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DEVELOPING METHODS FOR INCREASING READINESS OF THE MANAGERS OF COAL MINE DIVISIONS TO ACCIDENT-FREE OPERATION ACCORDING TO QUANTITATIVE ESTIMATIONS OF THEIR PERSONALITY CHARACTERISTICS

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РОЗРОБКА МЕТОДИКИ ПІДВИЩЕННЯ ГОТОВНОСТІ КЕРІВНИКІВ ДІЛЬНИЦЬ ВУГІЛЬНОЇ ШАХТИ ДО БЕЗАВАРІЙНОЇ РОБОТИ ЗА КІЛЬКІСНИМИ ОЦІНКАМИ ЇХ ОСОБИСТІСНИХ ХАРАКТЕРИСТИК

Purpose. To perform a quantitative estimation of the personal characteristics of managers of coal mine divisions and to develop a methods for increasing their readiness for trouble-free work.

Methodology. A complex method of research with methods of mathematical modeling, system, factor, mathematical, and information analysis, mathematical statistics, probability theory, reliability theory, psychophysiology methods, engineering psychology with the use of statistical data on injuries and accidents.

Findings. The dependence of the deviations on the regulatory decisions in a series of professional training on the specific number of experienced managers was established; an exponential dependence of the growth of professional knowledge of managers on the amount of information that received in the course of professional training was found; conditions under which managers' emergency actions approach to being automatic were defined. The criterion of professional readiness of a team of managers to control work in areas in an accident-free mode was proposed and substantiated. The criterion is directly proportional to their self-discipline when issuing directives to subordinates and in monitoring performance, vigilance in the analysis of situations and inversely proportional to blenching safety work breaches. A direct correlation between the frequency of accidents and the criteria of professional readiness of the team of managers to work without accidents was established.

Originality. For the first time, the relationship between personal psychophysiological characteristics of managers, their work experience, age and incidence of injuries at the mine as a result of emergency situations was defined.

Practical value. Methods for increasing the readiness of managers of coal mine sections for accident-free work according to the quantitative estimation of their personal characteristics were developed.

Keywords: *managers of a coal mine divisions, accident-free work, methods for increasing the readiness, quantitative estimation of personal characteristics*

Introduction. Working in high hazard environment in coal mines, miners often work overextending themselves physiologically. This leads to difficulties in predicting their behavior and in many cases is the cause of accidents. To avoid them, it is necessary to increase their personal readiness to work without accidents. The professional training of managers of the main mine divisions is an effective measure in this context. Scientific substantiation and application of such training in production activities is an urgent so-

cial task aimed at saving people who are the most precious national resource.

Currently, there are only general statements of the possible directions of solving emergent problems. Theoretical basis which is suitable for analysis and quantitative estimation of miner personal characteristics is still under development. Regarding investigations of accidents, analyzing their circumstances and causes, it has been established that human actions are determined, above all, by their mental temperament, then by the level of their professionalism and physical capabilities.

Analysis of recent research and publications. Significant contribution to the development of research studies on the specific aspects and solution of the problem as a whole has been made by foreign and Ukrainian scholars and experts and mine associations workers. Thus, University of Wyoming scientists (USA) has been analyzing the influence of production organization level on accidents at coal mines, estimating the mine safety with different infrastructure [1]. Scientists of the National Institute of Health and Safety (USA) perform a statistical evaluation of data on disability to develop methods for the hazard assessment of technological operations carried out in the mines [2]. Scholars' papers [3] analyze accidents in underground coal mines in Turkey, give the statistical relationship between the post, age and probability of accident occurrence as well as formulas to determine the total probability of an accident at a mine taking into account the number of miners; also the statistical model of analyzing risk factors, accidents and injuries at coal mines are given. In [4] the issues of participation and role of the employee and supervisor are reflected, behavioral negatives, a person's attitude to safety and the importance of workers' training are analyzed, causes and factors of injuries are given, the features and effectiveness of state supervision of safety and its influence on the industrial injuries are considered.

As a result of studying the problem, the modern approaches and investigation methods for studying miners' labor by certain sciences and disciplines are identified. They consist in determining the physiological, sanitary, psychological, sociological, economic, organizational and other characteristics and requirements to ensure labor regulatory conditions as well as miners' personal characteristics [5].

Unsolved aspects of the problem. However, in scientific aspect the methodology of quantitative estimation of personal physiological characteristics of managers and workers has not been developed yet. The scientific and methodological support of professional training for safety is also lacking. The system of professional training of division managers should be developed in such a way that their actions at work in an accident-free mode and in emergency cases are brought to a certain level of automaticity. Moreover, managers' actions are to satisfy all requirements of normative and legislative acts which allows eliminating the original cause and conditions of emergencies. Thus, quantitative estimation of personal characteristics of division managers and their relation to the ability to prevent emergency situations, which is used as methods, allows increasing the readiness of personnel to work without accidents is an urgent scientific task that is essential in ensuring safety in coal mines.

Objectives of the article. The purpose of the article is to perform a quantitative estimation of personal characteristics of coal mine division managers and to develop a method to increase their readiness for accident-free work.

Presentation of the main research. Based on the conceptual foundations of accident-free coalmining, the periodic assessment of readiness of the main division managers is proposed. The basis of their professional training involves the following scientific and methodological principles.

1. The action estimation principle

$$i(t)^* = \begin{cases} +i_{in}k_1, i = i_n \\ -i_{i0}k_2, i = i_0 \end{cases},$$

where $i(t)^*$ is value of knowledge obtaining function in the implementation of a game situation with the answers to questions; $i_{in}k_1$, $i_{i0}k_2$ are the amount of new knowledge obtained during training and the number of errors removed in, correspondingly; k_1, k_2 are the ability to assimilate knowledge or eliminate errors in the game situation.

2. The consolidation of collective desire principle (the group unity principle)

$$\sum_{i=1}^{n}(m+x+d)+W=(mx)N+dN+TC,$$

where N is the number of employees in the group who: m – can escape; x – want to do it and know that it is their duty (d); W is a manager's will – a special combination of their m, x and d; $(mx)N$ is a qualitatively new collective desire to escape, based on the realization that everybody can and wants to do it; dN is a collective support and assistance; TC is the concern of one for all and all for one (total concern).

3. The principle of necessity to bring the actions of managers in an emergency situation to the reflex level

$$R = R_0 e^n,$$

where R_0 is the basic level of reflexive action according to hesitation time and doubts before making a decision; n is the number of trainings.

4. The system assessment hierarchy principle.

As a result of the training, the growth of knowledge is

$$I_T = I_N + I_E + I_G,$$

where I_N is the knowledge that comes from a facilitator; I_E the a knowledge that comes from an expert; I_G is the knowledge generated in the process of making independent and collective decisions.

Probability (according to the level of deviations from regulatory decisions) is

$$D = 1-(1-D_M)(1-D_C)(1-D_E) = 1-\prod_{i=1}^{n}(1-D_i),$$

where D_M is the probability of a manager's knowledge; D_C is the probability of collective knowledge; D_E is the probability of an expert's knowledge; n is the rank of organizational structure of the training (n = 3).

5. The principle of developing innovative solutions

$$I_T = f(C, SO, T, D, \text{Det}),$$

where C is the completeness of information; SO is the subject orientation of information; T is the timeliness of information; D is the probability of information; Det is the level of the information details.

The growth of intensity of synthesis of ideas is

$$I(n, m) = I_B + I_N m + (ik_y)(m + n),$$

where I_B is basic knowledge on education and life experience; I_N is new knowledge of the work practice at a mine; m is the number of descendings into the mine (work experience); n is the number of repetitions of information (the number of trainings).

Conditions for innovative solutions occurrence are

$$P = \lim I(n, m) \to I(n, m) + \Delta i.$$

Mathematical modeling of prevention of emergency situations allowing for the psychophysiology futures of miners and their leader was as follows.

Relation of miners' characteristics to the final result of their work

$$A = \sum_{i=1}^{n} q_{di} k_{gi} \approx 3(n-m) q_A k_g \ ,$$

where A is output per face, t/day; q_A is a productivity per employee, t/person; $\sum_{i=1}^{n} q_i$ is a collective productivity of mining, t/day; 3 is the number of shifts of coal mining per day; k_g is integrated face readiness for coal mining in quantity A_l t/day.

Relation of psychophysiological characteristics of an employee to the labor parameters:

- the pursuit of material wealth

$$x = \frac{ZP + \Delta ZPS_x}{ZP_{\max}};$$

- sense of responsibility

$$\begin{cases} d_1 = \left(1 + \dfrac{\Delta q S_d}{q}\right)\dfrac{T_s - t_p}{T_s} \\ d_2 = TR - \Delta T_p S_{tr} \end{cases};$$

- psychophysiological capabilities and experience

$$m = \frac{T_e}{T} = \frac{N + \Delta NS_m}{H_w\left(1 - US_w\right)},$$

where x is the aspiration expressed in relative currency to earn more, to get other benefits which can be measured with money, UAH; ZP is payment, such as wage rate UAH; ΔZP is a desirable premium, UAH; S_x is an indicator that characterizes the "self-adjustment" for ΔZP, d_i is a call of duty of an employee to themselves and to the team expressed in terms of relative productivity units; TR is the number of accidents at while realizing q; S_{tr} is the commitment to safe work; ΔqS_d is the implementation of an employee's desire to contribute to a common cause more efforts when necessary (q); S_d is "self-adjustment" for additional help (advice, labor) to those who need it on the analogy of S_{ZP}; m stands for an employee's professional opportunities expressed in terms of relative power units N; ΔNS_m is implementation of additional capacity; S_m is "self-adjustment" for implementation ΔN; T_e is effective time during the shift T_s; U is the ability to spend less effort than others while performing activities; t_p is duration of breaks.

The scientific methods of training has been developed and for the first time dependence of a manager's readiness for successful actions in an emergency situation on the total new knowledge obtained during the training. Moreover, scientific foundation to create conditions for generating innovative solutions has been elaborated.

The results of professional training of the main mine division managers of one of the mining enterprises are presented. During the training, certain emergency situations such as "Fire within the division", "Sudden eboulement" in the workspace tunneling, cleaning excavation and their conjugation were simulated. In these situations, leaders of the divisions were operating characters on the posts of a "manager", an "underground miner", a "division mechanic", a "machinist of the underground facilities" and others on the staff. Four of the leaders in the training period formed a small integral group of professionals with different levels of experience, knowledge, skills, aspirations and other qualities typical of each individual. However, under conditions of training every leader had to make specific decisions to save each group member's life as well as their own lives. The solution was to be made quickly, but professionally, taking into account the situation, which conventionally prevented any error. Professional, civil and personal qualities were revealed individually for each manager. However, common features of group leaders were revealed that differed according to the mine where they work, their age and experience.

During the professional training, the leaders' action process in an emergency situation was considered as consisting of elementary operating acts: identification of an emergency situation, guidance by standards when making decisions as the situation progresses, informing other officials and miners about the situation, determining the order of leaving the workings, sequence of following the route, sorting miners into groups according to their age, experience, physical condition, etc.

The trends of changing personal characteristics of managers depending on their work experience were obtained for a mine of one of the production coalmin-

ing enterprises. It was established that the readiness of the team for each of the main mine divisions for the high-performance and safe work is determined by the amount of positive work experience, the features of the structure and dynamics of relationships in the "managers-workers" system. While preventing emergencies, the coefficient of readiness is estimated by positive dynamic of criteria of authoritarian-collaborating qualities of the chief, which is directly proportional to the level of their qualifications and varies polynomially with increasing work experience, and reaches extreme values at the stages of formation and stable tenure, equal, respectively, to 1/3 and 2/3 of the total experience.

The dependence of the decreasing frequency of accidents on increasing criterion of professional readiness of a team of managers to control the work at divisions in an accident-free mode was established.

The criterion is determined by the following equation

$$K = \frac{TP + V}{B},$$

where TP is the demand for making personal decisions and monitoring the implementation of directives, %; V is the vigilance to reports on threat to subordinates' health or loss of the division asset; B is blenching safety rule violations and other standards requirements.

The values of the criteria are listed in the Table.

The method for increasing the readiness of managers coal mine divisions for accident-free work includes: developing and approving a plan of professional training; determining general rules for professional training; formulating the open monologue thesis (conversations, dialogues); determining the questions of the facilitator during the game situation; determining the order of group organization, testing and professional training; developing the game situation scenarios for professional training; assessing the readiness of the main division managers of a coal mine for actions to prevent accidents; giving recommendations for improving the management of teams; calculating the economic efficiency of testing and professional training.

Based on the experience of professional training on labor safety of division managers, their deputies, assistants and mining masters, it follows: all trainees without any exception consider that the idea and its implementation are appropriate and such training should be definitely organized and conducted in Centers for Professional Advancement and mines; moreover, it is advisable to discuss, legitimize, refine or reject the technical proposals made by participants of professional training during meetings on safety issues.

Table

The values of criteria of professional readiness of division managers

Coalmines	Changing criteria of professional readiness of division managers		
	minimum	average	maximum
Mine 1	1.113	1.14	1.2
Mine 2	1.26	1.42	1.68
Mine 3	1.34	1.45	1.49

Decreasing occupational injuries confirm the feasibility of professional training for safety.

Working methods for ranking mines according to the state of their mining economy, technical equipment and the staff's professional level were developed. Probability of trouble-free performance in a given time interval $P(t)$ is adopted as an indicator of reliability and the readiness coefficient k_g at a given time is adopted for integrated assessment of reliability. To determine the performances of the systems with branched structure, formulas for systems of zero and first order were obtained.

Blocking unprofessional actions of an individual has to be ensured by special technical means of control, security, alarm and warning communication, systems of environment monitoring and equipment diagnostic with elements of forecasting and organizational measures. However, first and foremost the measurements to improve the technical and professional level by performers of all ranks should be introduced in the industry.

The calculations confirm quantitatively that economic losses from adopting incorrect decisions on appointing the management of mining or tunneling divisions can be hundreds of thousand UAH per day. A hour of face downtime due to a manager's error makes 16,111.00 USD for the mine with an average productivity of 2,000 tons, a price of raw coal of 700 UAH/t and production cost of 555 UAH/t; this is equal to the sum of the manager and his deputy salaries. The price of the same risk, but for a day face downtime is almost 20 times as much, i.e. 290 thousand UAH. To compare, up to 1000 m^3 of wood materials or 30–35 tons of fuel for vehicles can be purchased for the requirements of the mine using these finances. To produce 1 million tons of coal per year, it is necessary to pass 7–8 km of opening and tunneling workings of the mine. Delays in tunneling work are failures of the strategic level that are not corrected quickly. The rate of tunneling work is the main factor of stabilizing coalmining for a long time. The manager of a tunneling division must comply with the planned values of this indicator. Shortfall in tunneling volumes, for example, 100 m per year, will result in losses of the whole enterprise in the range of 1.8 to 2.1 million UAH. The planned rate of preparing reserves to slot considering raising production, for example, by 10 %, is 128–144 days. If there are 20 brigades of tunneling workers, each of them is to ensure the average rate of 6.4–7.2 m/day. The brigade should tunnel 100 m for 13.8–15.6 days. Losses due to poor performance versus plan will be 128–165 thousand UAH. With an average duration of downtime in the industry due to the

elimination of accidents of 1,500 hours or 62.5 days per year, the annual economic effect will be of 8006.25 to 10333.125 thousand UAH, i. e. an average of 9156.25 thousand UAH per year for a mine.

Conclusions.

1. Readiness to work in an accident-free mode of each team of divisions of high production mine is determined by the volume of production experience, features of the structure and dynamics of relationships in the "managers-workers" system. The increase of readiness to work in an accident-free mode is determined by the positive dynamics of criteria of professional readiness of the team leaders that increases with their work experience.

2. According to the professional training results, it was found that the efficiency of collective action of each working division, which is necessary for work without accidents, depends on the level of automaticity of managers' professional activities. As a result of production and regular training, this level is based on the uniqueness of their directives and correctness of solutions. Correctness of decisions and directives is determined by insistence on personal decisions and implementation of directives by subordinates, diligence while analyzing situations and rigidity to violations of safety rules that reach rational values in the last third of the working experience. In other words, it is necessary to speed up the improvement of professional readiness of young division managers, including their training.

3. Division managers' readiness to control works in an accident-free mode is determined by personal characteristics apart from knowledge and professional experience that is measured by length of service on duty. The most significant of these are: demand (TP) for completeness and quality performance of the work by themselves and subordinates, vigilance (V) to messages about the threat of loss of health and division asset and blenching (B) violations of safety rules.

For each team of medium-level managers in a coal mine, there are specific and generalized trends of change TP, V, B and other characteristics over time. The ratio $\frac{TP+V}{B}$ may be characterized as a vector of professional commitment and availability or as a criterion of readiness of team leaders to work without accidents, that is $K=\frac{TP+V}{B}$.

4. The relationship between frequency of injuries for several years of the mine work $\frac{N}{1000}$ and the criterion of professional readiness of the team leaders to work in an accident-free mode, which is inversely proportional, is determined. Comparing $\frac{N}{1000}$ to $\frac{TP+V}{B}$ it was established that with increasing levels of professional readiness of leaders to work in an accident-free mode from 1.113 to 1.68, the relative number of injuries decreased accordingly from 14–16 to 4–11.

5. Increase in knowledge depends on the amount of new data which comes from the facilitator, experts or is generated by those who are trained to make independent and collective decisions. Their compliance with standards depends on the objective evaluation system, based on its collective and expert components which are embedded in the organizational structure of the training.

6. On the basis of new scientific results, the methods for increasing the readiness of coal mine managers for accident-free work according to quantitative estimation of their personal characteristics, scenarios and methods of professional training managers of the main divisions of coal mines were obtained. Methods have been approved at the industrial level, implemented in a number of coal mines with the expected economic effect of 9,156.25 thousand UAH per year for a mine.

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Шевченко В.Г. Научно-методические основы оценки психофизиологических характеристик руководителей участков угольной шахты: монография / Шевченко В.Г. – К.: Наукова думка, 2013. – 280 с.

Мета. Виконати кількісну оцінку особистісних характеристик керівників дільниць вугільної шахти та розробити методику підвищення їхньої готовності до безаварійної роботи.

Методика. Використано комплексний метод дослідження із застосуванням методів математичного моделювання, системного, факторного, математичного, інформаційного аналізу, математичної статистики, теорії ймовірностей, теорії надійності, методів психофізіології, інженерної психології з використанням статистичних даних про травматизм і аварії.

Результати. Встановлена залежність відхилення прийнятих рішень від нормативних у циклі професійних тренінгів від питомої кількості досвідчених керівників; знайдена експоненціальна залежність росту професійних знань керівників від кількості інформації, отриманої ними у процесі професійного тренінгу; визначені умови, за яких дії керівників в аварійній ситуації наближаються до автоматичних. Запропонований і обґрунтований критерій професійної готовності колективу керівників до управління роботами на дільницях у безаварійному режимі, що прямо пропорційний їхній вимогливості до себе при розробці директив і до підлеглих при контролі виконання, пильності при аналізі ситуацій та обернено пропорційний лояльності до порушень безпечного режиму роботи; встановлена пряма залежність між частотою травматизму працюючих і критерієм професійної готовності колективу керівників до праці без аварій.

Наукова новизна. Уперше визначені залежності між особистісними психофізіологічними характеристиками керівників, стажем їх роботи, віком і частотою випадків травмування на шахті внаслідок аварійних ситуацій.

Практична значимість. Розроблена методика підвищення готовності керівників дільниць вугільної шахти до безаварійної роботи за кількісними оцінками їх особистісних характеристик.

Ключові слова: *керівники дільниць вугільної шахти, безаварійна робота, методика підвищення готовності, кількісні оцінки особистісних характеристик*

Цель. Выполнить количественную оценку личностных характеристик руководителей участков угольной шахты и разработать методику повышения их готовности к безаварийной работе.

Методика. Использован комплексный метод исследований с применением методов математического моделирования, системного, факторного, математического, информационного анализа, математической статистики, теории вероятностей, теории надежности, методов психофизиологии, инженерной психологии с использованием статистических данных о травматизме и авариях.

Результаты. Установлена зависимость отклонения принятых решений от нормативных в цикле профессиональных тренингов от удельного количества опытных руководителей; найдена экспоненциальная зависимость роста профессиональных знаний руководителей от количества информации, полученной ими в процессе профессионального тренинга; определены условия, при которых действия руководителей в аварийной ситуации приближаются к автоматическим. Предложен и обоснован критерий профессиональной готовности коллектива руководителей к управлению работами на участках в безаварийном режиме, который прямо пропорционален их требовательности к себе при выдаче директив и к подчиненным при контроле выполнения, внимательности при анализе ситуаций и обратно пропорционален лояльности к нарушениям безопасного режима работы; установлена прямая зависимость между частотой травматизма работающих и критерием профессиональной готовности коллектива руководителей к работе без аварий.

Научная новизна. Впервые определены зависимости между личностными психофизиологическими характеристиками руководителей, стажем их работы, возрастом и частотой случаев травмирования на шахте вследствие аварийных ситуаций.

Практическая значимость. Разработана методика повышения готовности руководителей участков угольной шахты к безаварийной работе по количественным оценкам их личностных характеристик.

Ключевые слова: *руководители участков угольной шахты, безаварийная работа, методика повышения готовности, количественные оценки личностных характеристик*

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