11th U.S./North American Mine Ventilation Symposium 2006 – Mutmansky & Ramani (eds)
© 2006 Taylor & Francis Group, London, ISBN 0-415-40148-8

Reducing belt entry fires in underground coal mines

W.J. Francart
US Department of Labor, USA

ABSTRACT: The use of belt air to ventilate working sections coupled with improved fire detection capability have been the major reasons for mine operators installing carbon monoxide detection systems in belt conveyor entries of underground coal mines in the United States. The advent of carbon monoxide monitoring systems may have contributed to reducing the frequency of reportable belt fires, but prevention of the conditions that allow fires to occur is more effective than detecting and extinguishing fires after ignition occurs. An analysis of reported mine fires in belt entries shows many belt fires could have been prevented with proper maintenance of the haulage system. This paper reviews the reported belt fires in underground coal mines for the period from 1980 to 2005. Also included in this paper is an analysis of ignition sources as identified in accident reports issued by MSHA investigators, as well as the factors involved in creating ignition sources.

1 INTRODUCTION

The use of belt air to ventilate working sections has been a major reason for mine operators installing carbon monoxide (CO) monitoring systems in belt conveyor entries of underground coal mines in the United States. Until the publication of regulations regarding the use of belt air in 2003, mine operators were permitted to use belt air only through a petition for modification of federal regulations, all of which required the use of CO monitoring systems. In many other mines, CO systems have been installed in lieu of typical point-type heat sensors (PTHS) because of the increased detection capability of the systems. Many mine operators have determined the additional cost of maintenance and calibration of CO monitoring to be an invaluable investment for improving fire protection for miners and mine property.

The majority of coal mine disasters have been due to explosions of methane and coal dust. Mine fires have been the cause of fewer disasters. However, the Wilberg mine fire in 1984 took the lives of 27 miners (Huntley 1986). Since 1980, only one other death has occurred during a belt conveyor fire. However, as miners escaping from the Marianna mine belt fire will relate, there is a real danger and potential for disaster when a fire occurs in a coal mine belt entry.

The Marianna belt entry fire (Strahin 1988) most likely resulted from frictional ignition of coal and coal dust at a belt drive which was not properly maintained. Compounding the dangers of the fire was the deluge fire suppression system at the drive being disabled, and unavailability of a water supply to fight the fire. A delay in evacuating miners contributed to five people being treated for smoke inhalation. Even though the mine was using a CO monitoring system as well as a PTHS system for fire detection, the fire apparently developed so quickly that miners were still in jeopardy. The accident points out that prevention of the conditions that cause fires is more effective than detecting and extinguishing flames.

2 HAZARDS OF BELT FIRES

Since 1980, belt fires have accounted for 15–20 percent of all fires reported to MSHA by coal mine operators. By definition, a mine fire is reportable to MSHA if it is not extinguished within 30 minutes of discovery. After the mine operator reports a fire, MSHA accident investigators will determine a possible cause of the fire. An investigative report, including a description of the accident, details of the detection method, extent of property damage, and method used to extinguish the flames is generated by MSHA. Depending on the extent of the fire, this report can consist of a two-page standard form (MSHA 7000-50a) up to a multiple-page report complete with Root-Cause Analysis (Paradies 2005). For this paper, accident reports on 62 belt entry fires for a 26-year period (1980 to 2005) were reviewed to identify and tabulate fire ignition sources, and to determine if maintenance of the belt conveyor was a factor in allowing the fire to occur. One fire was still under investigation and could not be included in this analysis.

The belt conveyor is the lifeline of the modern coal mine. If the belt stops, the flow of coal stops and mining ceases. Depending on the location of a fire within the belt, coal production can be disrupted for days, weeks, and historically has even been the death knell to a coal mine. In addition to the loss of production, fires can destroy mine infrastructure often requiring extensive rehabilitation to resume production. Besides replacing belting, structure and drives, mine roof conditions must be restored and in extreme cases, development of a new belt slope bottom has been necessary to restore coal haulage to the surface. Costs for containing, extinguishing and recovering a mine fire can run into the tens of millions of dollars.

The bad news can be rather grim, but there is encouraging good news. New fire detection system technology is evolving, allowing mine operators to detect fires before they cause extensive damage. A small fire is easier to control and extinguish than a large fire. In addition, many belt fires are preventable, as suggested by the findings of accident investigation reports. Proper maintenance of the belt and belt components may have prevented many of the sixty-one reported fires included in this analysis.

3 FREQUENCY OF REPORTED FIRES

Figure 1 shows the number of reported belt entry fires by calendar year from 1980 to 2005. The general trend is downward for the period, with the exception of four reported fires in 2002 and three in 2003. Except for the period from 2002–2003, the belt entry fire rate per 1000 mines is generally one to three fires per year, with an average of 1.8. In 2002–2003, however, the rate grew to nearly twice the typical rate and more than three times the average rate, to 5.7 per 1000 mines.

One company experienced two major fires in 2003 causing considerable interruption to production and damage to underground facilities. MSHA investigators attributed both fires to frictional heating caused by the belt contacting belt support structure. As a result of these fires and potential for additional fires, the company implemented a program to improve protection against major underground mine fires. Included in the program were increased emphasis on training of mine examiners to identify potential fire ignition sources, and emphasis of maintaining and testing fire suppression systems (Tolliver 2004).

4 IGNITION SOURCES

The majority of mine fires attributed to mining equipment ignition sources are due to equipment misuse, lack of maintenance, compromising safety controls and running equipment for long periods of time unattended (McPherson 1993). In the case of conveyor belts, these factors would include inadequate design, spillage and coal accumulations, failure to lubricate moving parts, failure to replace bad rollers, malfunctioning slippage switches at belt drives, inadequate examinations for hazards in the belt entry, misalignment of the belt, and improper installation. In most of these cases, frictional heating becomes the likely ignition source. Careless welding and cutting practices are other identified ignition sources (Mitchell 1996).

The belt drives and conveyor transfer points are considered by many to be primary ignition point sources for a number of reasons. Electrical sources are more likely to exist at drives, with drive motors and cables located nearby, and transfer of coal can cause spillage at these locations which, if not removed, can eventually build up to a point where frictional contact between coal and moving conveyor components occurs. MSHA acknowledged the increased potential in these areas when promulgating the 2003 regulations on the use of belt air on working sections by requiring fire detection sensors to be installed downwind of all belt drives.

The most common ignition source identified in the accident reports is frictional heating. Other sources included electrical equipment and conductors, welding and cutting operations, diesel equipment and hydraulics. Table 1 shows the breakdown of the ignition sources for reported belt entry fires for the period from 1980–2005. The ignition source could not be identified in 17 fire investigations due to extensive damage to the belt and belt entry. In most accident reports, the most likely ignition source was determined by investigators based on interviews of miners and conditions discovered underground. In 34 of the accident reports (56 percent), inadequate maintenance was identified as a contributing factor in the occurrence of the fire.

It is interesting to note that the number of frictional ignitions along the belt was equal to the number identified as originating at belt drives. While it is probable that many of the indeterminable sources were also at or near drives, the numbers indicate ignition along the belt is a significant concern. These fires have been attributed to friction between the moving rubber belt and wooden posts, friction between the belt and damage belt idlers (rollers) and friction between the belt and support structure.

5 FIRE DETECTION

The method of fire detection in belt entries is required by regulation to include sensors to measure the rise in temperature, or other types of sensors which provide equivalent detection capability. Commonly known as Point-Type Heat Sensors (PTHS), bi-metallic sensors measuring rise in temperature, were state-of-the-art

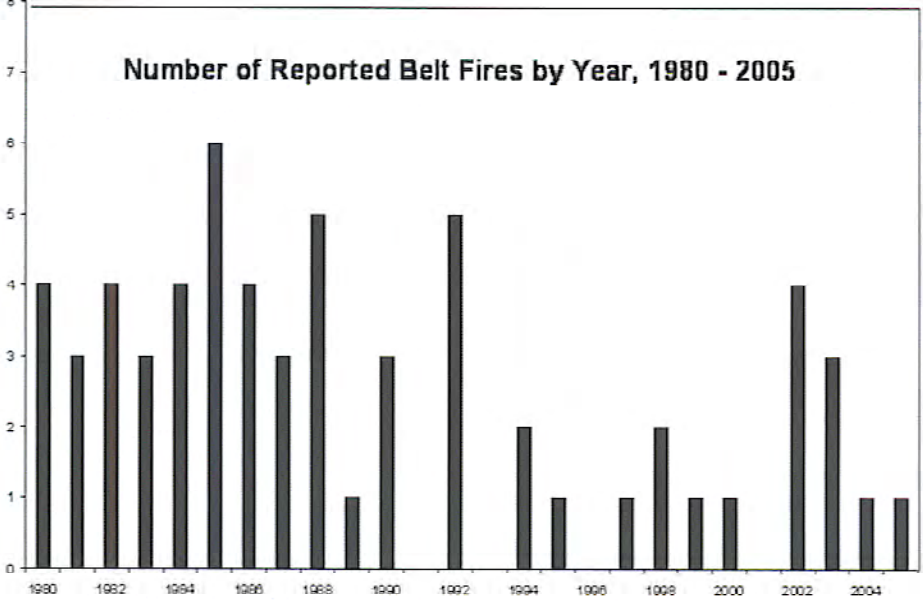

Figure 1. Number of reported belt fires by year, 1980–2005.

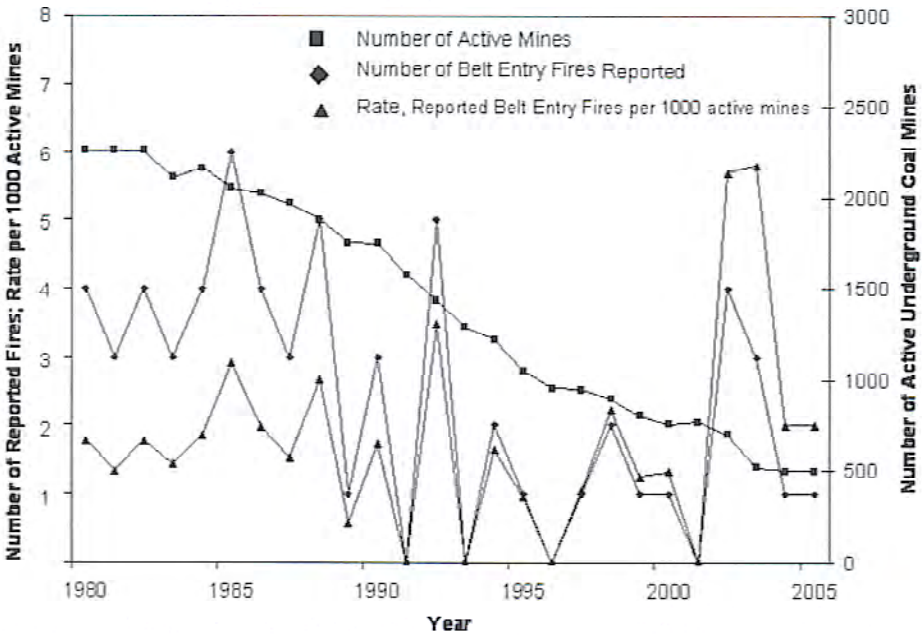

Figure 2. Number of active mines, number of belt entry fires reported, and fire rate per 1000 mine.

when hearings on the Federal Coal Mine Health and Safety Act of 1969 were held. These sensors are designed to activate when a predetermined temperature is reached, commonly 57°C. Because of the low ambient temperature in a coal mine, the size of fire needed to create such an increase in temperature must be rather large. The fire's heat intensity required for detection has been compared to the number of furnaces operating in an 8 room home (Mitchell 1996). For a nominal flow of 9.5 m^3/sec, the heat of more

Table 1. Ignition sources of belt entry fires 1980–2005.

Ignition source	Number of fires	Percent of total
Cutting and welding	5	8%
Friction at belt drive	11	18%
Friction along belt	11	18%
Hot rollers	6	10%
Electrical	8	13%
Diesel and hydraulic	2	3%
Indeterminable	18	30%

than 10 furnaces would be required to cause an alarm at a sensor only 15 meters downwind of the fire. This fire would be difficult-to-impossible to control at this size. The relationship is supported by a 1988 study by MSHA on belt fires, where only three of 29 fires were successfully detected by PTHS systems (Stephan 1989).

Current technology used for detecting fires in belt entries includes PTHS systems as well as carbon monoxide (CO) sensor systems. The CO systems are considered superior to PTHS systems for coal mine belt entries, as supported by an investigation report of a fire in one mine where both PTHS and CO fire detection systems were installed (Wilson 1996). As evidenced in the report of this fire, the CO sensors detected a fire early in development at a distance of 460 meters from the fire source. Heat sensors located within 9 meters of the fire did not activate at any time.

Numerous anecdotal incidents have been known by MSHA personnel over the years, showing CO sensor systems are effective for providing early warning for miners to escape hazardous situations, combating developing fires and avoiding or reducing losses due to fire damage. The implementation of these systems has been steadily increasing since the first installation in 1984, with over 20 percent of active mines currently using CO detection for compliance with federal standards (Francart 2005). In many cases the systems are not specifically required by MSHA, but rather are installed by mine operators as an alternative to heat sensor systems.

In promulgating regulations regarding the use of belt air to ventilate working sections, an economic analysis comparing the installation of CO-based detection with PTHS systems was completed. System purchase and installation costs for the two systems are equivalent at approximately 9,000 feet of belt entry development. Beyond 9,000 feet, CO system purchase and installation costs are less than PTHS systems. Maintenance costs of the CO system are significantly higher than PTHS systems due to calibration and repair costs. However, the potential savings in rehabilitation costs and lost production by detecting a fire in a timely manner can exceed the maintenance costs many times over.

For the period from 1980 to 2005, approximately 25 percent of all belt fires occurred in mines using belt air. Since the highest percentage of mines using CO systems during the period was approximately 21 percent, it may seem that mines using belt air may have a higher fire incidence rate. However, other factors complicate this analysis, the most significant being the size of the mine. Until the year 2000, most mines using belt air were multiple section mines, often with miles of belt conveyors. With a greater haulage infrastructure comes a greater opportunity for fire sources as the number of belt drives and length of conveyor belt increases.

Recently smaller mines have begun to use belt air on working sections. Because this ventilation method was made available to all mines without need for a petition for modification, this trend may strengthen. Federal regulations promulgated in 2003 require the use of CO monitoring systems in mines electing to use belt air to ventilate working sections. Technological advances are improving the detection capabilities of CO systems. The uses of diesel discriminating sensors and hydrogen discriminating sensors have reduced significant interference of diesel exhaust and hydrogen gas on CO sensors.

While extensive data on non-reportable fires is not readily available, there is little doubt that the use of belt air as a section intake has reduced the incidence and in some cases the severity of belt fires. For an 18-month period in 2002–2003, an MSHA survey indicated a total of 32 non-reportable fires were detected by CO monitoring systems (Francart 2005). Due to the size of fire needed to activate heat sensors, these fires would have likely grown into reportable fires if CO systems had not provided early detection.

6 REDUCING BELT FIRE POTENTIAL

While ignition sources for 18 belt entry fires could not be identified in MSHA accident investigations, after a review of the accident reports it was determined that many of the 17 could have been a result of frictional heating at a belt drive. It is probable that one in four fires in belt entries is related to frictional heat at a belt drive.

Fires at belt drives are often due to accumulations of coal which are ignited by heat produced by friction between the belt fabric and drive roller due to belt slippage, or friction between the belt and structure or other object such as a rock, post, crib or coal. Belt slippage can be caused by a number of factors, including inadequate belt tensioning; increased drag on the belt due to idler damage; spillage or roof fall; improper slippage switch installation or operation; and decreased friction

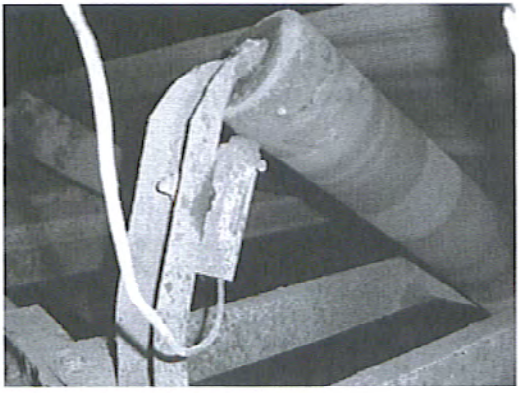

Figure 3. Slippage switch installation.

Figure 4. Belt cutting through structure.

coefficient between the belt and roller lagging due to improper or inadequate removal of contaminants or worn lagging.

Current federal regulations for underground coal mines require installation of slippage and sequence switches on underground belt conveyors. Slippage switches are often installed at belt drives to monitor the belt and drive roller movement. When the drive roller turns without belt movement, the switch is designed to de-energize the drive and eliminate the slippage.

Most conveyor slip switches are designed to operate on one of three principles; magnetism, centrifugal force, or photo-electricity. A common choice for underground use is a system utilizing a slip switch proximity sensor. These units work by detecting interruptions of a magnetic field by targets installed on a rotating shaft or roller. Slippage is detected by a change in the speed of rotation of the shaft or roller. In addition, a new technology that uses a computer generated signal to monitor motor current and voltage to detect a slow down in the belt is available (MSHA 2005). Figure 3 shows the installation of a magnetic field slippage switch on a belt roller. Regardless of the type of detection system used, the unit should be tested frequently. MSHA recommends that systems be checked at least once per shift.

Spillage along beltlines is sometimes attributed to misalignment of the belt (Swinderman 2002). Spillage provides a ready fuel for a fire, and thus is not permitted to accumulate in underground coal mines. Regulations require a program for regular cleanup and removal of these accumulations. Frequent and repeated spillage at particular locations has also been attributed to damaged belt structure and missing components. Often when a belt roller is found to be bad, it is removed from the belt without being immediately replaced. Immediately replacing the roller would likely interrupt production, so rollers are removed to be replaced at a later time.

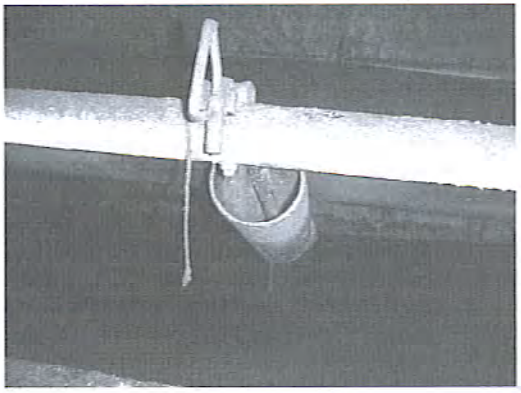

Figure 5. Damaged belt roller.

Other potential sources of heat for fire ignition are belt misalignment and damaged belt rollers. Figure 4 shows conditions in one belt entry where the belt was found to be cutting through the belt structure. The frayed edge of the belt is visible on the right side of the vertical support. In some cases the belt has been allowed to completely cut through the structure. These occurrences are often due to belt misalignment, and have been identified as potential ignition sources in accident investigation reports. One fire was ignited as a result of belt misalignment, as the loaded top belt ran out over the rollers contacting two wooden posts which had been ignited by the frictional heat.

Another potential ignition source is damaged belt rollers. Figure 5 shows a damaged roller which needs to be replaced because the roller bearings have been dislodged. Continued contact with the moving belt can cause wear and heat which can ignite coal dust, grease or other combustible materials. In extreme cases, belt rollers have been found with holes worn in the contact surface due to friction with the moving belt.

Electrical sources have accounted for approximately 13 percent of the ignition sources for belt entry fires reported in the study period. Cutting and welding along belt entries has been identified as the ignition source for just under 10 percent of the reported belt entry fires. These fires were often the result of carelessness on the part of the miner operating the torches. Proper work practices and adequate examinations can greatly reduce the potential for fire as a result of cutting and welding.

7 CONCLUSIONS

The downward trend in the number of reported belt fires has followed the trend in the number of active underground coal mines for the past 26 years. The rate of fires per 1000 active mines has been rather steady, with the rate ranging from one to three. The exception is seen in 2002 and 2003, when the rate rose to nearly six fires per 1000 mines. In only four of the 26 years were there no reported belt entry fires. While many reportable fire sources could not be determined, the most common ignition source reported is frictional heating.

The use of belt air to ventilate the working section has directly improved the fire detection capability in these coal mines due to the required use of CO monitoring systems. Technological advances have continued to improve early-warning capabilities of these systems. Intuitively, one could conclude that the use of belt air has reduced the number of fires reported by mine operators to MSHA.

However, mine operators cannot rely on the use of CO monitoring systems alone for early fire detection to minimize economic losses from a fire. Significant losses of production and property damage can occur when a fire is discovered in early stages of development. Only prevention through proper maintenance and examination can effectively prevent reportable belt entry fires.

REFERENCES

Francart, W. 2005. 2003 MSHA Survey – Atmospheric Monitoring Systems in U.S. Underground Coal Mines. SME Annual Meeting, Salt Lake City, UT.

Huntley, D. et al. 1986. Report of Investigation – Wilberg Mine Fire. Mine Safety and Health Administration.

McPherson, M.J. 1993. *Subsurface Ventilation and Environmental Engineering*. New York: Chapman and Hall.

Mine Safety and Health Administration. 2005. Accident Prevention Program Safety Ideas: Is Your Belt Slippage Protection Working? www.msha.gov.

Mine Safety and Health Administration. 1980–2005. Accident Investigation Reports.

Mitchell, D.W. 1996. *Mine Fires*. Chicago: Primedia Business Media.

Paradies, M. 2005 Root Cause Analysis Meets Goals for Safe, Reliable and Efficient Operations. System Improvements Inc.: Knoxville, TN.

Stephan, C., & Desautels, L. 1989. Underground Coal Mine Conveyor Belt Fires 1970-1988. Report Number 04-304-89, Mine Safety and Health Administration, Industrial Safety Division of Technical Support, Pittsburgh, PA.

Strahin, R., Wolfe, D., & Pogue, C. 1988. Report of Investigation – Marianna No. 58 Mine Fire. Mine Safety and Health Administration

Swinderman, R., Goldbeck, L., & Marti, A. 2002. Foundations 3. Martin Engineering, Neponset, IL.

Tolliver, W. 2004. Mine Emergency Preparedness. Presentation at SME/PCMIA Annual Joint Meeting, Greensburg, PA.

Wilson, W. 1996. Report of Investigation – Dilworth Mine Fire. Mine Safety and Health Administration.