Evaluation of Discriminating Fire Sensors in Two Underground Coal Mines

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ABSTRACT

Fire detection in underground coal mines using carbon monoxide (CO) based monitoring systems has been very effective in many mines. Many systems have been able to detect fires in early stages of development at very low CO levels. However in mines which use extensive diesel haulage and support vehicles, the systems have been less sensitive to early detection due to diesel exhaust contaminants elevating baseline CO levels. A new technology has been tested in two underground coal mines which is designed to discriminate between the CO produced by diesel engines and CO from a fire by correcting the CO concentration based on the nitric oxide (NO) concentration. This paper discusses the results of studies completed by MSHA at two of these underground coal mines. The technology employs a complex mathematical computation which is continually accomplished to improve fire detection capabilities for dieselized underground coal mines. Findings have shown the technology to be effective in significantly reducing levels for alarms while avoiding a "Chicken Little" complacency for nuisance alarms. This technology could be used for fire detection in any underground mines which utilize diesel equipment and carbon monoxide based fire detection systems.

KEYWORDS

Early Warning, Fire Detection, Discriminating, Diesel Engine, Carbon Monoxide, Nitric Oxide, Ambient, and Alarms.

INTRODUCTION

Atmospheric Monitoring Systems (AMS) have been very effective as early warning fire detection systems in underground coal mines. Early systems were capable of detecting hot belt rollers and belts rubbing on structures and posts.

After installation in mines using diesel equipment for haulage of men and materials, coal operators found the AMS systems issuing alarms on a frequent basis due to the carbon monoxide (CO) from the diesel engine exhausts. Diesel engine exhausts are capable of emitting sufficient levels of CO to activate alarms in the fire detection system. Such nuisance alarms can be a major hindrance in coal production since alarms require investigation and evacuation of personnel. As a result of too frequent nuisance alerts, miners began to be complacent, determining the latest alarm was 'probably just another diesel engine going by' or some other nonhazardous condition. This "Chicken Little" complacency is a very dangerous situation. If there would be an actual emergency, miners could fail to respond as needed, compromising their health and safety.

Historically, to compensate for the frequent alarms companies began to raise alert, alarm and ambient CO levels. Alert and alarm levels were as high as 25 and 30 ppm CO, which made the systems less sensitive to fire detection (Wirth, et al. 1995).

The Diesel Discriminating Sensor (DDS) was designed to differentiate between CO produced by diesel equipment and CO produced by a developing fire. The DDS technology was developed by researchers at Carnegie Mellon University and is marketed by CONSPEC (Grace, Guzman, 1990).
Figure 1 show graphically the relationship between the two gases and the corrected carbon monoxide values from the studies (Francart, Laage, 1998).

The accounting process involves the analysis of CO and Nitric Oxide (NO) concentrations and the relationship between these values. Because diesel engines produce both CO and NO, the DDS determines the ratio of the contaminant levels and calculate a Corrected CO (CCO) value. In the absence of a diesel engine, the CCO concentration will approach the actual CO concentration since mine fires produce little or no NO. Testing completed by the US Bureau of Mines concluded that the sensor could suppress the CO produced by the diesel engine while responding reliably to a mine fire (Litton, 1993).

This paper discusses the results of two investigations conducted in mines testing the use of the DDS technology. Both of the mines in this study used monitoring systems for fire detection in belt entries. Neither mine used diesel face equipment for coal haulage, but each used diesel scoops at the face and other support equipment in the intake haulageway.

The fire detection systems were installed as a requirement of a Petition for Modification of 30 CFR 75.350 and 352, allowing the belt entry to be used as a return in a two entry development and as an intake on a two entry longwall. The Proposed Decision and Order (PDO) sets requirements for the use of the system and requires provisions pertaining to the early warning fire detection system to be approved in the mine ventilation plan. Both the intake and belt entries are required to be monitored by the fire detection system.

TEST PROCEDURE

Three shifts were monitored at each of the two mines. Data logging MSA Passport instruments were placed at various locations in and near the section at points where DDS sensors were installed to measure CO and NO concentrations simultaneously. Diesel equipment activity was monitored to correlate CO and NO concentrations with equipment operation. Most activity was attributed to personnel carriers (Isuzu Pickups) and support vehicles traveling outby the section. A diesel scoop operated occasionally in the faces. Figure 1 also indicates data correlated with known periods of diesel engine operation from the time study. The spiking trend of passing diesel equipment is typical for engine contaminant levels (Wirth, *et al.*, 1995).

DATA ANALYSIS

The MSA Passport data files as well as the data files from the corresponding company DDS sensors were reviewed to determine the effects of the contaminant gases produced by the diesel equipment. The data was organized according to location and time.

From this review, it was determined that the DDS and MSA Passports provided comparable data trends. Readings were within +/- two parts per million in almost all cases for the CO and NO. Exceptions for the CONSPEC sensors were found to be due to miscalibrations and failing sensors.

In Figure 1, the response to the two different engine exhausts is distinguishable as the tractor emissions cause the CCO level to drop to zero, while the scoop emissions remain as a peak. Different operating conditions can also be distinguished for the same engine as the tractor and scoop peaks indicate.

The true measure of the DDS effectiveness is the reduction in the number of system responses to CO produced by the diesel engines. Table 1 shows the number of alert responses for CO for the associated alert level. The same data file was used to develop the projected alert activations based upon the CCO alert level. Typically, alert levels are set above an established ambient level. Table 1 includes the ambient level in the alert level.

Table 1. Reduction in Alert Level and Frequency.

	Mine A	Mine B
CO Alert Level *	15	15
CCO Alert Level *	8	9
Number of Alerts - CO	22	9
Number of Alerts - CCO	6	8

*includes ambient level

As indicated, alert level can be reduced, and the frequency of alert activations can be cut significantly at Mine A for the study period (81 percent). At Mine B, the reduction in alert frequency was not as significant (11 percent). However, the reduction in the alert detection level is a significant improvement for fire detection in both of these mines. Providing earlier detection of smoldering and developing fires is critical for safe escape for miners in the event of a mine fire (Mitchell, 1996). Using the lowest possible concentration for early warning will enhance early detection.

It is clear that the DDS technology cannot completely remove the associated CO produced by the engines due to the presence of different diesel equipment. Each engine produces the contaminants at different rates. Additionally, fluctuations in engine speeds and loads, which affect the emission rates of and relationship between the contaminants, can cause slightly different responses to the same piece of equipment. There will be a CCO value which will provide an operating baseline for normal production activities. This value would be comparable to an ambient CO concentration for a mine which does not use diesel powered equipment.

FIRE DETECTION ABILITY

While the DDS technology has not yet detected a fire, according to mine personnel it has detected hot belt rollers, welding and cutting operations in the vicinity of the DDS sensors, and has detected the action of spinning vehicle tires within the entry. These occurrences indicate the potential for early warning fire detection. However, documentation of these anecdotal occurrence seldom if ever exists.

Further analysis of data obtained from the fire detection systems did provide documentation of one such event. The effectiveness of the system in distinguishing between the CO produced by the diesel engines and that of other sources is shown in Figure 2. It is interesting to note on the response of the system to welding and cutting fumes between 14:00 and 14:15. With the absence of NO, the CCO concentration approaches the CO concentration as designed.

SYSTEM DEFICIENCIES

The DDS technology has demonstrated effectiveness in improving fire detection capabilities. However, the studies conducted by MSHA identified some deficiencies in the operation of the systems unrelated to the DDS. These deficiencies indicate a need for improved maintenance and training of personnel to ensure that the system performs as designed.

It was discovered that the addresses for two sensors at one mine were reversed. The computer was programmed to identify the readings from the intake entry as return readings and vice versa for two sensors in the same crosscut. This was confirmed by company testing and was corrected following the investigation.

Mispositioned sensors can delay detection of belt fires due to intake air dilution, obstruction or isolation from the fire contaminants. Sensor placement must be correctly maintained to provide early warning of a fire. The sensors in one belt entry needed to be positioned nearer the belt conveyor within the entry than was found in these investigations. Training of maintenance and utility personnel should emphasize the importance of maintaining proper sensor positioning.

Training for mine personnel responding to alerts and alarms underground was found to be very good. In the course of the investigation at one mine, a section alert was identified. Upon investigation, the source of the CO could not be identified and the section personnel were withdrawn outby the affected area as required. Although this was a nonhazardous event, the proper procedures were followed by the crew.

SUMMARY

The DDS technology has the capability to provide increased sensitivity for detecting fires at lower CCO alert levels, while reducing the frequency of alerts and alarms due to the diesel exhaust contaminants. Both of these factors improve the capability of the system and faith in the ability of the system.

As has been similarly documented in previous studies, the need to train employees to properly install, and maintain the systems are key elements for providing reliable fire detection systems. In combination with proper response to alerts and alarms by miners and confidence that the system will provide personnel with reliable and believable information, DDS technology can improve fire safety in mines utilizing diesel powered equipment.

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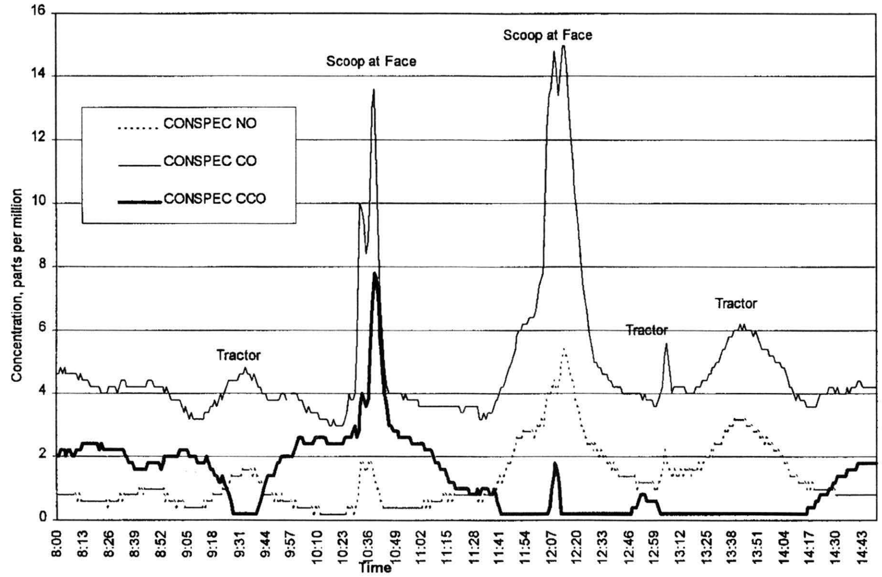

Figure 1. Typical DDS data annotated with time study conditions.

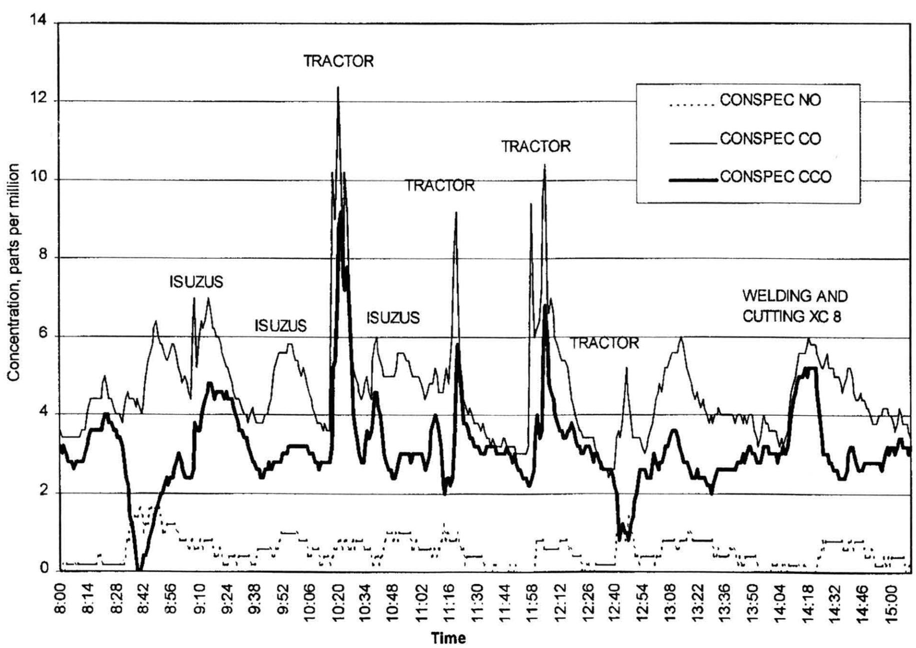

Figure 2. Annotated DDS data showing response to cutting and welding fumes.