Mine Fire Detection In The Presence of Diesel Emissions

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INTRODUCTION

A series of four coal combustion experiments (*1*)[1] was conducted at the National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory in the Safety Research Coal Mine to evaluate the response of optical and ionization smoke and CO sensors to a small 0.61 m square smoldering coal fire which transitions to flaming combustion in the presence of diesel emissions. With the increased utilization of diesel engines in underground coal mines, it is important to be able to discriminate fire products-of-combustion (POC) from diesel emissions. One proposed method to accomplish this is the deployment and interpretation of multiple sensors.

EXPERIMENTAL PROCEDURES

A schematic of the airways of 2 m height and 4 m width in which the experiments were conducted is shown in figure 1. Electrical strip heaters were used to heat a mixture of pulverized and 6 cm diameter coal slowly through smoldering to a flaming combustion transition with a CO production rate of approximately 0.001 ppm/s in ventilation air of 5 cu m/s. The fire sensors were positioned near the airway roof 148 m downwind from the fire. Diesel engines were operating for three of the four experiments 79 m upwind of the sensors. A spatially averaged path measurement of the POC was made with an optical smoke sensor (SA) which consisted of an infrared transmitter and receiver separated by an optical path of 9.65 m. Point measurements of the POC were made with a chemical cell, CO sensor, and an ionization smoke sensor (SB). Smoke optical density was determined from the measured optical obscuration of light in the 0.4 – 0.7 micron range over a 1 m path.

RESULTS

The optical fire sensor SA and the ionization sensor SB were quite dissimilar in their response to the initiation of diesel emissions. For experiment No. 4, figure 2 shows the response of smoke sensor SA and the CO sensor to diesel emissions from two diesel operated pieces of mining equipment, and figure 3 shows the response of smoke sensor SB and the CO sensor to the same diesel emissions. Time zero refers to the initial heating of the coal. For the three experiments with diesel emissions present, the optical sensor SA responds rapidly to the diesel emissions when the diesel engines were started with maximum signal changes between 4.7 and 19.2 pct, but returns to an asymptote within 1.5 pct of the ambient signal in the steady state diesel emissions. The ionization sensor SB responds with a signal change to an asymptote offset between 10.8 and 26.7 pct from the ambient pre-diesel signal. The characteristic response of the sensors to diesel emissions is due to the greater responsiveness of optical sensors to smoke particle size, and of ionization sensors to smoke particle concentration.

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[1]Italic numbers in parentheses refer to items in the list of references at the end of this report.

The response of smoke sensors SA and SB to the coal fire POC in the presence of diesel emissions for experiment No. 4 is shown in figures 4-5. The sensors respond continuously to a change in the POC associated with the increase in the measured CO concentration. Smoke sensors SA and SB respond similarly to the fire, as opposed to their characteristically different response to the diesel emissions in figures 2 and 3. The rate of increase in diesel emissions associated with starting the engine was much greater than the POC rate of increase associated with the coal combustion. In experiment No. 4, the average rate of increase in CO associated with the diesel engine's startup was 0.0716 ppm/s, and the average rate of rise in CO associated with the coal combustion was 0.00141 ppm/s. For the slowly developing coal fires in these experiments, sensor SA's signal had a small rate of increase, or remained constant, or continued to decrease for experiment Nos. 2, 3, and 4, respectively when the 5 ppm CO alert level was reached. However, a significant reduction in SA's signal, between 25.4 and 38.0 pct for experiment Nos. 2-4, had occurred in the case of coal combustion at the 5 ppm alert value as compared to the diesel engine's startup. Based upon previous considerations (*2*) for the definition of the alarm value for a smoke sensor with a continuous analog output signal as a 10 standard deviation change in the signal from its ambient value, the alarm times of the fire sensors were compared for the coal combustion processes. In the presence of steady diesel emissions, the ambient value is the time average in the diesel emissions background. The optical path smoke sensor alarmed earlier than the point type diffusion mode ionization smoke sensor, which alarmed prior to a CO alert value of 5 ppm above ambient for each of the coal combustion experiments. For the three coal combustion experiments with background diesel emissions, the average optical density at alarm time was 0.0025 m^{-1} for the optical sensor, 0.012 m^{-1} for the ionization point sensor, and 0.024 m^{-1} for the CO sensor.

A commercially available multiple sensor consisting of a NO and a CO chemical cell with an algorithm to use the history of the CO and NO produced by an operating diesel engine to discriminate from the CO produced by a fire was unable to distinguish a smoldering coal fire with a rate of increase of CO of 0.0014 ppm/s in a volumetric flow of 4.63 cu m/s. The sensor had been shown to be applicable to higher intensity fires.

CONCLUSIONS

The results of the experiments demonstrated that multiple sensors, which include an optical path smoke sensor and a CO sensor, can be used to detect a slowly developing coal fire in the presence of diesel emissions. This result is limited to the experimental conditions considered. An optical path smoke sensor and an ionization point smoke sensor alarmed earlier than the 5 ppm CO alert level for smoldering coal combustion in the presence of diesel emissions. Current research focuses upon a decision making process, such as a neural network, which can be applied to fire sensor response to a wide variety of fire and diesel emission conditions.

ACKNOWLEDGMENTS

The authors acknowledge the miners who maintain the Safety Research Coal Mine at the Pittsburgh Research Laboratory for their assistance in preparation of the experiments.

REFERENCES

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2. Edwards, J.C. "Overview of Mine Fire Detection." Second International Conference on Fire Research and Engineering, August 3-8, 1997, NIST, Gaithersburg, MD, Society of Fire Protection Engineers, pp. 489-499.

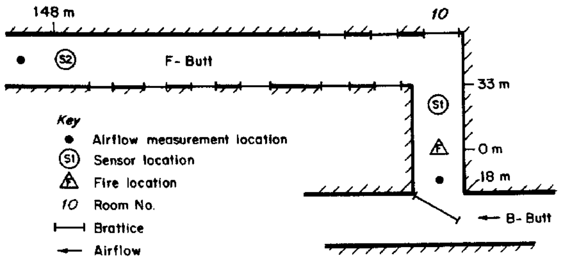

Figure 1.--Plan view of mine section.

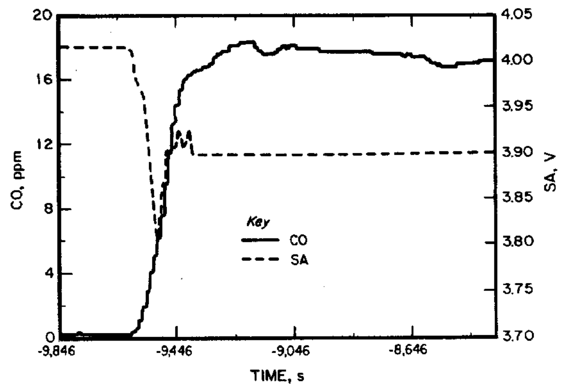

Figure 2.--CO and sensor SA response to diesel emissions.

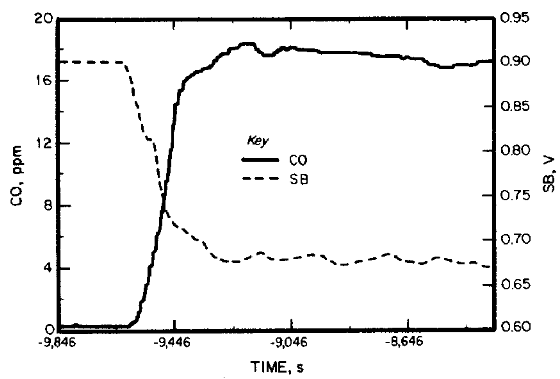

Figure 3.--CO and sensor SB Response to diesel emissions.

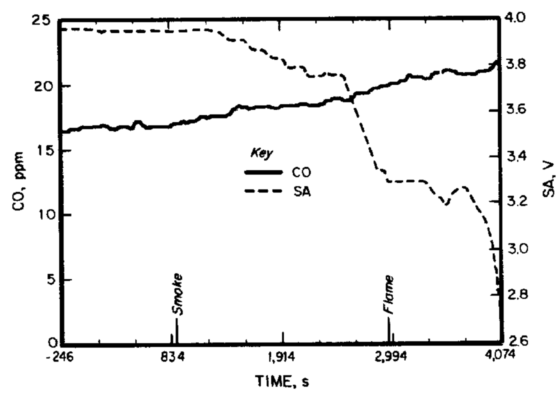

Figure 4.--CO and sensor SA response to coal fire.

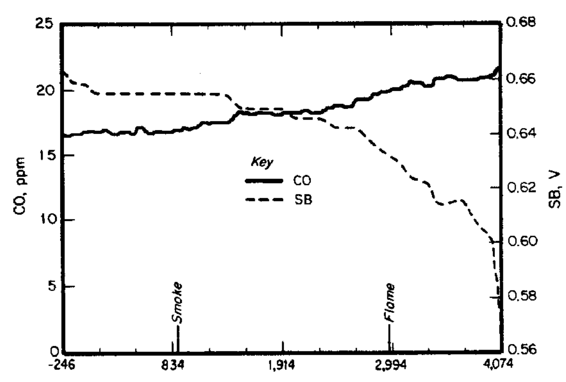

Figure 5.--CO and sensor SB response to coal fire.