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READINESS OF MINE TO EMERGENCY SITUATIONS AND CONCEPTION OF «ZERO RISK»

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Abstract. Unfortunately, emergency is an inherent feature of any dangerous manufacturing entity, what a coal mine is. A plenty of harmful and dangerous mining, geological and technogeneous factors with high risk of emergency occurrence acts in the mines. Therefore, personnel should be ready to reveal and eliminate such situations as soon as possible with no human losses and minimum economic damage. Conception of «zero risk» is useless for emergency situations, and minimization of «acceptable risk» is possible only on condition of correct organization of joint work of the system of against emergency protection (SAEP), plans of warning and elimination of emergencies. Today, maximum attention is paid to the liquidation of already happened failures. At the same time, most emergencies occur exactly by virtue of the fact that workers do not know or incorrectly interpret requirements of safety regulations established for the coal mines, or are not thoroughly familiar with priority actions on revealing the emergencies and requirements of the labour management system, though heavy consequences of emergencies are caused by incorrect actions of personnel or its inability to use current recommendations and the SAEP facilities. Therefore, in this work, we describe basic methodical approaches to creation and use of the first constituent of the SAEP system: preparation of its elements and training of workers on how to use them. In this article, we consider such issues as control of risk factors, specifying of measures for controlling unforeseen situations or emergencies, developing of principles for organizing work of the trouble crew, providing the personnel with necessary equipment and materials and training of methods for revealing, limitation and warning about the emergency occurred and actions to be undertaken during mobilization, deployment of special systems and after elimination of the emergency, as well as estimation and improvement of the whole system operation through the regular surveys and tests. It is concluded that readiness of personnel to the actions in emergency situations is ensured by integration of all necessary elements including creation of safety service, providing it with high-fi special equipment and regular reviews of efficiency of actions undertaken by this service.

Keywords: emergency situation, dangerous factor, coal mine, readiness to the emergency, zero risk, possible risk.

Introduction. Each enterprise (including mining) is a system of "man - technological devices". Both components are not perfect, so there is always a risk of errors, mistakes, failures of their joint work. Until recently, the assessment of the quality of this system was based on the concept of "zero risk", i.e. the possibility of error-free operation of the "man-machine" system was assumed in advance, with optimal or at least close to optimal results by selected safety indicators.

Practice has refuted these expectations. There can be no ideal functioning of a person or a mechanism - breakdowns or errors are always possible. Therefore, we have to be waiting for incidents or emergencies and be ready to eliminate them.

Work on the elimination of emergencies, emergency situations and incidents for various industries is regulated by [1], there are also relevant regulatory and methodological documents. In the coal industry, occupational safety requirements are regulated by the Rules of safety in coal mines [2], which contain as an appendix "Instructions for drawing up the plans of emergency liquidation" [3]. The plan of emergency liquidation (PEL) contains detailed information on measures to eliminate all possible mine emergencies, about evacuation of miners from emergency and threatening areas of the mine, the actions of state paramilitary rescue units (SPRS). The solution of these problems requires preliminary calculations and simulation modeling of possible options for the development of emergencies, so its solution is devoted to a number of scientific and applied research and software packages created on their basis [4-7,

etc.]. The implementation of the obtained results into mining practice testifies to the correctness of the proposed approaches.

However, this is true for the case if an accident occurred in the same place and under the same conditions as provided by the PEL. And if not, is it possible to reduce the risk of its occurrence? And is it possible to organize the preparation for possible emergencies in such a way that the risk of its negative consequences would be minimal?

Methods. The research of the Donetsk Coal Institute was devoted to the solution of this problem, which resulted in the creation of normative and methodological document [8]. Although it provoked a broad, and not always friendly, discussion in the mining community, this work should be praised.

Abroad, similar work is carried out actively and regularly. And not only because the proposed concept of "acceptable risk", i.e. risk, which does exist, but is sufficiently safety for the production processes, finds more and more supporters, but also because in these countries the company's readiness for a possible accident is elevated to the level of urgent need. In Ukraine, it is appropriate to create a system of against-emergency protection (SAEP) [2], which should not only contain effective means of localization and elimination of mine emergencies, but also aims to reduce the risk of its occurrence.

The emergency hazard to production processes and mine facilities is determined primarily by mining and geological conditions of field development and depends on the elimination of possible manifestations of natural and operational hazards, efficiency of SAEP and professional focus of mine personnel on accident-free work.

Dangerous mining and geological conditions for coal deposits mining, which provoke the manifestation of natural hazards, are widely known and do not require comments. The main dangers of natural origin are long-term overhang and extensive collapse of roof rocks, methane blowers, gas-dynamic phenomena, liability of coal to spontaneous ignition, explosiveness of coal dust, the presence of flooded areas of geological disturbances in the rock mass, increasing the natural temperature of rocks with depth etc.

Hazards of operational and man-made origin are divided into two groups:

a) disturbance of the natural state of the rock massif due to coal mining and extraction, which causes changes in rock pressure; redistribution of stresses in the rock mass and gas pressure in methane-bearing coal seams and rocks; man-made channels for hydraulic and aerodynamic communication between the earth's surface and the horizons under the development, as well as between the horizons, which causes the migration of groundwater and the delivery of oxygen with air to the surface of coal prone to spontaneous ignition;

b) the second group of factors of man-made origin includes (selectively): coal left in the pillars and in places of transition of geological disturbances; losses of coal in longwall and mined-out space; air leaks through ventilation structures and insulating jumpers; insufficient ventilation of dead-end workings and chambers; heating from friction of conveyor belts and executive bodies of machines; sparks and short circuits in electrical installations; violation of the rules of fire, explosive and repair works,

ventilation mode, dust and gas modes, measures to prevent gas-dynamic phenomena, rules of technical operation of electrical installations, machines and mechanisms.

The presence and manifestations of all these dangerous production factors, their interaction and the degree of participation in the technological process preceding the accident determine its type, place of occurrence, features, possible complications, severity of consequences, etc.).

On average, of about 2000 accidents happen in Ukrainian coal mines annually causing downtime of excavation sites for more than one day with total losses of coal production of 10-15 million tons. In the total number of accidents 80.2% are related to the operation of mining machinery and electrical equipment, and about 16.8% of emergencies are caused by landslides, gas-dynamic phenomena, underground fires, explosions and ignitions of methane-air mixture and coal dust.

Emergencies occur regularly in mines around the world, even in countries where formal risk control technologies are adopted as the primary strategy for improving mining safety, reducing risk of emergencies and mitigating their consequences. Therefore, it is important to create a single system of preparation for action in extreme situations, i.e. a comprehensive SAEP.

SAEP, as it is now understood, is a set of scientifically sound methods, engineering solutions and technical means of eliminating emerging accidents and maintaining the risk of their occurrence at the level of "acceptable". It is the second – emergency - component of the SAEP, which operates in the mode of control of "tolerable risk" under normal conditions, and if this level is exceeded it operates in the emergency mode.

But there is also the first component, which is unjustifiably focused on the concept of "zero risk". This is the readiness of the mine for emergencies. It is believed that if the organization is properly organized, safety requirements will be met automatically, and the "acceptable risk" of accidents will be "almost zero".

However, here lies a contradiction. To organize a proper coal production focusing only on its machine component is not easy, though possible. Which cannot be guaranteed given the human factor. A person cannot be programmed as a mechanism: the workers should be taught occupational safety and how to reduce risks of their work, to develop certain skills. This is the urgent need to create the first component of SAEP - a system of preparation of its elements and training workers how to use them (hereinafter - the system). This system should be based on an integrated approach to prevention of such situations and the ability to deal with them if they do occur.

By analyzing the components of the system, it is easy to see that all of them are to some extent implemented by the existing SAEP and their components – PEL and emergencies prevention plan (EPP). However, if there is almost complete clarity with the PEL (known locations of possible emergencies, approximate volumes of their complexity and distribution, measures for action and interaction of units involved in the liquidation of the emergency, training of workers to act in case of an emergency), the EPP is being implemented and aimed at reducing the need for PEL; a unified approach to SAEP as a coordinating center for all issues of prevention and elimination of emergencies does not exist yet. Creation of a legal, regulatory and regulatory-

methodical framework for the organization and use of SAEP in coal mines is only planned in the near future. Therefore, in this work we consider the main directions of the first part of this work, namely improving the preparedness of mines to the emergency occurrence and elimination. Moreover, since this work is very diverse, we will focus only on a specific type of emergency – fire, with slightly expanding the scope of consideration only in some cases.

As many researchers have proven, the "zero" risk of occurrence and liquidation of a mine emergency is a purely theoretical category - because its formation involves such unreliable components as environment and man. It is impossible to take into account and assess all the factors of their functioning and interaction, so we should use the concept of "acceptable risk" of the system "environment - man-made environment - man" functioning, eliminating the risk of death, injury and disease and sufficiently reducing material costs and losses. The relationship between these two concepts is expressed by the following pattern: the closer the "acceptable" risk is to "zero the faster safety costs grow. When the possible costs are exhausted, the risk must be considered acceptable. These considerations are used when planning the scope and capabilities of SAEP at the stage of preparation of mines for emergencies. In the event of an emergency, of course, this pattern is not used - a person's life has no monetary equivalent.

Emergency risk factors are assessed by using known criteria to determine whether the degree of risk is "acceptable". When the risk is high, the possibility of reducing the risk of an emergency, reducing its consequences, eliminating all or at least some of the factors, preventing their harmful effects is estimated. Identification and analysis of emergency risk factors allows to predict with high accuracy, by which scenario a certain situation will develop.

The development of standard scenarios for emergency preparedness is regulated by a number of foreign standards: one of the examples is the Australian standard AS/NZS 4360 (2004). It can be taken as a basis for the development of a similar standard for the conditions of the coal industry of Ukraine.

It is expedient to organize the emergency preparedness system on three levels.

First-level actions include the actions of a worker at detecting a dangerous situation or emergency, namely:

a) to warn a mining dispatcher about the situation and circumstances of the emergency;

b) to undertake basic fire-fighting measures, first aid to victims, evacuation from the emergency zone, etc.;

c) to leave the emergency zone or to go the shelter.

The second level of action after warning about the accident involves the work of specially trained units (SPRS, auxiliary rescue teams, fire brigades, etc.) that have the appropriate skills and equipment.

Level 3 actions are necessary in situations where the actions of the first two levels do not provide adequate safety or are ineffective, and involve the use of special systems, equipment and technologies.

Results and discussion. The interaction of the stages of exogenous fire development and liquidation is presented in Fig. 1. The process of liquidation of an accident and taking measures in accordance with the PEL and, if necessary, the operational PEL, can be divided into separate operations, numbered in the figure in circles.

The result of fire detection is timely transmission of the appropriate signal to the mining dispatcher (operation 1) who takes measures to activate emergency vent mode (EVM) and signalizes people about the beginning of evacuation. EVM is carried out by maintaining or changing the mode of operation of the main ventilation fans (MVF) and adjusting the amount of air entering the emergency and threatening areas, by means of local regulators.

The main principle of the choice of EVM is to limit the area of gassy zone contaminated by combustion products (operation 2) in order to increase efficiency in the further process of emergency evacuation of people from the workings of emergency (operation 3) and threatening (operation 4) areas of ventilation network.

Fulfillment of the tasks of emergency evacuation and actions of the SPRS units (operations 5 and 6) are interconnected in the initial period of the emergency response. Simultaneously with evacuation signal received by the people to be evacuated, a relevant department of the SPRS receives the task to move towards the group of people leaving the mine to assist them with the emergency evacuation. These actions can be corrected upon receiving operational information on the development of the emergency situation.

While fulfilling the PEL measures, the condition of the SAEP means and their compliance with the needs of taking measures and with the PEL is constantly checked, as well as against-emergency measures (operations 7-10) are clarified. As responsible mine specialists, SPRS and invited persons, who can be fully considered experts in the field of firefighting, are already arriving at the mine, further operational decisions can be made by using the expert assessment methods.

At the same time, even without waiting for the end of the second stage of emergency development and liquidation, an operational PEL (operations 11-15) should be drawn up and implemented).

Returning to Fig. 1, two points should be noted:

a) the basis for decision making at all stages of the fire development and elimination is the ventilation mode operated in the mine. At the first stage the mode is normal, at the second stage it is either maintained or adjusted by changing the flow rate and/or direction of ventilation flows. At the third stage the mode can be identical to the second stage or be changed depending on the conditions of the fire liquidation (operation 13); the mode can be changed more than once;

b) the stages of the fire development and elimination do not have clear boundaries. Thus, the formation of the gassing zone begins at the first stage and continues during the second and third until the complete elimination of the fire. Accordingly, it is adjusted by ventilation measures: at the second stage - to improve conditions of emergency evacuation of people, at the third stage - to improve and facilitate fulfillment of rescue and emergency recovery operations.

During the second and third stages, the strategy of the SPRS actions is carried out in the similar way. The second stage is assistance to evacuees and reconnaissance of the fire seat (operations 6, 9, 10), the third stage is the inspection of the mine in order to optimize the process of fire elimination (operation 15).

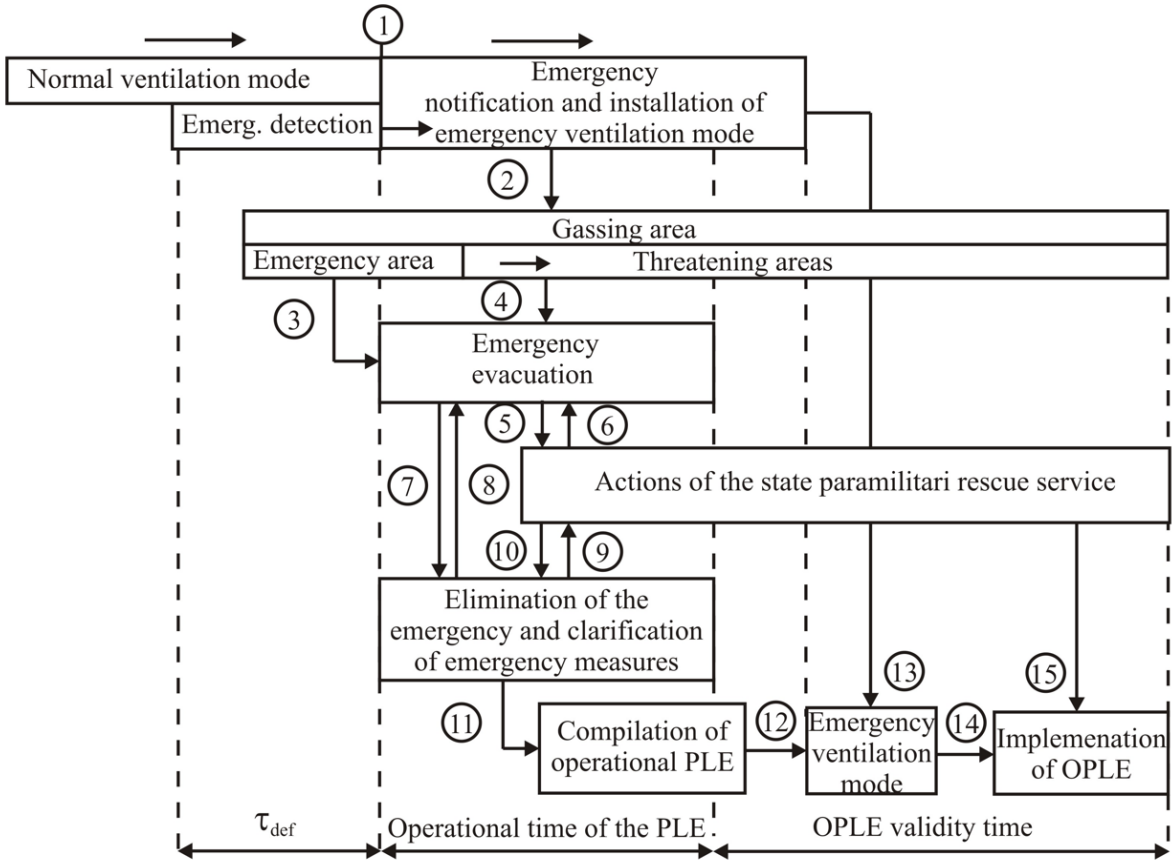

Figure 1 – Interaction of stages of development and liquidation of exogenous fire

Thus, the stages of the emergency development and elimination are separated in time (largely conditionally), but connected in space tactically, and can use the same initial and intermediate information. The value of τ_{def}, which is the source information of the SAEP element associated with the detection of fire at the first stage, is the initial information to determine the configuration of gassing zones at the time of making the decision to activate emergency ventilation and start emergency evacuation (it is the beginning of the second stage). Further, information on changing the configuration of the gassing area is used to adjust the course of emergency evacuation and the actions of the_SPRS units, and at the third stage - to change the ventilation mode to facilitate firefighting or isolation of the fire.

It is easy to see that the actions of the first level are the priority measures of the PEL, of the second level - the actions of special units during the operational time of the PEL, and of the third level - the implementation of measures if the PEL measures are not enough, i.e. implementation of operational PELand further emergency response strategy.

Mine personnel must be properly prepared for the accident, so clear coordination of all measures is needed to bring the situation under control quickly and effectively. Therefore, an emergency service is formed at the mine (we will continue to use this definition), the functions of which are performed jointly by the responsible employees of the mine and SPRS units_, which defines and combines emergency strategies, human resources and responsibilities, means and equipment, systems and methods. It works at all stages of the emergency situation development from the moment of detection of the emergency and the implementation of priority measures to eliminate the emergency and restore normal operation of the mine.

Today, shelters are increasingly used to evacuate and rescue underground personnel. Depending on the design, some shelters are served for self-rescue and communication with the emergency service in safe conditions (switching points to reserve rescuers), while others are designed to stay in them for a long time until help comes from outside (emergency air supply chambers, etc. (EASC)). The following factors should be considered when deciding on the installation of shelter facilities and choosing their type:

a) the probability that it will be impossible for people to leave the EASC on their own;

b) the time required for the evacuation of people by ordinary means to the surface can exceed the time of the protective action of the rescuer;

c) the ability or inability of underground personnel to escape without help from outside (state of health, level of physical preparedness for the emergency, injuries sustained as a result of the emergency, etc.);

d) the availability of facilities which allow people to find shelter in conditions of extremely low visibility and high stress;

e) the required size and capacity;

f) service systems (for EASC) - ventilation and air purification, cooling, communications, sanitation, food, etc.; for switching points to reserve rescuers, it is enough to provide the chamber with fresh air.

Some aspects of the organization of the collective rescue system of miners can be found in [9].

The communication system is available in all mines. It facilitates to manage and control works and improve job safety and allows to call for help. However, there are some disadvantages:

a) insufficient strength to withstand the effects of fire or explosion;

b) the use of headphones for negotiations are incompatible with the use of rescuers;

c) in most cases their location is not in the evacuation routes.

Therefore, the necessity, completeness and suitability of mine communication for emergency conditions should be carefully assessed. It is desirable that the emergency communication system be part of the overall system, although sometimes, for areas with the most significant emergency risk, it is advisable to organize a separate communication system designed for use only in emergency situations.

The need to control composition of the atmosphere after an accident must be carefully assessed.

The skills needed to act effectively in an emergency become understandable after identifying key risk factors and measures to prevent emergencies, establish an emergency team, develop appropriate procedures and identify the necessary tools and equipment.

The ability to act in an emergency situation assumes the skills to implement measures of the first and second levels. The training system should cover all necessary activities in the event of an emergency, namely: detection and containment of the emergency (firefighting by improvised means, evacuation, assistance to victims); warning (use of radio and telephone communication); mobilization and special measures (search and rescue of people, firefighting by using special tools, etc.).

Reviews, inspections and evaluations are conducted to assess the effectiveness of the entire safety system, individual procedures, tools, maintenance programs, equipment, staff training and individual skills. Such inspections shall be carried out at each establishment at least once a year for each type of possible emergency. Key elements of the system should be checked more often.

During the *horizontal* review, small individual elements of the overall safety system are inspected. Examples of such elements and possible drawbacks in their work are given in table. 1.

In the conditions of *vertical* review several elements of the system are checked at the same time by full-scale modeling of the emergency situation. This approach is used to test the initiation of SAEP, search and rescue methods, assistance, firefighting etc.

Employees of several divisions and special services may be involved in the exercises. Drawbacks identified in the operation of the tested elements of the SAEP should be carefully analyzed and, after making the necessary changes, tested in action in order to further improve the system.

Inspections, which must be carried out periodically, will make sure that the changed circumstances (people, systems, methods, equipment) have not adversely affected the structure of risk factors or the operation of the safety system.

Table 1 – Some drawbacks of SPAZ in the implementation of PLE measures

Element SAEP	Drawbacks
The first signs of an emergency	Inability to recognize, notify, register, take action
Emergency and evacuation warning procedures	Workers unfamiliar with evacuation procedures
Inclusion in self-rescuers	Workers are not familiar with rescuers
Firefighting equipment	Fire extinguishers are discharged, spray holes are painted over, fire hydrants are hidden or covered with rock
Alarms	Alarms are ignored
Gas control devices	Irregular maintenance and prevention

It should be noted that the first level of readiness of mines to eliminate emergencies is perhaps the most important because necessity and number of works of the second and third levels depend on the quality of its implementation. Therefore, in the coal mining industry there is a normative document [10], which details the requirements for checking the readiness of mines before approval plans of emergency liquidation by the SPRS. The document was prepared so carefully and thoughtfully that the forty-year period of its practical use did not necessitate any corrections, even in modern conditions of liquidation of emergencies in coal mines.

The document regulates:

- checking the technical readiness of mines for the approval of the PEL, which includes checking of:

…..a) fire protection of mines;

…..b) MVF;

…..c) emergency ventilation modes;

…..d) energy-mechanical equipment;

…..e) emergency exits;

…..f) means for rescuing and self-rescuing of people;

…..g) measures to eliminate the consequences of water breakthrough;

…..i) readiness of degassing means to eliminate emergencies;

- checking the organizational readiness of mines for the approval of the PEL, which includes checking of:

…..a) compliance of the PEL with the requirements [3] and other regulatory documents to the structure, composition, content, terms of preparation and commissioning, as well as the actual situation in the mine.

Note: since at the time of approval of the document [10] the joint work of the All-Union Research Institute of Mining Rescue (now -SPO "Respirator") and IGTM of the Academy of Sciences of UkrSSR on automated assembly and commissioning of the PEL just started, the document does not require verification of such works results. However, the cessation of the latter in Ukraine does not require the development of such requirements;

…..b) a plan for the interaction of SPRS and fire brigades, which can be involved in the elimination of emergencies:

…..c) readiness of auxiliary rescue teams to eliminate emergencies;

…..d) conducting training on the PEL at the mine:

e) emergency communication and signaling;

…..f) training of workers on rules of acting in case of emergencies.

The document provides samples of three acts and seven tables, the formation of which is mandatory for approval of the PEL by the management of the SPRS, which serves the mine.

As you can see, the document [10] regulates the verification of the inclusion in the PEL of all units of the emergency service of the mine and their interaction with SPRS. Fulfillment of all its requirements will greatly facilitate the work of the second and third stages of the liquidation of emergency.

Conclusions. Emergencies are often considered as unforeseen situations. However, the nature of emergencies changes with the change of industrial technologies. A comprehensive approach to understanding the dangers of working in the coal industry and what measures are needed to effectively deal with accidents is the analysis of risk factors. It is necessary to have a good understanding of technology of this analysis and conduct it regularly, especially if SPRS staff has to work in potentially dangerous conditions or at risk of explosion.

A good support for general safety system is training of all mine personnel on the risk factors associated with their work, how to timely identify an emergency and warn about it, as well as first-level actions and rescue skills in the event of an emergency.

Training is a mechanism which determines the real effectiveness of the safety system and the measures developed. Emergency preparedness is ensured by integration of all necessary elements, including the establishment of a safety service, providing it with high-quality special equipment and conducting regular inspections of its effectiveness.

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ГОТОВНІСТЬ ШАХТ ДО АВАРІЙНИХ СИТУАЦІЙ І КОНЦЕПЦІЯ «НУЛЬОВОГО РИЗИКУ»

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Анотація. Аварія, на жаль, є невід'ємною складовою небезпечного виробничого об'єкту, яким є вугільна шахта. У ній діє велика кількість шкідливих і небезпечних гірничо-геологічних і техногенних чинників, які обумовлюють високий ризик виникнення аварійних ситуацій. Тому шахта повинна бути готова до їх своєчасного вияв-

лення і ліквідації без людських втрат і з мінімальною економічною шкодою. Концепція «нульового ризику» непридатна для аварійних ситуацій, а мінімізація «прийнятного ризику» можлива лише за умови правильної організації спільної роботи системи протиаварійного захисту (СПАЗ), планів попередження і ліквідації аварій. У нинішній час найбільша увага приділяється ліквідації аварій, які вже виникли. В той же час багато аварій виникають саме внаслідок того, що працівники не знають або невірно трактують вимоги Правил безпеки у вугільних шахтах, недостатньо ознайомлені з першочерговими мірами щодо виявлення аварій, вимогами системи управління організацією праці, а важкі наслідки аварії обумовлені невірними діями чи неспроможністю використати навіть існуючі рекомендації і засоби СПАЗ. Тому нами охарактеризовані основні методичні підходи до створення і використання першої складової СПАЗ - системи підготовки її елементів і навчання ними користуватись. Розглянуті питання контролю чинників ризику, визначення мір, що дозволять справитись з непередбаченою ситуацією чи аварією, розробки принципів організації аварійної бригади, забезпечення необхідних обладнання і матеріалів і організації навчання персоналу методам виявлення, обмеження і сповіщення щодо аварії, а також діям при мобілізації, розгортанні спеціальних систем і після аварії, оцінки і вдосконалення роботи всієї системи шляхом регулярних перевірок і випробувань. Зроблено висновок, що готовність до дій у аварійних ситуаціях забезпечується інтеграцією усіх необхідних елементів, включаючи створення служби безпеки, забезпечення її високоякісним спеціальним обладнанням і регулярні перевірки ефективності її дій.

Ключові слова: аварійна ситуація, небезпечний чинник, вугільна шахта, готовність до аварії, нульовий ризик, допустимий ризик.

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