Cost of coal mine catastrophes

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Abstract

Mine fires, explosions, spontaneous heating and inundations are among the leading causes of catastrophes (unplanned, temporary sealing and recovery of major mines) and disasters (five or more fatalities). Many reports are available that detail company and agency efforts to determine the causes of catastrophes and reestablish mining operations, but the associated recovery costs are rarely included. Underground coal mine catastrophes are low-probability, high-loss events that happen nearly every year. Case studies of recent catastrophes that occurred from 1987 through 2001 suggest that large underground coal mines are more susceptible to fires and explosions than small mines. On average, when a catastrophe occurs, mine production drops by 50 percent, and the rehabilitation efforts can cost as much as $23 million plus $12 per incremental lost metric ton.

Introduction

This paper presents an initial evaluation of selected large coal mine catastrophes from case studies for the period 1987 through 2001. No proprietary information is included in the data used for this analysis. This report is a first step in providing a cost-estimating model to use in justifying investments necessary to reduce the frequency and/or severity of future occurrences of catastrophes.

Coal mine catastrophes are low-probability, high-loss events that happen nearly every year. Their occurrence is by nature unpredictable because with adequate forewarning more catastrophes would be prevented. The magnitude of economic loss from a catastrophe is relatively large compared to an operation's ongoing capital investment needs.

Coal production per mine is increasing rapidly, and the number of operating mines is decreasing in the United States. This tends to concentrate the investment and earning potential into fewer locations. Thus, the economic risk of business interruption from an average size mine catastrophe is probably increasing. Figure 1 shows that after about 1980 the average size mine increased from 100 kt to 450 kt/a (110,000 to 500,000 stpy). Fires, explosions, spontaneous heating and inundations are the leading causes of reported catastrophes. Most mines are reentered and eventually returned to production. Some mines are permanently closed.

Many reports are available that detail company and agency efforts to determine the causes of catastrophes and reestablish mining operations. Some information is available on preventing catastrophic events, on completely closing a mine or on the rapid rehabilitation of a mine. Few examples of the direct cost of business interruption, mine damage or the value of sterilized coal resources were found in the literature. Indirect losses such as individual wages, injuries, tax revenues, litigation, customer inconvenience or lost opportunity can be substantial but are beyond the scope of this paper.

No one company has the breadth of experience from their own company history to quantify the dollar risks and probability of occurrence of coal mine catastrophes. Other organizations may have some of the information, such as specialty insurance company loss experience, but it normally is confidential.

No state or federal agency collects this cost data. Agency mandates include protecting the health and safety of people and the environment but not the viability of business enterprise. For example, the U.S. Mine Safety and Health Administration's (MSHA) Web site states: "The mission of the Mine Safety and Health Administration is to administer the provisions of the Federal Mine Safety and Health Act of 1977 and to enforce compliance with mandatory safety and health standards as a means to eliminate fatal accidents; to reduce the frequency and severity of nonfatal accidents; to minimize health hazards; and to promote improved safety and health conditions in the nation's mines."

Success or failure of coal companies is tied to how they manage business risk. If catastrophe cost and probability data were available, then a measure of the potential loss could be estimated and used to justify preventative and mitigating projects using normal capital-budgeting methods. Risk-management techniques could be routinely applied to reduce company exposure and improve the wealth generation potential of the mining enterprise.

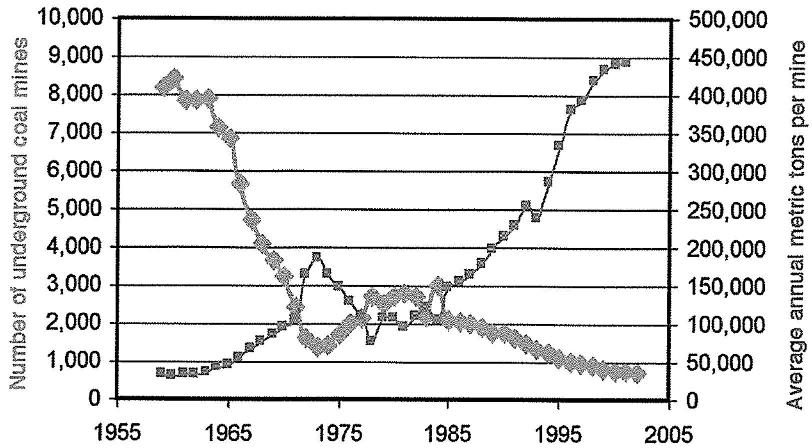
Catastrophes

Catastrophes are defined for purposes of this report as those events at active underground coal mines that result in unplanned sealing or major disruption of production due to fire, explosion, spontaneous heating or inundation. Other causes of premature mine closure, such as massive ground movements or earthquakes, occasionally may produce similar results but are not included because of lack of data.

Events listing. Table 1 lists 25 instances for the period 1987 through 2002 where a U.S. coal mine operation was significantly affected by a fire, explosion or inundation. Stated another way, about 1.5 events occur in an average year. This number is the same as for the period 1959 through 1986, where 1.5 events per year were also reported by the U.S. Bureau of

FIGURE 1

Increasing scale of underground coal mines. As the number of underground coal mines has decreased, average production per mine has increased. Data from MSHA Statistical Reports on the Web.



Mines (USBM) (Richmond et al., 1983; Dobroski et al., 1996).

The primary public source of information on these events is collected and published by the National Institute for Occupational Safety and Health (NIOSH), the USBM and MSHA. Detailed agency accident investigation reports are available on many of the events where injuries or fatalities occurred or the potential for significant

Table 1

Preliminary event listing: 1987 through 2002.

Year	Mine	Event
1987	Cumberland	Fire
1988	Marianna #58	Fire
1989	William Station #9	CH4 explosion
1990	Granny Rose No. 3	Explosives blow-out
1990	Mathies	Fire + explosion
1991	Fire Creek #1	CH4 explosion
1991	Golden Eagle	CH4 explosion
1992	Blacksville No. 1	Explosion - closed mine
1992	Southmountain #3	Explosion
1993	Meigs 31	Inundation - water
1994	Beatrice	Explosion - closed mine
1994	Day Branch #9	Ignition
1995	–	–
1996	Deserado	Fire
1997	Old Ben No. 26	Fire - Closed mine
1997	Galatia	Fire – LW gob
1998	Willow Creek	Fire – LW gob
1999	Sanborn Creek	Fire
1999	Loveridge	Fire + explosion
2000	West Elk	Fire
2000	Willow Creek	Explosion
2001	Crown II	Fire
2001	Jim Walter No. 5	Roof fall + explosions
2002	Big Ridge No.2	Fire – within months of closure
2002	Blue Diamond No. 77	Fire
2002	Quecreek No. 1	Inundation – water

loss of life was recognized. Note that, if the event is in litigation, government files are sealed and not accessible. This investigation ended in 2001 to insure that litigation did not interfere with data acquisition. Prior to 1994, the USBM compiled summary reports of multiple explosions (Richmond et al., 1983; Dobroski et al., 1996) and disasters (MSHA, 1998). Media stories, trade journal articles, Web sites, company publications and personal communications were used when available. Because there is no central tracking of all property loss occurrences, the list of catastrophes may not be exhaustive and further investigation is needed.

Several of these events are not strictly catastrophes. Three occurred at closed mines, such as the Old Ben No. 26, Beatrice and Blacksville No. 1 catastrophes. Old Ben Mine No. 26 was scheduled to close the day of the fire, so little real loss occurred. These events were not included in the comparison below.

The 2002 Quecreek Mine inundation is an obvious catastrophe with national media attention. All miners escaped or were rescued. Following the inundation, the mine was pumped out, reentered and is in production again. However, at the time of this report, the mine had not yet returned to full production, so not all the information needed for an evaluation was available. All events after 2001 are excluded from this report because of lack of complete data.

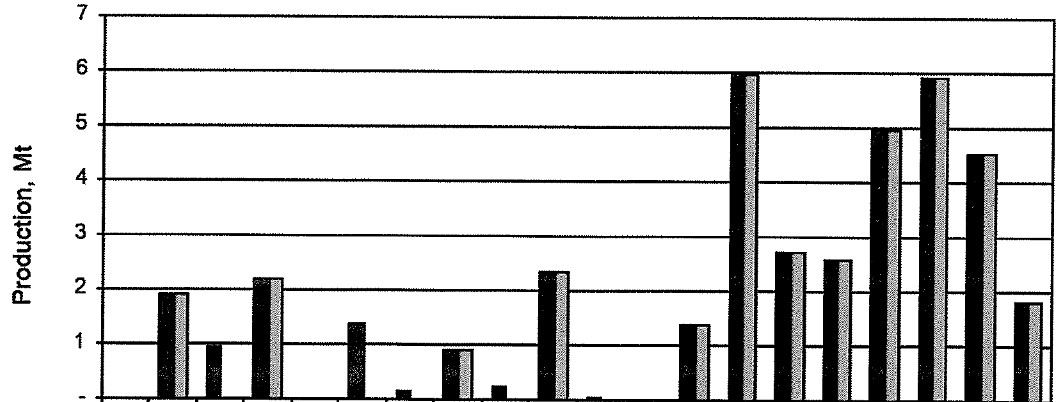
Comparison of mines. Eighteen mines meeting the catastrophe criteria, from 1987 through 2001, were compared to find if they have any distinct similarities or differences. In Fig. 2, the peak production reached before or after the event is shown in the year of the catastrophe. Note the appearance of the graph before and after 1997. The earlier 10-year time period shows an irregular frequency and size of mine involved in the accident, while from 1997 to 2001 there are one or two events per year and they all are in larger mines operating longwalls.

What is considered large for underground mines has changed over time. Figure 3 shows a distribution by production of the 250 largest underground coal mines for 2001 (MSHA Part 50 data). The top 14 mines produced 25 percent of the tonnage and the top 44 mines produced 50 percent out of a population of 769 active mines (mines reporting hours worked). In comparison, in 1994 the top 24 mines produced 25 percent and the top 70 mines produced 50 percent of the total production out of a population of 1,249 active underground coal mines. The median capacity mine size has changed from 1.4 Mt to 2 Mt (1.5 million to 2.2 million st) in seven years for a 5-percent compound annual growth rate. It is assumed that "large" underground coal mines are those that produce more than the median annual tonnage.

However, this does not mean only large mines have catastrophes. Events at smaller mines may not receive as much publicity or are otherwise under reported. Large mines are discussed in more detail below.

FIGURE 2

Peak production by year of catastrophe and mining method (1987-2001).



	1987	1988	1989	1990	1990	1991	1991	1992	1993	1994	1995	1996	1997	1998	1999	1999	2000	2000	2001
■ Annual production, Mt	1.91	0.93	2.19	0.02	1.36	0.17	0.90	0.23	2.33	0.06		1.37	5.97	2.72	2.55	4.94	5.90	4.54	1.80
□ Longwall mine capacity	1.91		2.19				0.90		2.33			1.37	5.97	2.72	2.55	4.94	5.90	4.54	1.80

Table 2 shows the location and seam for the most recent large mine catastrophic events. These seven catastrophes occurred in all U.S. underground coal mining regions. All the mines use the longwall mining method. The Willow Creek Mine had two catastrophes: the first was a fire and the second was an explosion with two fatalities. The explosions at Blue Creek No. 5 Mine resulted in 13 fatalities (which also makes it a disaster).

The fact that all catastrophes during the five-year period are in longwall operations is surprising. Longwall mining has proven to be safer from a ground-control perspective, especially under deeper overburden and it is more productive (in tons per worker day) than room-and-pillar methods. Consequently, most large underground mines with adequate reserves have converted to longwall equipment. However, the causes of these seven catastrophes are fires and explosions — hazards that exist in all underground coal operations.

Recent catastrophe summaries

Galatia Mine: The Galatia Mine was operated by Kerr McGee in Harrisburg, IL, with two longwalls in the 5 and 6 seams. The first heating event, in 1996, stopped production for one week at little loss. The second heating event on April 15, 1997, was detected from rising carbon monoxide levels around the 5 East LW. The crew felt two air blasts, some smoke was detected at a gob monitoring tube and MSHA issued a (103)k order as the mine was evacuated. When the fire was confirmed, water was injected and inerting operations began by the gob boreholes. The mine was never sealed. Mining resumed on the north LW while the fire area was under inert atmosphere. The approved recovery plan allowed the longwall to advance 9 m (30 ft) where it was recovered before the panel was sealed.

Kerr McGee announced that the 1996 production level of 6 Mt/a (6.6 million stpy) was the 1997 target and maximum for the facility. Approximately 1.5 Mt (1.7 million st) of production were deferred or lost in 1997. Employment levels reported to MSHA were stable through the period at about 650 people, and productivity dropped 25 percent for the year, i.e., from 36 t (40 st) per worker day in 1996 to 26 t (29 st) per worker day in 1997. The preliminary pretax cost estimate of the interruption in production and mine recovery is $38 million.

Willow Creek Mine: The Willow Creek Mine was opened in 1996 by Cyprus Plateau Mining Corp., in Price, UT, (a subsidiary of Cyprus Coal; later purchased by RAG America). Its projected capacity was 4.1 Mt/a (4.5 million stpy) and had a capital cost of $147 million to replace the Star Point Mine. Longwall production began nearly one year late in June 1998. Methane and other low flashpoint hydrocarbons were released at higher rates in the gob than expected, resulting in production delays. An explosion and fire occurred on November 25, 1998, near midnight. All miners were evacuated within 45 minutes with no injuries. The mine was sealed the next day.

Recovery was completed and continuous mining (CM) production resumed March 26, 1999. Panel 2 was developed with a functional bleeder and full production resumed in November 1999, one year after sealing. The

FIGURE 3

Production in 2001 by active underground mines.

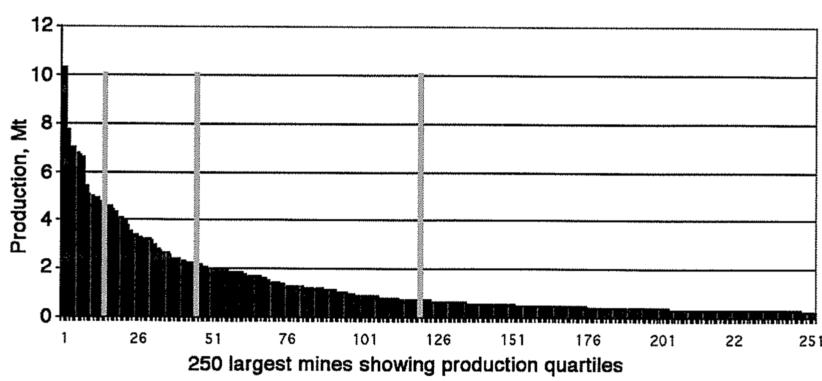


Table 2

Catastrophes by year, state, seam and mining method: 1997 through 2001.

Year	Mine	Event	State	Seam	Mining method
1997	Galatia	Fire	IL	Harrisburg No. 5	Longwall
1998	Willow Creek	Fire	UT	Castle Gate D	Longwall
1999	Sanborn Creek.	Fire	CO	B Seam	Longwall
1999	Loveridge	Fire/explosion	WV	Pittsburgh No. 8	Longwall
2000	West Elk	Fire	CO	B Seam	Longwall
2000	Willow Creek	Explosion	UT	Castle Gate D	Longwall
2001	Blue Ck. No. 5	Explosion	AL	Blue Creek	Longwall

combined workforce was cut by 110 from a total of 372 at Willow Creek and Star Point mines. Some employees were temporarily assigned to the Star Point Mine operating CMs to make up lost production. Only 70 miners were brought back as CM and LW production resumed and Star Point was permanently closed. Comparing the actual tons mined to the expected improving performance at a new mine, approximately 2.3 Mt (2.5 million st) were deferred in 1999 and 1.5 Mt (1.7 million st) of reserves were sterilized by the fire. Additional losses because of not reaching full production as scheduled are unknown. The preliminary pretax cost estimate lost production and mine recovery is $22 million.

On July 31, 2000, four explosions occurred in succession causing two fatalities. The mine was sealed a second time. The longwall panels were flooded to extinguish the fire. Another company reopened the mains in October 2001, but the mine remains idle and may be a total loss.

Sanborn Creek Mine: The Sanborn Creek Mine was operated by Oxbow Mining Co., Somerset, CO, with one longwall. Elevated carbon monoxide levels were detected while the longwall was being prepared to move, and miners were evacuated. An ignition in the bleeder inby the longwall tailgate caused a fire on Jan. 26, 1999, and the mine was sealed within 24 hours. A small explosion was noted on January 28, 1999. Boreholes were drilled to flood the fire area with water. Recovery began April 1, 1999, and rehabilitation began on May 22, 1999. The longwall restarted in November 1999.

Assuming that the annual production level before and after the fire was a normal increase from 1.5 Mt to 2 Mt (1.7 to 2.2 million st), approximately 790 kt (870,000 st) of production were deferred or lost. Employment levels were stable through the period at 169, and productivity held steady in the MSHA reports at about 31 t (34 st) per worker day, presumably because of a layoff of almost four months. The estimated pretax cost of the interruption in production and mine recovery is $8 million.

Loveridge Mine: The idle Loveridge Mine was operated by Consolidation Coal Co. with one longwall in the 8 North set of panels. A fire started on June 21, 1999, after welding/cutting was done while recovering equipment at the mouth of an abandoned panel. The fire progressed into the gob. The mine was sealed and 77 hours later it exploded blowing off the concrete cap on St Leo shaft. It was then sealed again. A later attempt to remotely construct bulkheads was unsuccessful. None of the cementatious pumped seals contacted the roof. Miners reentered the mine on July 24, 2000, and longwall production resumed March 1, 2001, on 8 North 6 Left.

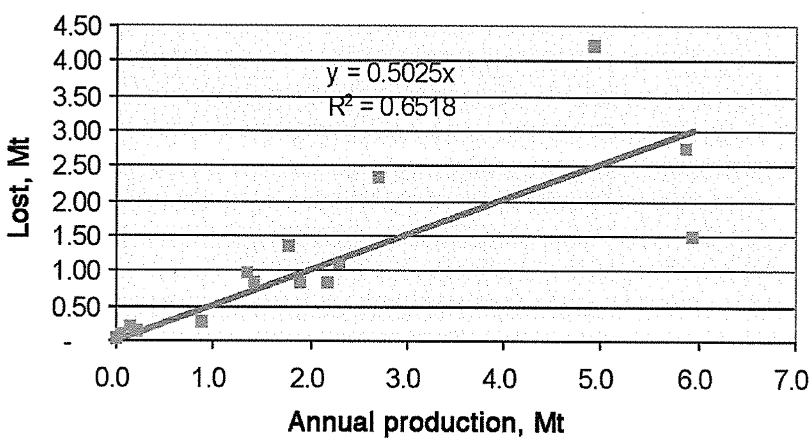
In 1998, Loveridge mined 4.9 Mt (5.4 million st), employed 447 people and achieved 40 t (44 st) per worker day. Because the market was weak until 2001, a 12-month total downtime is assumed, giving an estimated 4.2 Mt (4.6 million st) of deferred production. CONSOL published in its March 24, 1999, S-1 report to the U.S Securities and Exchange Commission (SEC), that the mine had 172 Mt (190 million st) of accessible reserves remaining. The preliminary pretax cost estimate of the interruption in production and mine recovery is $76 million.

West Elk Mine: The West Elk Mine was operated by Mountain Coal Co., a subsidiary of Arch Coal Inc., with a 3.7- to 4.3-m- (12- to 14-ft-) high longwall in the B Seam. Carbon monoxide was detected on Jan. 28, 2000, behind the seals in abandoned panels north of the mains. Remote concrete bulkheads were placed to isolate the fire from the gob and retain water. The fire area was flooded. The longwall was recovered on April 21, 2000, and the mine restarted production on July 12, 2000. The same well service contractor that Loveridge used was successfully building remote seals this time. The operator reported the sealing job cost $4 million to $5 million, plus idle mine expenses (Nyikos and Curtice, 2001).

Assuming that the production level in 1999 was normal at 6.5 Mt/a (7.1 million stpy), approximately 2.5 Mt (2.8 million st) of production were deferred during the first and second quarters. Delays due to subsequent methane problems in the new panels are excluded. Employment levels

FIGURE 4

Catastrophe lost metric tons compared with annual production (mines that returned to production).



were stable through the period at 308, and productivity dropped 50 percent for the year from a two-year average of 76 to 37 t (84 to 41 st) per worker day. The preliminary pretax cost estimate lost production and mine recovery is $50 million.

Blue Creek No. 5 Mine: The No. 5 Mine was operated by Jim Walters Resources (JWR) in the Blue Creek seam with one longwall at an annual production rate of 1.8 Mt (2 million st). This mine is the deepest and one of the gassiest mines in North America. According to JWR the No 5 Mine had at most five years of reserves left.

A roof fall on a longwall development battery charging station is believed to have caused an ignition and subsequent explosions on September 23, 2001. A second explosion resulted in 13 fatalities and forced the emergency sealing and partial flooding of the mine. The mine was reentered to build seals and recover the longwall on October 2, 2002. Limited development resumed in April 2002, and the remaining CMs resumed in the third quarter of 2002.

Approximately 15 months or 1.3 Mt (1.4 million st) of production were deferred or lost following the disaster through December 2002. Employment levels dropped 50 percent at No. 5 Mine in the fourth quarter from about 390 people. Productivity deteriorated from 16 t (18 st) per worker day in 2000 to an average of 6 t (6.6 st) per worker day in 2002. Some production crews were shifted to JWR #3 and #7 mines, where production was increased. The estimated pretax cost of the interruption in production and mine recovery is $43 million.

Correlations

Although the data and costs are incomplete, several patterns seem to occur in the data since 1987. First, there appears to be a weak correlation between the annual production level and the number of tons lost due to the catastrophe. Because most operations are aggressively trying to return to normal production, it seems reasonable that downtime and the related production losses would be minimized. In fact about 50 percent of the annual production will be lost during the recovery, in the range of 20 percent to 100 percent, as shown in Fig. 4. Only mines that returned to production are used in the chart.

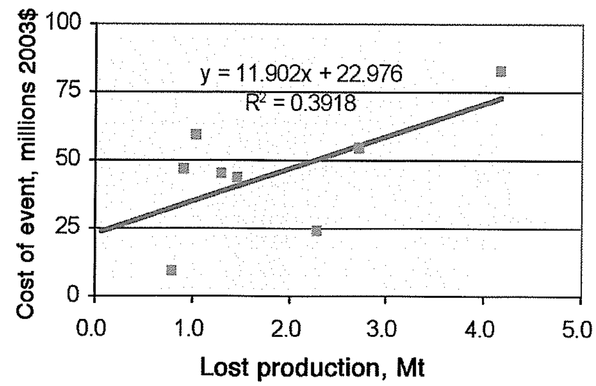
There is sufficient public data from SEC filings, MSHA data and news articles to estimate the cost of 10 of the 18 catastrophes. If the company disclosed the loss value, it is used. Otherwise lost revenue from fewer tons mined and the increased cost of emergency response activities are used for the preliminary estimate of the total catastrophe cost. Recognizing that this is a gross oversimplification, a weak relationship can be demonstrated between cost and the number of lost tons. In Fig. 5, the weak linear correlation indicates that large mines that have catastrophes incur on average $23 million in fixed costs plus about $12 per lost metric ton of production. Any catastrophic event should burden the company even if no production is lost. The calculated intercept seems higher that warranted. Additional work is needed to add small mine costs to the database.

Conclusion

Despite the best efforts of management, agencies and miners, catastrophes happen nearly every year. Published data suggests that large underground coal mines are more susceptible to fires and explosions than small mines. On average, when a catastrophe occurs, mine production drops by 50 percent, and the rehabilitation efforts can cost as much as $23 million plus $12 per incremental lost metric ton.

FIGURE 5

Catastrophe cost vs. lost production (large mines and preliminary estimates).



To put this into perspective, at a large mine producing 5 Mt/a (5.5 million stpy), the cost of a catastrophe amounts to 2.5 Mt (2.8 million st) of lost production plus $53 million in unbudgeted expense.

This paper identifies a preliminary order-of-magnitude cost of large underground coal mine catastrophes. Companies can use this cost as partial justification for allocating their investment dollars for projects that prevent or mitigate catastrophes. Budgets can be allocated based on management experience or when costs and benefits are known, using standard economic analysis and risk reduction methods. It is the author's opinion that it is more likely that safety projects that base their savings on real offsetting costs will be competitive with other capital needs. ■

References

Dobroski, H., Jr., Stephan, C.R., and Conti, R.S., 1996, "Historical Summary of Coal Mine Explosions in the United States, 1981-1994," U.S. Bureau of Mines, Information Circular 9440.

Mine Safety and Health Administration, 1998, "Historical Summary of Mine Disasters in the United States, Vols. I and II."

Mine Safety and Health Administration, 2002a, Mission Statement, http://www.msha.gov/MSHAINFO/MISSION.HTM, accessed Sept. 30, 2002.

Mine Safety and Health Administration, 2002b, "Mining Industry Accident, Injuries, Employment, and Production Data, Historical Statistics – 1931 through 2001," http://www.msha.gov/ACCINJ/accinj.htm. accessed Sept. 23, 2002.

Mine Safety and Health Administration, 2003, MSHA's Data Retrieval System as Developed by PEIR, http://www.msha.gov/drs/drshome.htm, accessed Feb. 20, 2003.

Nyikos, C.M., and Curtice, R., 2001, "Successful Application of Remote Seals to Extinguish a Mine Fire," SME/PCMIA Off-the-Record Meeting, Pittsburgh, PA.

Richmond, J.K., et al., 1983, "Historical Summary of Coal Mine Explosions in the United States, 1959-1981," U.S. Bureau of Mines, Information Circular 8909.