

MONITORING OF NITROGEN INFUSION TECHNOLOGY

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Infusion of nitrogen in goaf spaces has been applied for 27 years in mining worldwide. This technology was first used in the Rozelay collier in the Blanzky Coalfield, France [1]. It has been used in the Czech part of the Upper Silesian Coalfield (OKB – Ostrava-Karviná Coalbasin) since the early 1980s. A long-distance nitrogen supply pipeline has been operated in OKB since 1993 with the annual supply at 70 million cubic metres per year. With development of nitrogen sources the nitrogen infusion technology has become an efficient measure against spontaneous combustion. Use of nitrogen in mining is predominantly as follows:

- infusion technology as prevention of spontaneous combustion;
- infusion technology as suppression of spontaneous combustion;
- repression of underground fire .

If nitrogen is used for prevention, it is brought to goaf spaces before any signs of spontaneous combustion occur and coal temperature is equal to temperature of the adjacent rock.

Preventive infusion is aimed at keeping oxygen concentration within limits that are safe with respect to spontaneous combustion, in as large an area of a gob as practicable. Results of research [2], [3] and OKB practice indicate that the limit is around 10% of oxygen concentration. Donbas experience says that 14% is a safe limit of oxygen concentration for prevention of spontaneous combustion [4]. The nitrogen infusion technology as suppression of spontaneous combustion is applied if coal's temperature is higher than that of the adjacent rock and other signals of spontaneous combustion are observed. If this is the case, the gob fire suppression requires oxygen concentration lower than 10%. Experience observed in Lorraine Coalfield in France (H. B. L.) indicates that the target value of oxygen concentration should be 3–5 % if 30 – 40 l.min⁻¹ of CO is released before the nitrogen infusion [5], [6].

The present article deals with results of nitrogen infusion experiments in the years 2001 – 2002; such application took place in OKB in a depth of 800 m under the surface. Within the framework of these activities, concentration of oxygen was measured at two coalfaces to

which the nitrogen was brought. Oxygen concentration is measured on samples taken by sampling tubes with 50-metre mutual distances between sampling points distributed in intake and upcast roads in goaf before and after the nitrogen infusion. Results of this experiment are visualised in diagrams which show efficiency of inertisation under the particular conditions. It should be noted to the diagrams that, for the sake of visualisation, partial concentration areas in the goaf space are simplified to reflect only the values measured at edges of the areas. In the centre of this areas, more favourable (i.e., lower) oxygen concentration values can be expected due to a higher degree of consolidation of the goaf. On the opposite, the oxygen concentration values will be higher near the face breaks (outside of the infusion and sampling range) than shown in the diagrams.

Monitoring of Nitrogen Infusion at Face No. 138 202 of the Lazy Colliery

The experiment at face no. 138 202 took place in May 2001. It was aimed at verification of the oxygen concentration before and during the nitrogen infusion when the nitrogen-infusion point is situated from the intake road. The face was operated without any nitrogen infusion until aerodynamic and gas-dynamic conditions were stabilised in the goaf space, i.e., as far as 300 m from the thirl (start line). The longwall face was 170 m long and was extracted from the field within a 7–10° slanting line. It was secured with the aid of self-advancing roof. The coal cutter-loader machine's capacity was 3,800 metric tons per day in a 3.5 – 5.6 m thick layer. Volumetric flowrate of air on the intake was $26.3 \text{ m}^3 \cdot \text{s}^{-1}$; depression on the face was 7 Pa and the permeability of the goaf was 26 % (loss of wind through the gob). The methane exhalation capacity was approx. $13,600 \text{ m}^3 \cdot \text{CH}_4 \cdot \text{d}^{-1}$ at the time of the experiment. Iso-foam sealing dams were regularly set up in the intake and upcast road on the level of the face break, with mutual distances of approx. 15 m (total of 44 dams). The support of the roads were not liquidated. A regularly caved roof rocks consisted of sandstone to fine-grained conglomerate.

The sampling points were interconnected by lost metal pipes of diameter 100 mm leading from the intake and upcast roads; each branch contained 6 sampling tubes with 6 mm inner diameter each. Another 100-mm diameter branch was laid for nitrogen infusion from the intake road. The nitrogen used did not contain any residual oxygen. A diagram of sampling points in the goaf space is shown in Fig. 1..

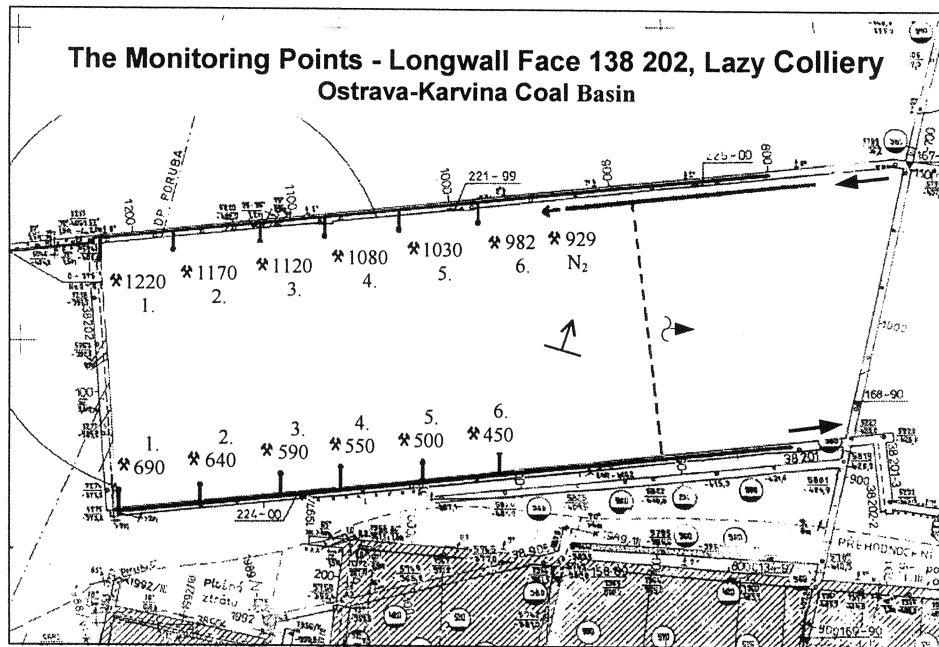


Fig. 1 Sampling diagram for face wall; face no. 138 202 of the Lazy Colliery

The sampling arrangement is shown in Fig. 2 and Fig. 3 shows oxygen concentration values before the nitrogen infusion. Oxygen concentration was regularly monitored by ejectors, taking dry samples, and by a Servomex 652A portable paramagnetic oxygen-meter. The infusion with intensity (volumetric flowrate) of approx. $1000 \text{ m}^3 \cdot \text{h}^{-1}$ was begun when the active face was 340 m from the thirl. The nitrogen-infusion point's distance from the face was between 40 and 50 metres on the days of the experiment. The distance of the nearest sampling point (point no. 6) from the nitrogen-infusion point was 53 metres. Fig. 4 shows oxygen concentration values after three days of nitrogen infusion with the volumetric flowrate of about $1,000 \text{ m}^3 \cdot \text{h}^{-1}$. When the infusion was begun, dynamic drop of oxygen content was monitored: after six hours of infusion the oxygen concentration went down to one half of its original value.

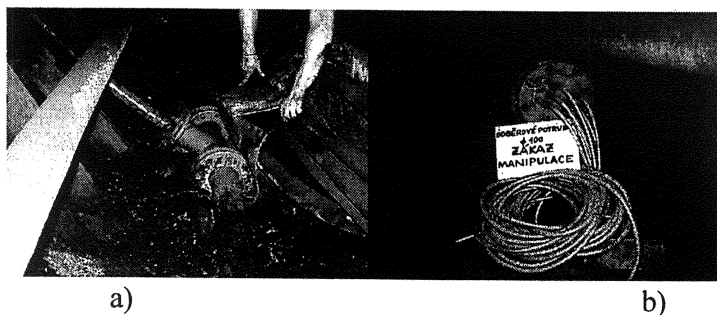


Fig. 2 Installation of sampling tubes in face no. 138 202 of the Důl Lazy Colliery,
 a) sampling mouthing b) flange of sampling tubes

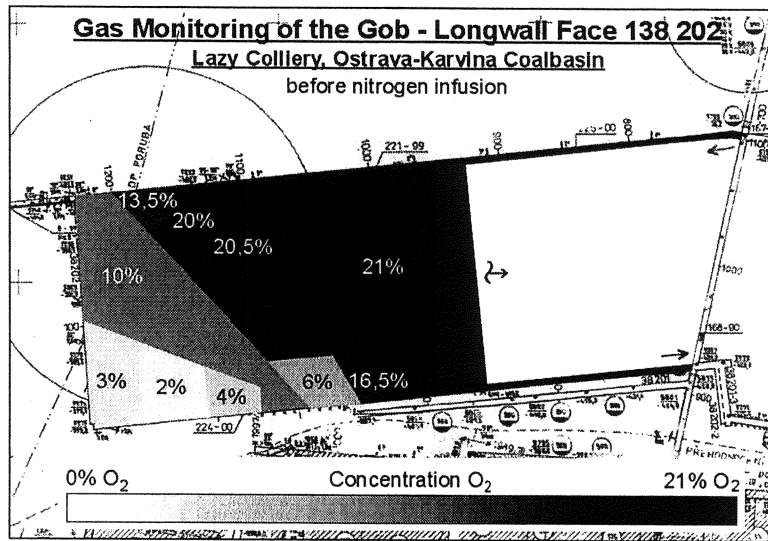


Fig. 3 Air condition in the goaf space, face no. 138 202 of the Lazy Colliery, before nitrogen infusion

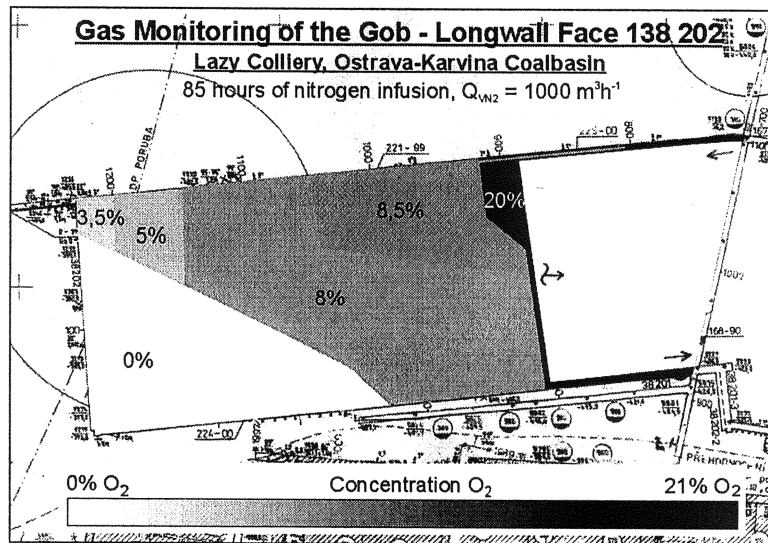


Fig. 4 Air condition in the goaf space, face no. 138 202 of the Lazy Colliery, after three days of nitrogen infusion at volumetric flowrate of $1,000 \text{ m}^3 \cdot \text{h}^{-1}$

Monitoring of Nitrogen Infusion at Face No. 140 103 of the Darkov 1 Collier

The second experiment took place at face no. 140 103 of the Darkov 1 Collier from June to October 2002. Monitoring of the goaf space mainly covered preventive nitrogen infusion and was focused on verification of the air condition during nitrogen infusion from two infusion points and after break of this infusion. The longwall face was 150 m long and was extracted from the field within a 3–10° slanting line. It was secured with the aid of self-advancing roof. The coal cutter-loader machine worked in a 2.5 – 4.8 m thick layer. Volumetric flowrate of air on the intake was $13.3 \text{ m}^3 \cdot \text{s}^{-1}$; depression on the face was 20 Pa and the permeability of the goaf was 44 %. The methane exhalation capacity was $3,382 \text{ m}^3 \cdot \text{CH}_4 \text{d}^{-1}$. Iso-foam sealing dams were regularly set up in the intake and upcast roads on the level of the face break. The support of the roads were not liquidated. A regularly caved roof layers consisted of claystone (0.5 – 5.5 m) and medium- to fine-grained sandstone. The face was worked 1 metre per day.

The goaf space was inertised by nitrogen infusion with the volumetric flowrate of $400 \text{ m}^3 \cdot \text{h}^{-1}$ from a molecule-sieve unit with a 1.5% residual concentration of oxygen into the thirl; and with the volumetric flowrate of $400 \text{ m}^3 \cdot \text{h}^{-1}$ from the central nitrogen pipeline network without residual oxygen concentration to an infusion point situated 40–90 metres from the face. The above-mentioned system was used for measurements of oxygen concentration, but the infusion pipe to the thirl was led in parallel with the sampling tubes of the monitoring system. Special pipe flanges were made for this purpose (of taking air samples).

Fig. 5 shows the oxygen concentration values in the goaf space during regular infusion of nitrogen at two infusion points (with the total volumetric flowrate of $800 \text{ m}^3 \cdot \text{h}^{-1} \text{ N}_2$). Fig. 6 shows the oxygen concentration values three days after the end of the infusion.

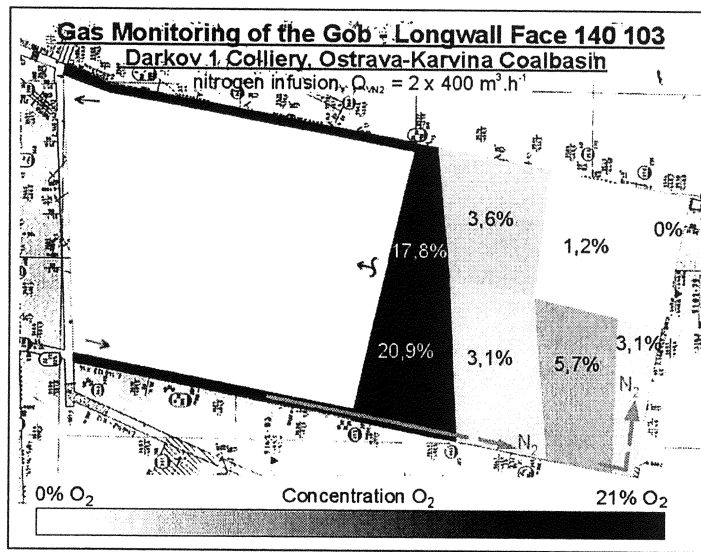


Fig. 5 Air condition in the goaf space, face no. 140 103 of the Darkov 1 Colliery, during nitrogen infusion

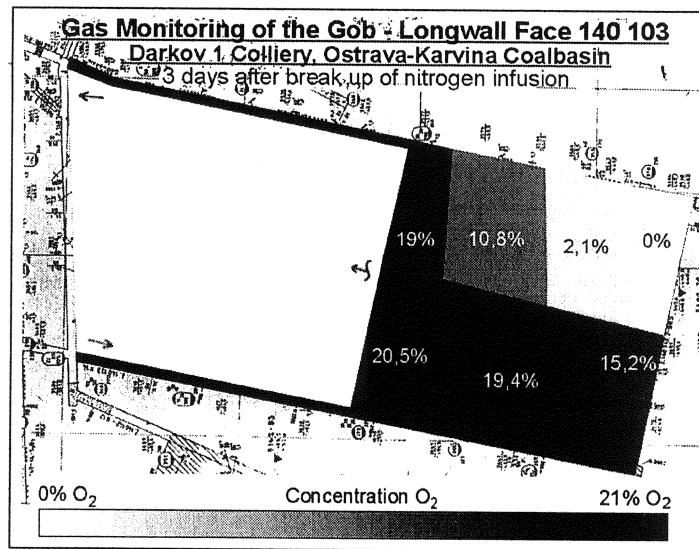


Fig. 6 Air condition in the goaf space, face no. 140 103 of the Důl Darkov 1 Colliery, three days after the end of the nitrogen infusion

Evaluation of Experiments

The above-mentioned experiments verified that the volumetric flowrates currently used in OKB are satisfactory for inertisation to prevent spontaneous combustion, i.e., reducing oxygen concentration to 10% in goaf spaces. The currently recommended volumetric flowrate

in OKB is $1,000 \text{ m}^3 \cdot \text{h}^{-1}$ of nitrogen per face. The results of these experiments indicate that, under conditions comparable with those of the experiments (parameters of the working face, length, thickness, velocity of work, etc.) and if the distribution of nitrogen infusion in the space is similar (the basic arrangement means infusion at 40 – 100 m from a break edge of the intake road in an active face), the target value of the oxygen concentration (10% O_2) can be expected in the goaf space if the applied volumetric flowrate of nitrogen is at 1.2% of the general body of air intake flow rate of a face. In OKB this means $500 - 1,300 \text{ m}^3 \cdot \text{h}^{-1}$ of nitrogen per active face (since intake flow rate of air is at $10 - 30 \text{ m}^3 \cdot \text{s}^{-1}$). The particular value of the nitrogen volumetric flowrate to be applied should be adjusted with respect to the specific conditions of the setup and to other factors affecting the situation. If the infusion is to be applied to suppress existing spontaneous combustion, i.e., if signs of the spontaneous combustion have already occurred, the required volumetric flowrate will be higher.

The present article was written within the supported VaV ČBÚ Project No. 2435/99/III, titled "Suppression of risk of coal spontaneous combustion occurrence, with special focus on indication and prevention methods." A more detailed description of the above-mentioned experiments can be found in [7] and [8].

Photos by A. Adamus

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"WWW.VSB.CZ/NITROGEN" NEWS

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The "www.vsb.cz/nitrogen" website [1] is devoted to compilations of information concerning nitrogen applications in the mine safety area. It was founded at the VSB-Technical University Ostrava in May 2001 and first introduced to the professional public at the International Conference of Mine Rescue on May 28, 2001, in Ustron, Poland [2]. Information about the website is also cited in the literature [3-6].

The content of the website has been updated seven times; it compiles information from 16 countries in which nitrogen is used in mining. The most significant updates from May 2001 include information about the first nitrogen application in Australia and China, nitrogen equipment in Kuzbas and Polish experience with units of molecule membranes.

Nitrogen was first used in Australian mining on July 21, 1986, in the Moura No. 4 Mine, which is situated 450 km to the northwest of Brisbane, Queensland. The event is documented in the literature [7] – cf. "www.warden.qld.gov.au". The information from Australia was sent to our website by Dr. David Clif from Queensland University.

Nitrogen was first used in Chinese mining for testing use of liquid nitrogen for mine fire extinguishing at the Moxinpo Mine in 1983. The information is documented in the literature [8] and is available on [1]/Discussion/ China. The information from China was sent to our website by Prof. Zhenquan Pei, retired professor of the CCRI (China Coal Research Institute).

Literary information by A.E. Cuprikov concerning use of liquid nitrogen and of nitrogen foam was compiled from Kuzbas. The Prokopievskugol Company operates a large liquid-nitrogen station in Kuzbas.

Experience with mobile units containing Generon molecule membranes has been observed in Poland. The HPLC-type units are finalised by the company Messer (Germany); one of them was supplied to Donbas by Polish rescuers.

The above-mentioned information is treated in more detail on the "www.vsb.cz/nitrogen" website under the respective country headings.

One of the goals of the website is to verify the historic development of nitrogen applications in mining. This historic development in countries with developed mining is documented under Discussion/Historical Trend; it covers 12 countries, information of which has been made available to the author. This list of countries is not yet complete.

Countries using gas nitrogen distributed by pipes include France (H.B.L - Houilleres du Bassin de Lorraine) and the Czech Republic (OKB - Ostrava-Karvina Coal Basin). Under these two countries' headings you can find data on total and specific consumption of nitrogen. The total of 10.17 million m³ of gaseous nitrogen was consumed in the H.B.L mines in 2002, with the specific consumption of 6.86 m³ per metric ton; in OKB the total was 69 million m³ with the specific consumption of 4.9 m³ per metric ton. The information for the "www.vsb.cz/nitrogen" website was provided by management of the main rescue stations of the mentioned coal basins.

An item "Technical Details" was added to cover nitrogen's physical and chemical properties and certain technical details of nitrogen foam (iso-foam, mechanical foam), measurement of volumetric flowrate and selected manufacturers of nitrogen equipment.

In August 2002, after more than one year of website operation, the author proposed a system of foreign correspondents informing the author about new articles and books on the topic. Specialists from Poland, Romania, Japan, China and Ukraine have so far agreed with the author's proposal – cf. "Correspondents."

The website will continue to compile information concerning nitrogen applications in mining worldwide. The author addresses the professional public with a call for cooperation.

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