# Analysis of the modernized system for monitoring environmental parameters in workings with hazard of explosive atmospheres

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Abstract: - Actual firedamp monitoring systems, placed in firedamp mines from Romania, interrogate the detection heads (transducers) at a 4 minutes period, in order to monitor methane concentration. In site, in this time, methane accumulations can occur and could result even explosions.

This paper presents a new system that monitors the methane concentration by interrogating the transducers at a period of 4 seconds. Concurrently, with the help of this system, even other environmental parameters are monitored, and the number of detection heads can be increased from 40 to 64 or more, as necessary.

*Key-words: - acquisition system, measurement and control, central computing unit, computerized recorder, intrinsic safety, explosive atmosphere* 

## **1** Introduction

The European standard that defines designing, production and test requirements for intrinsically safe systems for group I, provided for use entirely or partly in atmospheres susceptible to occurrence of firedamp, is EN 50394-1.

This standard supplements the requirements of EN 60079-11, requirements that apply to electrical apparatus used for intrinsically safe systems.

Installation requirements for a group II intrinsically safe system, designed according EN 60079-25, are specified in EN 60079-14.

The Directive [9] divides equipment into two groups.

**Group I** comprises equipment intended for use in the underground parts of mines, and to those parts of surface installations of such mines, likely to become endangered by firedamp and/or combustible dust [10].

**Group II** comprises equipment intended for use in other places likely to become endangered by explosive atmospheres.

#### **Equipment Group I category M1**

Equipment designed and, where necessary, equipped with additional special means to be capable of functioning in conformity with the operational parameters established by the manufacturer and ensuring a very high level of protection. Equipment in this category is intended for use in underground parts of mines as well as those parts of surface installations of such mines endangered by firedamp and/or combustible dust. Equipment in this category is intended to remain functional, even in the event of rare incidents relating to equipment, with an explosive atmosphere present, and is characterized by means of protection such that

a) either, in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection, or

b) the requisite level of protection is assured in the event of two faults occurring independently of each other.

#### Equipment Group I category M2

Equipment designed to be capable of functioning in conformity with the operational parameters established by the manufacturer and ensuring a high level of protection. Equipment in this category is intended for use in underground parts of mines as well as those parts of surface installations of such mines likely to be endangered firedamp and/or combustible dust. This bv equipment is intended to be de-energized in the event of an explosive atmosphere. The means of protection relating to equipment in this category assure the requisite level of protection during normal operation and also in the case of more severe operating conditions, in particular those arising from rough handling and changing environmental conditions.

Each part of an intrinsically safe electrical system shall meet the requirements for either category M1 or M2, depending upon whether it is

intended for operation in an explosive atmosphere or a potentially explosive atmosphere respectively. The complete system need not necessarily be in a single category, providing it is clear which parts relate to which category as described for M1 and M2.

Parts of intrinsically safe electrical systems are of category M1 if they comply with either

a) the requirements applicable to electrical apparatus of level of protection 'ia', or

b) the requirements of EN 50303 as they apply to intrinsically safe apparatus/circuits.

The faults shall be applied to the electrical

system as an entity and not to each item of electrical apparatus in the system.

Parts of intrinsically safe electrical systems are of category M2 if they comply with the requirements applicable to electrical apparatus of at least "level of protection 'ib'; but the fault shall be applied to the electrical system as an entity and not to each item of electrical apparatus in the system.

In purpose of analysis of intrinsically safe systems of group I, the flowchart from fig.1 is used:



Fig. 1 - Systems analysis flowchart

The electrical parameters and all characteristics of the interconnecting wiring specific to an intrinsically safe electrical system, insofar as intrinsic safety depends on them, shall be specified in the descriptive system document. Interconnecting wiring/cables shall meet the specific requirements for cables [3].

A multicore cable shall not contain any intrinsically and non-intrinsically safe circuits at the same time.

Where a multicore cable is to be used, the descriptive system document shall identify which of the cables described in [3] are to be used.

### **2** Description

The acquisition, measurement and control system is designed for integrated and simultaneous use in [1]:

- continuous and automatic measurement of environmental parameters (concentration of explosive or toxic gases);

- simultaneous remote recording of explosive or toxic gas concentrations;

- environmental parameters control;

- advanced system for environmental management;

- optical and acoustic signaling for pre-alarm and alarm thresholds, when exceeds preset gas concentrations;

- shut down of electrically driven machinery have exceeded areas that preset gas in concentrations.

System's functional technical characteristics are [1]:

rated voltage and frequency: 220V, 50-60 Hz:

- rated power: 680 W;
- rated current: 47 mA;

number of sensors (channels): 16÷64; -

operation mode: automatic;

transmission mode: frequency, digital (depending on sensor);

- measuring period of a line: < 8 sec. (depending on sensor);

- period of a measurement cycle: < 8 sec;

- results recorder: PC server;

- alarm transmission mode: simultaneously in up to 64 lines from any point of alarm in any line;

- maximum voltage that can be generated inside system: 220V

- operating temperature: -10°C, +45°C;
- relative humidity: 5% to 90% no condensation.

Basically, the system consists in the central industrial type box having that comprise the following: central computer unit, display, keyboard, acquisition drawers, alarm drawers, phone, UPS, isolating transformer, intrinsic safety barriers, sensors.

Each component will have an identification number, its status being verified and recorded continuously by the central unit.

The central computing unit is the main component of the measurement, acquisition and control system. This component takes data from the acquisition-sampling and alarm drawers, processes them, display them as values or graphical form, issues orders to the drawers and to the computerized recorder according to results [1].

Using this industrial computer, inside the system are called the following services:

- security service;
- measurement service;

system configuration service (used during programming).

The central computing unit has the following configuration:

- Housing 19" rack mount
- Display TFT LCD 8,4"
- Flat keyboard
- Redundant source ATX 400W •
- Processor Intel Core 2 DUO, 2,66 GHz •
- Memory RAM DDR II 1GB •
- Hard disk 160 GB •
- CD-ROM unit •

OS Windows XP Professional SP3 Integrated 2009



Fig. 2 Central computing unit

As seen in Figure 1, the keyboard design is included in a hinged lid fitted with key lock. This lid hides the CD-ROM and hard disk drive. This latter drive is equipped with another key lock to prevent unauthorized access.

The communication between central computing unit and recording unit IC-CTT is done through a network switch and connections are made using data cables type UTP Cat 5 fitted with RJ 45 connectors.

Computerized recorder is a computing and storing data system, based on an Intel processor, with the following characteristics:

• Housing 19", rack mount, 4U

• Display TFT LCD Samsung 19" resolution 1360 x 768

• Drawer type keyboard rack mount 19", 1U, PS/2

- 105 keys, Touch Pad
- ATX Power Source
- Processor Intel Celeron E1600 2,40 GHz
- Memory RAM 1 GB DDR II
- Hard disc SAMSUNG HD 252HJ
- DVD-writer unit

This unit takes data from the central computing unit to store information on a longer period of time, while displaying the diagrams of the measurement points on the mounted display on top of the cabinet.



Fig. 3 Computerized recorder

Sampling - acquisition drawers (Fig. 4) are designed to receive information transmitted by the gas sensors (up to 16 sensors for 1 drawer) in frequency, transforms this information into digital signals and transmits them further through RS 232 DB9 interface to the central computing unit.



Fig. 4. Circuit diagram of acquisition-sampling drawer

Acquisition drawers work in tandem with alarm drawers, communication between them being ensured via DB25 connections.

Drawers are powered by a voltage of 220V AC, independent power, the 37V DC voltage required by sensor lines being generated by the same drawers. The part of the drawer which is connected to gas

sensors and to alarm drawer is galvanically isolated from the part that is connected to the central computing unit.

On the front panel of each acquisition drawer there are 16 LEDs and each will flash during activation of reading information channel of corresponding LED.



Fig. 5 Acquisition – sampling drawer front panel

Reading the information provided by sensors is controlled by the central computing unit which can interrogate all sensors connected to the drawer in question, or just one sensor. Both, the time for reading information provided by sensors and the time for beginning of reading the information after stopping 37V DC voltage can be set via central computing unit's software.

To allow configuration of the software, each card has assigned a serial number stored on 16 bits. The serial number appears on each drawer as a label and must be used inside software in order to access that drawer.

To read information from the 16 sensors, each drawer has 16 constant current generators of 48 mA.

Acquisition - sampling drawers are linked between them via serial interface RS 232 DB9 and binding to central computing unit is performed through a serial port.

Serial communication between the central computer unit and acquisition drawer is based on work instructions and the numbering of sensors is from 1 to 16.

To ensure the telephone function a link is made between each input line (+) and a common point located at the back of the drawer (on the lines strip) through a non-polarized capacitor of  $1 \mu F/100 V$ .

Drawers have the capacity to be interchangeable and software configurable, according statements in case of damage.

Power scheme of these drawers is shown in the following figure.



Fig. 6 AE drawer power supply

Inside of central box are mounted three acquisition-sampling drawers and three alarming drawers. These are positioned just under the CPU, the first one (up-down counting) is an acquisition drawer followed by an alarming drawer, this pair of drawers being two times repeated towards downside part of the box. The computerized recorder is placed under the three pairs of drawers.

The supply of these drawers is made through the alarming drawers, so that to supply all the six drawers (three for acquisition and three for alarming), only one slot of the multiple socket that supplies the all equipment inside the box is occupied.

To complete the tandem working of the two types of drawers (acquisition-sampling and alarming) their interconnection by a cable provided with DB25 connectors at both ends (1 male plug, 1 female plug) is necessary. An acquisition drawer is connected only to the next alarming drawer by this cable. In this purpose, in the backside of the acquisition drawer a DB25 female plug is present [8].

The acquisition-sampling drawers together with the alarming drawers transmit and receive data to and from the CPU through some cables provided at both ends with DB9 connectors (1 female plug and 1 male plug). Thus, both the acquisition and alarming drawers have two DB9 connectors (1 female plug and 1 male plug) in the backside. The two types of drawers are connected in series, so that the female plug of the last downside drawer (for alarming) is connected with the male plug of the next drawer (for acquisition). The female plug of the acquisition drawer is connected with the male plug of the next alarming drawer (upwards), the connections continuing to ascend until the first acquisition drawer. From the female plug of the first drawer a connection is made, through an identical cable, to the serial port of the CPU, in order to communicate with all the drawers in this unit [8].

Corresponding to the role of receiver for information in the form of frequency from the gas sensors, the acquisition-sampling drawer has one terminal connector of the terminal clamp type. To avoid confusion, the clamps from string are numbered from S1+ to S16- and the last two clamps (33 and 34) are for telephone line.

At this connector 16 pairs of wires can be linked, associated with the maximum number of sensors that can be attached to a single drawer.



# Fig. 7 Measuring lines link to clamping connector of acquisition drawer

Each pair of wires is a measuring line which is connected at the end to a gas sensor. In order to connect, a measuring line has two clamps of the string. Clamps are denoted as:

- Si+ corresponding to positive polarity and

- Si- corresponding to negative polarity

where "i" has values in the range of 1 to 16 inclusive (Fig. 7).

Alarm drawers (Fig. 8) are designed to work in tandem with acquisition drawers, generating alarm signals on the lines connecting the gas sensors located in hazardous environment, with the following specifications: binding to the ground line is carried out by a resistance for a period time of 0.1 ms, at each 20 to 30 ms.



Fig. 8. Circuit diagram of alarming drawer

Each point of the alarm drawer has two control relays: one acted when receives the pre-alarm command and the second acted when receives the alarm command. Each relay is able to switch 3A at 220 Vac. Setting normally closed or normally open contact of relays is made with a jumper for each relay separately.

Alarm drawers are connected to central computing unit via RS 232 interface.

On the front panel of each drawer there are 16 red alarm LEDs, 16 orange pre-alarm LEDs and 16 blue LEDs. On the same front panel and on the LEDs columns related to channels are fitted 16 alarms reset buttons. Also, a general reset button for pre-alarms and faults is fitted in the center of the front panel.



Fig. 9 Alarm drawer front panel

LED's light indicates active status of it's corresponding channel, for pre-alarm or fault. Alarm on a channel can be stopped by pressing the reset button for that channel. Stopping alarms on all channels drawer is done with the general reset button. The resets are allowed only if prior permission was received from the central computing unit.

The alarm drawer is powered by 220 V ac voltage and 50 Hz generating all internal voltages as needed. In case of power off, the system is in OFF position and along with the return of voltage the system will pass under normal operation.

To allow configuration via central computing unit programs, each drawer will be identified by a serial number stored on 2 bytes. This number appears on each drawer as a label, and is used by control software to access drawers.

Between them, the alarm drawers are linked via serial interface RS 232 - DB9 connectors and binding to central computing unit is performed through a serial port. Serial communication between central computing unit and alarm drawer is done based on work instructions and the numbering of sensors is from 1 to 16.

Drawers have the capacity to be interchangeable and software configurable, according to statements in case of damage.

From the constructive point of view, the alarm drawer consists of [8]:

- Metallic enclosure;
- Front panel;
- Electric and electronic circuits boards;
- Acoustic alarm;
- Fans;
- Connectors;
- Conductors;
- Electrical energy switch.

**Metallic enclosure**, the same as the acquisitionsampling drawer, is made of plate sheet provided with vents. Inside, the enclosure has mounting supports of the same material, necessary to mount the internal components of the drawer. The upper part consists of a detachable cover, made of plate sheet, which is attached to enclosure with the help of three screws. Two handles are attached on the enclosure sideways, in order to ease drawer's sliding, on the rails used to mount the enclosure inside the box.

Front panel is made of two parts:

- a hinged cover, that has 16 red color alarming LEDs, 16 orange color LEDs for pre-alarming and 16 blue color LEDs mounted on a horizontal line. Also, corresponding to each LEDs column there are 16 resetting buttons mounted on the cover, separately for each channel. In the center of the cover there are two general resetting buttons and a key latch. On the backside of this cover a board is mounted, that contains the LEDs and resetting buttons electrical circuits.

- a fixed part in the back of the hinged cover provided with 3 LEDs to visually indicate when the drawer is energized.

The acoustic alarm runs an acoustic signal in case of alarm, and is placed in the front part of the alarming drawer inside. The type of acoustic alarm is SYR-08 and has 120 dB acoustic intensity.

**Fans,** that are two per drawer, have the role to cool down the components inside the drawer. Each of them is placed on a mounting support fixed to a side of the drawer, on its backside. The vented air is delivered to the exterior of the drawer, on the left, right and back sides.

The connectors are mounted on the back side of the drawer and divided in four categories, as follows:

<u>- Supply connectors</u>. The drawer is provided with a three poles dedicated male plug, for electrical energy supply (220 V c.a., 50 Hz).

Also, the drawer has a three poles dedicated female plug, for the transmission of electrical energy to other drawers.

<u>- Dedicated connectors for RS232 interface.</u> Two DB9 connectors (1 male plug and 1 female plug) ensure the communication with other drawers and the CPU.

<u>- DB25 connector</u> (male plug) to create the tandem with the acquisition-sampling drawer;

<u>- Clamping terminals type connectors.</u> These connectors are divided in two main columns corresponding to the pre-alarm and alarm levels servicing the commands resulted when reaching those levels (e.g. visual or acoustic warning, electrical energy cut-off, etc.).

Alarm drawers together with acquisitionsampling drawers transmit and receive data to and from the central computing unit through cables provided each at the two ends with DB9 connector (1 female plug, 1 male plug). In its turn, the alarm drawers and acquisition drawers at the back have two DB9 connectors (1 female plug, 1 male plug). Links of the two types of drawers are made in serial mode, so the female plug of the last lower drawer (alarm) is connected to the male plug of the immediately above drawer (for acquisitions). The female plug of the acquisition drawer is connected to the male plug of the next alarm drawer (up) and connections are continued upward vertically to the first acquisition drawer.

From the female plug of the first drawer, a connection goes through an identical cable to the serial port of the central computing unit, thus achieving the communication of all drawers with this unit.

Splitter transformer is to galvanically separate the circuits of acquisition, measurement and control of environmental parameters system.

Technical highlights of this transformer are:

- U<sub>max</sub>=250 V ac.;
- I<sub>max</sub>=15 A;
- test voltage:
- 2500 V between primary and secondary;
- 1000 V between windings and core

#### **3** Protection offered

For system, safety barriers provide two basic protections, namely:

- current and voltage limitation at the entry into an area with potentially explosive atmosphere [2] to a level where ignition of explosive atmosphere[6] cannot occur;

- deviation of accidentally currents by grounding, and preventing the emergence of accidentally voltages in the area with potential explosion hazard.

BSCT-2 intrinsic safety barriers [7] are certified as Ex components and placed in a cabinet with three compartments, as follows:

- compartment regarding the circuits of acquisition, measurement and control of environmental parameters system, without intrinsically security;

- main compartment, which contains safety barriers, kept permanently closed;

- section for intrinsically safe circuits, where are connected the lines that go in the area with hazard of explosion (underground).

Cabinet design meets the requirements for the type of protection intrinsic safety [7].

The main technical characteristics are:

- I<sub>N fuz</sub>=50mA

CTT 63/40 encoder has the role to transform a given electrical size of the CMI measurement transducer (combustion chamber) in frequency and to transmit it to the acquisition, measurement and control system.

The encoder has the following components:

- metallic housing [4];
- metallic lid;
- connectors;
- electric circuits plates;
- rubber gasket;
- fastening hexagon socket head cap screw.



Fig. 10 Encoder

The methane transducer CMI-677 with combustion chamber CF-671 (CERCHAR MS 79/67 certificated) – Ex 2000 consists of:

- cast graphite bakelite housing, with dimensions:  $90 \times 50 \times 35$  mm;

- graphite bakelite cover;
- rubber basket;
- sensor electronic board;
- combustion chamber;
- connector with 7 contacts;
- fastening screws for the transducer cover.



Fig. 11 – Methane transducer CMI-677

C.R.A. (automatic control circuit) is interconnected in the remote measuring circuit in order to transmit the impulse for disconnecting electrical energy in case of exceeding the alarm level or interrupting the measurement circuit [9].

The carbon monoxide measuring transducer type CCO 8310 (INSEMEX 931026/26.03.1993 certificate) consists of:

- metallic enclosure;
- metallic cover;
- connectors;
- electronic circuit boards;
- fastening screws.

Interconnection cables, in addition to that it must be intended to operate inside tele-mechanical devices such as those created with acquisition, measuring and monitoring environmental parameters system, in terms of protection against explosive atmospheres must:

a) be type A according to SR EN 50394-1:2004 or

b) be type B according to SR EN 50394-1:2004 and must be interconnected with only one acquisition, measurement and control of environmental parameters system (belong to a single system) or

c) be type C according to SR EN 50394-1:2004

For interconnection of electrical equipment inside intrinsically safe systems [5], only cables with external shell colored blue-light shall be used, or blue marking tape ends.

These cables must have conductors with minimum section of at least 0.5  $\text{mm}^2$  or 0.8 mm diameter.

Cables must be provided with protective outer

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sheath made of special rubber PVC or other synthetic material which does not cause burning according to SR EN 332.

Environmental conditions for operation:

- max/min temperature during transportation

-33°C÷+45°C;

- max/min temperature during operation

-20°C÷+40°C;

- relative humidity of the environment

80% to 25°C.

Working conditions (mounting position, vibrations, jarring)

- vibrations in the frequency range: 20÷60 Hz ma=1g;

Main technical parameters:

- rated insulation voltage: U<sub>i</sub>=60 V ca;

- rated operating voltage: U<sub>e</sub>=60 V ca;

- clamping section:  $S_f = max 4 mm^2$ ;

- no. of clamps / no. of cable entries: max 28 / max 8;

- type of protection: Ex ia I;

- degree of protection: IP 54;

- INSEMEX.SECEEX.ATEX.2005.12104X certificate.

The system will be marked legibly, visible and sustainable, at least with:

- manufacturer's name;
- type of equipment;
- marking the type of protection to explosion;
- reference to EC type examination certificate.

### **4** Conclusions

- system implementation by using a digital infrastructure provides the assembly with a particularly potential interconnection (interlock) with other monitoring or commanding systems.

- taking into account the explosion protection conditions even from design stage has permitted the achievement of a balanced integrated system from the point of view of functional and explosion protection aspects [9];

- the use of addressable hardware infrastructure provides a good flexibility to implement new system structures;

- the obtained fundamental parameters (measuring range, number of measuring points, storage capacity, interlocking capacity, etc.) relieve a successfully modernization intercession.

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