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STAND-ALONE HARDWARE ANALYTICAL SYSTEM AAK12 FOR DETECTION OF GEOLOGICAL FAULTS IN COAL BEDS WITH THE USE OF SEISMIC EXPLORATION IN MINES

The general-circuit solutions for stand-alone hardware analytical system AAK12 have been described taking into account the safety measures for its implementation in mines. The performance capabilities of the main units and modules of the equipment have been considered for analogue and digital processing of recorded seismic signals, visualization and on-line analysis of the current measurements, as well as for data storage for further computer processing. The AAK12 basic technical specifications have been given.

Key words: prediction of mining-geological conditions, stand-alone hardware analytical system, seismic signals, explosion protection, spark-safe electric circuit.

In the recent years, as the depth and geological conditions of coal mining have got more complicated, the hardware and methodological framework of in-mine geophysics should be improved, especially in the field of seismic exploration as the principal method for detecting different types of geological faults of coal seams [1, 2]. These faults drastically worsen the effectiveness and safety of mining operations. In addition to the above said, reliable and quick forecast of geological conditions is of particular relevance due to enhancing role of mechanization of coal production and use of state-of-the art techniques of mine development, which demand compliance with more strict requirements for completeness and accuracy of predictive geological and geophysical information. The means of complex mechanization of mining operations have been designed for specific ranges of variation of geological parameters of coal seams, with any changes beyond the acceptable limits leading to a decrease in the efficiency and safety of works and even to their suspension or termination. These special difficulties arise as a result of sudden, unforeseen geological disturbances provoked by single excavations.

The Ukrainian State Research and Design Institute of Mining Geology, Geomechanics, and Mine Surveying of NASU is one of the leading organizations in the field of scientific and practical study of the geological conditions of coal deposit operation with the use of the seismic exploration methods. The Institute deals with full-scale research and development projects involving a wide range of highly qualified experts and specialists with the help of cutting-edge equipment. More than six years ago, the Institute completed a basic research on the development of theoretical and methodological framework of in-mine geophysics by order of the National Academy of Sciences of Ukraine. At about the same

time, it finalized the development of mine seismic station СШ12К. The results obtained were focused mainly on implementing the in-mine seismic exploration methods based on the waves reflected and transmitted in the prepared extraction column, which at that time seemed to be very relevant. However, the hardware not being well-fitted to operation by method of seismic location where the signal/noise ratio reaches the critical level and a lack of specialized embedded software for effective data analysis (which is particularly important for forecasting the mining geological situation before doing a single excavation) currently have a negative impact on the effectiveness and efficiency of mine geophysical works and, ultimately, on the stable and safe production of coal.

In the context of the problem it should be noted that the foreign researchers are striving to improve the reliability of in-mine geophysics by increasing the ADC digit capacity and signal recording by individual modules without the use of traditional streamer, which allows them to significantly improve the quality of information received. The most similar foreign analogue of СШ12К equipment is the 24-bit modular seismic station *SUMMIT* [3] for in-seam seismic exploration manufactured by German firm *DMT*, but its widespread use in the coal mines of Ukraine is problematic because of hardware weight exceeding 200 kg. In addition, its dimensions preclude its delivery to the mine without the use of special equipment; it uses explosive sources of elastic vibrations only; and finally, it is impossible to analyze information in the mine conditions. Taking into consideration the growing demands of the coal industry for the quality and timing of forecast information, as well as a heightened pace of the development of new technologies and related machinery the results of the above studies can be regarded as necessary for improving the basic methodological developments and technical means of mine geophysics and for adapting them to the current conditions. On their basis, in 2012, a hardware analytical complex AAK12 has been designed and manufactured within the research project «Development of autonomous hardware-analytical complex for detecting the geological faults of coal-beds by seismic methods».

While developing the AAK12 prototype special attention was paid to the explosion protection, as it should comply with the legal acts of Ukraine on protection of health and safety for conducting research in the coal mines of all types, including hazardous with respect to gas and/or coal dust explosions [4—7]. EPL of AAK12 mine extra explosive-proof electrical equipment has been implemented with the use of protective «*non-sparking electric circuit*» [7]. The spark-safe electrical circuits of the complex have been ensured due to the use of the special modules of spark protection, which limit currents and voltage of non-sparking circuits in accordance with the requirements of § 1.5 GOST 22782.5. The blocks with increased supply voltage are equipped with additional galvanic separation units. This solution requires the use of several microcontrollers for functioning of separate units. Exchange of commands and data between the different units of AAK12 is realized through the chains having galvanic separation. AAK12 (Fig. 1) consists of the following blocks and modules:

1) A1 analysis unit (designed for controlling the operator of working cycles of the complex, storing the signals accumulated in non-volatile memory, visualizing the received signals, and making their final analysis);

2) A2, A3 measuring units (perform the commands of the analysis unit: signal amplification, filtering, and analog-digital conversion, primary processing and analysis of received signals);

3) A4 central communication unit;

4) A5 remote communication unit;

5) Time marker;

6) Micro-telephone headset;

7) Geophones (for converting the seismic signals to the electrical ones);

8) Float-mounting connector;

9) Adapter;

10) Coil;

11—13) Connectors; and

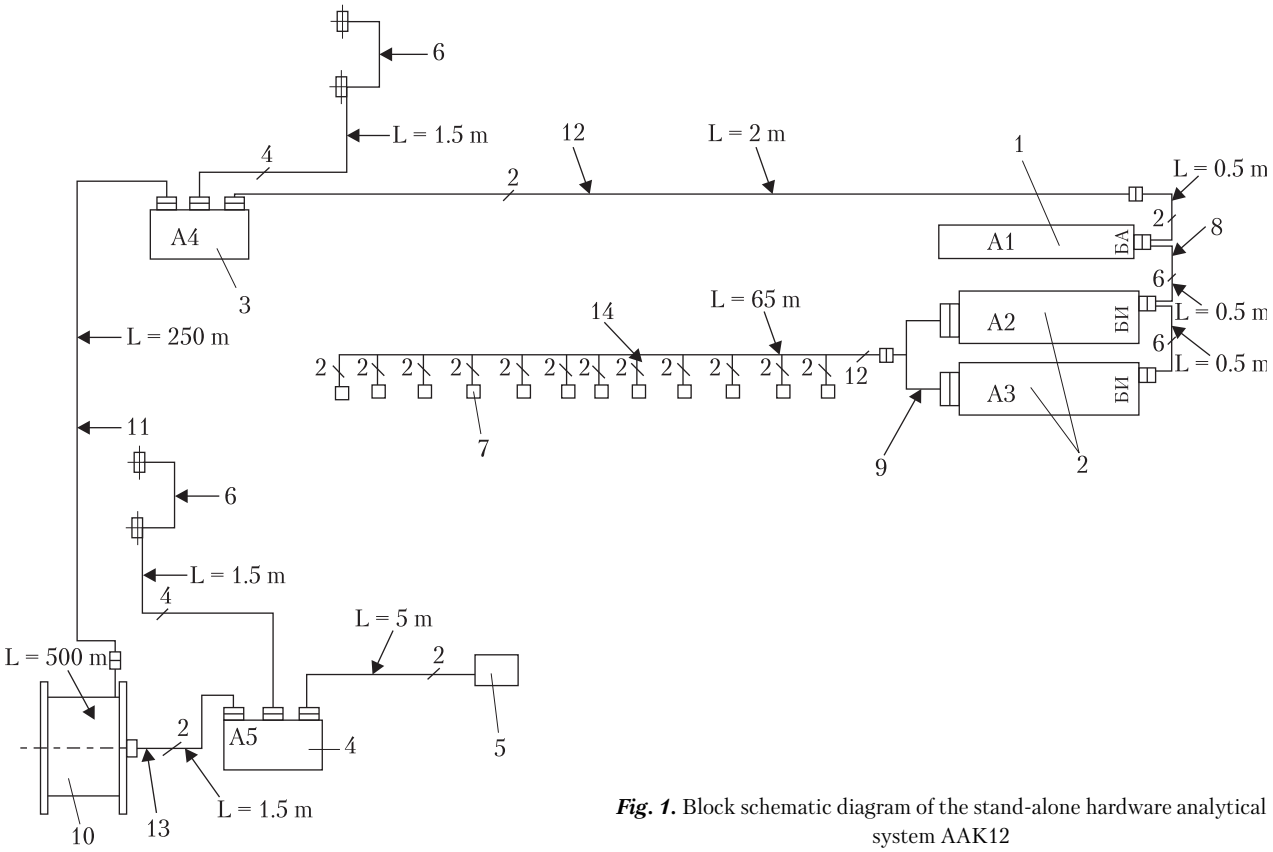

Fig. 1. Block schematic diagram of the stand-alone hardware analytical system AAK12

14) Streamer cable.

The central communication unit (3), the remote communication unit (4), the time marker (5), and the coil (10) are designed for synchronous operation of the complex blocks and for communication between the operator and the point of excitation.

The specific requirements for explosion safety of equipment impose restrictions on the interface hardware. In AAK12, there is used an interface with galvanically separated receivers and transmitters (standard EIA 422/V.11).

The analysis unit is a split-design profile (BOPLA) with the ends closed by screwed caps. The block contains: a battery pack, an explosion safety module, a regulatory control module, a CPU module, a memory module, a FLASH SDCARD module, a real time clock module, an LCD controller (320 x 240 pixels), a controller of 18-key membrane keyboard, an interface module RS-422, and an interface module of the communication unit. The analysis block has one 9-contact connector to connect the measuring unit and the communication unit. The exterior of analysis unit is showed in Fig. 2.

The stand-alone hardware and analytical complex consists of two identical measuring units, with each of them containing six seismic channels.

The measuring units perform the following functions:

- Amplification and filtering of geophone output signals;
- Transformation of amplified and filtered signals into digital form;
- Primary processing and analysis of the received signals;
- Lodging of conversion results to the analysis unit;

Fig. 2. Exterior of the stand-along analysis unit

Fig. 3. Exterior of the stand-along measuring unit

Fig. 4. Exterior of the remote communication unit

- Setting of parameters for signal amplification, filtering, and conversion upon commands from the analysis unit;
- Lodging of the parameters and status data of measuring units to the analysis unit;
- Offline check of measuring units and compensation of hardware errors.

The measuring unit comprises:

- An instrumentation plate which is the base plate designed to convert the amplified and filtered signals to digital form, as well as to monitor the battery status;
- Six amplifier cards for amplifying and filtering the output signals of geophones and for compensating the displacement of «0» channels;
- A processor card for controlling the resources of the measuring unit and the FLASH SD card, as well as for transmitting the accumulated signals to the analysis unit for further visualization and analysis;
- A spark safety card designed to provide the power supply and explosion safety of the measuring unit.

The instrumentation plate is a mother board to which the six amplifiers are connected via the connectors. In addition, on the board, there are located the buffer registers for communication with the processor board, the ADC, and the linear regulators.

The amplifier card consists of the following components: a pre-amplifier, active power supply filters of preamp, a controlled attenuator, a channel amplifier, a tunable low pass filter on switchable capacitors, a compensator of «0» displacement, and a linear power supply regulator.

The processor card consists of the following modules: an interface, a CPU, a RAM, and a FLASH SD. The spark safety card of the measuring unit includes amperometric resistors, two current mirrors, a protective power transistor, output voltage protective modules, and a regulator module.

The case of measuring unit is a split profile (BOPLA AVRN 1040) closed with screwed caps. The end caps have the connectors for connection to the analysis unit and the streamer of the stand-

alone hardware. One of the caps has a warning sign with the words «ОТКРЫВАТЬ В ШАХТЕ ЗАПРЕЩЕНО» («DO NOT OPEN IN MINE»); the level and type of explosion safety is РО Иа Х; IP54. The external view of the measuring unit is showed in Fig. 3.

The communication units are intended for synchronizing interaction of the pulse of seismic vibrations and the process of its registration, as well as for ensuring voice communication between the excitation points and recording of seismic vibrations.

The remote communication unit is designed to fix the time of signal from the time marker with respect to the pulse formation, synchronization, and transfer to the communication link. The central communication unit is designed to receive from the communication line the sync pulse and to form the pulse to start recording of seismic signal. Both the communication units are also designed to provide voice communications.

The exterior view of remote communication unit is showed in Fig. 4.

The principal technical characteristics of ААК 12:

Number of seismic channels	12;
ADC digit capacity, bit	12;
Range of recordable frequencies, Hz	From 5 to 4000;
Noise, mcV, maximum	0.5;
Channel-by-channel attenuation of signal, dB	+112;
Sample length	256; 512; 1024; 2048; 4096; 8192;
Number of accumulations	от 1 до 255;
LPF cut-off frequency of, Hz	125; 250; 500; 1000; 2000; 4000;
Sampling frequency, Hz	250; 500; 1000; 2000; 4000; 8000; 16000;
Capacity of non-volatile storage, Gbyte, minimum	2;
Channel similarity (amplification), %, minimum	98;
Crosstalk, %, maximum	0.05;
Level and type of explosion safety of the analysis unit, the measuring unit, the central communication unit, and the remote communication unit	РО Иа Х

Mass of the system's components, kg:

Analysis unit	1.2;
Measuring unit	1.1;
Central communication unit	0.4;
Remote communication unit	0.4;

Dimensions of the system's components, mm:

Analysis unit	211 × 140 × 36;
Measuring unit	183 × 110 × 45;
Central communication unit	113 × 108 × 35;
Remote communication unit	113 × 108 × 35.

CONCLUSIONS

The stand-alone hardware analytical system AAK12 has been designed and manufactured for getting detailed, reliable and timely information on availability and nature of geological faults in the rock mass, which drastically reduce the effectiveness and safety of mining operations under complex geological conditions of coal mining.

The mining studies with the use of equipment AAK12 cost about UAH 20 000 (according to the estimates made by the authors for the method of seismic location, on the basis of the applicable government rates). The expected economic effect of implementation of the system may reach several hundred thousand hryvnias per one mine working, due to minimizing the damages from emergency situations.

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АВТОНОМНИЙ АПАРАТНО-АНАЛІТИЧНИЙ КОМПЛЕКС ААК12 ДЛЯ ВИЯВЛЕННЯ ГЕОЛОГІЧНИХ ПОРУШЕНЬ ВУГІЛЬНИХ ПЛАСТІВ МЕТОДАМИ ШАХТНОЇ СЕЙСМОРОЗВІДКИ

Представлено опис принципів схемотехнічних рішень автономного апаратно-аналітичного комплексу ААК12 з урахуванням забезпечення безпеки його використання в шахтних умовах. Розглянуто функціональні можливості основних вузлів і модулів розробленої апаратури щодо аналогової і цифрової обробки реєстрованих сейсмічних сигналів, візуалізації і оперативного аналізу результатів поточних вимірювань, збереження даних для подальшої комп'ютерної обробки. Приведені основні технічні характеристики комплексу ААК12.

Ключові слова: прогноз гірничо-геологічних умов, автономний апаратно-аналітичний комплекс, сейсмічні сигнали, вибухозахист, іскробезпечний електричний ланцюг.

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АВТОНОМНЫЙ АППАРАТНО-АНАЛИТИЧЕСКИЙ КОМПЛЕКС ААК12 ДЛЯ ВЫЯВЛЕНИЯ ГЕОЛОГИЧЕСКИХ НАРУШЕНИЙ УГОЛЬНЫХ ПЛАСТОВ МЕТОДАМИ ШАХТНОЙ СЕЙСМОРАЗВЕДКИ

Представлено описание принципов схемотехнических решений автономного аппаратно-аналитического комплекса ААК12 с учетом обеспечения безопасности его использования в шахтных условиях. Рассмотрены функциональные возможности основных узлов и модулей разработанной аппаратуры при аналоговой и цифровой обработке регистрируемых сейсмических сигналов, визуализации и оперативного анализа результатов текущих измерений, сохранения данных для последующей компьютерной обработки. Приведены основные технические характеристики комплекса ААК12.

Ключевые слова: прогноз горно-геологических условий, автономный аппаратно-аналитический комплекс, сейсмические сигналы, взрывозащита, искробезопасная электрическая цепь.

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