quality of the control process and the efficiency of the distribution of the mixture by predicting the situational process of the rectification of the mixture with the help of a net model of the situational control, the basic parameters of which are the concentration of the working mixture, the transition temperature and quantity of phlegmy, increase in energy saving of the rectification column for the calculation of the correctness of the control solution and the optimization of the parameters.

References:

1. N.R. Yusupbekov., R.A. Aliev., R.R. Aliev., A.N. Yusupbekov. Intelligent control and decision-making systems. Textbook. -Tashkent “*National encyclopedia of Uzbekistan”,* **2014**. 490.
2. G.I. Madrusenko. “*Principles of creation and development of automated process control systems: models: Moscow”,* **2000**. 449.
3. S.V. Artemova. Methodology for constructing intelligent information and control systems for heat-technological devices: “*Tambov: TSTU*”, **2014**. 425.
4. A.Y. Torgashov. Control of optimal static modes of distillation columns based on non-linear process models: diss. cand. tech. science. “*Vladivostok Vlad GUES*”, **2000**. 144.
5. P.A. Aliev., A.E. Tserkovny., G.A. Mamedova. Production management with fuzzy initial information. Textbook. Moscow “*Energy nuclear publisher*”, **1991**. 240.
6. G.M. Ostrovsky., Y.M. Volin. New problems and theory of flexibility and optimization of chemical-technological processes with uncertainty. “*Journal theoretical foundations of chemical technology”*, **1999**. 578.
7. M.J. Mohideem., J.D. Perkins., E.F. Pistikopoulos. Optimal design of dynamic systems under uncertainty. “*Journal AIChE”,* **1996**. 2251.
8. Patent for the method (RU) No. patent 2509593S1, “*Published on 20.03*” **2014**, Bulletin No. 8.
9. Patent for the method (RU) No. patent 2558596S2, “*Published on 10.08*”, **2015**, Bulletin No. 22.
10. Patent for the method (RU) No. patent 2724772S1, “*Published on 25.06*”, **2020**, Bulletin No. 18.
11. Y.Sh. Avazov. Governance Model of the stochastic process of rectification of multicomponent mixtures based on fuzzy logic. Journal advances in intelligent systems and computing. “*Switzerland: Springer Nature*”, **2021**. 364.
12. Y.Sh. Avazov., U.T. Usmanov. Formation of fuzzy reference situations using linguistic variables in the control of rectification processes. Intellectual Property Agency of the Republic of Uzbekistan. “*Certificate No. DGU 04970*”, **2018**.