

# **A Transfer of Modern Technologies Enabling the Improvement of the Occupational Safety in Mining and Taking Actions Connected with Environmental Protection as a Domain of Activity of EMAG Technology Transfer Centre LLC**

*The article presents the review of modern systems and appliances within the scope of geophysics, automation and industrial metrology worked out in EMAG Institute of Innovative Technology which transfer is led by EMAG Technology Transfer Centre LLC. Selected solutions were presented, implemented in mining in order to increase the safety of staffs, comfort of their work and better and more economic and economical for environment of minerals exploitation.*

## **1. INTRODUCTION**

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EMAG Technology Transfer Centre LLC is a company set up in 2010 that a reason of its establishment was a legal act of 30 April 2010 of Research Institutes changing R&D units within 1 October 2010 in research institutes of limited production possibilities, manufacturing ones.

The scopes of activity of EMAG Technology Transfer Centre LLC are: geophysics, automation, electronics, hydraulics and processing in the scope of complex service, ie. production and completion of the systems and devices being a subject to the offer of a company and technical supervision over their implementation and exploitation, and also within the scope of warranty and post-warranty service.

In the present paper, the selected systems and devices offered by EMAG Technology Transfer Centre LLC. have been presented in the most essential scope, using materials, worked out by employees of EMAG Institute of Innovative Technologies: Zbigniew Isakow, Ph.D.; Artur Kozłowski, Ph.D.; Marek Kryca, Ph.D. and Irena J. Kuciara, M.A.

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## **2. GEOPHYSICAL SYSTEMS**

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Production of geophysical systems made by EMAG Technology Transfer Centre LLC is conducted under a licence of EMAG Institute of Innovative Technologies. EMAG Institute supervises commercialisation of systems and is an author of changes and modifications both in a software and hardware part of the systems.

To worked out systems destined to monitor and seismic hazard assessment it can be counted the following systems:

- destined to assess a seismic hazard in the area of the whole coal mine, including ARAMIS M/E Seismic System, equipped with digital transmission of seismometric signals together with a software allowing among other things for: assessment of emergency according to the rules of a complex method of assessment of bounces hazard in coal mines extracting hard coal (instructions No 20 and Nr 22 worked out by Central Mining Institute),
- dedicated to regions of a special hazard (longwall), including ARES-5/E Seismo-acoustic System equipped with velocity electrodynamic sensors together with OCENA\_WIN software,

- destined to the control of hazards of coal mines infrastructure (shafts, post-floatation tanks), including:
  - system for recording accelerations of shaft lining vibrations generated by tremors (ARP 2000 SZ),
  - system for recording accelerations of banks of hydrotechnic lakes vibrations (ARP 2000 H),
- destined to monitor surface hazards generated by mining exploitation including system for recording accelerations of surface vibrations and its deformations generated by tremors (ARP 2000 P/E System).

### 2.1. ARAMIS M/E – system with a digital transmission of seismometric signals DTSS

ARAMIS M/E Seismic System with a digital transmission of DTSS signals enables:

- location of tremors (ARAMIS\_WIN software) occurred in the region of a mine, together with determination of their energy and assessment of bounces hazard of seismology methods (specialist software package).
- constant acquisition of seismic signals in recording server.

Owing to DTSS Intrinsically Safe Digital Data Transmission, central supply of underground transmitters from the surface is possible and digital transmission of converted measurement signals to the surface.

Thanks to a large dynamics of registration of 110 dB and band of registered frequencies within the scope of 0-150 Hz and resistant to interferences of digital transmission, a system ensures a right registration both faint seismic phenomena from  $10^2$  J and phenomena of large energy without saturation and identification of characteristic phases of seismic courses. Depending on wideness of an object, system uses seismometers or optionally low-frequency geophones (GVu, GVd oraz GHa) as measurement sensors.

Conventionally, a system allows to record one component of seismic signal in each channel. There is possible a recording one, two or three components of X, Y, Z vibrations velocity optionally. Fig 1a presents a structure of ARAMIS M/E System.

ARAMIS M/E System in a hardware configuration in surface part consists of:

- processing server of ARAMIS M/E System,
- recording server of ARAMIS\_REJ System,
- system of DTSS seismometric signals transmission
  - constructed with SP/DTSS surface transmission station containing OCGA digital receivers and driver controlling the transmission ST/DTSS with GPS satellite clock.

Surface station works with SPI-70 seismometers (optionally low-frequency geophones) and NSGA seismic transmitters via SN/DTSS underground transmitting stations.

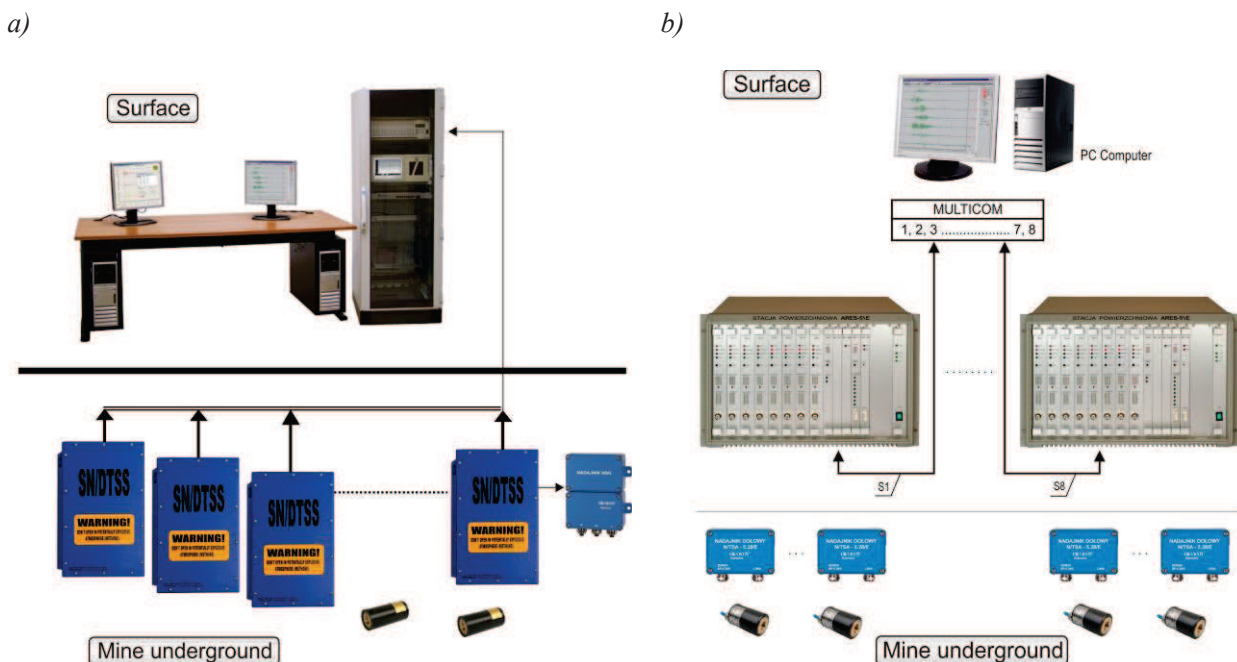


Fig. 1. System's structure:  
a) ARAMIS M/E; b) ARES-5/E (proprietary material)

ARAMIS M/E System ensures many practical functions, among others:

- receiving records from the recorder in a constant mode (automatic) with a preliminary processing (determination of characteristic signal phases, location of focus and energy evaluation) and presentation of seismograms,
- archiving of received records in systematic folders and presentation of seismograms for archived records,
- presentation of location result on a diagrammatic map of a coal mine (by location in an operator mode),
- introducing and modification of sensors description,
- interaction with other programs (e.g. ARP series of types).

There are applied analytical algorithms to:

- location of tremor focus by methods: standard one (on the basis of wave P), circles, S-P,
- determination of phenomenon energy by methods: complete, approximate with length of signal duration,
- spectroanalysis and digital filtration of selected seismic records.

Besides, owing to additional software package it is possible to conduct:

- record of small-diameter drillings,
- automatic assessment of bounces hazard according to seismologic method and small-diameter drillings or optionally seismo-acoustic one (if ARES System works as well) and according to summary and complex method.

System possesses a user-friendly program interface enabling to print a whole range of reports including a daily report of bounces hazard in a heading and summary reports of number and tremors energy in a heading. User has an option to introduce information concerning coal mine's structure (name of beds, regions, headings, headings coordinates, rotation progress etc.) and used assessment parameters (e.g. critical value (volumetric) of drillings for assessment according to small-diameter drillings).

## 2.2. ARES-5/E – seismo-acoustic system for bounces hazard assessment

ARES-5/E System (Fig. 1b) is destined for carrying out bounces hazard assessment according to the rules of seismo-acoustic method of state of bounces hazard assessment. The system bases on the data from seismic-acoustic observations in the regions

specially threatened with. In ARES-5/E Systems follows the processing using SP-5.28/E geophone measurement probe (fixed on anchors in side wall of advanced galleries) of velocity of mechanical vibrations of rock mass on electric signals, and then transmitting such signals on a surface to Mining Geophysics Station. In surface part of the system follows a digital processing of the signals and an analysis of converted data.

In hardware configuration of ARES-5/E System it may be differentiated two main parts: surface one – located in Mining Geophysics Station – and object one – its hardware elements are placed underground.

In surface part of the systems work:

- surface stations (maximum 8) – each one serves 8 measurements channels,
- processing server of ARES-5/E System with a software used for analysis of phenomena in seismo-acoustic band (*SystemAres*) and conducting an assessment of state of bounces hazard (*Ares\_Ocena*).

Each of the surface stations cooperates with SP-5.28/E Measurements Probes located in object part (with electrodynamic sensors type GS-14-L9) and N/TSA-5.28/E Transmitters.

ARES-5/E System possesses the *SystemARES* Software to analyse phenomena in seismoacoustic band and *Ares\_Ocena* for conducting the bounces hazard assessment. Owing to this it is possible to realise the following practical functions:

- strengthen and filtration of seismic-acoustic signals (N/TSA-5/E Transmitters),
- analog transmission of intensified seismic-acoustic signals on the surface (communications cable network and receiver systems of OA-5/E Surface Station),
- determination of parameters of seismic-acoustic parameters,
- detection and multichannel recording of larger seismic-acoustic phenomena with time synchronization via GPS clock,
- simplified location of larger seismic-acoustic phenomena,
- determination of arrangements of conventional energy of seismic-acoustic phenomena and activity of their occurrence,
- Analysis of registered data based on statistical methods using risk function,
- processing, visualisation and archiving recorded data according to a binding instruction within the scope of seismic-acoustic method of hazards state assessment.

### 2.3. ARP 2000P/E used for recording and analysis low-frequency vibrations of a ground and buildings

ARP 2000 P/E System is a telemetric digital one for recording and analysis of accelerations of low-frequency vibrations of ground and buildings on areas endangered by tremors and others (tectonic, transport etc.). It comprises two main parts: station and object one.

Station part is located in hazards control centre of the surface and consists of a computer or PC com-

puters to digital bidirectional radio communication (GSM-GPRS transmission) with object measurements and a software for archiving, visualization and preliminary processing of recording data.

Object part comprises three LKP-ARP Local Measurement Concentrators and CZP3X and/or ECP3X Tri-component Accelerometer Sensors or optionally SN/ARP Transmitting Stations with velocity sensors (SPI-70 seismometers or low-frequency tri-component geophone probes).

Hardware structure of the system was presented in pictorial form (Fig 2).

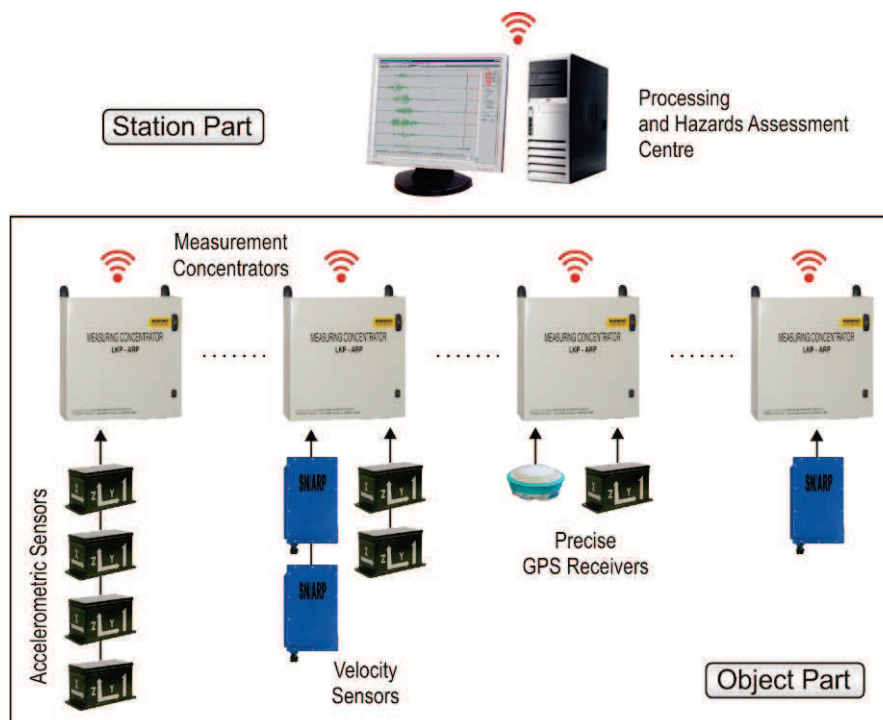


Fig. 2. Hardware structure of ARP2000 P/E System with four measurement positions (proprietary material)

ARP 2000 P/E System is characterised by dispersed structure making easier the realisation of control of large areas and gradual increase of system's possibilities. System is destined to tri-component, synchronous recording in many places of ground vibrations generated by shocks of different type. System allows on remote data acquisition using mobile telephony and their central processing in a point even very distant from a controlled area.

System performs a detection of vibrations of mining, seismic or transport origin, synchronous in time recording of signals from the sensors located in object part of the system, placed on practically unlimited area and their digital transmission via radio into processing centre. There are used two communication standards: GSM – switched data transmission – and GPRS – block data transmission. Additionally for testing and diagnostic purposes, communication with

concentrator in „off-line” mode is possible, directly by means of serial connection of portable computer type laptop (serial transmission – RS232).

Software of ARP 2000 System depending on version – ARP 2000 P/E or ARP 2000 H/E differs in methods of results interpretation. However, for shaft applications (ARP 2000 SZ/E) for the sake of other way of data transmission between concentrator and archiving computer, a separate communication software both for a local measurement concentrator and superior computer. Centre's software allows to record, archive and for preliminary processing of recorded data. Additionally, such a software enables an analysis of collected measurement data and conducting the assessment of harmfulness of vibrations effects according to seismic scales. In the process of shocks effect assessment on the surface, Polish standards and regulations are applied and also instruc-



tions worked out or approved by State Mining Authority. They are destined to use on areas being subject to influence of exploitation of mines. In ARP 2000 System, the algorithms enabling the assessment of emergency of the surface according to MSK, GSI-GZW-A and GSI-GZW-V scale have been implemented. As an option, there is a possibility to transfer the data to external specialist software.

#### 2.4. Tendencies of development of geophysical systems

Long-standing activity of EMAG Institute in the scope of working out and implementation systems and devices destined to assess the influence of shocks both in mining pits and on the surface of the ground allowed to implement about 100 systems of different generations, also outside the state limits: in Russia, Ukraine, in People's Republic of China (PRC).

For ages, such an activity has been led in close cooperation with main scientific centres and leading mines and copper ore mines. It led to standardise control-measuring apparatus applied in Mining Geophysics Stations. However, in order to manage users' requirements, EMAG Institute of Innovative Technologies conducts development works, aiming at:

- working out new sensors and probes for recording rock mass vibrations and optimal ways of their fixation in rock mass on account of metrological parameters including in roof holes,
- working out new methods of conditioning, processing seismic signals with a proper dynamics, phenomena detection, their recording, archiving, visualisation and analysis in order to detect natural hazards, such as: bounce or combined hazards and accompanied methane,
- working out new methods of assessment of harmful impact of mining tremors on mine's infrastructure and surface's building development,
- recognition of a process of roof rocks cracking in the aspect of bounces hazard assessment,
- working out new methods of control and analysis of stress' changes in the region before the frontage of longwall with the application of seismic wave to overexpose a rock mass,
- working out new methods of assessment of dynamic phenomena in roof, including location and grouping focuses of micro-seismic phenomena and improvement of hazard measure in a form of a computable function of a risk of shock occurrence,
- selection of analytic, geomechanical and geophysical method of assessment and monitoring changes

of bounces hazard state in the aspect of a possibility of conducting continuous monitoring of complex operation.

It will allow to implement to production and apply next generations of systems for monitoring and forecasting hazards connected with unbalancing rock mass for coal mines.

#### 3. CONTROL SYSTEMS AND INDUSTRIAL AUTOMATION SYSTEMS

To the most important systems and devices worked out by a team of automation specialists ones may be counted the following:

- steering and control systems of machines and devices for highly efficient longwall systems and face systems i.e.:
  - MAKS-DBC System – destined for wireless control of extracting machines (shearer loader) of a new generation with remote monitoring of machine operation,
  - SUK-2, SUK-1 Systems – destined to control roadheader from a operator's cabin,
  - SKD-1 System – innovative system for steering and to diagnose roadheader,
  - SKD-2M with MINOS System (monitoring of mine face's contour) – for wireless steering and diagnostics with an innovative solution, enabling directional machine navigation in axis of a drilled dog heading,
  - KID-220 System – for steering and diagnostics of roadheaders.
- systems of automatic control and steering, monitoring and visualisation of depth pumping stations,
- systems of control and monitoring of mining belt conveyors,
- sets of monitoring of operation of machines and underground devices: KAD-CAN – measurement of force of coal cutting, TAMY – control of air-flow in galleries, MOPS – monitoring of static capacity in selected props of powered roof support's sections,
- modern telecommunications solutions for wireless data transmission: RSO-26, RSO-27 (remote controls for shearer's steering), RSO-CH – remote control with steering joysticks of a shearer,
- control systems of automation in industry,
- other modules: PIMP – for data transferring (intrinsically safe pendrive), SET-5RS, SEM-1 – data bus separator,
- measuring devices for automation systems:

- RCC-1, PCC-X/Y, RCC-2, PCC-3, PAC Pressure Sensors,
- ICz-1 Proximity Detector,
- CVD-100, CVD-1000 Path and Velocity Sensors,
- CPW-1 Water Pressure Sensor,
- COP-2 Pump Tail Position Sensor ,
- Inclinos Angle Sensor,
- CPO 1/L, PPP-1 Oil Level Sensor.

### 3.1. Wireless control systems of shearers

The most developed solution is working out remote control and wireless methane detectors with on-line measurement. It allows to increase a degree of drilling automation and predicate of machine operation parameters, that meet the temporary conditions of mining. It allows to increase a degree of utilization of technical potential of a machine, limitation of machine wear resulting from improper operating, decrease of energy consumption of mining process and increase of safety level in gate end, what profitable influences on efficiency of driving dog headings.

SKD-2M is a wireless system of control and diagnostics with innovative solution enabling directional navigation of a machine in axis of a drilled dog heading. The idea of SKD-2 System bases on scattered structure of mutually connected functional blocks (modules) with each other, carrying out individual steering-diagnostic functions. Designed system is so-called open system, both in respect of hardware and software account. Large processing speed of the system allows to apply data processing algorithms for steering purposes and diagnostics of a great numerical complexity.

Such a system is destined to be applied in mining roadheaders, working in headings with a degree „a”, „b” and „c” of methane explosion hazard. Its basic functions are the following:

- local control of a machine from the level of PAK-1 Control Desk,

- wireless control of a machine from the level of RSO-CH Radio Control Desk,
- monitoring of operation parameters of particular machine subassemblies through series of sensors,
- monitoring of ripping head position regarding shearer or gallery,
- monitoring of longitudinal and transverse gradient of a shearer regarding the horizon,
- monitoring of shearer position regarding axis of a drilled gallery,
- diagnostics of separate sets of shearer,
- visualization of operating condition on LCD display,
- signalling of leading of ripping head to the limit of cross-section of a gallery,
- detection of failures and informing the user about their occurrence,
- internal communication through fast and reliable CAN 2.0 interface, optionally RS-485 with Modbus RTU protocol,
- visualisation of operating condition of shearer on the surface.

Established in SKD-2M construction of a scattering system enables in an easy and economical way to configure the system and implement it in any type of roadheaders of a middle and light class. In an operator’s cabin, on LCD display, there is a possibility to choose a board called „mining”, on which there is displayed a selected heading’s profile and a current position of ripping head towards such a profile with an added track of mined body of coal. Closeness of a ripping head to the limit of a calculated contour is signalled by a change of graphics colour of a section and it causes stoppage of motion of outrigger in direction that may cause crossing the limit of the section, what allows for precise and safe mining. Benefits of the system are minimization of caverns in pits, guniting of almost constant thickness by tunnelling but above all remote control of mining process.

The most significant elements of SKD-2M (Fig. 3) are:

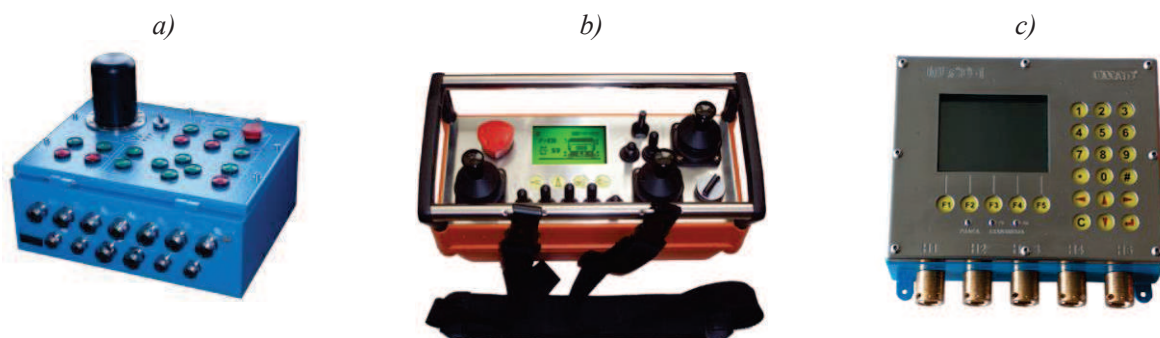


Fig. 3. Elements of SKD-2M: a) PAK-1 Steering-control Panel; b) RSO-CH Radio Control Desk; c) MLCD-1 Intrinsically Safe Display Module (proprietary material)

- PAK-1 Control-steering Panel (Fig. 3a) performs a central controller of roadheader that its main task is a direct control of machine operation. Software of panel's modules serves steering buttons: drives of ripping head, dust collector, sprinkling, hydraulics, feeder and control of conveyor and running. It controls an indication of CAN system bus and Bluetooth wireless transmission. A device signals a failure occurrence by means of sound signal.
- RSO-CH Radio Control Desk (Fig. 3b) is destined for radio steering of roadheader. A device communicates wirelessly with PAK-1 Control-steering Panel in band of 2,4 GHz. a pulpit is equipped with manipulators controlling the drive and motion of outrigger and 8 functional switches. The pulpit was supplied with LCD display, that a task is to visualise parameters and working condition of a machine, and display emergency-information messages.
- MLCD-1 Visualisation Module (Fig. 3c) – equipped with a colourful LCD display of a diagonal of 5,7 inches, that enables a visualisation of working parameters of a shearer and its components. By means of a keyboard, parametrization of control system is possible. Information about particular parameters is transmitted bidirectionally through CAN communication interface.

Hardware integrity of control system with the MINOS-2 System of monitoring shearer's ripping head significantly spread functional properties of SKD-2M and it improves in essential way the execution of a correct breakout in body of coal under a selected lining through generating the information about approach of ripping head to the limit of a calculated

section and about deviations from vertical, horizon and heading's axis.

MINOS-2 System consists of the following elements:

- sensors: CK-1 Angle Position of the outrigger on Y-axis (vertical) and X-axis (horizontal), CN-1 Levelling, CPK-2 Shearer Position,
- MP-2 Processing Modules,
- measurement sensors and converters,
- underground and surface visualisation.

What is more, through the integration of SKD-2M Control and Diagnostics System with  $\mu$ ZIST Transmission System, there were created two communication lines between shearer, local distant control-dispatching centre and surface dispatcher unit. Innovation with reference to current solutions (Fig. 4) is application of intermediate degree between the machine central controller and surface dispatcher unit.

Local mining industrial computer enables preliminary processing of large number of measurement data not only from the shearer control system but also from devices of mining atmosphere control in mine face. Stores of underground industrial computer will enable an application of industrial cameras and preliminary processing and data presentation for shearer operator's, service teams, mining inspectors and mine face team's needs.

It might be useful to mention that above-mentioned devices and solutions are implemented both in Poland and abroad. For instance, in next versions of MAKS Control and Diagnostics System there is equipped majority of shearer loaders operating in Polish mining, 30 coal mines in Poland in total (and 15 abroad).

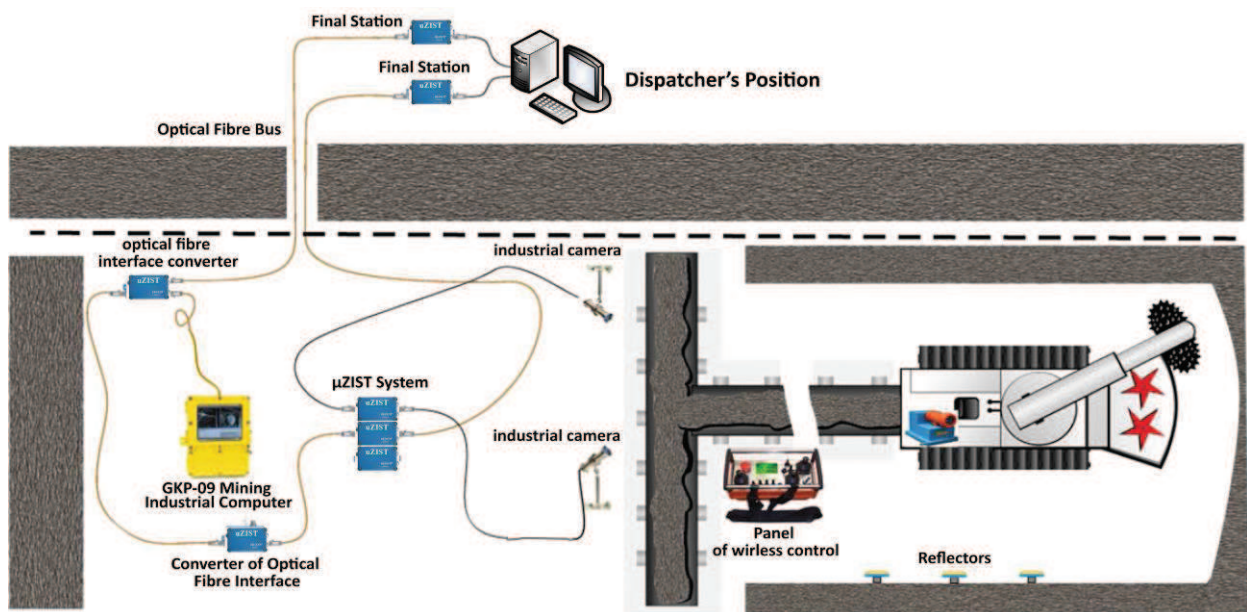


Fig. 4. Hypothetical application of integration of SKD-2M control system with  $\mu$ ZIST transmission system (proprietary material)



However SKD-1 System and MPT-1 one were implemented in LW Bogdanka SA Coal Mine. Numerous implementations took place in case of system of control and monitoring of operation of depth pumping station (P.G. Grodziec, P.G. Sosnowiec, P.G. Paryż, P.G. Katowice, P.G. Niwka-Modrzejów, together with the position in Main Dispatch Room in Central Plant of Coal Mine Dehydration). Foreign implementations took place in case of SUK-2 – Russia – and KID-220 – Belarus.

#### 4. CONTROL AND DIAGNOSTICS DEVICES IN HYDRAULIC SETS OF CONTROL SYSTEMS OF MACHINES WORKING IN ESPECIALLY HARD CONDITION

Long-term activity of EMAG Institute in the scope of working out and implementation the systems and devices enabled an elaboration of the whole series of types of intrinsically safe sensors, measurement converters and electrohydraulic and electropneumatic devices. To a group of two-state sensors, the following products can be classified as follows: PCC-3, RCC-2, CPW-1, CPO-2/L/T and much more technologically advanced analog sensors type PPP-1 and PAC-1. The whole range of control valves and electrohydraulic valves – ZES-40, SEMI-2, ZEW-1 – and electropneumatic – REPI, ZEP-1, SEMI-2.

In recent period one of the most often implemented solutions is PCC-3 Threshold Pressure Sensor. It is a hydraulic destined for signalling the exceeding or decrease a set value of medium pressure in hydraulic circuits supplied with oil or oil-water emulsion. Its wide range of a set switching threshold proves its universality. Additionally, in sensor's output circuit it is possible to apply sets of diodes, resistors in configurations adjusted to diagnostic systems' controllers used by receivers that eliminate the application of intermediate boxes and their additional certification.

From such a reason, sensors found application in the following devices: rack railways, floor railways, shearer loaders, roadheaders, hydraulic unit, diesel-hydraulic units, powered roof supports, drills. Among our clients there are such companies of mining branch: BECKER WARKOP Sp. z o.o., FAMUR SA, REMAG SA, PIOMA SA, KOPEX SA, and many other consignees, that found application for them as well.

#### 4.1. Steering devices in hydraulic systems of mining machines

Basic electrohydraulic valve offered by EMAG Technology Transfer Centre LLC is RBz 1÷6 Block Electrohydraulic Valve (Fig. 5a) made on the basis of RH10 executive control valve manufactured by FUH GEORYT and ZES-40 Steering Units (EMAG Institute). RBz 1÷6 Control Valves are successfully applied in MAKS Control and Steering Systems and MAKS DBC being an equipment of many shearer loaders produced by FAMUR S.A., in SUK-1 and SUK-2 control and diagnostics systems of roadheaders, in a system of follow-up stretching of chain of wall belt conveyer NaP and in other sets of electrohydraulic mining machines control.

ZES-40 Steering Unit (Fig. 5b) is made of intrinsically safe electromagnet and pilot valve, which hydraulic output signal is used to switch over executive valve. Such a solution allows to control the operation of power hydraulics elements working by nominal pressure of supply above 30 MPa and working flows exceeding 150 l/min by means of intrinsically safe electromagnets of power of merely 1,2 W (100 mA by voltage of 12 V). Such a low power consumption of a steering unit was reached owing to:

- maximization of electromagnet power through optimization of magnetic circuit of electromagnet from the point of view of receiving the utmost inductance (material of very good magnetic properties, large section of magnetic core, very small air-gap),

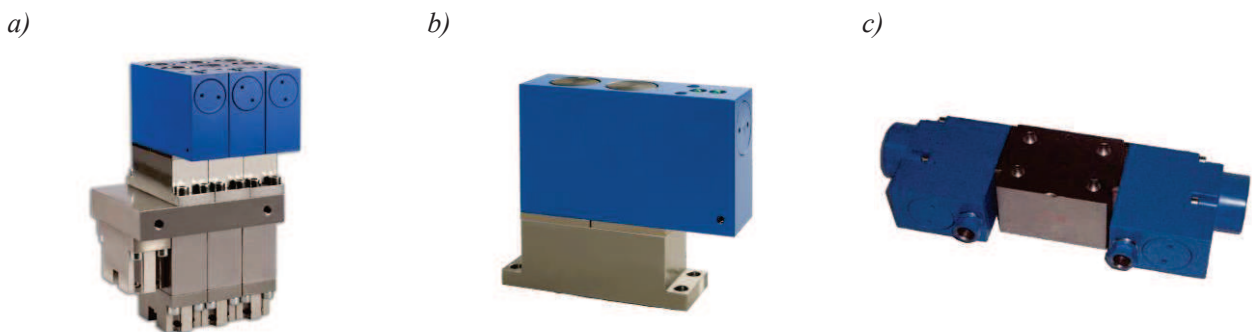


Fig. 5. Elements of control:

a) RBz-1÷6 Block Valve; b) ZES-40 Steering Unit; c) RPro-1 Proportional Valve (proprietary material)



– construction of pilot valve of a very low working stroke (about 0,1 mm) and not large section of valves requiring low power of switching over and allowing to limit to minimum electromagnet air-gap.

Working out and implementation of RPro-1 Proportional Valve (Fig. 5c) ensured a dynamic development of sets of hydraulic control. Combination of classic hydraulic elements with electronic control systems is a basis of electrohydraulic proportional technology. In many cases the application of proportional technology in hydraulic systems is a condition of precise and flexible operation of machines and devices. Owing to controlled switch-overs, it can be avoid to occur culminating pressure values. As a result mechanical and hydraulic elements are much more durable.

For the needs of control of devices supplied for compressed air a single SEMI-2/P Controller has

been worked out, that is an integral part of intrinsically safe electropneumatic valves of a very high medium's flows. In such valves a slide pneumatic valve of EMAG Institute's construction was applied. On the basis of this executive valve, REPI-\*/\*.\* electro-pneumatic valves have been worked out. REPI valves are commonly used for steering work of shaft's devices.

**4.2. Diagnostics devices in hydraulic sets of control systems of mining machines**

To control the condition of executive elements of mining machines serve worked out in EMAG sensors:

– pressure: threshold, PCC-3 two-stated pressure sensor (Fig. 6a) and PAC-1 analog pressure sensor (Fig. 6b),

a)



b)



Fig. 6. Pressure sensors: a) PCC- Two-state Pressure Sensor; b) PAC-1 Analog Pressure Sensor (proprietary material)

– medium level: CPO-2/L/T Oil Level Sensor (Fig. 7a) – with a signalling of medium decrease below specified minimum and PPP-1 Float Level Con-

verter (Fig. 7b) – ensuring analog measurement of medium level and temperature in closed tanks built-in in working machines,

a)



b)



Fig. 7. Medium Level Sensors: a) CPO-2/L/T Level Sensor; b) PPP-1 Float Level Converter (proprietary material)

– motion parameters: CVD-1000 Path and Velocity Sensor (Fig. 8a) – used for measurement of velocity and covered distance by displacing machines and devices and IPK-120 Angle Sensor – for

a measurement of position of ripping head of angle converter, and ICZ-1 Intrinsically safe Proximity Converter (Fig. 8b) – destined to detection of the presence of metal objects in the area of working of a converter.

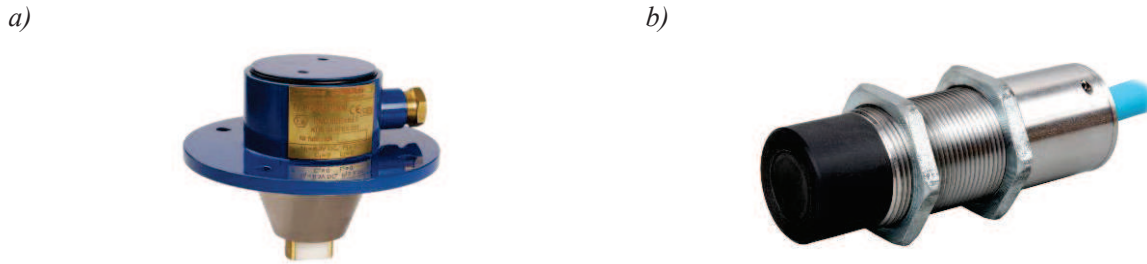


Fig. 8. Motion Parameters Sensors:

a) CVD-1000 Path and Velocity Sensor; b) ICZ-1 Intrinsically safe Proximity Converter (proprietary material)

#### 4.3. Electronic devices dedicated to systems of electrohydraulic control of mining machines

In EMAG Institute a family of devices functionally complete for building module systems of control and monitoring operation of mining machines working in especially hard conditions. It consists of among ot-

hers: BSHkm Block of Hydraulics Steering and Mechanisms Control (Fig. 9a) – elaborated for the needs of MAKS-DBC System – destined to control power hydraulics and working parameters of machines and devices used in extracting process. Such a block is adapted to be assembled on an extractive machine's body in a protected zone against mechanical hazards.

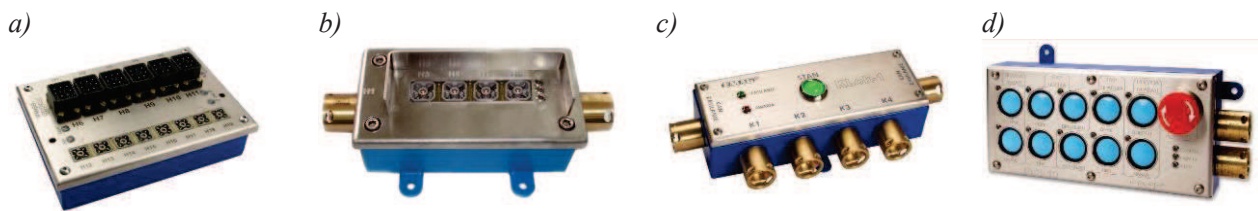


Fig. 9. Elements of Module Devices:

a) BSHkm Block of Hydraulics Steering and Mechanisms Control; b) EE-1 Expander of Electrovalves; c) KLok-1 Local Concentrator; d) PUS-10 Control Panel (proprietary material)

By the agency of BSHkm Block one may control the operation of five intrinsically safe electrohydraulic valves, besides it has measurement inputs enabling the data acquisition from 12 sensors controlling the condition of steerable machine.

For applications, in which there is required only control of electrovalve, the EE-1 expander of electrovalves has been worked out (Fig. 9b), that enables steering 4 or 8 electrohydraulic valves, depending on version of execution. Expander is a universal device supplied with voltage of 12 V and depending on needs it can be equipped with CAN interface or RS485.

The most universal device destined for operation in electrohydraulic control systems is 4-channel programmable input/output module called KLok-1 Local Concentrator (Fig. 9c). Each of the concentrator's channels might function as measuring input (voltage or current one) or binary output for switching over valves of electrohydraulic valve. Concentrator may cooperates with sensors of output voltage of 0÷5 V or current output of 0,2÷1 mA, 4÷20 mA.

For the needs of manual control in module steering systems and monitoring of operation of face machines, the PUS-10 Control Pulpit has been worked out (Fig. 9d) ensuring switchin on/switching off the function of steering according to the condition of buttons and emergency stop of the device after pushing emergency button.

#### 5. POWER ELECTRONIC SYSTEMS OF MACHINES AND DRIVES

One of the most developing services is modernization of existing drives that depending on specificity of such systems comprises:

- carrying out converters for regulation of rotational speed of drives with asynchronous slip-ring motors in set of thyristor cascades, switched on in a circuit of motor rotor and having parameters dependent from such rotors every time,
- working out of systems of regulation of rotational speed of drives of high power with asynchronous

- slip-ring motors, with frequency converters of low (690 V) and medium voltage (6 kV),
- manufacturing and testing converters for drives of direct current (mainly hoisting machines with direct current motors).

### 5.1. Cascade driving systems

Scope of realised modernizations of drives depends on type of motor applied in a drive. In case of modernization of drives with synchronous motor, it includes modification of synchronous motors for wound-rotor induction motors and developing thyristor converter creating a subsynchronous cascade with motors. In case of mining stations of ventilators of primary ventilation, it is possible a solution (economical) with one common thyristor converter for two drives, enabling their alternating operation with regulated rotational speed.

Modification of a motor from synchronous one to wound-rotor induction motor consists in replacement the rotor of synchronous motor by wound rotor, asynchronous. Modernization of a drive include also control system of the whole drive (including starting system). Such a set is equipped with microprocessor controllers, it realises, among others, the following functions:

- steering of switching on and switching off the drive,
- operation in a cascade system or with shorted rotor (in bypass system),
- control of condition of supportive devices of converter system and the whole drive prior switching on for operation and blocking switching on,
- control of efficiency of particular components during operation and switching off in case of their un-serviceability.

Drive's steering takes place by means of Operator Pulpit placed in control unit in which there are additional elements of steering, signalling and control as well.

Application of microprocessor controllers in control system causes large possibilities in the scope of monitoring both drive's readiness for operation and work oneself. As a result of drive's preparation to work, on a controller panel there is displayed a message of a readiness to switch on and in case of lack of availability, there is displayed a message of missing signals and specifies such signals in a form of scrolled list. Actuation of protections causing emergency drive shut-down causes a message display informing about the shut-down reasons. Such information is stored in "breakdown history" and may be displayed on demand, in any moment.

From large drives of modernised in above-mentioned scope – in two coal mines of Jastrzębska Spółka Węglowa S.A. – there are among other things: drives of ventilators of primary ventilation of power of 2500 kW and compressor drive modernised in case of enabling a regulation its capacity by change of rotational speed from  $Q \cong 16000 \text{ m}^3/\text{h}$  to about  $8000\div 10000 \text{ m}^3/\text{h}$ . It was applied a system of thyristor cascade to regulate rotational speed of compressor motor of power of 1800 kW for voltage of 6 kV.

### 5.2. Systems of fans capacity regulation with frequency converters

Other way of improvement of ventilation system efficiency is the application of frequency converters for regulation rotational speed of ventilators of primary ventilation. A system with frequency converters supplied induction cellular motors for voltage of 690 V and rotational speed of 369 rotates/min, put into effect in one of the coal mines of Katowicki Holding Węglowy S.A. enables a change of drive's speed in a wide, practically not entirely used in this scope in case of ventilators. It is high-performance, energy-saving driving system replacing traditional ways of regulation of ventilator's capacity. In order to increase working reliability necessary for ventilators of primary ventilation, a bypass system was predicted to make possible power supply of motor directly from converter transformer with the omission of frequency converter without regulation of rotational speed.

Modernization of the whole ventilators' stations of primary ventilation is connected with modernization of ventilators' drives and it allows to enclose them with a monitoring and visualisation system and ensuring the air parameters control. It is an additional factor of increasing the human safety of the people doing a job in conditions of a special coal mine environment hazard.

### 5.3. Systems of velocity regulation and control of direct current drives

In recent years in EMAG Institute a thyristor converter of rated current of 4000 A and maximum rectified voltage of 750 V with a possibility of parallel switching has been worked out. Usage of microprocessor units in control and regulation system enabled acquiring high dynamics and motions fluency of converter's drive of hoisting machine and ensured a possibility of operation visualisation and monitoring emergency conditions what definitely improved and rationalized a machine operation.

TR-4 Thyristor Converter is destined for supplied driving systems of high powers, including hoisting machines in mining. As it was mentioned, it is adjusted to work in parallel.

The primary converter is controlled by microprocessor controllers placed in a separate switchbox where except control of thyristors they realise functions of current and speed regulators and functions of converter's protections as well.

In order to conduct a regulation functions it was applied a microprocessor controller that performs, among others, the following functions:

- regulator of current type PI,
- regulator of speed type P or PI,
- control of rate of change of a given speed,
- control of converter's work (protection of current trace),
- control of a correct functioning of a controller,
- giving the speed after determined ramp,
- steering of induction converter (during reversion).

The second controller put in practice the protection functions, among other things:

- control of temperature sensors conditions and microswitches of fuses,
- control of currents in particular thyristor bridges giving consideration to maximum current, uniformity of currents spreading and uniformity of load phases,
- visualisation of emergency conditions of converter on operator panel.

Occurrence of whichever of emergency condition is signalled on operator panel by means of a proper message.

One of more interesting types of implementations was the execution of converter and start of direct current drive of power of 2250 kW, for voltage of 650 V for balancing machine of turbo-rotors for ALSTOM POWER in Wrocław. It is a drive for which a high precision of rotational speed regulation is required and characterised very large range of changes of inertia moment of driven machine.

#### 5.4. Systems of power electronic control for locomotives

Significant possibilities gives a modernization of steering of locomotives applied underground of coal mines.

It is offered among others: complex system of power electronic control for LGT-22 wire locomotives manufactured by ASEA. Their modern power-supply and control system is characterised by independent control of two propulsion motors with the possibility of detection of driving wheels spin. Be-

sides, control system enables to drive two locomotives in arrangement in series and remote control (drive without machine operator) in moment of loading and unloading of winning.

The next innovative solutions are:

- power electronic control of locomotives – OPT-2 Flame-proof Traction Speedometer located both in Ldag-05 locomotives and in LeaBM-12 locomotives equipped in control system manufactured by APATOR or TUSO/M, TURO A Equipment,
- Indicator of storage battery discharge with diode display resistant to shocks replacing currently applied indicator instrument,
- Traction speedometer and discharge indicator type UML (Fig. 10), that possesses worktime counter, counter of ridden kilometres and can ensure data archiving (function of tachometer) in cooperation with a new TUSO/M Control System.



Fig. 10. UML Speedometer (proprietary material)

#### 5.5. Compensation

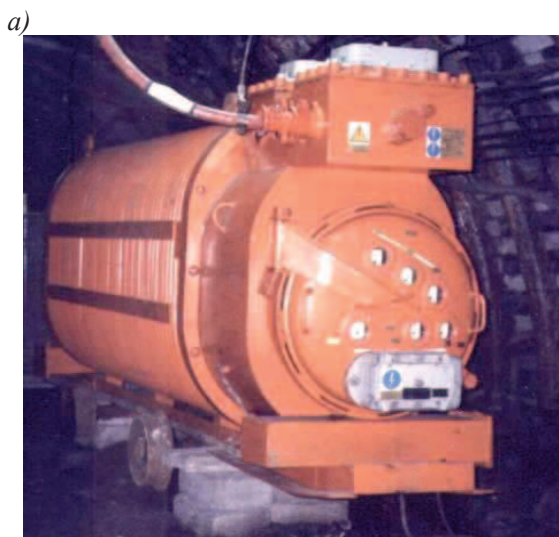
A possibility of selecting power for needs of power electronic systems enable compensation systems type ZCO (Fig. 11a) and ZK (Fig. 11b), offer by EMAG Technology Transfer Centre LLC.

Rated power of compensation system can be selected for needs of power electronic system from among the value to 1200 kVAr, by 2 compensation ratios, in set of automatic operation (steering of reactive power controller), with switching apparatus in form of Rollarc 400 contactors.

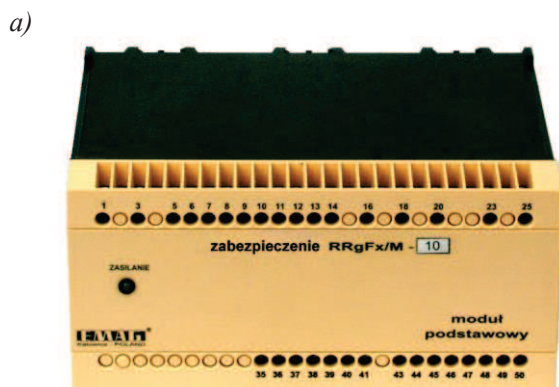
#### 5.6. Protections

A significant importance for occupational safety have Leakage Protections (Fig 12). One of the offered ones is RRgFx/M Central Leakage Protection (Fig. 12a) that is destined to protection against dangerous effects of ground insulation failure in TT networks of a nominal voltage to 1140 V.





Rys. 11. View of compensation sets on working places: a) type ZCO; b) type ZK (proprietary material)



Rys. 12. Leakage Protection: a) Central type RRgFx/M; b) Blocking type RRgB (proprietary material)

Functional properties ensure:

- cooperation with growth or decay release,
- optional choose of working mode of actuation interlocking – active or inactive interlocking,
- actuation memory (interlocking) – at least 48 hours,
- possibility to connect the protection to power network in any place,
- signalling of: insulation condition, phase capacity, type of failure, actuation.

Other type of protection is Blocking Leakage Protection type RRgB (Fig. 12b) destined for protection against dangerous consequences of switching on under working voltage of a section – outlet of tri-phase electrical power network with insulated neutral point of a nominal voltage to 1140 V, 50 Hz, showing failure of ground insulation. Protective functioning of such a protection consists in blocking of a possibility of switching on a monitored section of a network under voltage in case of occurrence, in any point, failure of a ground insulation. The protection is destined to install in chambers of electric

apparatus of vehicle transformer stations and contactor sets of normal or explosion-proof, flame-proof structure. Contact output circuit of a protection is adjusted to cooperate with control circuits of contactor switches.

## 6. DEVICES FOR QUALITATIVE-QUANTITATIVE PARAMETERS CONTROL OF MINERALS IN SYSTEMS OF ENRICHMENT PLANTS MONITORING

Conducted in EMAG long-term research on working out measuring methods and technological solutions enabling a control of qualitative-quantitative parameters in enrichment plants of minerals made possible a creation of a complex offer allowing for meeting almost all potential user's needs. Modernization works let to improve many solution, keeping

them on a highest technological level and adjustment to detailed client's requirement.

In technological processes of enrichment plants there are applied complex control systems that integrates machines and devices operation with many measurement appliances (in majority of non-electric quantities). Data gained from the sensors are processed in proper microprocessor controllers using specific algorithms proper for a given process.

Contemporary programmable control systems allow for a precise analysis and diagnostics of actual condition of production devices. Increase of precision of internal supervision over correctness of machines' operation is undoubtedly related to significant increase of signal and data numbers connected with predicted, possible or existing events. Application software contains possibilities of alarming about interferences (including emergency conditions) in work of production process with the graphic and text exposure and transferring commands (orders) to particular controllers realising specified control functions.

In the offer of EMAG Technology Transfer Centre LLC there are the following solutions worked out in EMAG Institute connected with measurements of qualitative parameters of minerals: densimeters, ash meters (absorptive, dispersive, measuring a natural gamma radiation, optical ones), microwave moisture meters (absorptive, dispersive and resonant), meters of potassium content in potash salts, analyzers of elements content using X-ray fluorescence, industrial automation systems cooperating with meters of minerals quality, electrohydraulic systems of mining machines control.

### 6.1. Measurements with the application of man-made isotopes

Isotopes are applied in systems characterised by difficult measurement conditions where the access to analysed medium is limited. The example may be isotopic densimeter destined to density measurement, concentration, percentage of two-component mixtures transported hydraulically or pneumatically via pipelines. Potential users are plants of: processing mining raw materials, industrial waste materials, processing and utilization of waste, production of building materials. The device ensures the realisation of on-line, touchless measurement, not introducing limitations of the flow.

Absorptive and dispersive ash meters applied depending on technological conditions are used for measurement of ash content in coal transported by means of belt conveyor. Depending on realisation,

there is applied a method based on a phenomenon of absorption low and mid-energetic gamma radiation (back-scattering). In case of cooperation of ash meter with moisture meter it is possible to enumerate a calorific value.

Isotope as a source of ionizing radiation is applied in PYLOX Analyser. Ionizing radiation originated from the source knocks out the electrons from particular atoms creating ions. Such activated atoms emit secondary radiation of energies characteristic for a given element. Analysis of energy spectrum of activated radiation gives information about the type and quantity of a given element. A device finds an application to determine mixtures parameters such as: ash, non-flammable parts of mining dusts and copper, sulphur and other elements contents.

### 6.2. Measurements basing on natural gamma radiation

Analysers making use of measurement of natural gamma radiation found application in ash meter destined to on-line measurements (RODOS), laboratory (GAMMA-NATURA 2) and in portable ash meters as well. Universality of a method results from lack of artificial isotopes and connected with them permissions for exploitation, issued by National Atomic Energy Agency (PAA). Cooperation of ash meter with microwave moisture meter enables to enumerate a calorific value. Ash meter is destined for measurements on belt conveyor cooperates with conveyor balance. It follows that the level of natural radiation depends not only on ash content but also on quantity of material in measurement area. Such ash meters are manufactured in a version destined to use in a area endangered of explosion of coal dust or methane and in a safe zone. Large measurement zone assures a good averaging of a measured material and partly compensates low level of radiation. Receiving stable indications requires measurement time prolongation.

Worked out in EMAG, measurement method enabling for determining KCl contents in potash salts transported via belt conveyor was applied in SILVOS Meter. Conducted exploitation research showed correctness of analytical algorithms and working stability of a device in conditions of high environment temperature and aggressive surroundings (Fig. 13).

It was stated that it is possible to receive measurement uncertainty below 0,7% KCl by ensuring constant counter geometry. Measurement conditions may ensure through a selection of place of device development, building of system of forming material stream in front of measuring zone or building a de-

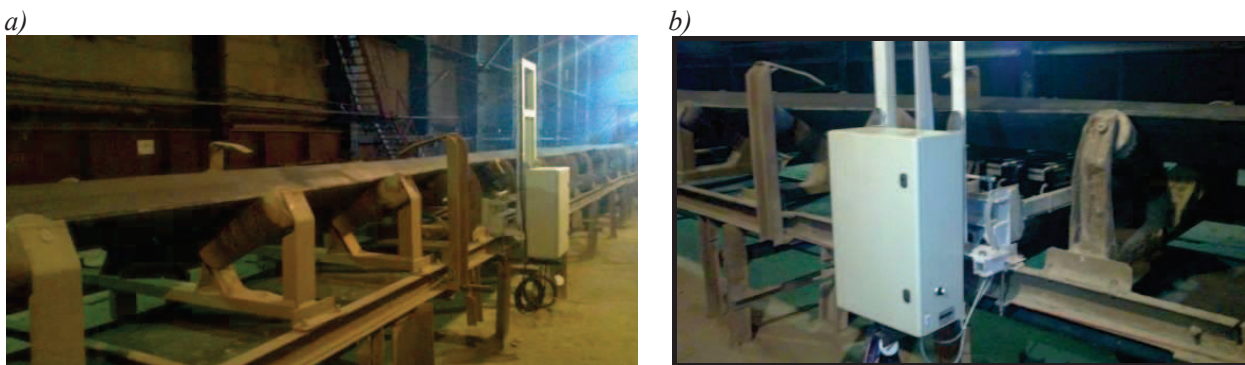


Fig. 13. SOLVOS System for measurement potassium content during exploitation research

vice detecting and compensating the impact of crosswise displacement of material towards axis of measurement zone.

MPOF2 Optical Ash Meter is a device (Fig. 14a) destined for on-line measurement of ash in flotation deads of hard coal.



Fig. 14. MPOF2 Ash Meter:  
 a) General view – basic elements: 1 - measuring head, 2 - visualization module,  
 b) view of a built measuring head

Measurements can be conducted directly on overfalls of deads in flotation machines or in cumulative collectors (troughs) of deads, on condition meeting proper metrology requirements. Presented results allow for current assessment of correctness of conducting flotation process and may be used to its regulation and be the information about necessity of flotation machines correction. Current control of flotation deads is very important from economic and ecological point of view. A right course of flotation process influences on a quality of final products. Final products of a process are not only a concentrate but also stone and pure water.

Measuring head body is permanently half-depth dived in flowed flotation deads (Fig. 14b). It was made of constructional material – polyamide reinforced with glass fibre, owing to this, it is resistant to

corrosion, occurring chemical compounds (especially petroleum derivativated ones) and mechanical failures. In order to keep a declared measurement uncertainty  $1\sigma \leq 3,5\%$  it is necessary to meet minimal metrology requirements:

- diving measurement head in flotation deads on the depth  $\geq 20$  cm,
- ensuring laminar flow of suspension below a head (lack of air vesicles),
- concentration of flotation deads  $\geq 15$  g/l,
- granulation of solid phase  $\leq 0,7$  mm.

If the granulation of concentration of flotation deads amounts to under 15 g/l then the sample would become too „transparent”, what negatively impact on measurement accuracy.

Described above groups of devices may function both independently – meters monitoring processings



and can be stuck in systems of automatic regulation. Such solutions ensure the execution of atypical measurements of high accuracy and transmission and visualisation of actual results for a selected location, for instance supervision stations or control ones. Results are recorded in databases and presented in the form of tables and diagrams.

## **7. SUMMARY**

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The scope of so far, successfully finished implementations and perspectives of further sale of the systems is large. Attractiveness and innovation of worked out offer results from properly executed R&D phase, effectively carrying out marketing activity, a good preparation of commercial, multilingual

version of the systems and its complete documentation for potential user at the state and abroad.

Elaborated and implemented systems enable the improvement of occupational safety and contribute to environmental protection.

Led by EMAG Institute of Innovative Technologies content-related works on working out systems and devices of a new generation cause that the offer of EMAG Technology Transfer Centre LLC is modern and meet the requirements made by systems' and devices' users in mines of surface and underground mining.

*In the present article, the materials and documentation worked out in EMAG Institute of Innovative Technologies have been used.*

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