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A survey of atmospheric monitoring systems in U.S. underground coal mines

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Abstract

In 1995 and 2003, the U.S. Mine Safety and Health Administration (MSHA) conducted surveys to determine the number of atmospheric monitoring systems (AMS) that were being used in underground coal mines in the United States. The survey reports gave data for the different AMS manufacturers, the different types of equipment monitored, and the different types of gas sensors and their locations. Since the last survey in 2003, MSHA has changed the regulation requirements for early fire detection along belt haulage entries. As of Dec. 31, 2009, point-type heat sensors are prohibited for use for an early fire detection system. Instead, carbon monoxide (CO) sensors are now required. This report presents results from a new survey and examines how the regulation changes have had an impact on the use of CO sensors in underground coal mines in the United States. The locations and parameters monitored by AMS and CO systems are also discussed.

Introduction

The last survey conducted by the U.S. Mine Safety and Health Administration (MSHA) on atmospheric monitoring systems used in underground coal mines in the United States was in 2003 (Francart, 2005). A total of 146 active mines were surveyed. The survey report states that since 1995 there had been a steady increase in the use of atmospheric monitoring systems in underground coal mines as the technology of carbon monoxide (CO) sensors was improved by manufacturers. Atmospheric monitoring systems had become more reliable, and some CO sensors could be purchased with the capability to discriminate between the CO produced by a fire versus CO produced by diesel equipment. This increase in reliability had reduced the number of false alarms and the response time. The faster response time to a developing fire allowed miners to take the necessary action to put out the fire or exit the mine.

At the time of the last MSHA survey, some mines still used point-type heat sensors to detect the presence of a fire on conveyor belts. This detection method works by measuring the temperature of the air around the sensor. As a fire starts to develop, smoke and hot gases are produced from the combustion process, and the air is heated up. Once the air and gases reach a designated temperature detected by the point-type heat sensor, a fire alarm signal is generated. Studies have shown that the response times for detecting the presence of a fire using CO sensors are much shorter than when using point-type heat sensors (Conti and Litton, 1995).

Since the last MSHA survey in 2003, regulations have changed on the type of automatic fire detection systems permitted to be used in conveyor belt entries. As of Dec. 31, 2009, point-type heat sensors are not permitted to be used for fire detection in underground coal mines in the United States. Instead, CO sensors are required as a replacement under Title 30 of the Code of Federal Regulations, Part 75.1103-4, or 30 CFR 75.1103-4 (MSHA, 2017).

This study will examine how the change in the above regulations has affected the current use of CO sensors in underground coal mines in the United States compared with their use based on the last MSHA survey. Importantly, in the previous MSHA survey in 2003, the data were recorded for producing and nonproducing coal mines. In this study, only the data from producing coal mines were recorded. Data were collected from a total of 235 coal mines for this study with the help of the MSHA district offices.

CO system versus AMS

Although it is mandated by MSHA regulations to use CO sensors in the belt entry in underground coal mines for an early fire detection, MSHA makes a distinction between an atmospheric monitoring system (AMS) and a CO system. An AMS is defined in 30 CFR 75.301 as a network consisting of hardware and software meeting the requirements of 30 CFR 75.351 and 30 CFR 75.1103-2 and capable of (1) measuring atmospheric parameters, (2) transmitting the measurements to a designated surface location, (3) providing alert and alarm signals, (4) processing and cataloging atmospheric data and (5) providing reports. For the purposes of 30 CFR 75.301, an early-warning fire detection system using newer technology that provides equal or greater protection, as determined by the Secretary of Labor, will be considered an AMS (MSHA, 2017).

A CO system is a network of CO sensors placed at fixed locations to measure CO concentrations and provide automatic warning signals at the location of the sensor when the concentration of CO reaches the warning level. An AMS is basically a CO system with additional sensors. It can be a network of CO sensors to measure CO concentrations, but the network has the capability to add other types of sensors to measure other gas concentrations and parameters such as fan stoppage, fan pressure or ventilation parameters.

The difference between the two systems is determined by how they are used, according to 30 CFR 75.351(a) (MSHA, 2017). The system is defined as being an AMS (1) when it is monitoring the methane concentration at the section return (30 CFR 75.323(d)(ii)), (2) when air-ventilating electrical installations are used to ventilate working sections (30 CFR 75.340(a)(1)(ii)), (3) when the belt air is used to ventilate the working section or an area where mechanized mining equipment is being installed or removed (30 CFR 75.350(b)), or (4) when it is used for the on-shift examination for methane in each return split of air from each working section during each shift that coal is produced (30 CFR 75.362(f)).

Compared with a CO system, an AMS also has more requirements in terms of operation, maintenance and record-keeping. The mine operator must designate an AMS operator to monitor and promptly respond to all AMS signals. The AMS operator must have as a primary duty the responsibility to monitor the malfunction, alert and alarm signals of the

AMS, and to notify appropriate personnel of these signals. The AMS operator must be trained annually in the proper operation of the system, and the training of an AMS operator must include travel to all sections every six months. An AMS requires initiation of an investigation with an automatic surface alert signal 5 ppm above ambient. Alert, alarm and malfunction signal records from an AMS must be maintained for one year. The records should include date, time, location, type of sensor, cause of activation, and all maintenance. Records cannot be susceptible to alteration — secure book or electronic record — and must be kept separate from other records and identified by a title. The person entering a record must also include his or her name, date and signature.

For the current survey data reported here, Table 1 lists the numbers of AMS and CO systems and and their respective percentages. It is apparent that the majority of surveyed coal mines have installed CO systems. This may be explained by the fact that a CO system is less expensive and has fewer regulatory requirements in relation to inspection, operation and maintenance to meet than an AMS. In the 2003 MSHA survey, AMS and CO systems were not distinguished, so a direct comparison between the surveys is limited.

Types of sensors

Table 2 shows the types of sensors in mines and the maximum and minimum numbers of CO, methane (CH_4), oxygen (O_2), smoke, air velocity, thermal and hydrogen (H_2) sensors from the current survey. All of the mines were required by law to have all belt conveyors equipped with CO sensors for early fire detection. Depending on the size of the system, the number of CO sensors in a system can vary between two and 300. Compared with the previous survey, the maximum number of CO sensors used in a system increased to 300 from 215, while the minimum number stayed the same.

The CH_4 sensors were used at 17 percent of the mines, compared with 25 percent of the mines in the previous MSHA survey. The maximum number of CH_4 sensors used at a mine was 20 and the minimum number was 1. The percentages of O_2 and smoke sensors used in mines, 6 percent and 2 percent, respectively, are comparable to the results from the 2003 survey, where less than 10 percent of the mines used O_2 and smoke sensors. From the current survey, air-velocity sensors were used by 9 percent of the mines, with 20 as the maximum number at a mine and one as the minimum number. Thermal, nitrogen oxide (NO) and H_2 sensors were used by 2 percent or less of the mines. Although very few mines used thermal sensors, one mine had installed 191 of them. The minimum number of thermal sensors was four. The maximum and minimum numbers of NO and H_2 sensors were the same — three and one, respectively — compared with the data from the previous MSHA survey.

Parameters monitored

Table 3 shows the parameters that are monitored by AMS and CO systems in U.S. mines. As mentioned, regulations require that CO sensors be used on belt conveyor systems for fire detection in underground coal mines in the United States. When the 2003 survey was taken, point-type heat sensors were still allowed to be used for fire detection on belt conveyors, and

90 percent of the mines used an AMS in the belt entry. Battery charging stations were monitored by 14 percent of the mines, which has not changed since the 2003 survey. Fan stoppage was monitored by 27 percent of the mines, a decrease of 15 percentage points from 42 percent in the 2003 survey. Fan pressure was monitored by 11 percent of the mines compared with 32 percent in the 2003 survey, a decrease of 21 percentage points. Electrical installations were monitored by 8 percent of the mines, compared with 32 percent of the mines in the 2003 survey, a decrease of 24 percentage points. This basic decreasing trend continues as motor amperage monitoring decreased by 20 percentage points, pumps monitoring by 18 percentage points, water-level pressure monitoring by 15 percentage points, coal storage monitoring by 12 percentage points and ventilation parameters monitoring by 8 percentage points. The other parameters that were monitored by 6 percent of mines were air locks, diesel fuel storage, seals, vibration on fans, temperature of bearings, and air compressors.

Use of diesel equipment

Table 4 shows the numbers of mines with diesel equipment and the percentages based on the current survey. Of the total of 235 mines surveyed, only 85 mines, or 36 percent, used diesel equipment. This percentage is lower than the 48 percent recorded in the last survey, indicating a trend of less diesel equipment usage in the coal mining industry.

System manufacturers

Combining AMS and CO systems, Table 5 shows the numbers of systems installed in terms of their manufacturers. Pyott-Boone Electronics (North Tazewell, VA) was the leading manufacturer with 161 systems, or 67 percent of all installations surveyed. Compared with the previous MSHA survey, the number of installed Pyott-Boone systems greatly increased to 161 from 53, or to 67 percent from 36 percent of all installations. By comparison, the number of installed AMR systems (AMR Inc., Rocky Gap, VA), which were the second most systems installed in the last survey, only increased to 32 from 28. The number of installed Conspec systems (Conspec Controls, Charleroi, PA), which were the third most systems installed in the last survey, decreased to 25 from 27. The percentage of total installations for both AMR and Conspec dropped in this survey, indicating the dominance of Pyott-Boone for current combined CO and AMS installations in the mining industry.

Table 6 shows the average number of CO sensors per mine by manufacturer and the largest and smallest system of CO sensors. The highest average number of CO sensors used in the surveyed mines was Conspec’s 84. In the 2003 survey, the highest average number of CO sensors used by a manufacturer was MSA’s 91 (MSA, Cranberry Township, PA). In the current survey, MSA had no CO/AMS systems installed in underground coal mines. The largest system of CO sensors installed in an underground coal mine was 300, by AMR. The smallest number of CO sensors installed in an underground coal mine was two, by Pyott-Boone. In the 2003 survey, the smallest number of CO sensors installed in underground coal mines was two, by Rel-Tek (Rel-Tek Corp., Monroeville, PA) and Pyott-Boone.

A total of 235 coal mines were surveyed in this study. As one mine may have multiple CO systems, the total number of systems shown in Table 1 is 237. As one CO system may consist of components from multiple manufacturers, the number of systems installed in terms of manufacturers in Table 5 is 242.

Summary

The implementation of AMS or CO systems in underground coal mines in the United States has ensured the necessary fire detection capability required by federal regulations. Compared with the last MSHA survey in 2003, the survey results reported in this study show that every U.S. coal mine has either a CO system or AMS installed for fire detection and the monitoring of other parameters. Early detection is important for preventing the growth of a fire on a belt conveyor to improve safety for miners and minimize damage to the mine. In the survey results reported here for 235 producing coal mines, 14 percent of the mines used AMS and 86 percent used CO systems. The difference between the two systems depends on how they are used in the mine. The low percentage use of an AMS may be partially due to fewer mines using belt air to ventilate working sections.

Compared with data from the previous MSHA survey from 2003, the percentage of mines that use CH_4 sensors decreased 8 percentage points, while there were no significant changes in the use of other sensors. The percentages of parameters monitored in underground coal mines were significantly lower compared with the data from the 2003 survey in every category except for belt conveyor, probably because of financial constraints. Diesel equipment usage in coal mines also dropped by 12 percentage points compared with data from the 2003 survey. Finally, there are fewer sensor manufacturers in the market today than in 2003. As one related example, Pyott-Boone has increased its market share to 67 percent, from 36 percent in the previous survey. It is possible that the number of manufacturers could continue to decrease as more mines close due to the current condition of the coal mine industry.

Acknowledgments

Disclaimer

The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the NIOSH. Mention of any company or product does not constitute endorsement by NIOSH.

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Table 1

Number and proportion of installed carbon monoxide (CO) systems and atmospheric monitoring systems (AMS) based on the current survey for producing coal mines in the United States.

	Quantity	Percent
CO systems	204	86
AMS	33	14

Table 2

Percentages of different sensors used in underground coal mines in the current survey.

	Percent of mines	Minimum number of sensors	Maximum number of sensors
CO	100	2	300
CH_4	17	1	20
O_2	6	1	20
Smoke	2	1	14
Air velocity	9	1	20
Thermal	2	4	191
NO	1	1	3
H_2	2	1	3

Table 3

Parameters monitored as a percentage of the AMS and CO system installations in the current survey.

Parameter	Percent
Conveyor belt	100
Battery charging station	14
Fan stoppage	27
Fan pressure	11
Electrical installations	8
Motor amperage	9
Pumps	11
Water level pressure	14
Coal storage	3
Ventilation parameters	7
Others	6

Table 4

Diesel equipment in underground coal mines in the current survey.

	Quantity	Percent
Diesel equipment	85	36
No diesel equipment	150	64

Table 5

Systems installed in the current survey in terms of manufacturers.

Manufacturers	Number of systems	Percent
Pyott-Boone	161	67
AMR	32	13
Conspec	25	10
Matrix	15	6
Other	9	4

Table 6

Average number of CO sensors per mine in the current survey, in terms of manufacturers.

Manufacturers	Average number of CO sensors per system	Largest system	Smallest system
Pyott-Boone	27	246	2
AMR	54	300	6
Conspec	84	179	12
Matrix	45	194	4