

# Modern monitoring with preventive role for a production capacity

**Cristian Tomescu<sup>1</sup>, Constantin Lupu<sup>1</sup>, Andrei Szollosi-Mota<sup>1</sup>, Florin Rădoi<sup>1</sup>, Emeric Chiuzan<sup>1</sup>**

<sup>1</sup> National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani, 32-34 G-ral. Vasile Milea Street, Petrosani, Romania

E-mail address: insemex@insemex.ro

**Abstract.** In the process of exploitation of coal, the appearance of the phenomenon of spontaneous combustion represents a risk factor identified by the subjective and objective the causes, which requires the development of appropriate prevention methods. In order to control the risk, shall be drawn up incipient intervention solutions with preventive function, which consist in the direct and indirect measurement of the working environment, of the temperature of the coal massif and of the concentrations of gases, O<sub>2</sub>, CO<sub>2</sub>, CO. Monitoring instruments which fall within the modern concept for proactively anticipation is represented by thermography applied in the exploitation of coal and by the gas chromatograph for the analysis of the air collected. The drawing up of thermal maps on the basis of the thermograms and analysis of the chromatograms resulted represents the binome for assessing and treatments of the spontaneous combustion risk, which will be discussed in this work.

## 1. Introduction

Depending on the laboratory determination method, in Romania are five risk groups for coal self-ignition. Monitoring a production capacity from the spontaneous combustion occurrence point of view is a preventive measure required for ensuring the occupational health and safety level for the workers and for the coal bed in exploitation. It consists in direct measurements of the work environment for O<sub>2</sub>, CO<sub>2</sub>, CO gases concentrations and in indirect measurements by gas-chromatographic analysis for air samples collected from the underground atmosphere and data processing in a table of fire indexes, whose interpretation provides us the normality or hazard situation. Classic thermometer measurements applied underground does not always reflect the real situation of coal layer temperature, from the exploited space, or the surrounding rocks, from objective or subjective reasons of the work procedure application. Contactless thermometer eliminates these drawbacks, enables automatic measurement of hot or cold temperature nuclei, thermal scanning, generating the possibility of drawing in the shortest time a thermal map. Based on the thermal maps are taken technical-organisational measures for preventing/fighting against coal self-heating, by using direct prophylactic measures for treating coal, [1, 2,3].

## 2. Monitoring a production capacity

### 2.1. Classification of coal on the basis of self-ignition risk

Depending on the laboratory determination method, in Romania are five groups of coal self-ignition risk, classification to whom a function corresponds [4], (Table 1):



- Method of determining the risk of self-ignition [5, 6] in gaseous oxygen environment with classification function: the temperature gradient  $\Delta T/20'$ ;
- Method of determining the risk of self-ignition in a liquid medium (perhydrol) function classification: the reaction rate  $v_r$  ( $^{\circ}\text{C}/\text{min}$ ), [7].

**Table 1.** Classifications of coal self-ignition risks

Group classification	The behaviour of coal	
	in gaseous oxygen environment / the temperature gradient $\Delta T/20'$	in a liquid medium (perhydrol) / the reaction rate $v_r$ ( $^{\circ}\text{C} / \text{min.}$ ).
<b>Group I</b>	Coal without risk of self-ignition, $\Delta T/20' < 5^{\circ}\text{C}/20'$	Coal without risk of self-ignition, $v_r < 3^{\circ}\text{C}/\text{min.}$
<b>Group II</b>	Coal with low risk of self-ignition, $5^{\circ}\text{C}/20' \leq \Delta T/20' \leq 20^{\circ}\text{C}/20'$	Coal with risk of self-ignition, $3^{\circ}\text{C}/\text{min} \leq v_r \leq 10^{\circ}\text{C}/\text{min.}$
<b>Group III</b>	Coal with medium risk of self-ignition, $20^{\circ}\text{C}/20' \leq \Delta T/20' \leq 35^{\circ}\text{C}/20'$	Coal with pronounced risk of self-ignition, $v_r > 10^{\circ}\text{C} / \text{min.}$
<b>Group IV</b>	Coal with high risk of self-ignition, $35^{\circ}\text{C}/20' \leq \Delta T/20' \leq 50^{\circ}\text{C}/20'$	-

## 2.2. Advanced monitoring tools

### 2.2.1. Gas chromatographic analysis

Using direct measurements for  $\text{O}_2$ ,  $\text{CO}_2$ ,  $\text{CO}$  gas concentrations are calculated to fire indexes frequently used in Romania: Graham index ( $R_1$ ) and Breathing index ( $R_2$ ).

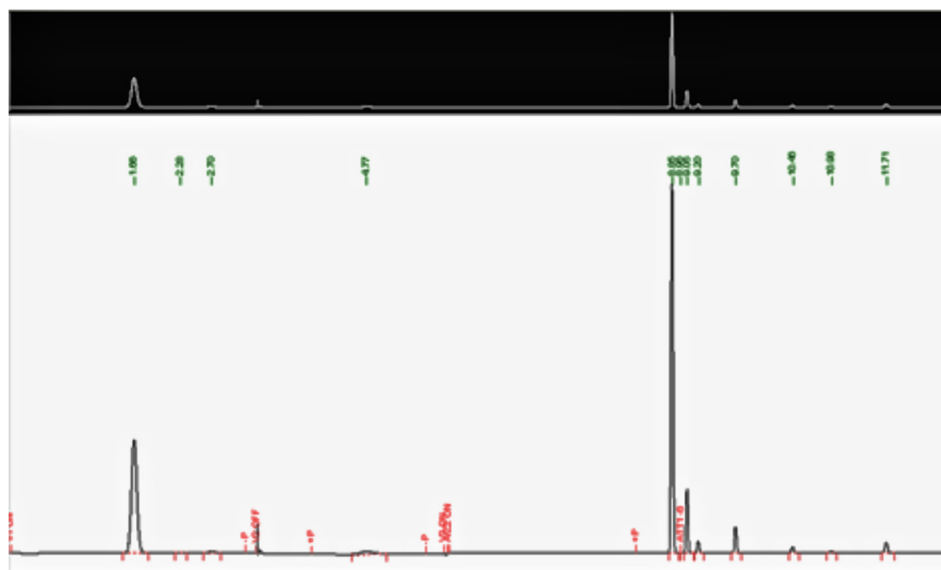
$$R_1 = \frac{+ \Delta \text{CO}}{- \Delta \text{O}_2} \cdot 100 \quad (1) \quad \text{and} \quad R_2 = \frac{+ \Delta \text{CO}_2}{- \Delta \text{O}_2} \cdot 100 \quad (2)$$

in which:

- $+ \Delta \text{CO}$  – increase of carbon oxide concentration compared to the reference level;
- $+ \Delta \text{CO}_2$  – increase of carbon dioxide concentration concentrations compared to the reference level;
- $- \Delta \text{O}_2$  – decrease of oxygen concentration compared to the normal value; the Graham index is determined when  $- \Delta \text{O}_2 \geq 0,2\%$ . The Breathing index is determined when  $- \Delta \text{O}_2 \geq 0,5 \%$ .

Gas-chromatography is the analysis method applied for determining aliphatic saturated hydrocarbons concentrations (methane, ethane, propane, butane, pentane) and non-saturated (ethylene, acetylene) hydrogen and carbon oxide from the atmosphere of active, inactive or closed underground mine workings, having a determination limit of 1ppm (0,0001%) for each component, figured in the chromatogram (Figure 1).

Ethylene ( $\text{C}_2\text{H}_4$ ) and acetylene ( $\text{C}_2\text{H}_2$ ) indexes are fire indexes resulting after the processing of air samples collected, whose values resulted, interpreted along  $R_1$  and  $R_2$  and compared to reference values from the international engineering literature in the field provide an image on the state in which the production capacity is found at some time.



**Figure 1.** Chromatogram of the analysed gas

### 2.2.2. Thermography and thermovision

Thermovision and thermography (THV / THG) are similar elements that relate to modern technology, which analyses by thermal scanning a system under investigation in terms of temperature using infrared detectors (IR). Detectors used in non-contact thermometry, called thermovision / thermography cameras similar in shape and size with video cameras working in infrared portion of the electromagnetic spectrum.

The temperature of the coal layer or in the operated sites is a parameter that is directly proportional to the development of the phenomenon of spontaneous combustion. Thermography (Thermovision) is the measurement of infrared thermal field by recording and visualization of temperature distribution on the surface layer of coal or exploited space by measuring the infrared radiation (IR). Thermal processes can be observed and analysed in a timely manner, route control can be managed effectively with high-resolution thermal images. Among the range of thermal imager camera instruments that can scan and visualize fields in the target object's temperature, with automatic recognition of hot and cold spots INCD INSEMEX Petrosani is equipped with the equipment Dräger UCF 7000 (Figure 2).



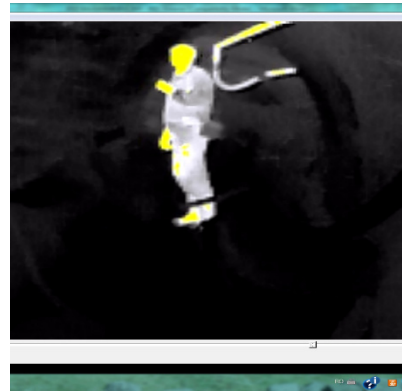
**Figure 2.** Thermovision camera, [8]

With this equipment is obtained not only the visualization of the temperature fields and temperature values of the target objects in the non-invasive system.

At the level of a coal face, during the monitoring period it can be obtained an overall thermal image Figure 3. In this case were not detected heating zones. You can also monitor the IR spectrum of the personnel from the coal face, Figure 4.



**Figure 3.** Stope thermogram

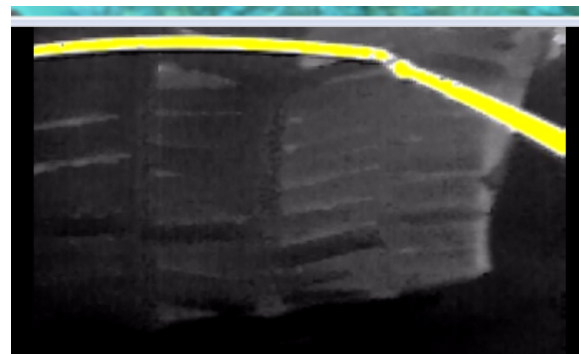


**Figure 4.** Stope- Human thermogram

In the event that the scraper conveyor shows temperature increases by friction, this phenomenon can also be detected Figure 5. Or if there are overburdened electric cables, it can be achieved their thermal footprint, Figure 6.

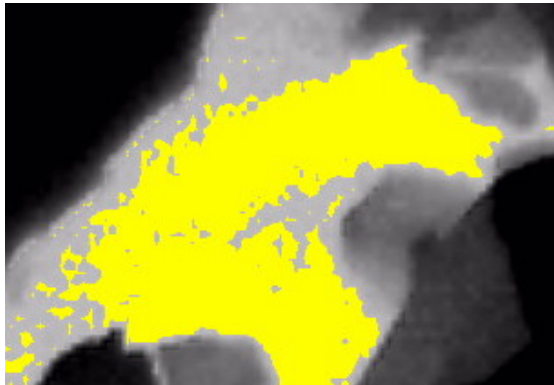


**Figure 5.** Stope - scraper conveyor thermogram

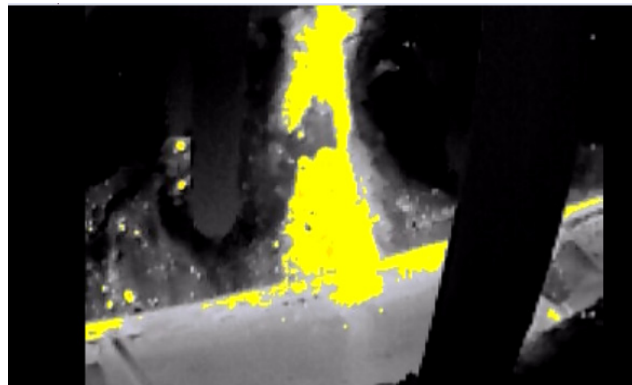


**Figure 6.** Stope – electric cable thermogram

If there are high-temperature water leaks at the level of a stope it can be obtained the thermal print for this process, Figure 7. In the case of existing in the exploited space or at the level of coal layer a spontaneous combustion process, then the discharged coal has higher temperature than normal temperature Figure 8.

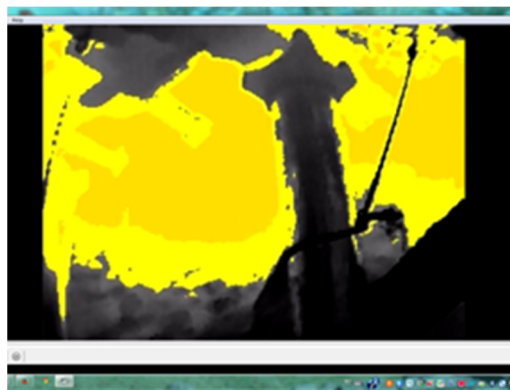


**Figure 7.** High temperature water thermogram



**Figure 8.** Hot discharged coal thermogram

If the spontaneous combustion is in progress the at the coal surfaces there are areas with higher temperature as seen in the Figure 9.



**Figure 9.** Stope – Coal from the massif thermogram

### 3. Interpretations of fire indexes and thermograms

#### 3.1. Graham index ( $R_1$ )

Graham index ( $R_1$ ) may take values higher than zero depending on the oxidation process state (Self-heating, self-ignition, fire) as follows:

- $R_1 < 0,4$  – normal situation
- $R_1 \geq 0,4$  – start of self-ignition, situation in which is imposed the application of preventive measures;
- $R_1 = 2 \div 3$  – lower limit of the self-ignition process, case in which the fire hazard is imminent;
- $R_1 \longrightarrow 25$  – existence of an endogenous fire;
- $R_1 \longrightarrow 60$  – existence of and exogenous fire.

#### 3.2. Breathing index ( $R_2$ )

This index is characterized by the following values:

- $R_2 < 60$  – normal situation;
- $R_2 \geq 60$  – start of self-ignition process.

### 3.3. Ethylene ( $C_2H_4$ )

If the ethylene concentration is above 0,0005% then it is considered that the oxidation process is initiated. For values of  $C_2H_4 \geq 0,001\%$  the process reaches the self-heating phases, and in case of an endogenous fire it reaches values  $C_2H_4 \geq 0,006\%$ .

### 3.4. Acetylene ( $C_2H_2$ )

Acetylene concentration in the self-ignition state reaches values  $C_2H_2 > 0.0001\%$ .

For characterizing the phenomenon these indexes are taken into analysis and for interpreting the phenomenon is taken into account the value(s) which indicated the most hazardous situation.

### 3.5. Thermography

As presented in the previous subchapter from images captured from a production capacity, the interpretation of thermographs is performed over the colour spectrum.

Yellow colour indicates a threshold of the reference temperature, regulated from approx. 30°C, and colour shades up to orange indicate threshold temperatures reaching more than 250°C, when coal is ignited. Having a quadrangle of measurements of the production capacity and the information resulting from the monitoring action, there are centralized on the draw up of thermal maps, based on which are drawn up technical-organisational measures programs for preventing-fighting against coal spontaneous combustion phenomena.

## 4. Conclusions

- Within a production capacity, the spontaneous combustion occurrence phenomenon is imminent and represents one of the major risk factors from the coal mining industry.
- Depending on the method of determination in laboratory, in Romania are five groups of self-ignition of coal.
- Modern monitoring of a production capacity comprises direct measurements of gas concentrations from the underground atmosphere, gas-chromatography analyses and contactless thermometry, by using thermovision cameras.
- Information and obtained results interpretation, as fire indexes or thermal scans of the temperature fields provide the possibility for drawing up very rapidly a thermal map.
- Thermal maps are auxiliary tool for making technical and organizational measures to prevent the phenomenon of spontaneous combustion.

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