

ANALYSIS OF METHODS FOR PREVENTING AND FIGHTING THE SELF-HEATING PHENOMENA OF COAL USED IN JIU VALLEY MINES

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Abstract: *This paper deals with the analysis of two cases of coal self-heating from two longwall mining within the coal exploitations belonging to Complexul Energetic Hunedoara, phenomena that started similarly but later evolved differently, as a result of prevention methods applied or not applied in each case. For the analysis of these self-heating phenomena, the data collected after the occurrence of the first signs were used, respectively the emission of carbon monoxide in the longwall mining area, until the moment of desertion and closure of the longwall with dams in the first case and eradication of the phenomenon in the second case. By analyzing in parallel the two cases, several conclusions are drawn which may help to counteract these types of phenomena that may occur in the longwall exploited in similar conditions.*

Keywords: *self-heating, coal, prevention measures, longwall*

1. Introduction

The coal self-heating phenomena are a permanent threat to the safety of the coal field and of the workers from the coal mines in Jiu Valley. Since the beginning of coal mining in Jiu Valley, there has been a continuous concern for preventing and fighting these phenomena. Many studies and experiments have been carried out, a series of procedures have been developed and many measures have been implemented to reduce the risk of endogenous fires. The choice of measures applied in each case shall be made according to the characteristics of each longwall mining, taking into account the risks arising from their application and last but not least the costs of implementing these measures.

2. Description of the prevention methods applied to the longwall mining in Jiu Valley

Currently, the *method of nitrogen inerting*, accompanied by some classical processes, is the state-of-the-art technology in the field of preventing and fighting spontaneous combustion at the mines in Jiu Valley.

The inerting method has been applied in Western Europe since 1974 (Germany, France), but has gradually spread to Eastern European countries [1].

This technology meets the following objectives:

- quick lowering of O₂ concentrations and the maintenance in the 4th area of the explosive triangle of gas concentrations during the dam construction and closure of fire areas;
 - decrease in combustion intensity due to reduced oxygen concentration (O₂);
 - delaying the occurrence of spontaneous combustion in an exploitation area;
 - reopening in a shorter time the closed areas;
 - improving the working conditions of mine rescuers due to the physical properties of the gas.
- At the same time, the widespread use of nitrogen is due to the many advantages it has, namely:
- the possibility of use in liquid or gaseous state;
 - transportation, without problems, in liquid state with the help of tankers;
 - generation of large quantities of N₂ liquid and the possibility of their vaporization;

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- high degree of safety of inerting technology;
- by-product resulting in the oxygen manufacturing process.

From the point of view of the strategy for preventing and fighting spontaneous nitrogen combustion, two inerting tactics are known, namely:

a) area inerting - consists in introducing nitrogen at flow rates between $100 \div 500 \text{ m}^3 / \text{min.}$ in an area affected by spontaneous combustion and wholly or partially dammed, in which case at least the inlet part of the air stream is closed;

b) object inerting - consists in the direct flooding of spontaneous combustion or inert gas fires, with a flow rate below $100 \text{ m}^3 / \text{min.}$, without interrupting the aeration of the area (e.g. spontaneous combustion or endogenous fires located in the exploited area).

In Jiu Valley mines, nitrogen inerting was used as a method to prevent self-heating phenomena, by creating nitrogen curtains in the exploited space of the longwall mining, especially the method of longwall faces with top coal caving mining, where the quantities of coal left in the exploited area are quite significant, but also the other methods, where due to some deficiencies of exploitation there are quantities of coal left in the exploited area.

By making these nitrogen curtains on the natural path of air flow through the exploited area, the amount of oxygen that reaches the coal left behind the longwall is significantly reduced.

Recently, several schemes of preventive inerting of the exploited area have been used: the introduction of nitrogen through the drillings made from the head and base galleries of longwall; by introducing nitrogen on the columns of pipes left behind the longwall on the floor of the basic galleries of the previously exploited slice; by introducing nitrogen on the columns of pipes left behind longwall on the floor of the basic galleries of the slice in operation; introduction of nitrogen into the exploited space of the previous slice, through pipes left behind the insulation constructions. Following the experiments performed, the best results were recorded when combining the methods of introducing nitrogen on the columns of pipes left behind the longwall on the floor of the basic galleries of the slice previously exploited with the introduction of nitrogen through drilling in the head galleries.

Silting consists in introducing, through special installation, mixtures of substances directly into the exploited area [2].

Lately, especially in undermined longwall mining, silting with ash coming from the power plant has been used. As means of implementation of the method, there are used silting installations that are part of all mines in Jiu Valley. The ash coming from the power plant is stored on the surface and transported by means of a scraper conveyor to a mixing funnel where, together with the water, in a ratio of 1: 1; 2: 1, forms the core that follows the underground pipe path to the established place. The analysis performed on fire prevention and control procedures in terms of their efficiency and scope, showed that silting of the exploited area has a high efficiency if it is performed correctly and on time [3].

The essential feature of the ash is that it keeps for a long time an appreciable amount of water, an important factor in terms of isolating the exploited area against air flows. Following the study of the ash properties, a series of elements that must be taken as a basis when establishing the silting technology, the underground transport of the ash and the distribution in the exploited space, the filtration of the core have resulted, such as:

- the ash adheres to the surfaces coming into contact and for this reason it is not recommended to be stored in evacuation silos under its own weight or by sliding;
- the fine granulation of the ash (97% smaller than 0,5 mm and respectively 84% smaller than 0,1 mm) provides the hydraulic transport of the particles over long distances in the exploited space, filling the gaps and clogging the cracks in the layer and the surrounding rocks;
- the fineness of the grains and the viscosity of the core, allow the establishment of the underground transport principle and the choice of the functional parameters of the installation;
- the property of high humidity long-term retention as well as the adhesion of the ash to the surfaces coming into contact ensures the creation of watertight areas against the circulation of air flows.

Treatment of the area exploited with aerosols from inhibitory substances (phosphate class). The study of the theory of "pyrite oxidation" led to the conclusion that substances in the phosphate class can have inhibitory effects on the process of carbon self-oxidation, the class of phosphate compounds has an inhibitory action on coal oxidation, manifested by decreasing the tendency of coal self-oxidation. [4] Based on laboratory and in situ experiments, it was found that phosphate inhibitors act both to decrease the final oxidation temperature and on the temperature gradient.

By using trisodium phosphate in operation in the form of aerosols, it was found that the inhibitor reduces the release of heat from the oxidation process (self-oxidation), not allowing the process to pass into the self-ignition phase, although the oxidation process takes place [5].

3. Description of the two longwalls that are subject of the study

3.1. *Front longwall with undermined bed coal mining no. 24-25, layer 3, bl.II, sublevel I, from Lonea Mine*

Geological-mining conditions of the longwall:

Characteristics of layer 3, bl. II, in the area:

- normal thickness: 30 m;
- inclination: roof = 25 ° - locally below 25 °; bed = 27 °;
- length of the block: 230 m;
- layer structure: the area has sterile intercalations;

- classification of coal from the point of view of the self-ignition susceptibility: the coal in the area was classified in group IV - self-igniting coals with high risk of self-ignition in oxygen gas environment depending on the temperature gradient, by INSEMEX Petroșani [6] and in class V of spontaneous ignition (the most unfavourable), depending on the minimum development time of endogenous fire, by the Polish GIG Institute [7].

Characteristics of the surrounding rocks:

- the bed of layer 3 consists of sandstone clays and gray clays, layered with carbonaceous plant remains;
- the roof of layer 3 consists of a complex of sandstone and clayey rocks of grey colour, fossiliferous, with frequent traces of plants;
- the area of occurrence of the phenomenon is strongly faulted (horizontal fault);
- gas release regime: the relative methane flow of the longwall field taken into account is $q_r = 4.961 \text{ m}^3/\text{t}$, $q_a = 69817 \text{ m}^3 / 3 \text{ months}$;

- block II is located N-E of Lonea mining field;

Technological and technical characteristics:

The place of the phenomenon occurrence: in the exploited space of the longwall undermined bed mining no. 24-25, layer 3, bl. II, sublevel I.

Geometric parameters of the longwall:

- height of the front longwall: 2.5 m;
- height of the undermined bed: 7.5 m;
- longwall opening:
 - at two beams: 2.5 m;
 - at three beams: 3.75 m;

- average longwall length: 56 m;

- total length of longwall field direction (longwall no. 24-25): 90 m, of which exploited until the date of occurrence of the phenomenon: 18.8 m.

Exploitation technology: exploitation method applied at the time of the phenomenon: "Exploitation framework method with undermined coal bed for thick layers and medium inclination (α layer = $25^\circ \div 45^\circ$)".

Applied aeration system: under the general depression of the mine.

Aeration parameters: $Q_{\text{necessary}} = 164 \text{ m}^3 / \text{min}$, $Q_{\text{realized}} = 196 \text{ m}^3 / \text{min}$.

Longwall support: SVJ 2500 pillars, GSA 1250S beams and GSA 570S beams, braided wire mesh bandage. Exploited space routing system: behind the front line.

Prophylactic measures applied to prevent endogenous fires: instrumentation with ash coming from thermal power plants and substances to prevent fire occurrence, treatment with sodium bicarbonate, spraying with aerosol solution (trisodium phosphate H_2PO_3).

Average speed of longwall advancement since its opening: 6.68 m / month.

3.2. *Front longwall with undermined bed coal mining no. 1W, layer 3, block VII, elevation 286, from Vulcan Mine*

Geological-mining conditions of the longwall:

Characteristics of layer 3, bl. II, in the area:

- normal thickness approx. 30 m;
- inclination 35° - 45°;
- length of the block: 270 m;

- layer structure: with intercalations. In this area layer 3 is made up of several coal intercalations, alternating with gray-black clays.

- Coal in this area (block II, layer 3) is classified in group III - coal with medium risk of self-ignition in the environment with gaseous oxygen depending on the temperature gradient, by INSEMEX Petroșani ($V_r = 28,14 \text{ }^{\circ}\text{C} / \text{min}$ and $\Delta T / 20 = 48 \text{ }^{\circ}\text{C} / 20'$) [8].

Characteristics of the surrounding rocks:

- bed: grey sandstones, sandstone clays, weakly cemented sandstones;

- roof: complex of sandstone and grey clays;

- the area does not show major tectonic disturbances.

- gas release regime: the relative methane flow of the longwall field taken into account is $q_r = 6,39 \text{ m}^3 / \text{t}$, $q_a = 100716 \text{ m}^3 / 3 \text{ months}$;

Technological and technical characteristics:

The place of occurrence of the phenomenon: in the area of the beam columns with no.12-18 (numbered from the bed to the roof) of the front longwall with undermined bed no.1W, layer 3, block VII, elevation 286.

Geometric parameters of the longwall:

- height: 2.5 m;

- height of the undermined bed: 7.5 m;

- opening of the longwall: - at two beams: 2.5 m;

- at three beams: 3.75 m;

- average length of the longwall: 49 m;

- total length of longwall field direction: 270 m, of which exploited until the date of occurrence of the phenomenon: 47 m;

Exploitation technology: exploitation method applied at the time of the phenomenon: "Exploitation framework method with undermined coal bed for thick layers and medium inclination ($\alpha \text{ layer} = 25^{\circ} \div 45^{\circ}$)".

Applied aeration system: under the general depression of the mine.

Aeration parameters: $Q_{\text{necessary}} = 172 \text{ m}^3 / \text{min}$, $Q_{\text{realized}} = 184 \text{ m}^3 / \text{min}$.

Longwall support: SVJ 2500 pillars, GSA 1250S beams and GSA 570S beams, braided wire mesh bandage. Exploited space management system: behind the front line.

Prophylactic measures applied to prevent endogenous fires: instrumentation with thermal power plant ash and substances to prevent fire occurrence, treatment with sodium bicarbonate, spraying with aerosol solution (trisodium phosphate H_2PO_3).

Average speed of longwall advancement since its opening: 6.25 m / month.

4. Data interpretation and analysis

For the analysis of phenomenon evolution at Lonea Mine, gases taken from three different areas were taken into account, respectively behind the support in the area of the beam column no.64, behind the support in the area of the beam column no.40 and behind the support in the area of the beam column no.15, the counting being performed from the head gallery (directional gallery on the bed) to the basic gallery (directional gallery under the roof).

For the analysis of the self-heating phenomenon from Vulcan Mine, the data collected after the appearance of the first signs have been used, respectively the release of carbon monoxide in the longwall area, until the moment when the concentrations of carbon monoxide reached 0.

Taken into account that the self-heating phenomena took place in the beam columns area no. 12-18 (numbered from bed to roof), for the evolution of the phenomenon were taken into consideration the gases taken from this area, although they appeared, sporadically, distillation gases in other areas of the longwall.

From the daily records of gas concentrations, gas that were taken during the period when the highest concentration of carbon monoxide was recorded in the monitored areas, were taken into account. During the monitoring periods, a series of measures were applied to prevent self-heating phenomena, which were analyzed in accordance with the subsequent evolution of the phenomenon, both in terms of immediate effect and in the medium and long term.

The evolution of the phenomenon from E.M. Lonea falls into the typical phenomena of this kind that took place in the Jiu Valley mines, with a slow evolution at first (the first 30 days), then a constant acceleration until the development of an endogenous fire (the next 30 days) and the closure of the longwall for the safety of workers and of the coalfield, followed by passive firefighting measures behind the dams that closed the longwall.

At a more in-depth analysis of the evolution of the phenomenon, at the same time with the activities carried out in the longwall and the prevention measures applied, a series of correlations can be noticed that can

be made between them. Thus, it is noticed that after the completion of the beam lifting operation and the start of the coal removal operation from the undermined bed, both in the early phase (first 30 days) and in the accelerated evolution phase, there is a tendency to decrease the concentrations of carbon monoxide measured in the monitored areas. This phenomenon can be explained by the fact that at the end of the beam lifting operation, the longwall section becomes constant and large enough to decrease the depression on the exploited area by a significant percentage, which has two immediate consequences that are reflected in the values measured in the longwall.

The first consequence is the decrease of the air supply to the heated areas behind the longwall, thus slowing down the development of the self-heating phenomenon, which is a beneficial thing in trying to lead the phenomenon to an involution.

The second consequence, by decreasing the depression on the heated area located in the exploited space, the quantities of distillation gases aspirated to the free area of the longwall were smaller and much easier to dilute by the fresh air circulating in the area adjacent to the longwall, resulting in lower values of the concentrations of these measured gases, which does not necessarily indicate a slowdown in the development of the self-heating phenomenon or even an involution of it but only an alteration of the measurements made in order to monitor the phenomenon. This aspect was not taken into account at that time, which led to the incorrect assumption that there is an improvement in terms of the evolution of the phenomenon and a relaxation of the measures applied (reducing or even stopping silting operations, stopping aerosol instrumentation based on trisodium phosphate, postponing the start of inerting of the space exploited with nitrogen, etc.).

From the analysis of the chart with the evolution of gas concentrations (fig.1), especially carbon monoxide, it is noticed that after the self-heating phenomenon has passed the incipient phase, the development is accelerated, and in the last monitoring period (before closing the longwall mining) there is a shift of the focus towards the air outlet area from the longwall, following the depression created by the general ventilation of the mine. This was also favoured by the fact that the longwall area from the bed of the layer was neglected in terms of prevention actions (no drilling was carried out for silting or nitrogen instrumentation in this area).

Another aspect worth mentioning, which can be considered as a determinant for this migration of the fire, is the fact that in an attempt to open the angle between the longwall and the directional gallery under the roof (which at the beginning of the monitored period was about 70°), withdrawals were made consisting of production cycles only on the half towards the longwall roof, and the bed side remained in place, so the pre-crushed coal in this area remained in contact with the air for a longer period of time, leading to its self-heating.

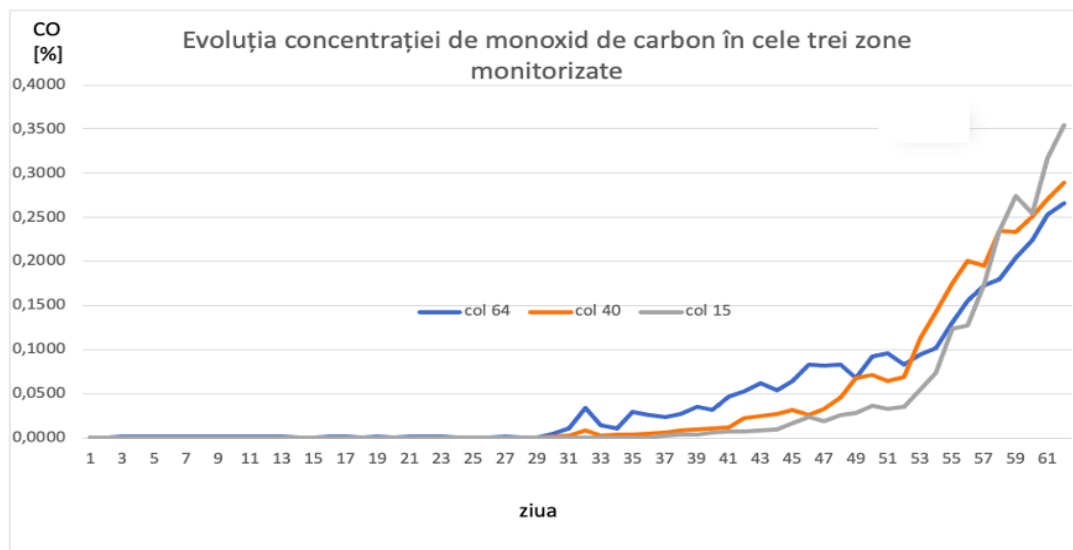


Fig.1. Evolution of the carbon monoxide concentration in the three monitored areas of the longwall faces with top coal caving mining no. 24 – 25, str. 3 bl. II sublevel I of Lonea Mine

Following the analysis of the events prior to the occurrence of the self-heating phenomenon, of the effects of the prevention measures applied before and after the occurrence of the first signs of self-heating, as well as of the subsequent development of the phenomenon, the following conclusions can be drawn:

1. The evacuation of coal from the area of the intersection of the longwall with the directional gallery under the roof was not carried out entirely, large quantities of coal remaining in the exploited space of the longwall, and the proper evacuation was not carried out by personnel in charge of this activity. Also, the control

of the mining pressure in this area was delayed compared to the rest of the longwall. In addition, the area was not properly treated with substances to stop the development of the fire (baking soda, trisodium phosphate aerosol solutions, etc.). Thus, the conditions for the occurrence and development of a self-heating phenomenon in this longwall were created.

2. The aeration of the longwall was not done properly in the sense that the air circulation was forced through the exploited space in the area under the roof of the longwall, given that between the longwall and the directional longwall under the roof, an angle of about 70° has been kept. Another major deficiency in the ventilation in this longwall is the fact that the control of air flow was achieved by ventilation constructions located upstream the longwall, by creating additional resistances, thus forcing air circulation through the exploited space of the longwall.

Following the measurements, it was found that approximately 10% of the air flow entering the directional mine gallery under the roof passed through the exploited space (only 90% of it was in the free section of the longwall in the first 5 m after the intersection with the gallery, air flow from the longwall reaching the value from the directional gallery under the roof only in the last third of the longwall).

In these conditions, taking into account the time required for the tight closure of the exploited space as a result of directing the mining pressure, as well as the route of air flow through the exploited space, we can consider that an area between 5 and 8 meters behind the longwall received an air supply with a high concentration of oxygen (fig. 2), which favours the appearance and development of coal self-heating phenomena.

Another deficiency of the way of ventilating the longwall was adding over $30 \text{ m}^3 / \text{min}$ of the air flow achieved compared to the necessary, which brought an additional supply of oxygen to the areas with self-ignition potential.

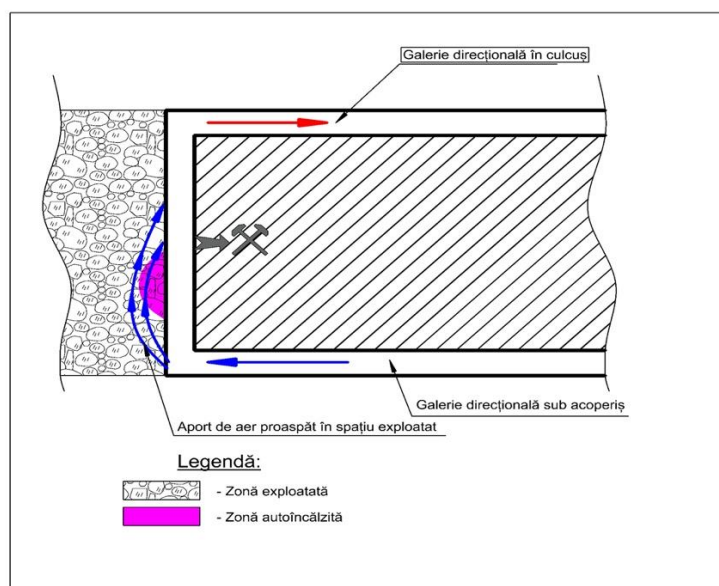


Fig. 2. Air circulation through the exploited space favouring the development of self-heating zones

3. The silting achieved was not effective due to two reasons:

a) the correct ash-water ratio was not used (1: 1; 1: 2); the subsequent examinations showed that the ash-water mixture was in a ratio of 1:12. Silting aims to fill and close the gaps in the solid and the exploited space, and in this case, the large amount of water instrumented on the silting columns, washed the ash, possibly deposited in the gaps and created more space for air circulation through the solid and space exploited, thus becoming from a method of prevention a favourable factor for the occurrence of the phenomenon of self-heating;

b) the drillings performed for silting were not carried out properly, both from the design phase, as they were not designed to reach the areas where they could have had maximum efficiency (above the potentially heated areas) and from the execution phase, the boreholes not being tubed along their entire length, being highlighted the existence of solid cracks in the drilling area and the ash water did not reach the fire area, this being lost on the drilling route.

4. Inerting of the exploited space with nitrogen: although the inerting of the exploited space with nitrogen was achieved from the first more conclusive signs of the occurrence of a self-heating phenomenon, it failed to stop it from the early stages. Following the event, after a more in-depth analysis, it was concluded that the nitrogen injected into the exploited space did not have the expected efficiency due to several causes:

a) The nitrogen was instrumented in the exploited space by means of a column of plugged tubes, left on the floor of the work in the area of the directional gallery under the roof, column that was not protected, thus assuming that when carrying out the operation of controlling the mining pressure, the inerting efficiency of the exploited space decreasing considerably due to the fact that the depression created on the exploited space significantly modified the planned nitrogen circuit through the exploited space, failing to reach the fire area (fig.3);

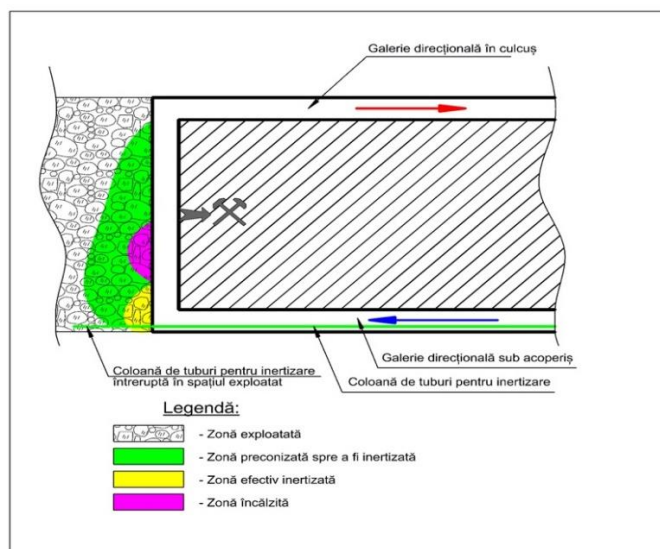


Fig.3. Nitrogen circulation through the exploited space at longwall faces with top coal caving mining no. 24-25, layer 3, bl. II. sublevel I of Lonea Mine

b) Until the development of an independent pipeline network for silting, the nitrogen column was also used for this operation. During silting the nitrogen instrumentation was interrupted, which led to an inerting inefficiency. During the interruptions of nitrogen instrumentation, the depression created on the exploited space favored the oxygen supply of the self-heating zones, on the natural circuit of nitrogen displacement, the volume of inerted air, in which the oxygen reached values below 4%, was replaced by a volume of air with an oxygen concentration of more than 20.5%. The nitrogen inerting installation used, in optimal conditions, without losses, provides a maximum flow of $16 \text{ m}^3 / \text{min}$, with a concentration of 96% N_2 and 4% O_2 . Given that the intersection of the longwall with the directional gallery under the roof (basic gallery) was at an angle of about 70° , the supply of fresh air through the exploited space was also significantly higher than normal. Considering that approximately 10% of the air flow entering from the base gallery in the longwall reaches a distance of about 5÷8 in the exploited space, at a measured air flow of $196 \text{ m}^3 / \text{min}$, it results that about $20 \text{ m}^3 / \text{min}$ air passes through the exploited space in the first area of the longwall. Taking into account that of the $16 \text{ m}^3 / \text{min}$ of nitrogen produced by the installation effectively underground, at the end of the column the flow reaches about $10 \text{ m}^3 / \text{min}$, it turns out that for every hour in which the nitrogen installation was shut down, it was necessary to operate 2 hours only to compensate for its non-operation, thus the calculated volumes of nitrogen for filling the exploited space in order to counteract the oxidation of the coal left behind the longwall do not correspond to the real need. Additionally, by repeatedly stopping and starting the nitrogen inerting installation, in the already heated area, the “bellows” effect was created, thus intensifying the phenomenon.

c) At the moment of intensification of the phenomenon, corroborated with the occurrence of air circulation areas through the exploited space and above the longwall as a result of the coal evacuation operations from the undermined bed, distillation gases were released in the work front area. This phenomenon has been misinterpreted, leading to the conclusion that there is a phenomenon of self-heating of coal in front of the longwall. Under these conditions, nitrogen instrumentation was started in front of the longwall through the existing boreholes to wet the coal and silt the area, while inerting the exploited space, which led to additional losses of nitrogen flow to reach the exploited space. The actual amount of nitrogen reached in the exploited space cannot be estimated, because the instrumentation in parallel and on the column left on the floor of the gallery under the roof behind the longwall and on the boreholes in front of the longwall was not carried out under strict control, but by random opening of valves at the branches of the main inerting column.

In the case of the phenomenon from Vulcan Mine, as in the case of Lonea Mine, the evolution of the phenomenon was a classic for the self-heating phenomena of coal, developing to a certain point, and then as a result of well-applied countermeasures this phenomenon entered the regression phase, reaching to be completely stopped. (fig.4.)

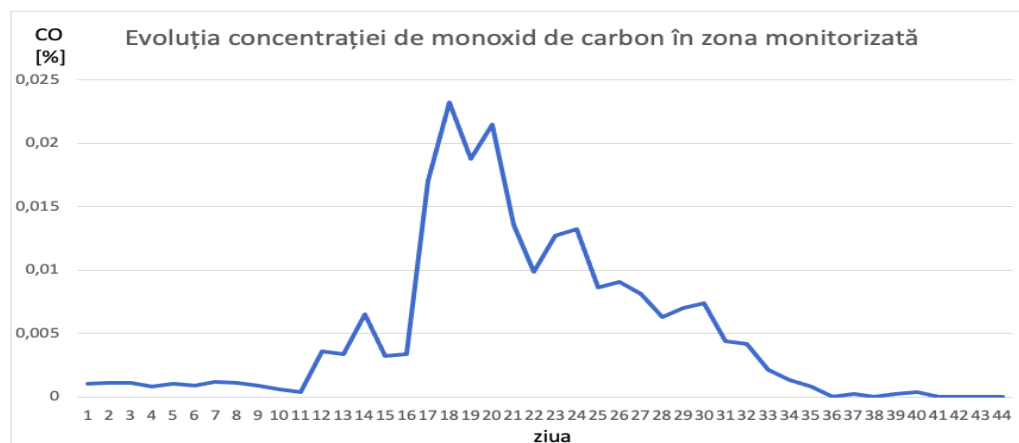


Fig.4. Evolution of the carbon monoxide concentration in the three monitored areas of the longwall faces with top coal caving mining no 1W, layer 3, block VII, level 286, of Vulcan Mine.

From the analysis of the phenomenon evolution, in the same time with the activities carried out in the longwall and the prevention measures applied, a series of correlations can be observed, similar to the phenomenon in Lonea Mine.

Thus, there is a decrease in gas concentrations after the completion of the beam lifting operation and the start of the coal evacuation operation from the undermined bed, thus validating the observation made in the case of the previously analyzed phenomenon, meaning that by adjustment of the longwall section, the depression on the exploited space is significantly reduced with the consequences mentioned above, but with the experience of the phenomenon at Lonea, the measures applied to counteract the phenomenon were not weakened.

Another finding is that, initially, the phenomenon had an upward trend, although it was instrumented with ash from the power plant, consistently, and the aerosol spraying installation operated at normal parameters. With the onset of nitrogen inerting of the exploited space and stopping the silting operation, due to the fact that there was no second functional pipeline network to be able to operate both nitrogen and power plant ash, there is an increase in gas concentrations. This increase can also be attributed to the fact that by introducing an additional amount of gas (nitrogen) into the exploited space, an additional pressure was created, which pushed the distillation gases accumulated behind the longwall to the free space where it was measured. In this phase, nitrogen was introduced into the exploited space through the pipes left on the floor of the longwall behind the discharge line. After the achievement of the second pipeline network and the start of simultaneous instrumentation with nitrogen and ash from the power plant, the first beneficial effects appeared and the concentrations of distillation gases decreased.

Another measure that led to the inhibition of the phenomenon was the introduction of nitrogen into the exploited space and through the pipes left in the exploited space of the previous sublevel as well as through drilling in the bed area (the area of evacuation of contaminated air from the longwall), creating an area of high pressure in the exploited space near the longwall towards the side from the bed (fig.5) and thus counteracting the depression created on the exploited space by the general ventilation of the mine, causing a significant decrease of air circulation through the heated area behind the longwall, leading to a decrease of oxygen supply to the fire, preventing the development of the phenomenon and leading it to involution.

From the analysis of this phenomenon made after fighting it, several main conclusions can be drawn:

1. The method of exploitation with longwall faces with top coal caving mining involves coal losses in the exploited space, which creates a potential risk of self-heating phenomena in the area of the exploited space. At this longwall, subsequent examinations led to the fact that in the area from the bed of the layer the amounts of coal lost in the exploited space were higher than expected. Although specific preventive measures were applied (aerosol treatment, silting, sodium bicarbonate treatment), they did not specifically targeted this area, as they were applied more persistently in the area from the roof, and in the absence of stronger prevention measures applied in the area from the bed, this coal began to heat up.

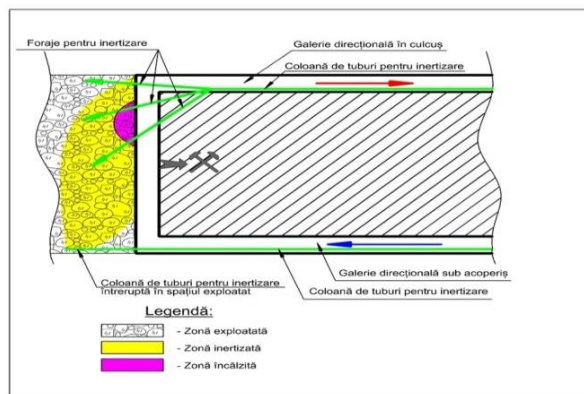


Fig.5. Achieving nitrogen inertia of the exploited space in the longwall faces with top coal caving mining no. 1W, layer 3, block VII, level 286, of Vulcan Mine

2. When the first signs of self-heating appeared, measures were taken to reduce the depression created on the space exploited by several actions. Thus, works were carried out to increase the mining section on the directional gallery under the roof, thereby decreasing the aerodynamic resistances upstream of the longwall and reducing the volume of air passing through the exploited space. The adjustments in the ventilation circuit were made by ventilation constructions (doors) located downstream of the longwall, so no additional depressions were created on the exploited space.

3. As in the case of the phenomenon at Lonea Mine, in the first phase there were no separate pipeline networks for silting and nitrogen inerting. Until their achievement, the efficiency of nitrogen inerting was low due to the fact that by stopping the nitrogen instrumentation for the silting operation, the nitrogen introduced previously it was lost, the atmosphere in the fire area from an inert one in terms of oxidation became conducive to the development of the phenomenon through the supply of oxygen when the nitrogen instrumentation actions were ceased.

4. Simultaneous application of methods to counteract the phenomenon, respectively silting the area, inerting the area both by introducing nitrogen on the air inlets in the exploited space (pipes left on the floor in the exploited space in the roof area) and on the maximum depression area from the bed area (by drilling from the directional gallery from the bed to the exploited space), the instrumentation of trisodium phosphate aerosols directly in the longwall, as close as possible to the self-heated area, not only in the directional gallery from the roof, led to preventing the development of an endogenous fire.

5. Conclusions

Currently, at the mines from Jiu Valley, the main technical methods to prevent coal self-heating phenomena are silting of the exploited space, inerting with non-cryogenic nitrogen, instrumentation of aerosols based on trisodium phosphate, treatment of the exploited space with baking soda.

The success of these methods to prevent the occurrence of self-heating phenomena and then to stop the evolution until the development of endogenous fires, depends to a large extent on their correct application and especially on their simultaneous application.

The analysis shows that both phenomena had a typical development for this type of event, following the evolution described by the model designed by Professor Henryk Bystron in 1997 [3] which follows the process of evolution and involution of spontaneous combustion, based on variation, over time, of the carbon monoxide and temperature developed during the process.

Another conclusion is that the main determining factor for the occurrence of self-heating phenomena is the supply of oxygen to areas where significant amounts of coal have remained, such as the space exploited in longwall using the undermined coal bed method. This can be reduced by several methods such as:

- building ventilation networks through which the air flow is constantly achieved through active works, avoiding the forced passage of air flow through the exploited space as a result of additional resistances on the air inlet area in the longwall;

- achieving sufficient air flows for a normal atmosphere in the longwall, but limiting the achieved flow to a value as close as possible to that of the calculated required air flow. The routing of air flow shall be achieved through ventilation constructions downstream of the longwall;

- adequate silting of the exploited space by drilling both the head gallery and the base gallery in order to cover the entire front line of the longwall, as well as the compliance with the water / ash ratios requirements to achieve the required ash layer in the exploited space;

- inerting of the exploited space with nitrogen, this method having two components. The first component consists in removing oxygen from the inerted area, and the second by creating an additional pressure on the air outlet area of the exploited space thus counteracting the depression created by the fans used for general aeration of the mine.

The success of counteracting self-heating phenomena depends largely on the involvement of personnel in the correct exploitation of the coal deposit and the application of preventive measures throughout the extraction of coal, by choosing the correct prevention measures, tailored to each case, and by firm decisions applied quickly by the personnel in charge of coalfield security.

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