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Improved safety in the use of electric energy in coal mines

The article features the possibilities to develop a high-speed switching device. The device has been designed to work in dangerouns coal mines with gas- and coal dust explosion hazards. Once the switch is implemented, the number of accidents and breakdowns in coal mines is likely to decrease.

key words: electric energy, electric energy supply, coal mine, explosion, switch off, ignition source, short circuit, magnetic station.

1. INTRODUCTION

Safe use of electric energy in power supply systems dedicated to the mining industry, where there are gas- and coal dust explosion hazards [13], is traditionally based on two operations. The first operation is regular check-up (renovation) in order to maintain proper status of all electric devices, with particular focus on their electric insulation. The second operation is to cut off the damaged section of the grid in the shortest possible time.

This concept corresponds to the issue of providing safety in general-purpose electric power networks. However, it is not enough in the case of industrial facilities with explosion hazards – particularly mines. Firstly, due to objective reasons (such as mobility of mining equipment, high humidity and degree of dustiness, complex maintenance of electric equipment), it has not been possible, so far, to provide high-quality, stabilized and safe operations of electric power supply systems in mines. Secondly, disconnecting a damaged element with the use of a traditional switch (overhead, gas or vacuum switch), with respect to the time needed for the current protection to start working, is 200 ms [1]. During that time, when the concentration of gases in the atmosphere is high, an explosion is inevitable, with all its consequences [10]. Therefore the time to disconnect safely electric power from the emergency section, with a proper reliability coefficient, will not be more than 300-400 microseconds [3]. Due to this reason it is necessary to develop new devices that would enable to switch off electric power in a short time.

The objective of the undertaken research was to improve the safety of electric power supply systems in coal mines of all categories, with respect to the content of gas and coal dust in their atmospheres. To achieve this, the following tasks were performed:

- An explosive switch-off device with a very high speed of operation was developed (switch-off time up to 100 microseconds).
- A new three-phase switch was developed.
- The concept of a new-generation magnetic station was presented.

2. PROBLEM DEFINITION

The requirements concerning the operating speed of switches working in explosive atmospheres are high. Therefore it is practically impossible to protect against explosions the environments with methane-air mixtures if an ignition source originates there. The organizational and technical operations performed in the mining industry all over the world only allow to reduce the probability that the following two events coincide: the gas content increases and an ignition source originates.

The concept and practical development of a solution that would allow safe use of electric power in explosive environments, including gas mines, has become a scientific and business challenge recently.

It is commonly known [4-6] that previous attempts to design a high-speed switch, based on traditional types of explosive materials, e.g. TNT (explosive bolt rule), proved to be inefficient, as it is not possible to follow the rules of safe use and storage of explosives in widely understood industrial conditions. What is more, the mining industry is characterized by high-value power surges.

At present, both in the mining industry [2,7] and other industrial sectors [8,9], there are new, safe and ecological technologies whose goal is to achieve the electrohydraulic effect. The fulfillment of these ecologically clean processes in different industrial sectors enabled to approach the issue of developing a whole set of electric explosion-protection devices.

3. APPLICATION OF ELECTROHYDRAULIC ELEMENTS TO IMPROVE THE SAFETY OF ELECTRIC POWER USE IN MINES

The development works were performed in a certain succession. The major element that enables to achieve the stated objectives is a cut-off valve [11] which will be connected into a synchronous three-phase system. This system is equipped with a mechanical three-phase system which reduces the voltage generated by the load, if the load is an electric motor (Fig. 1) [12].

The switch is composed of an overcurrent protection set (1) connected to a three-phase grid, a generator of surge currents of the electrohydraulic installation (2) connected with fuses (3) which have a form of hollow casings with ring-shaped undercut (4) filled with a dielectric liquid (5).

Each fuse installed in any of the three phases of the grid has a pair of electrodes (6). The electrodes are placed in a casing and their ends are connected with an electric cable (7). The other ends of the electrodes, those outside the casing, are in a series circuit and are connected to the outlets *1* and *2* of the generator (2). The rigid terminal block (8) of each fuse is connected to an AC power supply network, i.e. to the phases *A*, *B*, *C*, or a DC power supply network (in the latter case only two fuses are required). The rigid terminal block (9) which contacts the fuse casing (3) is composed of two parts connected by a flexible cable (10). This terminal is connected to the protected network: points A^1, B^1 and C^1. The bottom parts of all chambers (3) are equipped with blade-contact short-circuiting devices (11) which ensure the connection that the earth-fault circuit (12) is connected and fixed by means of springs (13) and a pair of stationary contacts (14).

In addition, Fig. 1 features an electric motor (15) and an alarm point $K^{(3)}$. The springs (13), which connect two parts of the rigid terminal (9) with the omission of the flexible cable (10), are stretched.

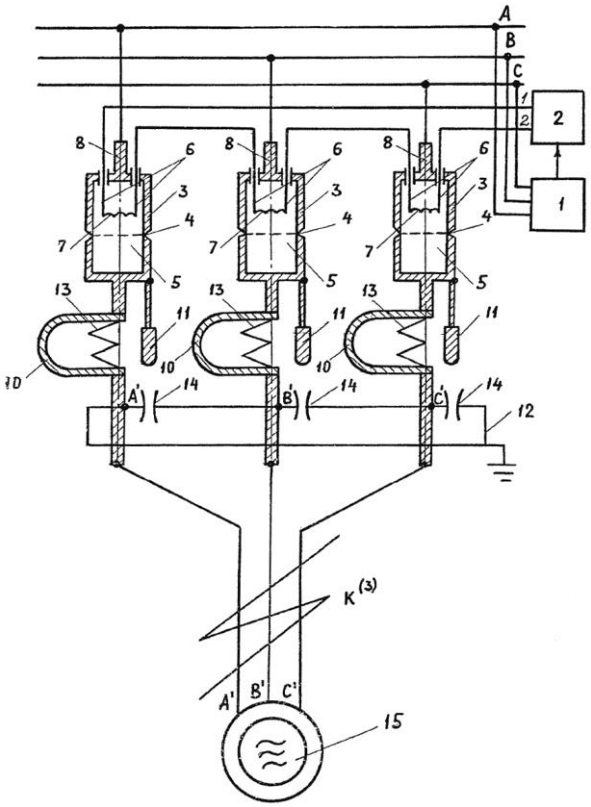

Fig. 2. Diagram of the protection device

If there is a short circuit in the protected network (point $K^{(3)}$), the current in the power supply network A, B, C increases. As a result of that, the fast operating protection (1) is switched on. It sends an impulse to the generator (2). The generator, in turn, sends a current impulse to the series-connected cables (7) placed in the dielectric liquid inside the fuses (3). Next, as the short-circuit cables get burned simultaneously (7), the pressure inside the fuse casing (3) increases violently, causing a break on the undercuts 4. Thanks to the acquired kinetic energy, the lower part of the fuse with the short-circuiting device (11), connected to the switch by means of a flexible cable (10), enters the stationary contacts (14) with high speed (without vibrations), making an earth circuit (12).

The spring (13) keeps the short-circuiting devices (11) in the stationary contacts (14) and ensures the reliability of the contacts. Thus, the currents of possible extra power supply coming from the rotating motor (15) are blocked by the circuit (12) due to the fact that the damaged point is short-circuited. The parameters of the cables (7), i.e. material, diameter, resistance, are selected in such a manner that the

cables burn almost simultaneously ensuring a small-range electrohydraulic effect.

Using the proposed device to cut off the electric grid of manufacturing facilities with explosion hazards allows not only to separate quickly the damaged section but also to perform its short circuit. This way the extra power supply coming from the rotating electric motor is cut off too.

Figure 2 features the oscillograms of load currents achieved with the use of a one-phase device. While analyzing the figure, it is possible to observe that in each case the time of switching off the load currents by means of the electric explosive device fits a millisecond range (from 0.25 to 1.01 ms). When the device is used to protect the electric grid in an emergency state (switching off short-circuit currents), the time of the switch-off does not exceed 100 ms (Fig. 3).

The presented device can be used in a more extended system which allows an emergency cut off of the endangered sections in the mine.

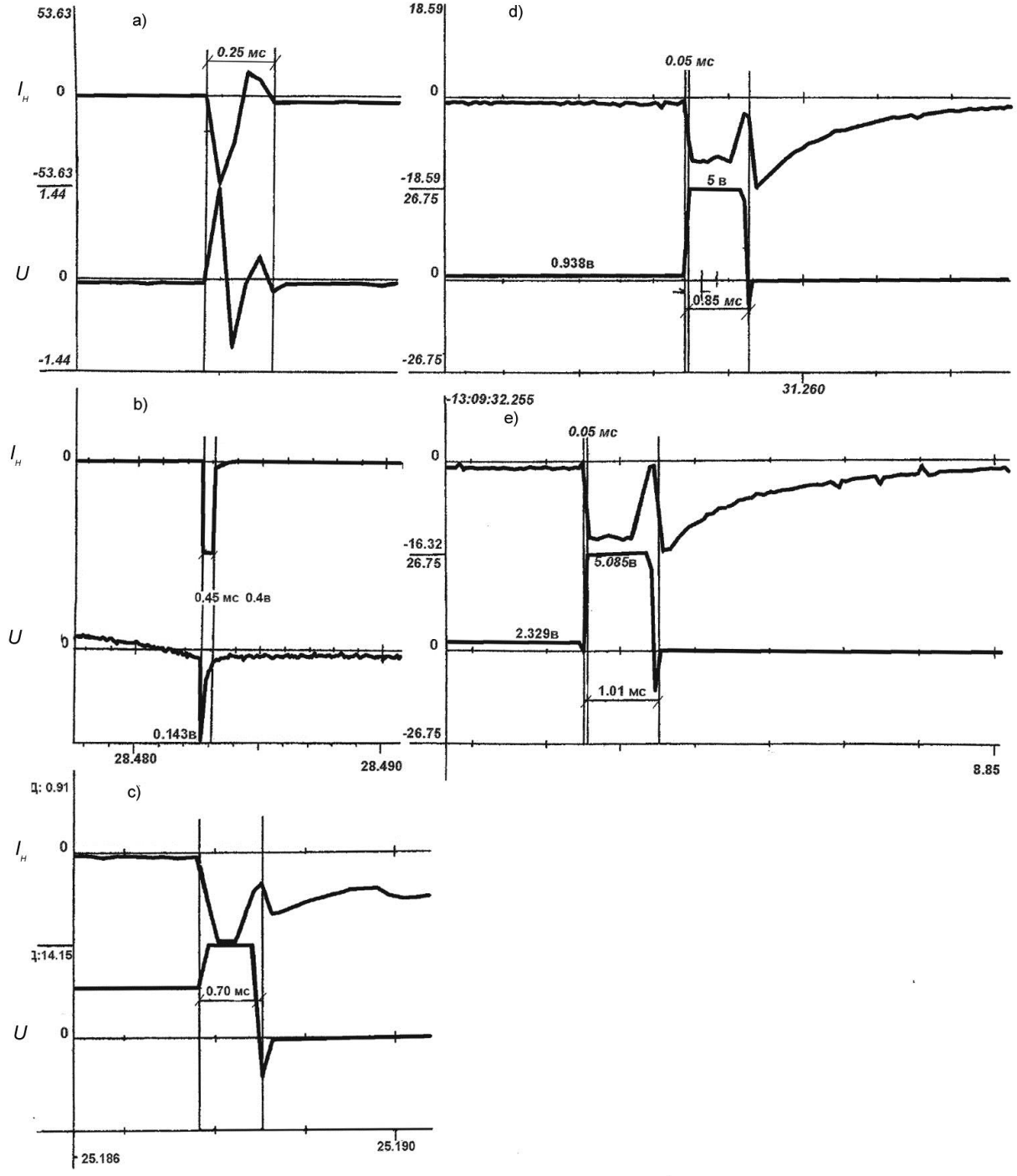

Fig. 2. Typical oscillograms of switching off short-circuit current within 250 microseconds (a), 450 microseconds (b), 700 microseconds (c), 850 microseconds (d), and 1,010 microseconds (e)

Figure 4 presents a typical diagram of electric power supply to the haulage road along with the distribution of electrotechnical equipment in the road. It can be seen in the figure that the start-up apparatus placed in the underground distribution point of the mining district can be successfully replaced by a new-generation station (Fig. 5) which makes use of ecologically clean protection devices and is developed on the basis of fast operating electrohydraulic explosive fuses (EGDP-1, EGDP-2, EGDP-3 and EGDP-4).

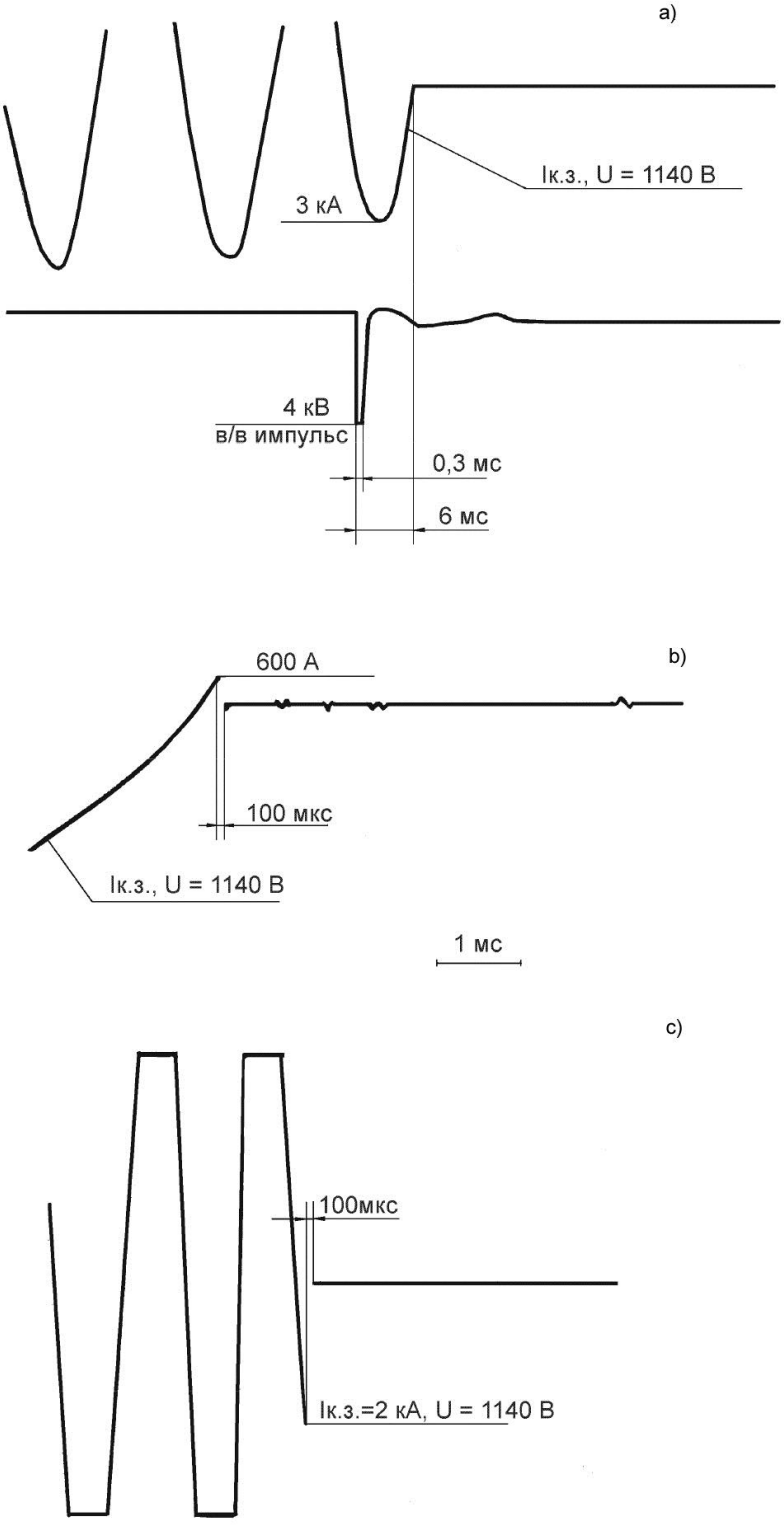

Fig. 3. Oscillograms of switching off short-circuit currents whose value is 3 kA (a), 600 A (b) and 2 kA (c)

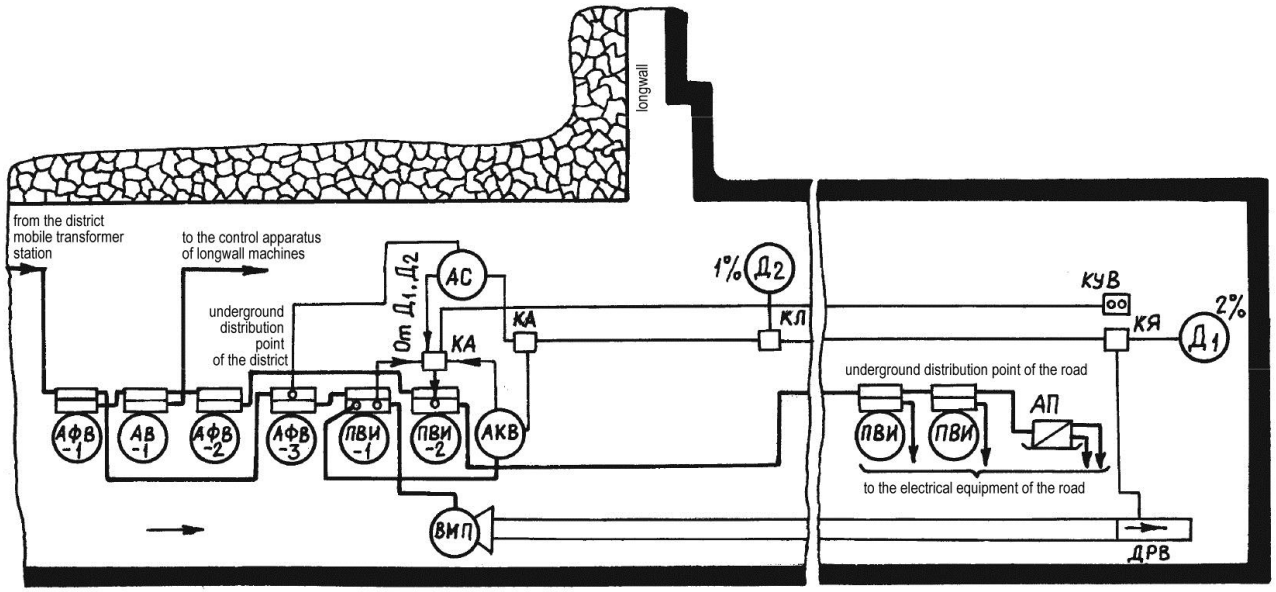

Fig. 4 Typical diagram of electric power supply to a haulage road and distribution of electrotechnical equipment

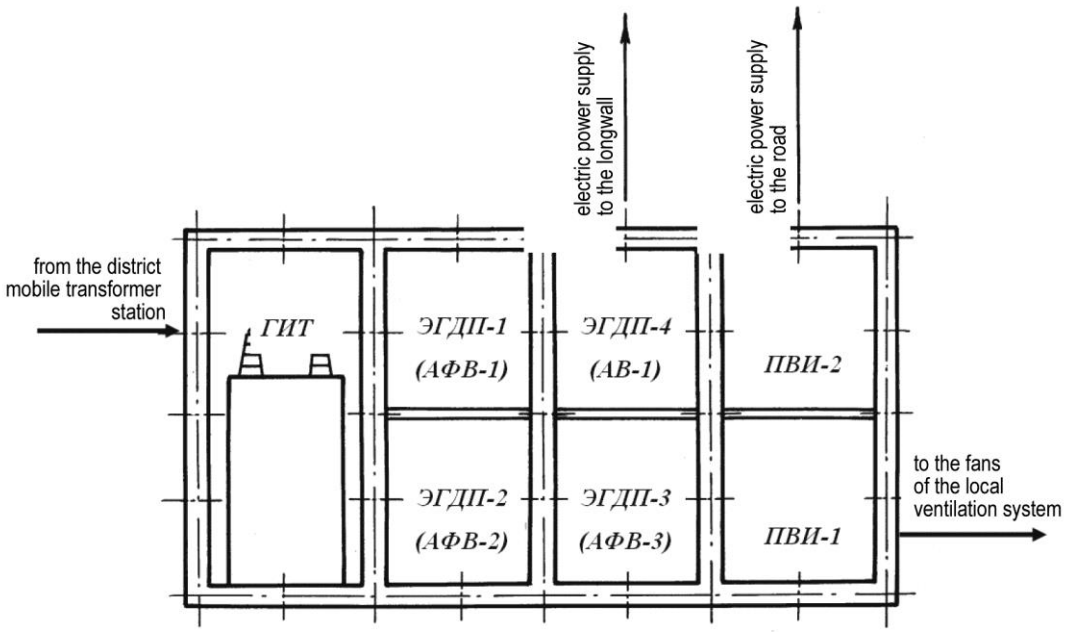

Fig. 5. New-generation magnetic station based on fast operating electrohydraulic explosive elements.

When the common pulse-current generator is switched on, the station should ensure the work of all four fast operating protection devices which act as automatic switches AFW-1, AFW-2, AFW-3, AW-1.

4. CONCLUSIONS

The conducted research resulted in the development of a high-speed explosive device based on electrohydraulic elements. The device enables to cut off the damaged section of the grid before an ignition occurs in the surrounding environment.

The device was the basis to develop a three-phase new-generation switch. The performed works enabled to develop a concept of an explosion-proof magnetic station composed of new elements. The concept allows to improve the safety of underground electric power supply systems for all categories of coal mines.

References

1. Legal and standard regulations on work protection (Ukraine) NPAOP (10.1-1.01-05) Safety regulations in hard coal mines. 2005, p. 398.
2. Kolesov O.A., Mnukhin A.G., Vaynshtayn L.A., Shevetchenko B.D., Olkhovitchenko W.A., Yemyelianienko V.I.: Testing the possibilities to raise the efficiency of hydrodynamic impact on coal-bering strata through the application of electrohydraulic effect. Proceedings of the 5th Scientific and Technical Conference, Nikolaev, 1992, pp. 8-10.
3. Kolosiuk W.P., Tkatchuk S.P., Ykhno S.A.: Explosion and fire safety of mining equipment. Osnova 2000, p. 694.
4. Korolkov, W.L., Datsenko W.A., Shymkyevitch G.J.: The use of an explosive switch to limit the current. Promyshlennaya elektronika 7, 1979, pp. 33-35.
5. Korolkov W.L., Sivkov A.A.: Reducing power surge in the explosive switch. Apparaty nizkovo napriazhenia 1979.
6. Korolkov, W.L., Datsenko W.A.: Protection of electric power networks with the use of an explosive switch 0.4 kW. Izviestii Vuzov – Energetika 11, 1977, pp. 113-117.
7. Mnukhin A.G.: Application of electrohydraulic technologies in the mining industry during the mine liquidation process. Materials from the international seminar – Experiences in liquidating non-prospective in Ukraine, Russian Federation and Kazakhstan. Donetsk 2002, pp. 117-118.
8. Mnukhin A.G., Briukhanov A.M., Goroshko I.P., Pantchenko N.I., Riedia W.N.: Application of dis charge and impulse technology with a view to recover the capacity of a water supply system in big metallurgical works. Mjetally i litje Ukrainy 6, 2003, pp. 49-51.
9. Mnukhin A.G., Mnukhin W.A.: Device for cleaning inner surfaces of water pipes in metallurgical works. Scientific papers of the National Mining University (2)12, Dnepropietrovsk 2003, pp. 203-205.
10. Mnukhin A.G., Briukhanov A.M., Mufiel L.A., Goroshko I.P, Yordanov I.V., Gromovoy N.A.: Device protecting against short circuits. Ukrainian Patent 29361. Bulletin 1, 2008.
11. Mnukhin A.G., Briukhanov A.M., Mufiel L.A., Goroshko I.P, Yordanov I.V., Gromovoy N.A.: Device for protective switch-off in electric circuits of production facilities with explosion hazards. Ukrainian Patent 38871. Bulletin 2, 2009.
12. Rozlovsky A.I., Scientific foundations of explosion safety while working with gases and flammable fumes. Khimia 1972, p. 368.
13. Trenczek S.: Poziom potencjalnego niebezpieczeństwa w rejonach eksploatacyjnych kopalń (Level of potential hazards in exploitation areas of mines). Mechanizacja i Automatyzacja Górnictwa 8, 2010, pp. 30-38.

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