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USE OF AIR-AND-WATER SPRAYING SYSTEMS FOR IMPROVING DUST CONTROL IN MINES

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Abstract
This article describes air-and-water spraying systems, designed at the KOMAG Institute of Mining Technology, used in longwall shearers, in roadheaders, at transfer points of conveyors and in roadways. The simple and lightweight design of roadway spraying systems ensures that the solutions can be used anywhere that dust occurs in the air. The spraying systems form an integral part of longwall shearers, and their function is to reduce airborne dust levels and to prevent methane explosion. The use of air-and-water spraying systems can reduce dust concentration by up to 80% and they contribute to a significant reduction of dust concentration in the air. Some results of tests concerning the effectiveness of air-and-water spraying devices are presented, verification tests of the author's solutions for spraying nozzles are also discussed.

Keywords
safety, hazard, air dustiness, dust, air dust reduction, air-and-water spraying

1. INTRODUCTION

The activities of coal mines are associated with numerous technical and natural hazards, with dust as one of the most important. Preventive measures aimed at increasing occupational safety as well as awareness of mine personnel are still improving.

One of the aspects regarding airborne dust is the spreading of combustible coal dust and its deposition in the workings which may cause explosion. Coal dust deposits have been found to be the cause of explosions and, in turn, mine disasters[1].

Another aspect of airborne dust is the presence of rock dust in the air, especially containing free silica. Long term exposure of the human respiratory system to dust causes pneumoconiosis, an incurable occupational lung disease (Lebecki 2004). Statistics (Konopko ed. 2010) show that there are about 500 new cases of pneumoconiosis every year suggesting not enough is being done in this area. The high concentration of production, followed by the decreasing number of extraction fronts intensifies dust emission to the workings.

Protecting mining personnel against air dustiness is usually limited to the use of personal protective equipment and water spraying systems in longwall shearers, roadheaders and at transfer points of conveyors.

Water spraying used so far is found to be not efficient enough in dust control and it consumes a lot of water. That is why KOMAG decided to work on a new type of spraying system to improve dust control in mine air. The development of a series of new air-and-water spraying devices is the result.

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2. CHARACTERISTICS OF AIR-AND-WATER SPRAYING SYSTEMS

As the result of cooperation between the KOMAG Institute of Mining Technology, JSW S.A. (Jastrzebska Spolka Weglowa SA – the mining company) and KOPEX Machinery SA (manufacturer of longwall shearers), an air-and-water spraying system for a longwall shearer was designed and implemented as the first system used in a longwall shearer on an industrial scale to reduce the risk of methane ignition during the mining of longwall shearers. Clouds of highly atomized water around the cutting drum offer protection against accidental methane ignition outside the mining area (Prostański, Rojek 2006; Prostański et al. 2008). Methane ignition was not reported when longwall shearers with air-and-water spraying installation were used.

After the first tests it was shown that air-and-water spraying is highly efficient for controlling dust mine air.

Original nozzles called STK (Prostański 2008; 2011b) were designed for the system. Their design and air-water supply parameters fully met the requirements of collieries. In this solution, air-and-water nozzles consume less water than traditional water nozzles and at the same time they have a much better atomized stream.

The air-and-water spraying systems are used in all types of longwall shearers (Prostański 2011a) offered by KOPEX

Machinery. Since they have become a common installation in collieries, a significant increase in the efficiency of dust reduction has been reported (Prostański 2011a) and there have not been any methane ignition incidents in longwalls.

Positive results of air-and-water spraying curtains used in longwall shearers resulted in designing a similar solution for roadheaders. As a result of activities undertaken by KOMAG and REMAG S.A. (roadheader manufacturer), the air-and-water spraying curtain (Fig. 1) was designed and commissioned for all types of roadheaders (Libera et al. 2010) manufactured by them. The new system consumes less water for dust suppression.

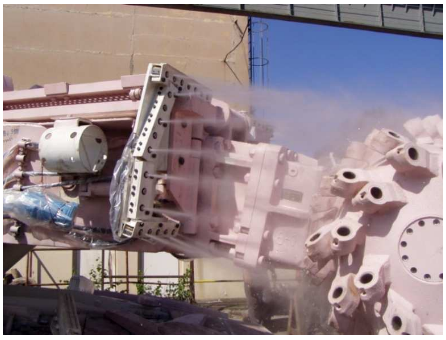

Fig. 1. Air-and-water spraying curtain in a roadheader (Libera et al. 2010)

Apart from mining fronts and mine faces, the transfer points of conveyors are also places that produce significant levels of dust. During run-of-mine conveyor transportation in a stream of fresh air, the transfer points located on the intake side of a longwall significantly increases dust concentration, exceeding maximum allowable concentration (MAC). During run-of-mine conveyor transportation in a stream of used air, the transfer points generate dust far from the mining fronts.

MAC means the concentration of coal dust, above which people cannot work without personal equipment for protecting their respiratory system.

According to Polish regulations, MAC is equal to 4 mg/m^3 for total coal dust, and for respirable fraction it is equal to 2 mg/m^3.

The Bryza-1200 transfer point spraying system, designed by KOMAG (manufactured by Elektron S.C.) and Virga spraying system (produced by Hellfeier) totally solved the airborne dust problem. These are simple devices consisting of a frame with air-and-water nozzles and a feeding unit. Due to their very high efficiency in suppressing airborne dust and water consumption ranging between 0.5 and 2.0 dm^3/min, the collieries became interested in them. The development of a roadway dust barrier was the next step in solving the dust problem.

Components of the Bryza-1200 transfer point sprinkler were used in building the CZP BRYZA roadway dust barrier. The device has water consumption ranging between 1.5 and 3.0 dm^3/min and efficiency of airborne dust reduction over 50%. It reduced dust concentration below the MAC level. The solution was used in several collieries for the removal of dust from the outline of headings covering a distance of approx. 100 m and for increasing the floor moistness. It ensures the extension of time between operations of dusting the heading with rock dust by about 50%.

A newly developed design of a spraying installation for processing plants has all the advantages of the Bryza device. Collieries were interested in implementing the solution because of its low water consumption, simple control and high efficiency of dust control.

2.1. Two-medium spraying nozzles

STK type air-and-water spraying nozzles (Fig. 2) were designed for air-and-water spraying devices developed by KOMAG (Prostański 2011b, 2012b). The nozzles have a monolithic design with two inlet openings to supply the mixing chamber separately with water and compressed air. Water is atomised and ejected from the chamber in the form of aerosol. The outlet opening has a diameter of 1 - 3 mm, depending on the nozzle use (Prostański 2011b, 2012b). STK nozzles, depending on their purpose, have a flow rate of 0.1–1 dm^3/min for water and a 50–100 dm^3/min for air, under pressure below 0.5 MPa. STK nozzles produce drops of median diameter between 20 and 50 μm, where 90% of the drops produced by nozzles do not exceed 90 μm, and 10% of the drops do not exceed 10 μm (Prostański 2011b, 2012b) (Fig. 3).

Fig. 2. STK air-and-water spraying nozzles (Prostański 2011b)

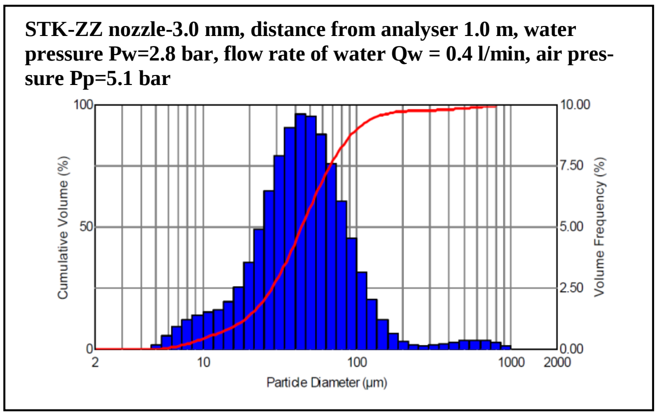

Fig. 3. STK-ZZ-3 nozzle drop size distribution (Prostański 2012b)

In the next design versions, the diameter of the spraying nozzles was changed as well as the shape of the mixing chamber, the external design features of the nozzles were modified also.

The air-and-water spraying nozzles, irrespective of their design and diameter of nozzle orifices, have to produce a stream of drops of very similar size and size distribution. Depending on the expected airborne dust level, the type and amount of nozzles should be selected in such a way that enough drops are produced to eliminate dust accompanying the run-of-mine transfer.

2.2. Spraying installations of longwall shearers

The efficiency of spraying systems in the reduction of airborne dust concentration in mines was assessed during tests in operational conditions.

A study (Prostański 2011a) has been conducted in the longwall with the use of a KSW-880EU shearer to compare the efficiency of airborne dust reduction between the air-and-water spraying system with STK nozzles and a water spraying system with G-243 nozzles installed in a cutting drum (Fig. 4).

Measurements of dust concentration were made with the use of CIP-10 gravimetric dust meters. They allow measuring the weight of total dust as well as the weight of its respirable fraction. Dust meters suck the air at a rate of 10 dm^3/min and force its circulation through dust meter filters collecting dust from air. The dust meters were always suspended on the longwall shearer close to the cutting drum. The measurement was taken only during the cutting of solid coal.

Measurements of dust concentration showed that the concentration of *total suspended particulate matter* produced by the cutting drums of the longwall shearer with the use of water spraying was over 170 mg/m^3, while the concentration of respirable fraction of dust was about 12 mg/m^3. When the air-and-water spraying system was used, the measured *total suspended particulate matter* was found to be reduced to 100 mg/m^3, while the concentration of respirable fraction did not exceed 1 mg/m^3.

The above mentioned tests showed that the efficiency of airborne dust reduction is higher in the case of using the air-and-water spraying system (*42%* for *total suspended particulate matter*, and *93%* for respirable dust) than in the case of using the water spraying system. Respirable dust concentration is lower than MAC during longwall shearer cutting when using the air-and-water spraying system. Dust concentration at the operator's workstation, when mining direction is against the flow of fresh air is given in Fig. 4.

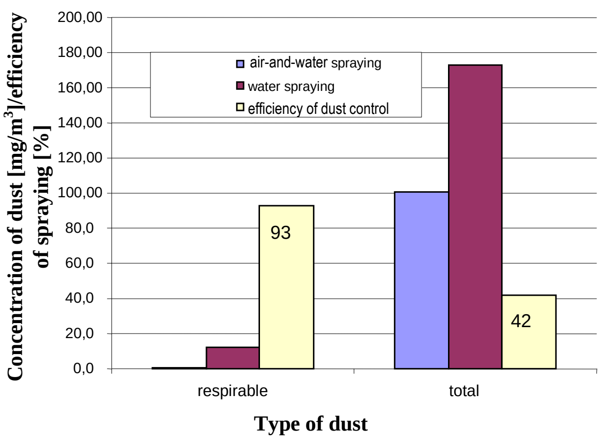

Fig. 4. Efficiency of dust control with air-and-water spraying and water spraying (Prostański 2011a)

Further tests (Prostański 2012a), conducted with another KSW-880EU longwall shearer, using the same methodology (Prostański 2011a) also showed that an air-and-water spraying system has higher efficiency than just water alone.

2.3. VIRGA transfer point spraying system

Using the knowledge and experience of KOMAG specialists in air-and-water spraying to control airborne dust, it was possible to design the VIRGA spraying system (using air and water) to control dust in belt conveyors and flight-bar conveyors. The system was used in the flow of fresh air along the haulageway in the BRZESZCZE colliery. The flexibility of the solution enables using it at all types of transfer points of conveyors and other sources of dust.

The VIRGA spraying system installed along haulage ways was designed according to the requirements of the Brzeszcze colliery. Having analysed the needs of the mine, three possible designs of spraying systems were prepared. Each of them required 2 dm^3/min of water under pressure of 0.3 MPa, and 250÷350 dm^3/min of compressed air under pressure of 0.3 MPa.

After installing the VIRGA spraying system in the conveyor of the run-of-mine transportation system from longwall 128 in seam 401, at level 740 m in Brzeszcze colliery, tests regarding the efficiency of dust control in the mine air were conducted.

The air-and-water VIRGA spraying system was installed on straight transfer point of the belt conveyor, on the angular transfer point of belt conveyor (located as far as possible from the longwall inlet) and on straight transfer point of beam-stageloader (Grot type) as close as possible to the longwall inlet.

Measurements taken at all the transfer points facilitated evaluating the efficiency of reducing the concentration of dust in the air with the air-and water spraying devices of the VIRGA system.

With the use of the VIRGA air-and water spraying system, in all of the selected measuring points, the average concentration of total suspended particulate matter and respirable fraction of dust were found to be significantly lower than the measured average concentration of dust in the air without spraying (Prostański, Ryszka 2012).

The highest average concentration of total suspended particulate matter and respirable fraction of dust was measured at the transfer point at a flight-bar conveyor. Total suspended particulate matter without the spraying system was about 136 mg/m3, while with the use of the VIRGA system the highest average concentration of the total suspended particulate matter was about 31 mg/m^3. Concentration of the respirable fraction of dust, without spraying was 26.7 mg/m^3, with the use of the VIRGA air-and-water spraying system the highest average concentration of respirable fraction of dust was 4.3 mg/m^3.

The lowest concentration of dust was measured in an angled transfer point. Total suspended particulate matter without a spraying system was 12.1 mg/m^3, while with the use of the VIRGA system it was 3.2 mg/m^3, i.e. below MAC level. The average concentration of respirable fraction of dust, without spraying, was 5.9 mg/m^3 and with the use of the VIRGA air-and-water spraying system it was 1.2 mg/m^3 (below MAC level).

The results showed that the air-and-water spraying devices of the VIRGA system installed at a transfer point had a high efficiency of controlling dust. The VIRGA air-and-water spraying system ensured achieving an efficiency between 74 and 82% in reducing the total suspended particulate matter,

(Fig. 5) and efficiency between 80 and 84% in reducing the respirable fraction of dust (Fig. 6).

The values associated with air dust produced in the incline conveyor belt no.545 of longwall 128, show a proportional increase in air dustiness towards longwall 128, both in total suspended particulate matter and in its respirable fraction. With air-and-water spraying, independent to air dustiness, a very similar level of efficiency of reducing air dustiness in all the transfer points was obtained. Measurements of dust concentration and the determination of reduced dust concentration_are given in Fig. 7. The average efficiency of reducing the total suspended particulate matter was approx. 78% and for respirable fraction of dust over 80%.

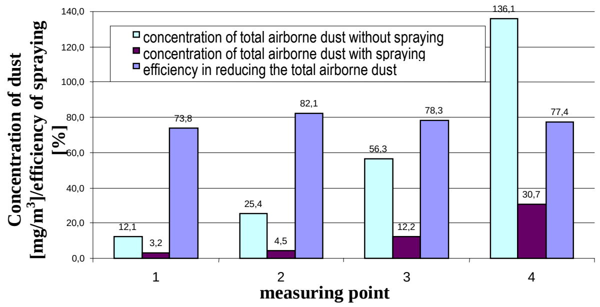

Fig. 5. Measurement of the concentration of total airborne dust and efficiency in reducing the total airborne dust concentration using the VIRGA air-and-water spraying system (Prostański, Ryszka 2012)

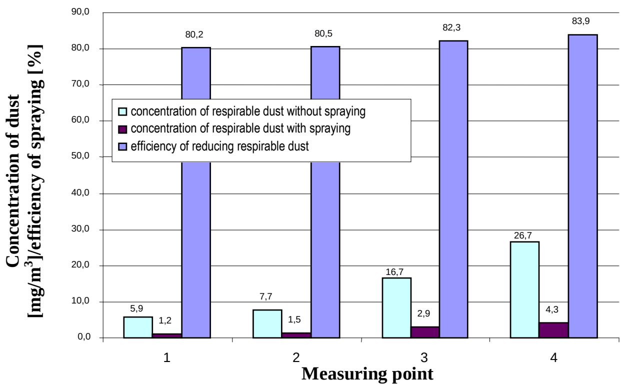

Fig. 6. Measurement of the concentration of respirable dust and efficiency in reducing the respirable dust fraction using the VIRGA air-and-water spraying system (Prostański, Ryszka 2012)

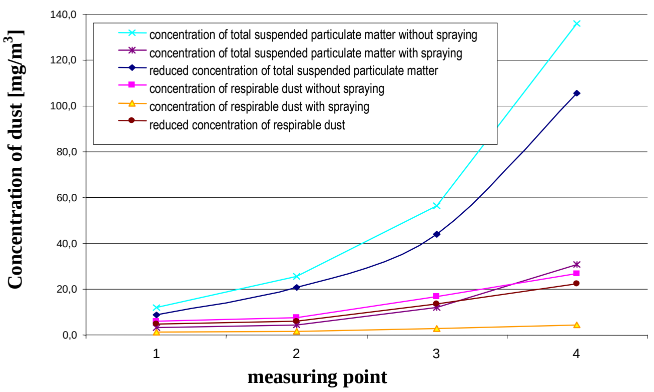

Fig. 7. Dust concentration distribution and dust reduction: total suspended particulate matter and respirable fraction (Prostański, Ryszka 2012)

2.4. Bryza-1200 transfer point sprinkler

Bryza-1200 transfer point sprinkler (Bałaga, Siegmund, Urbanek 2012; Prostański 2012b) consists of three basic components:

- frame with a bank of spraying nozzles
- grate
- control box

The sprinkler is fed with water and compressed air under pressure available in the mine network.

A standard frame of the sprinkler is equipped with three spraying banks, with 3 nozzles each. Each of the nozzles is fed with water at a flow rate of approx. 0.1 dm^3/min and air at a flow rate of approx. 50 dm^3/min. The sprinkler equipped with five air-and-water spraying nozzles has a water flow rate of about 0.5 dm^3/min.

The first unit of the Bryza-1200 transfer point sprinkler was installed at a transfer point of a conveyor belt in the LW Bogdanka S.A mine, where it was tested (Fig. 8).

Fig. 8. First application of Bryza-1200 transfer point sprinkler (Prostański 2012c)

With the use of the Bryza-1200 sprinkler with a water flow rate of about 0.5 dm^3/min dust concentration was reduced by 67%, up to 82% for different directions of the spraying stream to a transfer point (Fig. 9) (Prostański 2012c). Such a high reduction in airborne dust concentration was reached not only due to the spraying of well atomised water by compressed air, but also due to installing a grate, where wet dust and dry dust could settle.

The positive results of the efficiency tests in reducing the airborne dust concentration, easy handling and reliability of the sprinkler installed in the LW Bogdanka mine led to another 20 Bryza-1200 sprinklers were installed there. The efficiency of reducing the dust with the air-and-water system for two variants of the arrangement of the spraying system in relation to transfer points of conveyor belts is given in Fig. 9

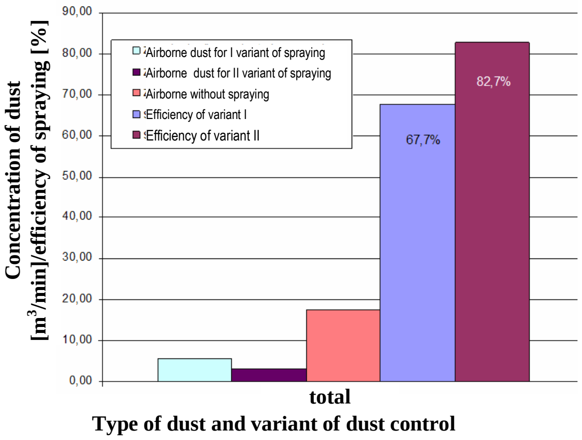

Fig. 9. Measurements of total airborne dust concentration and efficiency of dust control using Bryza-1200 sprinkler (Prostański 2012c)

2.5. Bryza roadway dust barrier

The Bryza roadway dust barrier (Fig. 10) is a modification of the Bryza sprinkler. The aim of the design is to reduce airborne dust concentration in air circulating in roadways (Prostański 2012b).

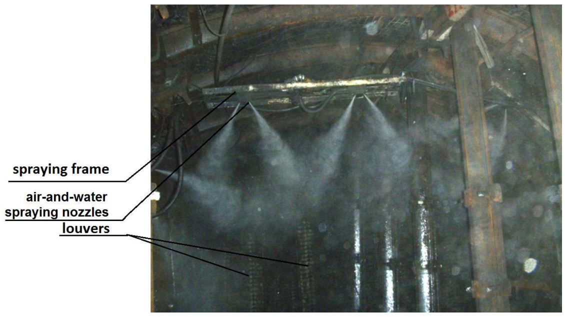

Fig. 10. A Bryza roadway dust barrier (Prostański 2012b)

A roadway dust barrier consists of the following components:

- frames with banks of spraying nozzles
- fixed louvers
- sliding louvers
- a control box

The barrier is equipped with three spraying frames, with three spraying nozzle banks each, where three nozzles can be installed. A standard version of a Bryza barrier is equipped with about 15 air-and-water spraying nozzles of a total flow rate of water of about 1.5 dm^3/min. As in the case of a Bryza 1200 transfer point sprinkler, the volume of compressed air and water is controlled by a preparation unit.

The drops of sprayed water collide with dust particles increasing their mass. Then the particles settle on the louvers (Fig. 11) hanging on chains and arranged in a labyrinth filter along the whole surface of a heading to capture most of the wet dust, and to enable safe passage of mine personnel. To enable passage of a suspended monorail or transported long objects, the barrier is equipped with sliding louvers.

Fig. 11. Dust settled on louvers (Prostański 2012b)

The first unit of the Bryza roadway dust barrier was installed in the maingate of the Budryk colliery. Measurements of dust reduction, when using the BRYZA barrier, taken in the Barbara Experimental Mine, presented in Fig. 12, shows the efficiency of dust reduction between 40% and 50% of total airborne dust. During tests, water condensed on the side walls along the entire working washing away the dust that had settled on it in a section of about 100 m. Moreover, moisture in the floor increased enough to extend time intervals between operations of dusting the heading with rock dust by about 50% (Prostański 2012b).

Positive results during the implementation of the Bryza roadway dust barrier in the Budryk colliery regarding the suppression of airborne dust resulted in installing another dust barrier in the tailgate.

The tests ordered by the mine showed that airborne dust concentration behind the barrier was reduced by about 50% (below MAC).

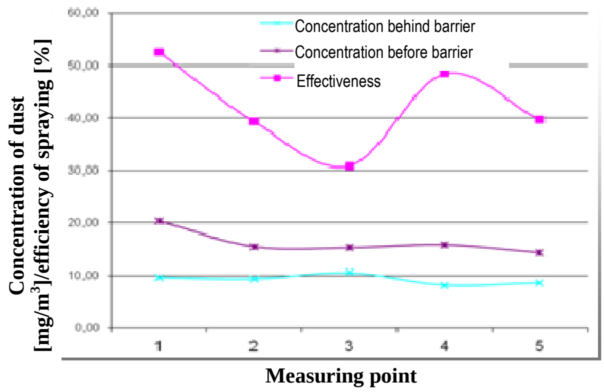

Fig. 12. Efficiency of reducing the airborne dust concentration behind the Bryza roadway dust barrier measured along the width of a working (Prostański 2012b)

3. SUMMARY

The air-and-water spraying systems designed by KOMAG significantly reduce dust concentration in mine air.

The spraying systems are intended for areas in a mine with significant dust generation, where there is a need for clean air.

The two-medium spraying nozzles require just a small volume of water (between 0.1 and 0.4 dm^3/min) and a small volume of air (between 50 and 150 dm^3/min).

The air-and-water spraying installation developed at KOMAG to eliminate the hazard of methane ignition, turned out to be a useful tool in dust reduction as well. During the longwall shearer operation, the concentration of total dust was reduced by 42%, and the concentration of respirable fraction was reduced by 93%. At present, all types of longwall shearers manufactured by KOPEX Machinery can be equipped with such an installation.

The VIRGA and Bryza-1200 spraying devices, designed for belt transferring points, are also very effective in dust control, exceeding over 70% of dust reduction.

The BRYZA roadway dust protective barrier reduces dust concentration by about 50% in the entire roadway cross-section. The results of coal dust control meet the full expectations of the mines. Additional advantages, such as an increase of floor moistness and the elimination of dust from roadway outlines at the length of about 100 m in the case of the BRYZA dust barrier were also found.

Flexibility of the discussed solutions for dust control allows using them in other areas, where a similar problem of airborne dust may exist.

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