



Title

REPORT

FIRE DETECTION ON BELTS

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Fire Detection on Belts

An underground mine fire is not only a serious threat to life, but also results in economic losses, such as losses of mining equipment, coal reserves, production, and jobs. Mine fires can spread rapidly and are both difficult and dangerous to extinguish. If they are not contained in the early stages, portions of a mine or the entire mine must often be sealed for long periods.

During the incipient stages of a fire, smoke and gaseous products including CO are produced and released into the mine atmosphere. If these products are not detected in the early stages of combustion, they can result in severe hazards to personnel in remote and confined areas. Many underground mine fires are discovered in their early stages by mine personnel who often must make a split-second decision to either fight the fire or escape. The success of safely controlling and extinguishing an incipient mine fire depends on several factors, such as awareness of the fire hazards, availability of effective fire fighting equipment, qualifications of the personnel, and amount of response time. If a coal mine fire cannot be contained by direct fire fighting methods within a few hours after discovery, the chances of successfully extinguishing the fire without sealing the mine are greatly diminished.

The successful detection of a developing fire in a mine entry using CO or smoke sensors requires that three events take place, each with an associated time frame. The first detection event that must occur is that the developing fire must be large enough or extensive enough to generate bulk average CO or smoke levels greater than, or equal to the alarm threshold levels of the sensors. Bulk average levels are obtained when fire-produced CO or smoke mixes with the ventilation airflow. The time it takes for sufficient CO or smoke to be produced depends upon the type of fire and the ventilation rate. For a liquid fuel fire, this time is short because the total surface area of the liquid fuel is involved very rapidly from the moment of ignition. For a more slowly developing coal fire, this time increases. If smouldering exists at a sufficient intensity, detection of the smouldering stage of a fire is possible. If the smouldering period is short and flames erupt before detection, then the coal fire must attain a sufficient intensity to generate the required CO or smoke levels for the alarm thresholds.

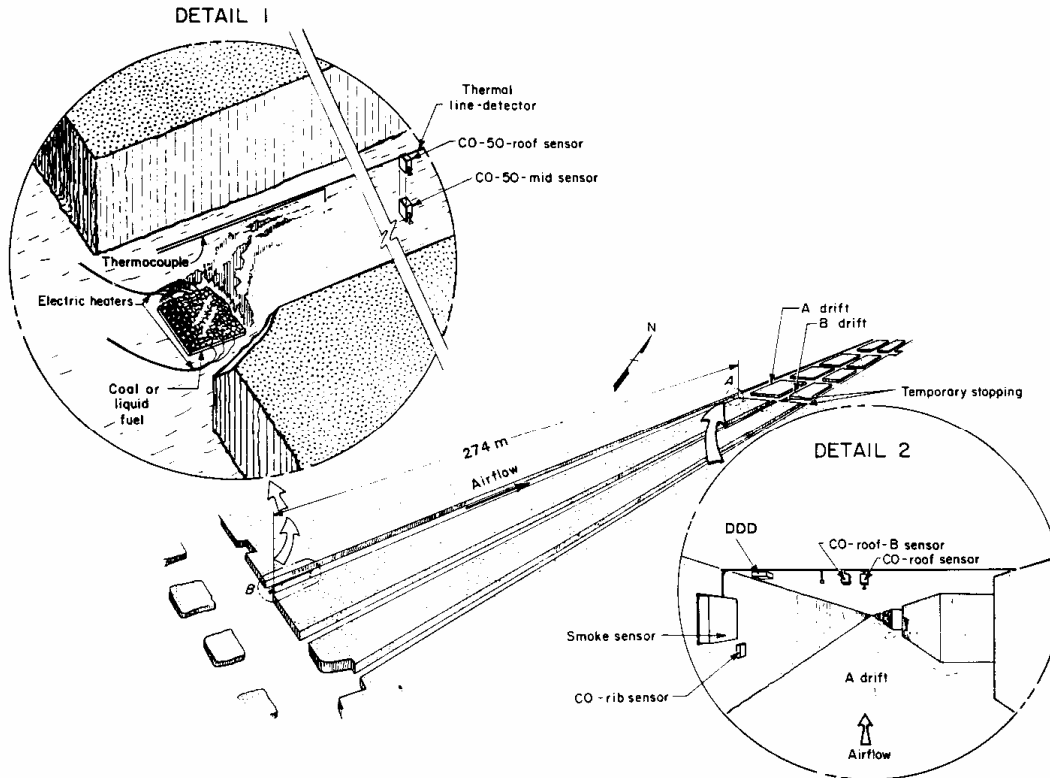
The second detection event that must occur is the transport of the CO or smoke from the fire to the sensor location. The transport time is computed by dividing the sensor spacing by the air velocity. At low air velocities this time can be long, resulting in a significant delay in the time to alarm. Increasing the airflow decreases the travel time, but also dilutes the CO and smoke levels.

The third detection event is the sensor response time. Although, in general, most sensors respond rapidly, the use of a sensor with a long response time can increase the time to alarm.

The combustion products leaving the fire are hotter than the ventilation air and, as a result, rise vertically toward the roof because of induced buoyancy forces. The greater the temperature difference between the fire products and the ambient air, the greater the buoyant velocity in the vertical direction is. This effect creates a layer of combustion products stratified near the roof downstream of the fire. Within this stratified layer, the levels of CO or smoke may be several times the bulk average levels. The point of formation of this layer downstream of the fire and the actual levels of CO and smoke that exist within the layer depend upon the relative values of imposed air velocity and buoyant gas velocity. As these hot gases move downstream, the layer dissipates because of cooling and turbulent mixing with the ventilation airflow.

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Detectors located near the roof take advantage of this effect and provide earlier warning than detectors placed lower do, especially when located in close proximity to the developing fire. Detectors located along the vertical centre-line of an entry may be too low and may fail to detect a fire occurring immediately upstream because all of the CO or smoke is layered near the roof.



FLAMES FROM COAL-CONVEYOR BELT PILE.

SENSOR RESPONSE TO COAL-BELT FIRES:

Figures 1 and 2 are typical traces of the various fire sensors that were mounted in a drift for a slow-developing coal-conveyor belt fire. The data collected from the CO sensors are shown and indicate the level of CO in parts per million with respect to time. The CO alarm levels were set at 10ppm, and the tests were conducted at an air velocity of 0.58 m/s.

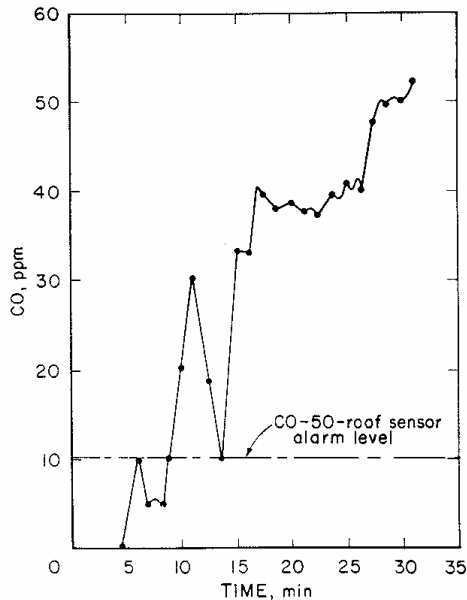


FIGURE 1: CO concentration at 15.2 m roof station as function of time.

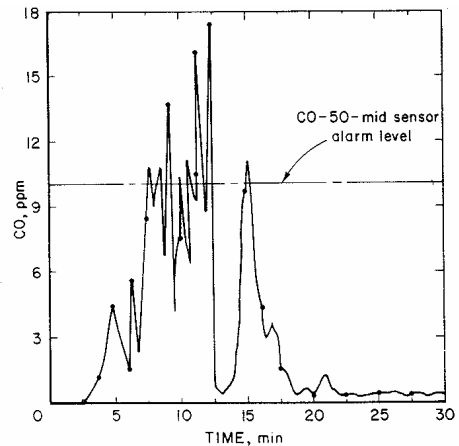


FIGURE 2: CO concentration at 15.2 m mid entry station as function of time.

The table below lists the response time (T_A) of the various sensors for a test conducted at an air velocity (V_0) of 0.56m/s. In this test, visible smoke was first observed from the coal pile 2.5min after power was supplied to the strip heaters, and flaming was observed 12min into the test. For this test the smoke and CO travel time from the fire to the 274 metre station was 8.2min. The earliest observed response was from the CO-50-roof sensor. This is to be expected, since the combustion products rise to the roof. The smoke sensor responded to smoke that was actually produced from the smouldering fire. In other words, the smoke levels at alarm were actually produced about 5 minutes into the test, and it took an additional 8.2 minutes for this smoke to reach the sensors. These delayed alarm times clearly show the impact of travel time on fire detection.

Sensor	Distance from fire, m	Alarm time, ¹ min:s	T_A		
			5 ppm CO, min:s	10 ppm CO, min:s	15 ppm CO, min:s
CO-50-roof	15.2	NAp	4:20	5:40	7:17
CO-50-mid	15.2	NAp	6:11	² 6:22	² 8:49
CO-roof	274	NAp	19:03	29:11	31:51
CO-rib	274	NAp	19:03	29:31	31:23
Smoke	274	13:50*	NAp	NAp	NAp

NAp: Not applicable

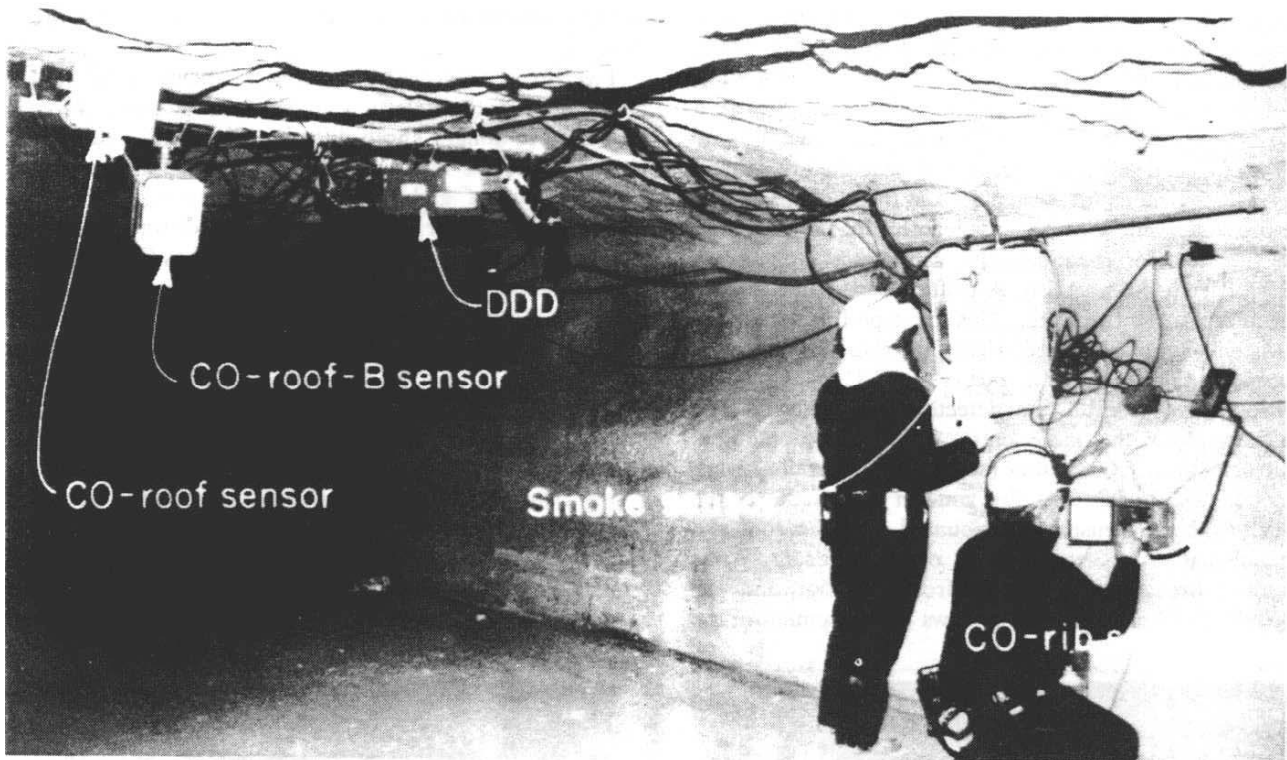
T_A : Response time

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The effects of the 10ppm alarm threshold levels were also dramatic, especially when the alarm times between 5 and 10ppm are compared. For the CO-roof and CO-rib sensors, an additional 10 minutes were required to reach 10ppm. At the 15ppm CO level, the average time for CO sensors at the 274 metre station to respond was 31 minutes, almost 17.5 minutes longer than that of the smoke sensor. It is also worth noting that by subtracting the travel time from this response time (31 minutes minus 8.2 minutes), the 15ppm CO response did not occur until 11 minutes after flaming was first observed.

The other point to note from the data is that the two CO sensors of the same bran, CO-roof and CO-rib, responded at almost the same time, even though one was located near the roof, while the other was located on the rib, approximately 1.4 metres from the roof. These results indicate that by the time the CO reached the 274 metre station essentially complete mixing of the fire-produced CO with the ventilation airflow had occurred.

All of the times discussed above are significant, especially when it is realised that rapid response and warning may mean the difference between life and death of underground personnel.



COMPARISON OF ALARM TIMES OF SMOKE SENSORS AND CO SENSORS AT FOUR AIRFLOWS FOR SLOW-DEVELOPING COAL-BELT FIRES:

The superiority of smoke sensors over CO sensors is quite evident from data presented in the table below. This table shows the alarm times of the smoke sensors at four airflows for slow-developing coal-belt fires and the corresponding CO level at the time of the smoke alarm. The smoke and CO sensors were located 274 metres in by the fire.

At the average CO level of only 1ppm, the smoke detector had already reached the alarm threshold. This data is consistent with previous data, on the average, at a smoke optical density of 0.44m^{-1} (alarm level), the CO is 1.8ppm for smouldering coal fires.

Air velocity m/s	Time to smoke alarm, min:s	CO at smoke alarm, ppm
0.48	11:15	1
0.61	14:15	1
0.76	13:15	1
1.09	11:05	1

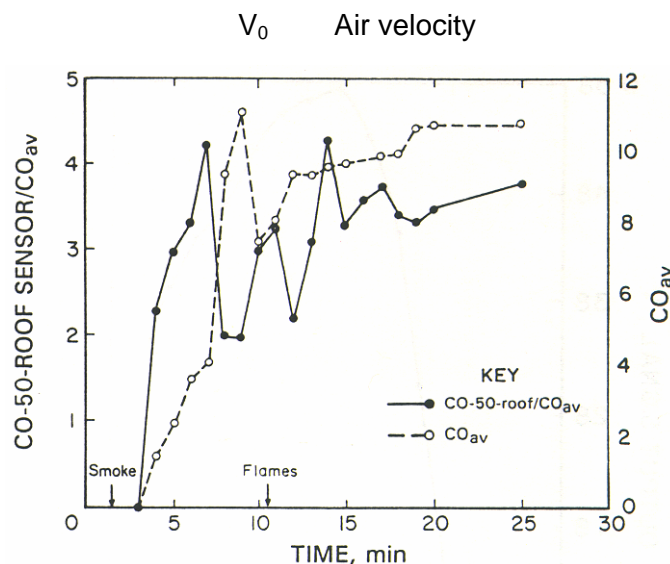


FIGURE 3: Comparison of bulk average CO (CO_{av}) produced at fire with ratio of roof CO to average CO versus time for coal-belt fire.

Figure 3 plots the bulk average of CO produced by the fire and the ratio of the roof CO at the 15.2m location to the bulk average CO versus time for a slowly developing coal-belt fire at an air velocity of 1.09m/s. For this data, the average CO levels of three CO sensors at the 274 metre station are used, subtracting the travel time (4.2 minutes) from the fire to the sensors. It is obvious that location of a sensor near the roof immediately downstream from the fire takes advantage of the buoyancy-induced stratification that occurs. For instance, at 7 minutes into the test, the bulk average CO was only 4ppm, yet the CO-50-roof sensor measured almost 17ppm because of the stratification.



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SUMMARY AND CONCLUSIONS

The results clearly indicate that in these full-scale tests the sensitivity and response times vary depending on the type of sensors, their locations, and the ventilation rate. Smoke sensors alarm more quickly, usually when CO levels are in the range of 1 to 2ppm. At low airflows, travel times from the fire to the sensors can be significant and effectively degrade early warning capability. Sensor placement near the roof takes advantage of buoyancy-induced stratification and allows response much earlier to fires located in close proximity upstream of the sensors.

The results also demonstrate the unique ability of the diesel-discriminating detector to prevent false alarms in the presence of diesel exhaust, unlike other sensors, while still maintaining the capability to respond rapidly to a developing fire.

The data clearly shows the advantages of smoke and CO sensors.
