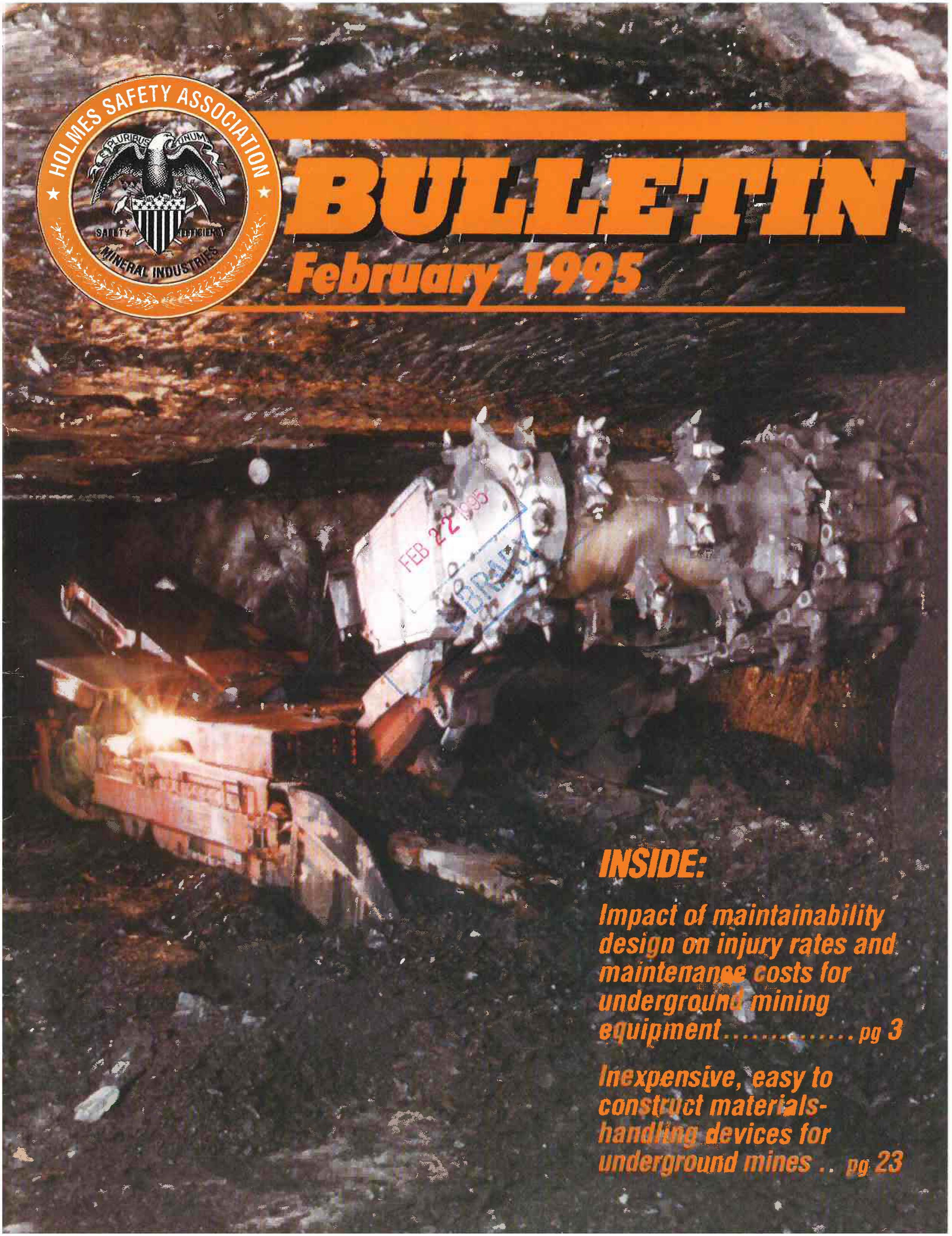

HOLMES SAFETY ASSOCIATION

BULLETIN

February 1995

INSIDE:

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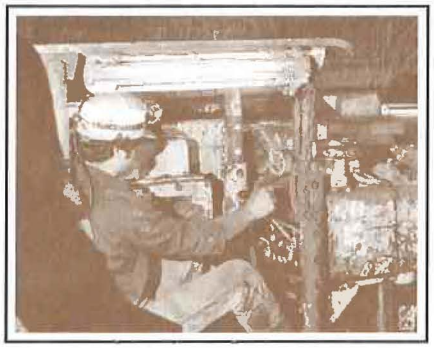
*Cover photo of the Joy 14CM10 continuous miner courtesy of **Joy Technologies Inc.** We welcome any materials that you submit to the Holmes Safety Association Bulletin. We especially need color photographs (8" x 10" or larger—color negatives are acceptable) for our covers. We cannot guarantee that they will be published, but if they are, we will list the contributor(s).*

contents



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KEEP US IN CIRCULATION

The Holmes Safety Association Bulletin contains safety articles on a variety of subjects: fatal accident abstracts, studies, posters, and other health and safety-related topics. This information is provided free of charge and is designed to assist in presentations to groups of mine and plant workers during on-the-job safety meetings.

Holmes Safety Association monthly safety topic

Fatal machinery accident

GENERAL INFORMATION: A 55-year old drill helper, with 24 years of experience, was fatally injured when the pick-up truck he was working on rolled forward and pinned him under the rear axle and shock absorber.

The operation is a surface coal mine producing an average of 150 tons per day. The mine operates 2 shifts per day, 5 days per week, and employs a total of 12 workers.

DESCRIPTION OF ACCIDENT: About 6:20 AM, on the day of the accident, the mine foreman began the on-shift inspection of the 010-0 pit. Operations, which started at about 6:30 AM, included stripping overburden with a dragline and loading coal trucks with a diesel powered shovel. The mine foreman completed the on-shift inspection and began performing routine supervisory duties on the job site. At about 6:40 AM, the drill operator and the victim, a drill helper, arrived on mine property. They proceeded to their work site, which was located on a bench above the pit. The drill operator stated, subsequent to the accident, that as he and the victim were driving to work on the day of the accident, they heard slapping noises in the rear-end of the pick-up truck. They determined that the noise was coming from the rear drive shaft and that the transmission yoke needed to be tightened.

The drill operator conducted a pre-operational equipment check on the truck-mounted Davey drill and started the drill engines. Drilling operations began at about 7:20 AM.

At about 10:30 AM, the mine foreman began operating a dozer adjacent to the drill to extend the drill bench. Work progressed in this area without incident and 14 holes were drilled from 17-22 feet in depth. At about 12:00 PM, as the drill operator was drilling the 14th hole, he observed the victim working under a pick-up truck located adjacent to the drill. The truck was a Ford F-150 4-wheel drive, pick-up truck and was used by the drill operator and the victim for travel on the job site.

The drill operator completed drilling the 14th hole and began looking for the victim, who routinely moved the drill truck to the next drill-hole location. The drill operator found the victim pinned under the rear axle of the F-150 pick-up truck which had drifted forward about 5 feet. At about 12:20 PM, the victim was found lying on his back under the F-150 pick-up truck. The back of the victim's neck was pinned under the rear axle on the driver's side of the truck. The victim's chin was forced into his chest, and his right shoulder was pinned under the rear driver's side shock absorber. The distance from the ground to the bottom of the shock absorber measured 7 inches. The distance from the ground to the bottom of the axle measured 10 inches.

The drill operator immediately flagged the mine foreman who ran to a service area about 100 yards away and instructed a mecnanic to drive the boom-truck to the accident site. The hoist on the boom-truck was attached to the rear bumper of the pick-up truck and used to lift the truck off of the victim. The mine foreman used a mobile telephone to call for an ambulance. The victim was removed from under the pickup truck and the dragline operator administered first aid. The drill helper was unconscious but continued breathing without assistance. The ambulance transported the victim to the hospital. The victim sustained a fractured cervical vertebrae and multiple injuries to the thoracic region. He died more than seven months later as a consequence of his initial injuries.

Subsequent investigation revealed that one of the two U-clamps that secured the rear drive shaft to the yoke connected to the rear differential was found on the ground under the rear bumper of the pick-up truck. Two wrenches were also at this location. The other U-clamp was in place but both nuts had been removed. The horizontal distance from the in-place U-clamp to the U-clamp on the ground measured 60 inches, which aproximates the distance that the pickup truck drifted forward.

The transmission of the truck was in the "park" position and the parking brake had not been set. Additionally, the vehicle wheels had not been blocked against motion. When the drive shaft was disconnected from the rear differential, the gear resistance was removed which allowed the truck to move.

CONCLUSION: The accident occurred because the F-150 pick-up truck was not blocked against motion while repairs were being performed.

Impact of maintainability design on injury rates and maintenance costs for underground mining equipment

By Richard L. Unger[1] and Kirk Conway[2]

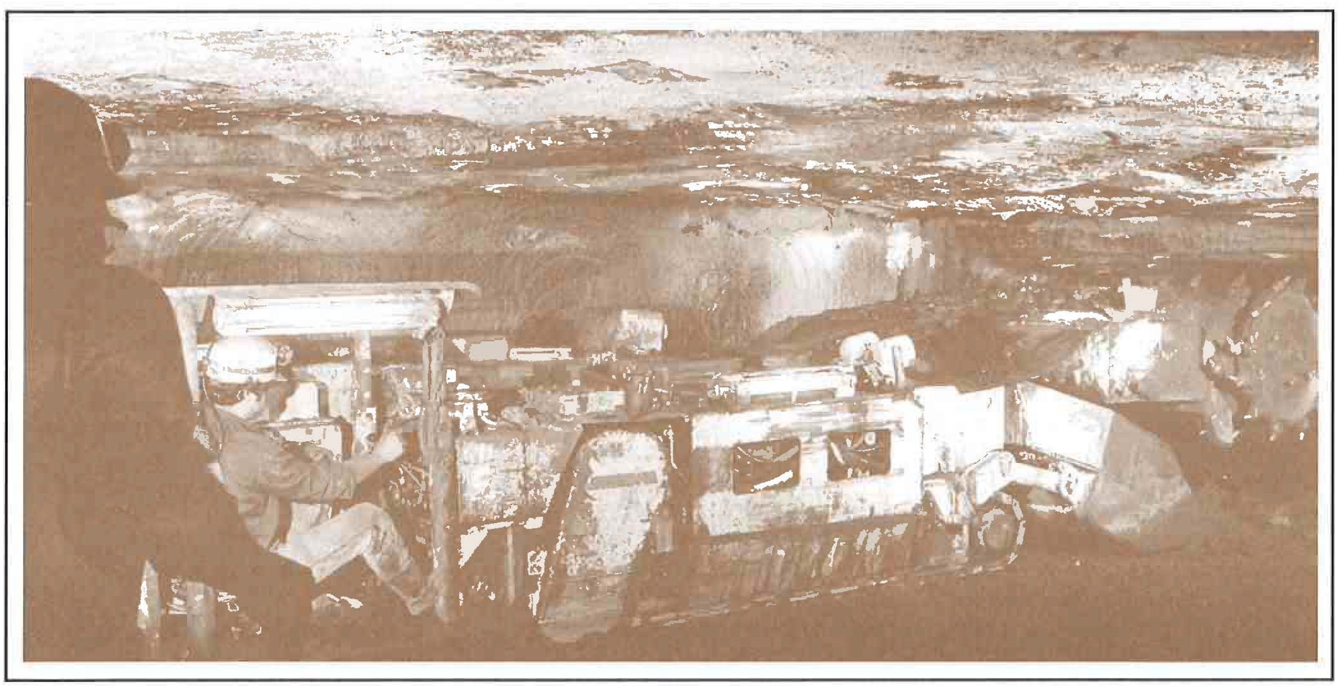
Abstract

In the U.S. underground coal mining industry, maintenance of the mining equipment accounts for over **30%** of the lost-time injuries. In addition, the steadily increasing cost of maintaining this equipment has focused attention on the need to find ways to contain or reduce these expenses. To obtain a better understanding of why maintenance injuries occur, the U.S. Bureau of Mines (USBM) has conducted a research project to analyze the design of underground mining equipment with respect to ease of maintenance and maintainer safety. The objective was to identify design factors contributing to these high injury rates and maintenance costs. The work included a review of relevant maintainability design literature, analysis of maintenance-related accident data, field reviews of equipment design in underground operating environments, and interviews with mine maintenance personnel and equipment manufacturers. Based on the findings, a set of maintainability design recommendations have been prepared and published. The documents include basic maintainability engineering information for equipment designers, as well as a **buyers' guide** to assist purchasers of mining machinery in evaluating the maintainability of equipment.

Introduction

In the 1950s underground coal mining equipment consisted of relatively simple but rugged machines powered by electric motors and hydraulics. These machines were used to cut, dig, load, and transport coal from the mine face to the surface. The machines were maintained by mine maintenance personnel armed with a basic knowledge of hydraulics, electricity, and mechanical design. These maintainers were expected to repair all of the equipment at the mine site using only simple hand tools.

Over the years, the basic mining machine has been transformed into powerful, complex mining systems. To boost productivity, the horsepower and size of the original machines have been increased. To enhance unit productivity, machines were designed to perform multiple functions. To increase throughput, continuous miners, longwall and shortwall systems and continuous haulage were introduced. To reduce injuries,



numerous safety features have been added to the machines. To protect the miners' health, environmental control systems have been tacked on.

With few exceptions, however, little improvement in the basic design of equipment for maintainability has been made. In many cases, equipment maintainability has been sharply decreased. Many of the above design changes were achieved by simply modifying existing machine designs. On certain mining machines, sharp reductions in maintainability and, consequently, maintainer safety were experienced as a result of added-on safety and environmental systems designed only with the machine operator in mind.

Even with all of the above changes, the maintainer is still expected to service and repair these ever more complex machines. This must be accomplished in an operational setting providing little in the way of new maintenance tools, procedures, automatic test equipment, or other technology-based maintenance aids and in an environment that usually lacks proper lighting and clearances. All in all, there has been little concern directed at the well being of the maintainer. It is no wonder that equipment maintenance has traditionally accounted for one-third of all lost-time injuries in underground mines. This injury rate persists in spite of concerted efforts on the part of mine management to minimize accidents, the Mine Safety and Health Administration's (MSHA) efforts to enforce health and safety rules, and USBM efforts to conduct safety research.

In addition to the safety of the maintainer, another area of concern has been the escalating cost of mining equipment maintenance. Underground equipment maintenance typically accounts for 25% to 35% of the total mine operating costs. These costs have continued to rise over the years despite efforts to contain them. Mine operators have attempted to gain control of these steadily increasing costs through (1) optimization of scheduled maintenance operations, (2) reductions in maintenance staff, (3) reduction and better control of spare parts inventories, (4) contracting for maintenance support, and (5) deferring nonessential maintenance.

Unfortunately, little attention has been focused on the design of the mining machine itself with respect to maintenance costs. The cost of maintaining a machine is, after all, a direct function of:

1. Maintenance frequency and failure interval for the machine and major components.
2. Time and labor required to complete unscheduled maintenance actions.
3. Time and labor required to complete routine maintenance tasks.

A review of current mining equipment design suggests that considerable improvements in safety, as well as substantial cost savings, could be achieved with relatively simple design improvements. For example, by relocating difficult to access, but frequently replaced, hydraulic valves and hoses on certain roof bolters, this 1-hr. plus removal and replacement (R/R) task is reduced to a 5-min. operation. Improved component accessibility and increased ease of R/R tasks reduces the maintainer's risk of injury. Numerous other maintenance improvements could be realized with minor design changes on new or existing equipment. As part of its program to enhance the safety of mine workers, the USBM completed a project entitled "Assessment of the Maintainability Design of Underground Mobile Mining Equipment," which was performed by VRC Corp. The final report was published in 1988 (*1*).[3] Other papers published by the USBM based on this work are listed in the references (2-6*)*.

Design-induced maintainability problems

The USBM analyzed underground coal mining equipment with respect to design for maintenance and maintenance personnel safety. A maintainability design review and human factors analysis of equipment was completed at nine operational coal mines. Mining machines in large and small mines operating in high- and low-seam coal were surveyed. Conventional, continuous, and longwall operations were included. Shuttle cars, scoops, roof bolters, continuous miners, longwall equipment, undercut machines, face drills, utility vehicles, and personnel carriers were reviewed. The survey identified the following design limitations that directly impacted maintenance time, cost, and personnel safety.

1. Accessibility problems: Inability of maintenance personnel to access failed or suspected components to inspect or remove and replace them. Accessibility problems resulted from:
   a. Inadequate access opening size.
   b. Poor layout of components in a compartment, necessitating R/R of nonaffected parts to access the failed units.
   c. Inability to access mounting bolts or connectors or to use required tools.
   d. Installing components in inaccessible interior cavities and running cables inside the frame or chassis where they cannot be reached.
   e. Locating fasteners and mechanical interfaces where they physically cannot be reached unless the machine is partially or completely disassembled.
2. Inadequate component-handling capability and component-machine interface design.
3. Inadequate design for routine maintenance: Inability to quickly remove and replace leaking hydraulic hoses and water lines, to remove and replace failed hydraulic valves, to perform routine lubrication and to perform visual and physical inspections.
4. Inadequate fault isolation capability:
   a. Difficulty determining the precise cause and location of a failure.

Table 1.—Maintenance-related injuries in underground coal mining industry in 1981 (8)

Code	Type of accident	Mine maintenance		Machine maintenance	
		Number injuries	% total	Number injuries	% total
1	Stationary object	185	5.6	272	8.9
2	Moving object	2	Neg.	6	Neg.
3	Concussions	0	0	1	Neg.
4	Falling object	611	18.4	511	16.8
5	Flying object	62	1.9	62	2.0
6	Rolling object	61	1.9	18	Neg.
8	Struck by, NEC	231	6.9	265	8.7
17	Fall, walkway	8	Neg.	7	Neg.
18	Fall on object	3	Neg.	5	Neg.
21	Caught, moving-stationary	169	5.1	190	6.3
22	Caught, moving objects	6	Neg.	9	Neg.
23	Caught, collapse	2	Neg.	0	0
24	Caught, NEC	261	7.9	292	9.6
25	Rub, abrade	3	Neg.	1	Neg.
26	Bodily reaction NEC	2	Neg.	2	Neg.
27	Overexertion, lifting	1,132	34.1	793	26.1
28	Overexertion, push-pull	78	2.3	147	4.8
29	Overexertion, welding	112	3.4	13	Neg.
30	Overexertion, NEC	360	10.8	37.3	12.3
33	Contact hot object	3	Neg.	26	Neg.
36	Inhale noxious fumes	1	Neg.	8	Neg.
38	Absorb noxious fluid	26	Neg.	25	Neg.
39	Flash burns, electrical	0	0	2	Neg.
42	NEC	1	Neg.	2	Neg.
43	Insufficient data	2	Neg.	6	Neg.
	Total	3,322	NAp	3,036	NAp

NEC—Not elsewhere classified Neg.—Negligible NAp—Not applicable

b. Accessing components to perform visual inspections and to perform checks.

c. Limited or no designed-in fault diagnostic capabilities.

d. Lack of effective failure indices.

5. Increased maintenance burden resulting from poor design and placement of components, subjecting them to impact damage.

6. Poor design with respect to resources available: Need for maintenance personnel to "jerry-rig" tools, to handle 45-kg (100-lb) to 450-kg (1,000-lb) components, and to substitute brute human strength to overcome poor component interface design or lack of requisite tools.

7. Equipment complexity resulting from poor layout: Crowding of components into compartments without regard to the need to maintain or replace individual items, overlaying hoses and power cables, and making R/R needlessly difficult.

8. Design conveniences: Multiplying the number of valves, connectors, and other high-frequency replacement components as a design convenience.

Equipment design and maintenance safety

A summary of maintenance-related accident statistics in the underground coal mining industry in 1981 is presented in Table 1. A majority of the maintenance injuries involve strains-sprains, low back injuries, and crushing injuries. These injuries typically occur during R/R of components weighing from 16 kg (35 lb) to over 450 kg (1,000 lb) (*7*).

In many instances, two or more workers with crowbars, 4 by 4s, or other makeshift tools must manually remove the component from the mining machine or lift it into place so that it can be secured. In most cases, no provisions have been made during component-machine interface design to provide for mechanical assist in the R/R process (*7*). A review of mining equipment design suggests that, in many cases, this designed-in assistance could be readily achieved. For example, adding guide pins to hold components while they are being bolted or unbolted. If incorporated, the guide pins would minimize personnel exposure to the types of injuries identified in Table 1. They would also expedite the R/R process itself.

One of the objectives of maintainability engineering is to minimize the need to manually handle components. With proper design and engineering, all components should be provided with mechanical means to interface them with the machine itself. With optimized maintenance design, it is reasonable to assume a substantial reduction in maintenance-related accidents.

Human error and design for maintenance

So-called human error is a problem that must be addressed in design as well as during operation and maintenance of complex equipment (*9-13*). Errors may occur in operating mining machines, performing maintenance tasks, or in making management decisions. Fortunately, most human errors result in limited negative consequences (e.g., lost time and production waste). In many cases, the error ends up costing the party involved time or money. Unfortunately, in a smaller percentage of cases, people are injured or killed and equipment destroyed.

Dramatic evidence of the impact of a maintenance error was the 1979 American Airlines DC10 crash that killed 272 people. This crash was directly attributed to maintenance error. The probability of recurrence of this type of error was reduced

Table 2.—Representative maintenance task error rates (13)

Action	Object	Error description	Error rate[1]
Observe	Chart	Improper switch action	1,128
Read	Gage	Incorrectly read	5,000
Read	Instruction	Procedural error	64,500
Connect	Hose	Improperly connected	4,700
Torque	Fluid lines	Incorrectly torqued	104
Tighten	Nuts, bolts	Not tightened	4,800
Install	Nuts, bolts	Not installed	600
Install	O-rings	Improperly installed	66,700
Solder	Connection	Improper solder joint	6,460
Assemble	Connector	Bent pins	1,500
Assemble	Connector	Missing part	1,000
Close	Valve	Not closed properly	1,800
Adjust	Linkage	Improperly adjusted	16,700
Install	Orifice	Incorrect size installed	5,000
Machine	Valve	Wrong size drill and tap	2,083

[1]Per million operations.

substantially by means of a simple component design change.

Operationally induced errors

What does human error have to do with mining equipment maintainability? In an interesting review of the subject, researchers report that a significant percentage of all operational equipment failures are human error induced (*11-12*). In fact, human error accounted for:

1. Fifty to 70 percent of all electronics failures.
2. Sixty to 70 percent of all aircraft and missile failures.
3. Twenty to 30 percent of all mechanical failures.

Many of these are operator induced errors resulting in machine damage or prolonged down time. Maintenance requirements could be reduced by designing out these types of errors. Other errors are made by maintenance personnel while performing maintenance tasks (*13*).

Maintenance-induced error rates

The above study also reports that 20% to 25% of all failures are directly traceable to maintenance errors. A separate study found 25% of all maintenance problems to be human error induced during maintenance operations (*11*). Another study reports human error rates for specific types of maintenance tasks. These data, summarized in Table 2, were derived from an earlier study (*13*). The values are indicative of the error rates found in many industrial and military settings.

Another maintenance study reports that the average human reliability in adjusting or aligning tasks is 0.0987 (*13*). This value suggests that out of every 1,000 attempts to adjust a component, you can expect 13 errors. Many of these errors could be eliminated through improved design of the component-machine interface. Although not directly applicable to underground mining operations, the above error rates are suggestive of the types, frequencies, and sources of human errors in maintenance. It is reasonable to assume that similar error-rate patterns could be expected in mine maintenance operations.

Table 3.—Typical mining equipment maintenance errors

Frequency	Type of error
I	Install incorrect component
S	Omitting a component. Parts installed backwards. Failure to properly torque. Failure to align, check, or calibrate. Use of incorrect fluids, lubricants, or greases.
O	Reassemble error. Failure to seal or close. Error resulting from failure to complete task due to shift change. Failure to detect while inspecting. Failure to lubricate. Failure to act on indicators of problems due to workload, priorities, or time constraints. Failure to follow prescribed instructions.

I Infrequent (less than once per year).
S Somewhat frequently (2 to 5 times per year).
O Often (over 5 times per year).

Errors in underground mining equipment maintenance

Representative underground mining maintenance errors have been identified, with the major types summarized in Table 3. It was also possible to identify a number of factors contributing to maintenance-related human error. These include:

1. Confined workspaces: Crowded equipment bays.
2. Inability to make visual inspections.
3. Inaccessible components:
   a. Lube points that could not be reached.
   b. Adjustment points that are hard to access.
   c. Major components that could not be reached.
4. Poor layout of components in a compartment.
5. Inappropriate placement of components on machine.
6. Poor or no provision for hose and cable management.
7. Lack of troubleshooting guides and tools.
8. Lack of positive component installation guide pins and other installation controls.

9. Insufficient task inspection and check-out time.
10. Cumbersome or inadequate manuals.
11. Excessive weight of components being manually handled.

Listed below are several engineering design improvements that reduce maintenance errors:

1. Improved component-machine interface:
   a. Design interface so that the component can only be installed correctly (e.g., irregular bolt pattern).
   b. Provide mounting pins and other devices to support a component while it is being bolted or unbolted.
2. Improved fault isolation design:
   a. Designate test points and procedures.
   b. Provide built-in test capability.
   c. Clearly indicate direction of fault.
3. Improved indicators, warning devices, and readouts to minimize human decisionmaking.
4. Use of operational interlocks so that subsystems cannot be activated if they are incorrectly assembled-installed.
5. Use of positive decision guides to minimize human guesswork:
   a. Arrows to indicate direction of flow.
   b. Correct type of fluids or lubricants.
   c. Correct hydraulic pressures.
6. Design to facilitate detection of errors:
   a. Locate connections on front of component to facilitate visual inspections.
   b. Lay equipment out in a logical flow sequence.

If maintainer-induced errors could be reduced by 50%, overall equipment availability would be increased by more than 10%. These reductions can be achieved through improved design.

Maintenance safety costs

Maintenance operations account for a significant percentage of all coal mining accidents and injuries. MSHA accident statistics for 1984 suggest that maintenance-related injuries account for 33% of all lost-time accidents (*14*). These accidents impact mine operating costs in the form of decreased productivity, increased benefits costs, and increased insurance rates.

Many injury accidents can be directly traced to equipment design in this and other studies (*6*). Inadequate accessibility, lack of means to lift and maneuver heavy components, inability to visually observe the maintenance task being performed, inadequate maintenance safeguards, and other design-induced problems account for a significant percentage of maintenance accidents. Improved accessibility, enhanced component-machine interface, and simplified maintenance procedures could have a positive impact on these statistics. Improved maintenance safety will reduce maintenance as well as overall operating costs.

Cost of mining equipment maintenance

Reliable maintenance cost data are not currently available across the underground coal mining industry, although several industry estimates are available. These estimates, however, vary substantially from source to source.

Informal data gathered over the past several years reveal that equipment maintenance costs range from 20% to over 35% of total mine operating costs. Actual values varied based on the size and type of mine, mining technology employed, management attitude toward maintenance, and other factors.

Factors contributing to maintenance costs

The current review of mine maintenance operations suggested that the following factors contribute to equipment maintenance costs:

1. Management attitude towards maintenance: Attitudes range from "when it breaks—fix it" to strong top management support for professionally planned and implemented preventive maintenance (PM) programs geared to reducing unscheduled equipment down time and to controlling maintenance costs.
2. Skill of maintenance management personnel: The skills required to organize and manage an effective mine maintenance program differ from the skills required to perform "hands on" maintenance of mining equipment. Poor maintenance management contributes to increased costs.
3. Maintenance training and experience: Poor maintenance skills on the part of maintainers resulting from inadequate training; lack of job performance aids, manuals and guides; and complexity of maintenance tasks.
4. Maintenance environment: It is an entirely different task to maintain a continuous miner in a 91-cm (36-in) coal seam than it is to maintain one in a well-equipped standing height underground repair shop.
5. Age of equipment: Older equipment tends to be smaller and inherently simpler in design. As a result, older machines are somewhat simpler to maintain. Newer equipment tends to be larger, more complex, and overlaid with numerous "add-on" systems and components, making accessibility and the basic maintenance process more difficult.
6. Maintenance errors: Reliable data are not available, but most maintenance personnel interviewed informally concede that maintenance errors contribute substantially to overall maintenance costs. Removing and replacing nonfailed items, troubleshooting one system too long, not replacing suspected components during a previous maintenance opportunity, failing to install or repair a component correctly, failing to test a component prior to reassembly, and related errors account for an estimated 10% to 25% of all maintenance time.
7. Design of equipment itself: Certain makes and models of mining equipment are designed to facilitate maintenance and repair, while the basic design of other models hinder maintenance actions.

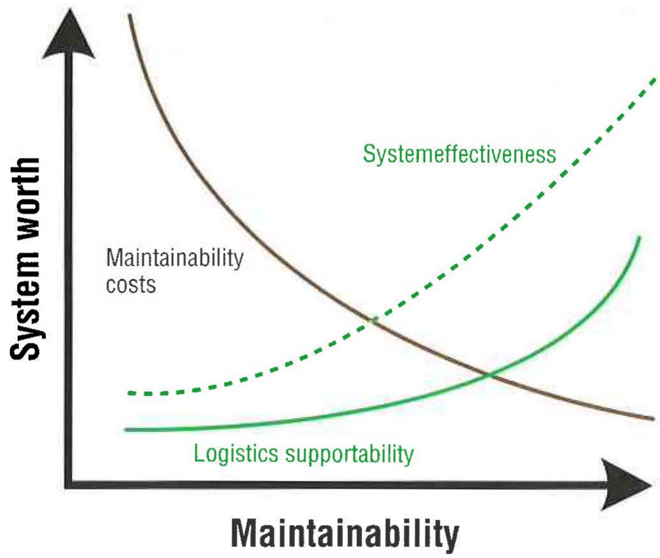


Figure 1.—System worth versus maintainability (13).

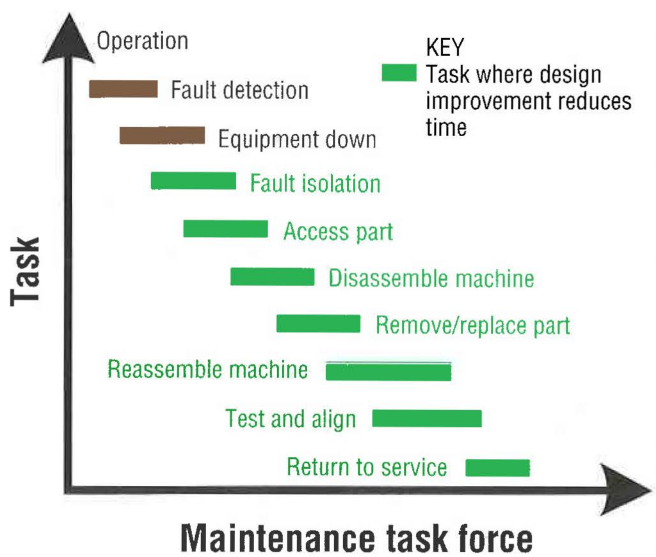


Figure 2.—Sample maintenance task sequence.

8. Regulatory compliance: Safety and environmental control devices required for regulatory compliance add to the complexity and increase maintenance costs.

Cost of design for maintainability

The value or worth of any machine resides in its ability to generate a return on investment. If a machine has an initial cost of "Y" dollars, it must produce "Y plus" dollars of coal to have a positive worth or value. On this assumption, it is possible to illustrate the cost savings derived from improved design for maintainability using simple economic models.

There are many economic models that can be used to compute the worth of equipment. For this discussion, a simplified model will suffice. Figure 1 presents an overview of this model. (Readers interested in a more comprehensive treatment are referred to references 8, 15, 16, and 17.) The following model suggests that the worth **(W)** of a piece of mining equipment can be defined as:

$$W = I + C + M - P,$$

where:
I = initial purchase price of machine,
C = cost per hour to operate machine,
M = maintenance costs per hour of operation,
and **P** = production value per hour of operation.

The initial purchase price of the piece of equipment is fixed or "inelastic." It is set at the time of purchase. The price is simply amortized per hour over the useful life of the machine. Of course, the more hours of production it sees, the lower the amortized cost per hour.

The cost per hour to operate the machine is relatively fixed or "inelastic" and composed of the following cost elements:
1. Labor costs for the machine operator(s), support personnel, and immediate production supervision.
2. General overhead costs, which include insurance, utilities, royalties, brokerage, and related costs.
3. Cost of mining supplies and materials.
4. Other management and administrative costs.

The cost to maintain consists of the following cost elements, some of which are fixed and some of which are relatively "elastic":
1. Labor costs for maintenance personnel.
2. Cost of spares, replacement parts, and supplies.
3. Loss of production during maintenance.
4. Cost per hour of idled machine operators.
5. Other maintenance-related costs.

The costs of replacement parts and maintenance supplies are also relatively inelastic. Certain savings can be realized with careful buying. The cost of labor and other overhead items, on the other hand, are a function of the duration of repair time for unscheduled corrective maintenance **(CM)** actions.

More importantly, a reduction in repair time for downed equipment contributes positively to the overall worth equation by increasing the time available for production. Thus, decreased time to repair not only reduces direct maintenance costs, but also increases the production per hour, thereby offsetting other costs. If we look at the maintenance process again, we observe many points at which time can be saved through improved design for maintenance (Fig. 2). Several of these points include:
1. Prediction of pending failures to facilitate PM scheduling.
2. Decreased fault isolation time.
3. Reduced component access time.
4. Decreased inspection and diagnosis time.

5. Diminished component R/R time.
6. Reduced test and alignment time.

A review of underground maintenance task completion times at two large mining operations revealed that the time required to change hydraulic hoses on continuous miners and shuttle cars ranged from 15 min. to over 3 hrs. The estimated average time for a failed hydraulic hose R/R was over 35 min. Examination of these machines revealed that the time differences were directly linked to accessibility of the hose connectors. In several cases, two or more nonfailed components had to be removed to access a failed hose connection.

By relocating several components or rerouting hoses, maintenance personnel could directly access over 90% of all hydraulic line connections on the surveyed machines. This would have reduced the average hydraulic line R/R time to well under 15 min. per replacement.

If a maintainability design standard for new or rebuilt machines specified that all hydraulic hoses had to be removed or replaced in less than 15 min., the average repair time for this task could be reduced 50%. Similar performance criteria could be developed for other maintenance tasks. The result would be significant reductions in all maintenance task completion times.

Evidence from other civilian and military research efforts suggest that PM and CM task time reductions of from 40% up to 70% are achievable with planned maintainability design efforts (*15-16*).

Productivity

Productivity represents the other side of the maintainability issue. Productivity is a function of the machine producing coal. Hence, it is directly impacted by the speed and ease with which the mining machine can be repaired and returned to service. The more rapidly a machine can be returned to production, the more productive it will be.

Productivity is expressed in terms of the units (of coal) produced by a machine per unit of time. The greater the number of hours the machine is available to produce coal, the more productive it is going to be. For example, suppose that a continuous miner has a rated production capacity of 907 kg/h (100 st/h). Further, suppose that the same miner requires an average of:

1. One hour of PM per shift, and
2. One hour of CM per shift.

Assume that the mine operates the equipment during two production shifts per day for 300 d/yr. Hence:

(300 h PM + 300 h CM) x 2 shifts = 1,200 h/yr.

If the CM and PM time could be reduced by 50%, this would result in the following increase in productivity:

(1,200 CM and **PM h/y) x 0.5 = 600 h/yr savings**

600 h/yr x 90,000 kg/h (100 st/h) = **54 million kg/yr** (60,000 st/yr) per machine increase.

If the mine were operating eight miners, this 54 million kg/yr (60,000 st/yr) per machine increase would be the equivalent of adding another miner with no additional increase in cost.

54 million kg/yr (60,000 st/yr) **x 8 miners = 432 million kg** (480,000 st) annual increase.

Actual analysis of the design of three different continuous mining machines during this project suggested that productivity improvements exceeding the above example could be achieved with relatively simple redesign efforts.

Conclusions

The following conclusions were derived from this study of maintainability in the underground mining industry:

1. There is little evidence of the systematic application of maintainability design principles, concepts, or criteria to the design of operational underground coal mining equipment.
2. Similarly, there is little evidence of systematic application of human factors engineering principles, concepts, or criteria being applied to the design of this equipment with respect to maintenance.
3. Reduced task completion times and fewer maintenance problems were reported for the 10 most frequently performed maintenance tasks on older and smaller machines than for newer more complex equipment. This appears to be the result of simpler design on the older equipment.
4. Increased task complexity and completion times were generally reported for the newer, larger mining machines. This appears to be the result of increased design complexity, larger and heavier components to be handled, overlaying of safety and environmental control systems over the basic machine design, and inadequate accessibility to components.
5. For certain machines, heavy maintenance tasks could be performed on the surface or in high roof underground shops equipped with requisite lifting devices. The same maintenance tasks were extremely difficult, time consuming, and risky to perform at the mine face, where they often have to be completed.
6. With the exception of machines produced by 1 small mining equipment manufacturer, maintenance task completion times for the 10 most frequently performed maintenance tasks could be reduced from 10% to 30% or more with relatively simple design improvements.
7. Application of accepted human engineering design standards and criteria could substantially reduce maintenance risk. Over one-third of the reviewed maintenance lost-time injuries were traceable to equipment design deficiencies. Estimates of actual maintenance risk reduction resulting from redesign of the equipment could not be derived from the data.

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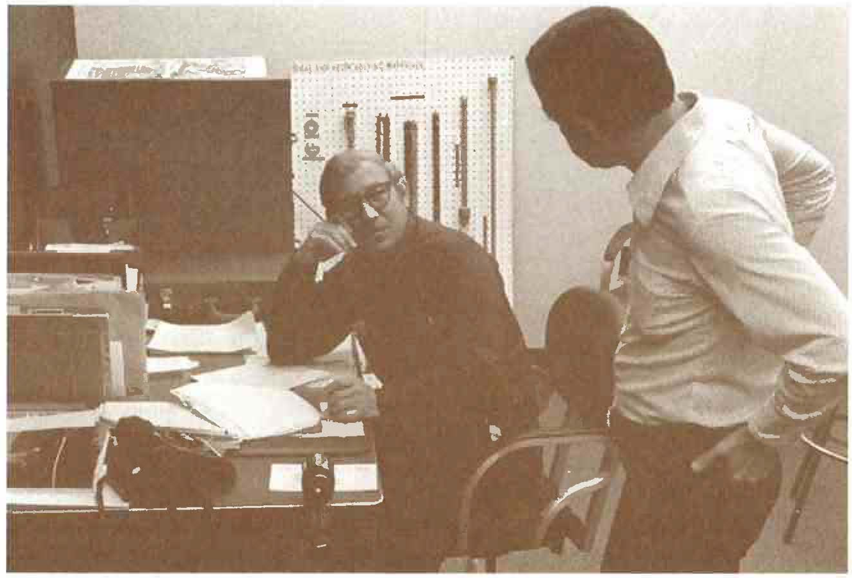


Appendix—— Maintainability design checklist

This appendix presents an example maintainability design checklist for coal mining equipment. The purpose of the checklist is to provide a summary of design review points for the maintainability assessment of new or existing underground equipment. It specifically focuses on the identification of equipment design features, tasks, or procedures that impact equipment down time, repair costs, labor hours, and maintainer skill level requirements.

Some of the checklist points are general in nature. The checklist was designed to be used across all categories of underground equipment. The intent is to draw attention to design features and maintenance procedures that will increase maintainability requirements. The reader is encouraged to adapt this checklist to site-specific or machine-specific requirements by:

1. Inserting specific performance criteria for various categories of maintenance tasks. For example, all hydraulic lines on a shuttle car should be replaceable in 15 or 25 min.
2. Adding or deleting checklist items for different categories of equipment. Environmental control equipment, for example, would be included on face equipment and not on shuttle cars or mantrips.
3. Adding additional checklist items based on site or equipment specific maintenance histories or experience, company maintenance standards, or other factors.

Guidance on how to develop local maintenance standards is provided in the USBM final report "Maintainability Design of Underground Mining Equipment" (*1*). Several definitions are provided to clarify items in the actual checklist. These include:

1. Primary maintenance zone: The zone or area from the side or the end of a mining machine inward 45 cm (18 in).
2. Secondary maintenance zone: The area from a point 45 cm (18 in) from the side or end of the machine to a point 45 cm (18 in) from the opposite side or end of the machine.
3. Tertiary maintenance point: A maintenance point outside the primary and secondary maintenance zone. An example would be a lubrication point on the end of a conveyor boom.
4. Immediately accessible: A component that can be reached, removed or repaired without having to open access covers,

remove other components, or disassemble other components.

5. Maintenance point: Any point on the machine where:

a. Two components are joined, or

b. A component is mounted on the machine chassis, or

c. Where hoses, cables, and lines are attached to a component.

Maintainability design checklist for underground coal mining equipment

General maintenance reduction	Adequate Yes	No
Hydraulic hoses, electrical cables, and water hoses are securely attached along their length to protect against abrasive wear, pinching or other damage.	☐	☐
All cables and hoses are protected to minimize exposure to impact or fall of roof damage.	☐	☐
Power feed cables enter the machine or the cable reel from the side to minimize exposure to vehicle wheels or tracks.	☐	☐
All components, systems, and devices are located where they are protected from fall of roof damage.	☐	☐
All exterior mounted machine features and components are protected from impact, scraping, or collision damage.	☐	☐
Operator controls and displays are protected from impact, fall of roof damage, or inadvertent activation.	☐	☐
Components subject to wear are designed for self-adjustment where possible.	☐	☐
Where self-adjustment is not practical, the design provides components that can be manually adjusted for wear to minimize the need to tear down.	☐	☐
Design provides for a self-lubricating system for all bearings, joints, and other wear points on the machine.	☐	☐
Design provides for bearings and seals with wear or failure monitoring capability to permit scheduling of maintenance prior to actual component failure or component damage.	☐	☐

General maintenance reduction	Adequate Yes	No
Design provides hour meters (e.g., on conveyor circuits), volt meters, and ammeters (e.g., on electric drive motors) to assist in wear assessment and maintenance management.	☐	☐
Design provides for gears, bearing, hydraulic cylinders, and other impact or load-absorbing components of sufficient size or rating to handle peak impact loads.	☐	☐
Design provides for adequate derating for bearings, motors, and hydraulic systems to minimize overload related failures.	☐	☐
Vehicle frame is adequately designed to prevent cracking or other fatigue-induced failures at:		
➤ Hydraulic cylinder attachment points.	☐	☐
➤ Articulation points.	☐	☐
➤ Other frame load-bearing points.	☐	☐
➤ Welded seams.	☐	☐
Provides for shock and vibration isolation of critical components.	☐	☐
Interlocks are provided to prevent vehicle from being trammed or moved with components deployed or extended that are easily damaged:		
➤ Stab jacks.	☐	☐
➤ Drill booms.	☐	☐
➤ Tail booms.	☐	☐
➤ Automated temporary roof support (ATRS) components.	☐	☐

General maintenance reduction	Adequate Yes	No
➤ Cutting heads.	☐	☐
➤ Canopies.	☐	☐
Protective covers are over all body cavities containing components, hoses, lines, or maintenance points to prevent buildup of muck and debris.	☐	☐
Expanded metal grating is used for floors or other designs to prevent accumulation of water, mud, and debris in equipment bays, crevices, and body cavities.	☐	☐
Rubber tires are protected by fenders, bumpers, or guards from collision and rib impact.	☐	☐
Mechanical linkage systems are protected from impact and fall of roof.	☐	☐
Roof bolter geometry is designed to prevent overelevation damage to boom lift mechanism.	☐	☐
Disc- and drum-type brake systems and components are protected from coal dust, rock, and other debris to minimize wear and damage.	☐	☐
Mounting holes and brackets are designed to permit installation of functionally similar parts produced by different manufacturers.	☐	☐

Safety and environmental design features	Adequate Yes	No
Required safety equipment is properly installed and protected, but easily accessed for repair:		
➤ MSHA-required lighting.	☐	☐
➤ Fire suppression system.	☐	☐

Maintainability design checklist for underground coal mining equipment

Safety and environmental design features	Adequate Yes	Adequate No
➤ Panic bars.	☐	☐
➤ Methane detectors.	☐	☐
Dust control equipment is located for easy inspection and servicing:		
➤ Dust bins and filters are easily accessed, opened, and serviced.	☐	☐
➤ Water spray nozzles are easily accessed for adjustment or replacement.	☐	☐
➤ Fan motors are readily accessed for repair or replacement.	☐	☐

Design standardization features	Adequate Yes	Adequate No
Design provides for standardization of the following items throughout the machine:		
➤ All mechanical components.	☐	☐
➤ Hydraulic connectors, valves, hoses.	☐	☐
➤ Electrical components and connectors.	☐	☐
➤ Water hoses and connectors.	☐	☐
➤ Fasteners and other attachment devices.	☐	☐
➤ Bolts, nuts, and fasteners.	☐	☐

Design features for routine maintenance	Adequate Yes	Adequate No
Routine service points are clustered in one or two locations in the primary maintenance zone including:		
➤ Lube points.	☐	☐
➤ Hydraulic filters.	☐	☐
➤ Environmental system filters.	☐	☐
➤ Fuel tanks on diesel-powered equipment.	☐	☐
➤ Belt or chain adjustments.	☐	☐
➤ Line bleed valves.	☐	☐

Design features for routine maintenance	Adequate Yes	Adequate No
Fluid-level indicators are provided on fluid reservoirs and in the primary maintenance zone for ease of inspection.	☐	☐
Routine inspection points are all clearly visible and labeled including:		
➤ Relief valves.	☐	☐
➤ Drain plugs.	☐	☐
➤ Wear points.	☐	☐
➤ Hydraulic line connections.	☐	☐
➤ Personnel safety equipment. Test points for stand-alone or built-in test equipment are located in the primary maintenance zone.	☐	☐
All mechanical adjustment points are located in primary maintenance zones.	☐	☐
Quick connect type couplers are installed on frequently changed hydraulic lines, water hoses, and cables.	☐	☐
Quick-release fasteners are used on doors or covers for routine inspection points.	☐	☐
Only one type of hydraulic fluid is used on the machine.	☐	☐
Oil seals are easy replaceable types.	☐	☐
Design reduces to a minimum the number of spare parts and components required to support maintenance:		
➤ Common hoses.	☐	☐
➤ Connectors.	☐	☐
➤ Valves.	☐	☐
➤ Drive belts, chain, etc.	☐	☐
➤ Cables.	☐	☐
➤ Nuts and bolts.	☐	☐
➤ Washers.	☐	☐

Design features for routine maintenance	Adequate Yes	Adequate No
Routine service points are not located behind other components or structural members, in enclosed spaces, or in the secondary maintenance zone (e.g., more than 46 cm (18") from the side or the end of the machine).	☐	☐

Design features for troubleshooting	Adequate Yes	Adequate No
General design and layout provides for rapid and positive identification of component malfunction:		
➤ Fluid leaks.	☐	☐
➤ Pressure loss.	☐	☐
➤ Shorts.	☐	☐
General layout facilitates visual inspection of major components, connections, couplers, interfaces, and potential damage points.	☐	☐
Hydraulic, electrical, and mechanical system schematics permanently affixed to machine to facilitate troubleshooting.	☐	☐
Hydraulic, electrical, and other systems can be easily traced throughout the machine.	☐	☐
The following pertinent information is immediately available to the maintainer:		
➤ Component or system identification.	☐	☐
➤ Proper direction of motion or fluid flow.	☐	☐
➤ Correct fluids.	☐	☐
➤ Amperage and other electrical information.	☐	☐
Self-checking features are designed into critical components or systems where possible:		
➤ Major hydraulic systems.	☐	☐
➤ Cooling systems.	☐	☐
➤ Electrical circuits.	☐	☐
All mechanical interfaces are visible from the sides or end of the machine.	☐	☐

Maintainability design checklist for underground coal mining equipment

Design features for trouble-shooting	Adequate Yes	No
Manual test points are located in the primary maintenance zone for all critical systems or subsystems.	☐	☐
Test points are designed to eliminate or minimize the need to remove components for testing.	☐	☐
Locate test points in one or two locations where practical or in a single test panel.	☐	☐
Test points are coded or labeled to identify recommended or acceptable pressure, temperature, or voltage ranges.	☐	☐
Test points are labeled and are located close to the control or display they are associated with.	☐	☐
Built-in test capability and/or test equipment provided to monitor wear on critical bearings or other wear points such as:		
➤ Continuous miner cutterhead.	☐	☐
➤ Gathering arms.	☐	☐
➤ Articulation bearings on scoops.	☐	☐
➤ Hydraulic pumps.	☐	☐
Test set instructions for built-in test equipment (BITE) are attached to the machine at the point of service.	☐	☐
Automatic test equipment (ATE) sensors are provided that operate without disturbing or loading the system under test.	☐	☐
Fail-safe design for all ATE where failure of test equipment will not cause failure of the mining machine.	☐	☐

Design features for repair and replacement	Adequate Yes	No
Provisions are made for adequate towing or movement of disabled machine to maintenance area:		
➤ Tow cable attachment points.	☐	☐
➤ Designated push points.	☐	☐
➤ Tow bar attachment points.	☐	☐
Design features are incorporated to facilitate jacking, hoisting, or lifting of machine to expedite maintenance and repair:		
➤ Designated jack points with jack plates designed to prevent jack slippage.	☐	☐
➤ Attachment points for overhead lifting devices.	☐	☐
Design features are incorporated to facilitate lifting, hoisting, or manipulating heavy components and machine features:		
➤ Built-in attachment hooks.	☐	☐
➤ Lift bolt attachment points.	☐	☐
➤ Lifting guides or pins.	☐	☐
➤ Provisions for forklift arms.	☐	☐
➤ Built-in swing boom arm.	☐	☐
➤ Designated lift points.	☐	☐
All areas of the machine are designed to be self-cleaning and designed to eliminate (minimize) the accumulation of rock, coal, mud, and water	☐	☐
All components are labeled to positively identify part number-type, component ratings, types of lubricant-fuel required, direction of flow, and other pertinent information.	☐	☐
All components and interfaces are designed to be installed only one way—the correct way.	☐	☐
Design eliminates the need for special tools or jigs to perform required maintenance.	☐	☐
All major parts used are readily available from local suppliers or vendors.	☐	☐
All mounting bolts are directly accessible and unobstructed to permit use of required hand tools without having to remove or disassemble adjoining components.	☐	☐

Visual inspections and accessibility	Adequate Yes	No
All maintenance points should be visually accessible from the side or the end of the machine and should provide line-of-sight inspection capability.	☐	☐
Design provides for clear and rapid visual identification of parts that may have to be replaced or repaired.	☐	☐
Approved glass covers should be installed in all access opening covers if routine inspection of maintenance points are required.	☐	☐
Access openings should be large enough to permit visual contact with the component being worked on while the work is being performed.	☐	☐
Visual access openings should not be located on the top of machines unless the average roof height above the top of the machine is 61 cm (24") or more.	☐	☐
Visual access openings should never be located under the main chassis of the machine or behind other components that may restrict visibility.	☐	☐
For less frequently performed maintenance tasks, the maintenance point may be located behind a protective cover. The component, however, should be directly visible when the protective cover is removed.	☐	☐
Maintenance and service points should be located no further than 91 cm (36") from the maintainer's head at time of inspection.	☐	☐

Design for physical accessibility	Adequate Yes	No
All components are accessible from the side or the end of the machine.	☐	☐
All drain valves for compressor tanks, reservoirs, and sumps are accessible from the side or the end of the machine.	☐	☐
All other maintenance points are accessible from the sides or ends of the machine.	☐	☐

Maintainability design checklist for underground coal mining equipment

Design for physical accessibility	Adequate Yes	No
All components that require repair, replacement, or adjustment every 2,000 hrs. or less should be directly accessible (can be removed-replaced without having to remove other components) from the sides or ends of the machine.	☐	☐
For components with an expected service life of over 2,000 hrs., only one other component should have to be removed to access for removal or replacement (R/R).	☐	☐
For components that must be disassembled to be repaired or inspected (e.g., bearings), no more than four R/R task steps (e.g., remove part A, remove part B, etc.) should be required to access the targeted part.	☐	☐
All components weighing more than 23 kg (50 lbs.) or more should be removed from the side or the end of the machine and should not have to be lifted up and over the machine frame or other components.	☐	☐
Hinged or quick-release access opening covers should be used where practical with the hinges on the side or bottom so that door will remain open during maintenance.	☐	☐
A minimum number of bolts or fasteners should be used on access covers, equipment bay doors, or other protective shielding.	☐	☐
For components weighing more than 45 kg (100 lbs.), access openings and workspace should be sufficient to permit the attachment of hoisting or lifting devices.	☐	☐
Screws, nuts, and bolts should be located to permit use of requisite hand tools to remove or replace them.	☐	☐
Access openings should be sufficiently large to permit removal and replacement of all components contained in that area.	☐	☐
Nonhinged access opening covers weighing more than 23 kg (50 lbs.) are designed with built-in handles or lifting device attachment points.	☐	☐

Design for physical accessibility	Adequate Yes	No
All components can be removed and replaced in a straight line from their place of attachment (components do not have to be maneuvered around or over structural features or components).	☐	☐
Design provisions are made to support components weighing over 23 kg (50 lbs.) while they are being unbolted or bolted into place.	☐	☐

Hydraulic system maitenance design	Adequate Yes	No
Fluid reservoirs have adequate storage capacity to ensure uninterrupted operation between shifts.	☐	☐
Dual in-tank or stand-alone filters are installed on each fluid system to minimize component and control valve wear.	☐	☐
Hydraulic system filters are located in the primary maintenance zone and use permanent or cartridge-type filters.	☐	☐
Hydraulic meters and gauges are located in the primary maintenance zone.	☐	☐
Quick-disconnect-type hydraulic line connectors are used where practical.	☐	☐
Hydraulic systems are designed to be fail safe with the system or components reverting to a safe or neutral position in event of loss of power.	☐	☐
Hydraulic circuits are permanently labeled to identify circuit, direction of fluid flow, recommended pressure settings, and high- and low-pressure lines.	☐	☐
All hydraulic valves are labeled to positively identify the system-subsystem operated by that valve; the label should not be on the valve itself.	☐	☐
Design uses seals that are visible after installation to ensure that they are not inadvertently left out during maintenance.	☐	☐

Hydraulic system maitenance design	Adequate Yes	No
Design uses armor-coated flex hoses where hoses are subject to abrasive wear or impact damage.	☐	☐
Design provides for automatic bleeding of major hydraulic system(s).	☐	☐
Physically incompatible connectors are specified where there is a danger of mismating connectors from adjoining systems.	☐	☐
Design provides metal shielding to protect electrical and other sensitive equipment in the event of hydraulic fluid leak.	☐	☐
Design prevents the accumulation of hydraulic fluids in the event of leaks or hose breaks.	☐	☐
Design provides for hydraulic system drains at the lowest physical level in the system.	☐	☐
Hydraulic system fittings and valves are staggered to provide improved access to each system's connectors.	☐	☐

Mechanical system maintenance design	Adequate Yes	No
Design provides for minimum manual adjustment of all mechanical systems, except to correct for wear.	☐	☐
Self-adjustment designs are incorporated where practical.	☐	☐
Adjustments that cannot be designed out should:		
➤ Be completed without the requirement to disassemble the unit.	☐	☐
➤ Be reduced to the minimum number of steps possible to complete.	☐	☐
➤ Not require removal or replacement (R/R) of other components to complete.	☐	☐
➤ Be incorporated into other required maintenance on the same component.	☐	☐
➤ Incorporate range limits to present over-adjustment damage.	☐	☐

Maintainability design checklist for underground coal mining equipment

Mechanical system maintenance design	Adequate Yes	Adequate No
Design precludes the need for special tools or hardware to install, adjust, or align mechanical components.	☐	☐
Components and mechanical interfaces are designed with the minimum number or pivots, bearing surfaces, and other moving part wear points to minimize maintenance requirements.	☐	☐
Mechanical system locks or locking devices are incorporated wherever mechanical locking is required for maintenance.	☐	☐
Design avoids the use of through bolts for installation or assembly where the nuts are not accessible to the maintainer.	☐	☐
Design locates high failure-rate components outboard in the primary maintenance zone.	☐	☐
Design provides for coverings or boots for exposed connectors, universal joints, and other interacting mechanical parts to protect them from mud, coal dust, and other debris.	☐	☐

Electrical system maintenance design	Adequate Yes	Adequate No
Design provides overload or other electrical protective devices for all major electrical circuits, each of which is equipped with a "kickout" indicator light for easy troubleshooting on:		
➤ Drive, conveyor, cutterhead, and gathering arm motors.	☐	☐
➤ Lighting.	☐	☐
➤ Electric power takeoffs.	☐	☐
Design routes all electrical cables on machine to avoid damage from abrasion, pinching, or cutting.	☐	☐
All electrical cabling is routed to permit easy removal and replacement. Cabling is not routed under machine chassis, in the center of boom arms, or in other difficult-to-access locations.	☐	☐

Electrical system maintenance design	Adequate Yes	Adequate No
Electrical connectors are isolated from hydraulic fluid leaks, fuels, water, and other liquids.	☐	☐
Quick-disconnect-type electrical connectors are used where possible.	☐	☐
All electrical equipment cabinets are equipped with interlock that terminates power to the unit when the access cover is removed.	☐	☐
A manual override is provided for all cabinets equipped with shutoff interlock.	☐	☐
Breakers and other overload protective devices are in a central location in the primary maintenance zone.	☐	☐
Electrical connector pin patterns are coded to permit connecting cables only to the appropriate receptacle.	☐	☐
Uses electrical plugs in which the alignment pins extend beyond the electrical pins.	☐	☐
Design makes receptacles "hot" or "cold."	☐	☐
Uses contact pins no larger than 30 cm (12") to resist being bent upon insertion and withdrawal of the connector.	☐	☐
Design uses right-angle plugs to avoid sharp bends in the electrical cable.	☐	☐

Personnel protective equipment maintenance	Adequate Yes	Adequate No
Personnel protective equipment is designed and located to facilitate inspection, repair, and replacement of the following systems:		
➤ Dust control.	☐	☐
➤ Methane monitoring.	☐	☐
➤ Operator protective canopy (as required).	☐	☐
➤ Operator panic bars.	☐	☐
➤ Emergency power cutoff devices.	☐	☐

Design for mechanical safety	Adequate Yes	Adequate No
Protective guards are provided on or around all moving mechanical parts adjoining to where maintenance personnel will be working.	☐	☐
Mechanical lockout devices are provided where maintenance must be performed at location that exposes maintainer to moving components (e.g., under a cutterhead).	☐	☐
Design prevents components from slipping or falling as they are being unbolted for repair or replacement.	☐	☐
Mechanical components are located to prevent maintainer from being exposed to energized equipment, hazardous fumes, hot surfaces, or other hazards during repair operations.	☐	☐
Mechanical components that require the use of heavy springs are designed so that the springs cannot inadvertently dislodge, causing damage or personnel injury.	☐	☐
Design provides for warning plates where mechanical assemblies, linkages, or components are under high strain or loading.	☐	☐
Design routes hot exhaust pipes away from locations where routine maintenance will be performed.	☐	☐
Design prevents failure of high-stress-loaded component from damaging other components or injuring personnel.	☐	☐

Storage battery maintenance	Adequate Yes	Adequate No
Design isolates routine machine maintenance points from battery fumes.	☐	☐
Design prevents leaking battery acid from accumulating in equipment compartments or operator station.	☐	☐
Batteries are installed in a location that permits use of overhead lifting device to remove or replace them.	☐	☐

Courtesy of Mines Accident Prevention Association, Ontario, Canada

Holmes Safety Association monthly safety topic

Fatal fall of roof

GENERAL INFORMATION: A 37-year old mine supervisor was fatally injured and a 32-year old driller was seriously injured when an extensive roof fall occurred. The roof fall occurred while they were attempting to dislodge loose rock from the mine roof with an Ingersoll-Rand Jumbo Drill. The victim was buried in the fall and the injured driller was trapped in the cab of the jumbo drill. The victim had a total of 10 years 5 months mining experience, all at this operation, with the last 8 years 2 months as a mine supervisor. The injured driller had a total of 13 years 7 months mining experience, all at this operation, with the last 7 years 3 months as an underground driller. The injured driller had also served as an extra supervisor underground for about one year.

The operation was an underground limestone operation. The mine normally operated one 10-hour production shift per day, 7 days a week with the exception of Thursdays when two 10-hour shifts were worked. A total of 106 persons was employed. Twenty-five of these employees worked underground.

DESCRIPTION OF ACCIDENT: On the day of the accident, the victim and the injured driller reported for work at 6:00 AM, their normal starting time. They drilled a floor shot in the 11 South 240 area of the mine and then drilled some loose rock in the roof of the 11 South 206 heading. They then proceeded to the 11 South 2W heading to scale down some loose rock in that roof. The injured driller stated that he extended the drill steel and as it struck the loose rock he saw a flash of rock falling. The injured driller thought he saw the victim turn to run when the fall came in through the windshield and side windows of the drill cab.

The injured driller was pinned in the drill cab but was able to use his cap lamp to check the time which was about 11:30 AM. The injured driller knew that when he and the victim did not appear for lunch, someone would come looking for them. About noontime, a cousin of the victim came to the area to check on the two men and discovered the rock fall. After making voice contact with the injured driller, he contacted the office and secured help. Two rescuers went to the drill and pried open the right door of the drill cab, removed the rocks that were pinning the injured driller and extricated him from the cab. No contact could be made with the victim. It was presumed that the victim was buried beneath the rock fall.

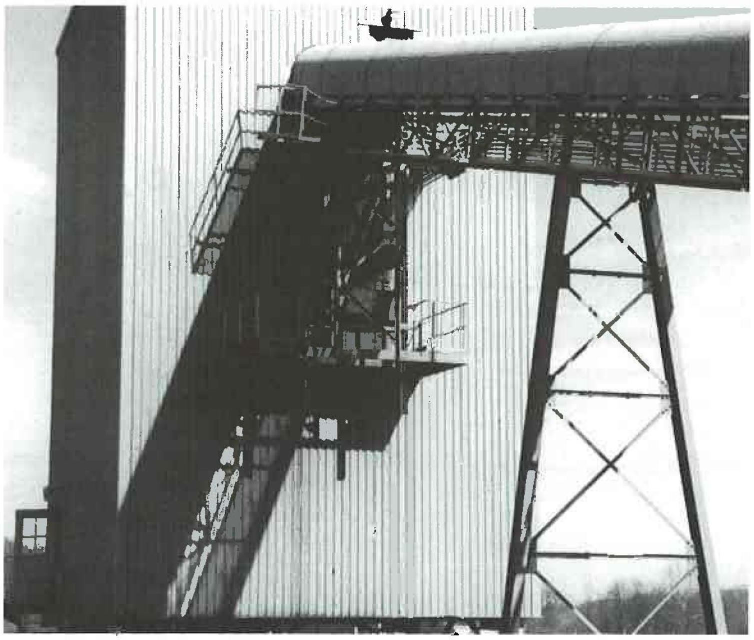
The local rescue squad was contacted and arrived a short time later. The injured driller was transported to the surface and life-flighted to the hospital where he was admitted for his injuries.

Efforts to recover the victim were continuous until interrupted by additional small rock falls which posed a hazard to recovery workers. Unstable roof conditions prevailed and considerable care and time had to be taken to ensure the safety of the recovery team throughout the entire recovery process. Additional lighting was brought in to better evaluate the area and aid the rescue workers. Personnel from a nearby mine were brought on site to evaluate whether their mechanical scaler could aid in the recovery process. It was determined that their scaler did not have a sufficient reach to safely scale the affected area. An additional hindering factor in the recovery operations was the fact that the victim's exact location was not known in relation to the hazardous overhead conditions.

Three search dogs were brought to the mine to determine the exact location of the victim. After about 1 hour, the team leader stated that all three dogs had indicated that the victim's location was in the pile about 12 feet from the outer edge. His body was found in that area and recovered at about 2:40 PM on the third day of recovery operations.

CONCLUSION: The cause of the accident was the failure to ensure that scaling was conducted from a safe location that would protect miners from overhead hazards and the failure to provide equipment necessary to safely scale the mine roof. A contributing factor was the failure to support the ground by following the company's General Mining and Roof Control Plan. The 11 South 204 production heading was more than twice the specified width of 35 feet, as listed in the plan. The initial 50- by 50-foot pillar size was not maintained where the strength of the rock strata was diminished by karst conditions—an area of irregular limestone in which erosion has produced fissures, sinkholes, caverns, and streams.

Empowerment of the employees at the Conesville Coal preparation plant



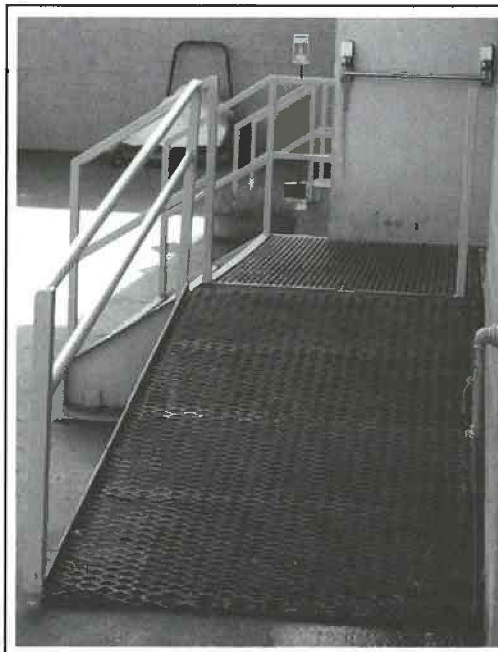


Photo 1 at left, work platforms at elevated belt takeups; photo 2, right, sloped walkway to permit easier access.

The Conesville Coal Preparation Plant employs about 40 workers and processes about 1,850,000 raw tons of coal annually. The company has a systematic approach to the elimination of hazards. All employees are involved in the identification of hazards and the development of solutions to eliminate these hazards by engineering controls and/or training. The leaders of this are members of the ergonomics committee and the UMWA safety committee. Ergonomics Committee members include: George Moran, and Richard Norris, UMWA Safety Representatives, Steve Wilson, Safety Supervisor, and Dave Leppa, Plant Manager. This committee meets monthly. Steve Wilson, George Moran, and Richard Norris also make a safety tour of the facility monthly.

On May 4, 1989, at 7:45 PM, an employee was operating a 777 Caterpillar off-highway truck when the vehicle suddenly caught fire in the engine compartment. The employee immediately exited the cab. Within seconds, the truck was totally engulfed by flames. The accident report indicated that a hydraulic hose must have ruptured, spraying hot hydraulic fluid on to the turbo resulting in the fire. The truck had to be totally rebuilt.

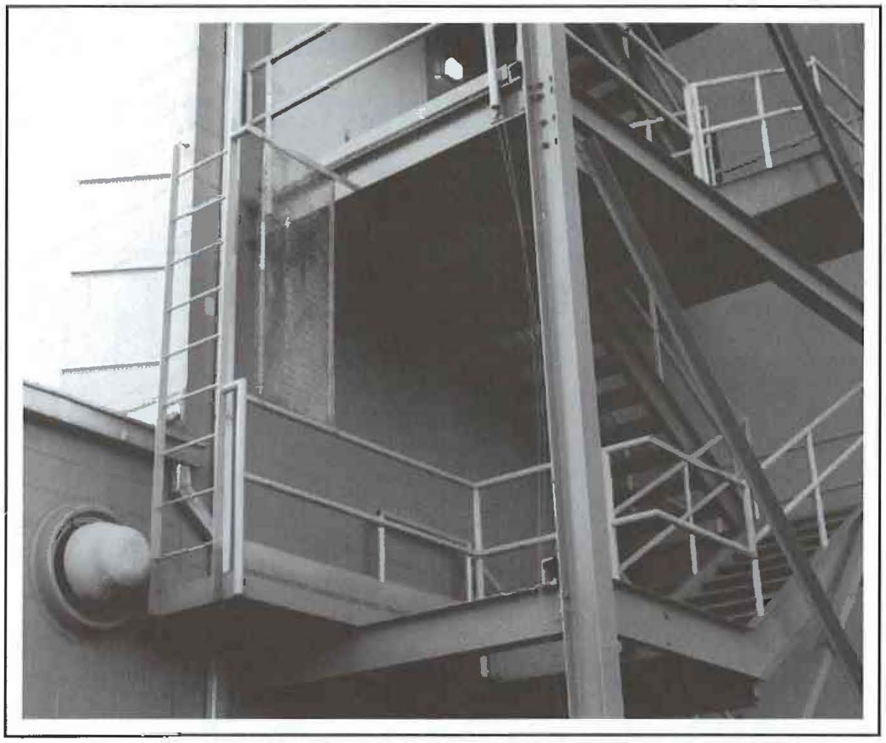
If the door handle would have been broken or not working properly, the employee would not have been able to escape quickly and probably would have been injured.

In safety, we should always expect the unexpected and make sure we have avenues of escape in an emergency. Sometimes people disregard items such as a door handle; however, as this incident demonstrates, escapeways are important.

This truck was subsequently operated on a daily basis without any problems until May 18, 1993, when another fire occurred in the vehicle. Ironically, this time the driver stopped the truck, set the parking brake, manually activated the fire suppression system, and safely walked away from the truck.

The only cost this time was to repair the leak, and recharge the fire suppression system. When Conesville's 777 Caterpillar was rebuilt following the 1989 incidents, a fire suppression system was installed to protect the employees and the equipment. The company also has installed fire suppression systems on other equipment including: two 777 dozers; a 988 end loader; and a water truck. Additional initiatives that the Conesville committees have suggested include

Photo 3 above, shows guards to protect supports from accidental strikage. Photo 4 at right, a fixed guarded ladder. Photo 5 below right, installation of stairway to check fluid levels in pumps.

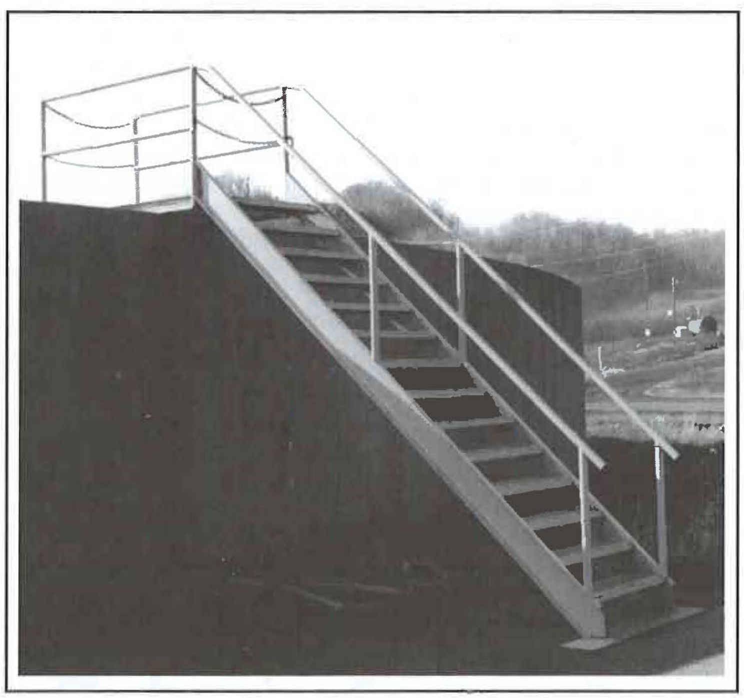


the following: a metal fixed ladder equipped with safeguards installed to permit safer access to the building roof for people who have to work on the air-conditioning system (Photo 4); and, a sloped walkway installed outside the entrance to permit a safer and easier means of transporting gas cylinders and wheelbarrows (Photo 2). They have also installed work platforms at elevated belt takeups (Photo 1). A slipping hazard occurred when the drain pan for the air compressors overflowed, and this was eliminated by piping the drain pans to a floor sump.

A stair-type ladder was provided to help ensure safer access to check fluid levels in the pumps on the lower floor level (Photo 5). These are just a few of the innovative ideas implemented by the committees that have resulted in positive safety solutions to recognized hazards. This mine is on the RVRP list (Repeat Violation Reduction Program) and the commitment of management, labor, and MSHA has indeed been a factor in the reduction in repeat violations and accidents at this operation.

A similar accident occurred at another mine in the same area, which caused the operator to have to drive into a ditch, and immediately bail out of the truck cab which was engulfed in flames. This fire was caused when a loose can of ether burst spraying its contents across the cab heater. The operator's vest caught fire and his beard was singed. In both cases the operators needed to be able to escape quickly.

This resulted in a policy not to permit any aerosol cans within the cabs of any equipment. The Conesville Coal Preparation Company adopted the same policy, and made accommodations for the storage of aerosol cans outside of the cabs.



Submitted by James F. Myer

Statewide mine safety contest winner stresses importance of safety to miners' families

Joseph Renner, Sr., fourth from the left, is shown being presented with a framed copy of the poster depicting his winning slogan by Conrad Spangler of the Virginia Department of Mines, Minerals and Energy. Also present, but not identified, are Perry Co. quarry officials and members of Renner's family.

Berryville, Va.—Mining has been a family tradition for the Renner family, and according to Joseph Renner, Sr., a third generation miner at the Stuart M. Perry Company quarry in Berryville, Va., working safely is an important part of that tradition. Renner, winner of a safety slogan contest sponsored this spring by the Virginia Department of Mines, Minerals and Energy (DMME), believes that miners should work safely for the welfare of their families as well as themselves.

From this philosophy he coined the slogan, *"Mine safety is like money in the bank—Your family depends on it."* Renner's winning slogan is now featured on a poster that will be distributed to mineral mines statewide. A framed copy of the poster was presented to Renner on Thursday, October 27, by DMME Division of Mineral Mining Director Conrad Spangler in a ceremony attended by Stuart M. Perry officials and Renner's family and co-workers.

According to Spangler, the contest was designed to increase mine safety awareness at Virginia's small mineral mines, those employing 20 or fewer people, which comprise 85% of all mineral mines in the state. "The mine safety slogan and poster contest is intended to positively reinforce the importance of mine safety to the individual miner. We believe it is an effective means of promoting mine safety awareness by directly involving miners and encouraging them to consider the benefits of safe work practices," Spangler said.

The poster will be distributed by the DMME to every mineral mine in Virginia in an effort to promote mine-safety awareness. The photographs show Renner, a plant superintendent at the quarry, operating a front-end loader on the mine site and posing with his family in front of a bank vault, courtesy of The Bank of Clarke County. Bringing the importance of mine safety even closer to home, featured in the photo is the fourth generation of Renner to work at the Stuart M. Perry operation, Joe Renner, Jr. The Renners reside in Clarke County.

Spangler expressed his appreciation to the Stuart M. Perry Company and The Bank of Clarke County for their cooperation during the photo sessions. "We are especially appreciative of the Stuart M. Perry Company's support of the contest and our efforts to promote mine safety awareness. They have taken a great deal of pride in having one of their employees as the contest winner, and this is a reflection of their commitment to their employees and to mine safety," Spangler noted.

From a press release of October 28, 1994, by Mike Abbott of the Commonwealth of Virginia Department of Mines, Minerals and Energy, Ninth Street Office Building, 8th Floor 202 North Ninth Street, Richmond, VA 23219

Effects of dust control binding agents on the oxidation of stockpile coal

by D.C. Roe and B.A. Uytiepo

In large coal handling facilities, such as power plants, incidents involving self-ignition or "hot spots," which result from atmospheric oxidation of coal, can be quite common but are certainly unsettling. Self-ignition or spontaneous combustion of coal can be remedied but could also be avoided. At a midwestern electric utility, Northern States Power, the ability of certain dust suppressants to inhibit coal oxidation was investigated. Various binding agents (or agglomerating agents) were applied on western coal and temperature profiles of stockpiled coal were measured to evaluate the oxidation inhibiting effects of the binders.

Since natural oxidation of coal takes place when it is exposed to air, oxidation proceeds slowly upon mining and intermediate stockpiling of the coal. The spontaneous heating associated with oxidation leads to loss of heating value and, in some cases, ignition of the material. It has been shown that oxidation is accelerated in the presence of moisture. The role of moisture is associated with raising the bulk temperature of the coal. This, in turn, effectively increases the rate of oxidation.

Under normal conditions, pile compaction reduces the intrusion of air and moisture. The relatively small amount of heat generated can be dissipated to the surrounding environment. Unfortunately, these ideal conditions are not easily achieved when operating a large coal handling facility such as those commonly found at power plants.

In addition to air and moisture, there are several other factors that influence the oxidation of coal. These include rank, particle size and volatile matter of the coal being stockpiled. Most of these factors are affected by, or related to, conditions on the surface of the coal. Another important attribute of coal, which is largely dependent on surface conditions, is its dustiness. In most cases, coals with lower surface moisture, higher friability and smaller particle size have a greater potential for generating fugitive dust.

One of the most effective ways to control dust is to apply treatment that alters the surface of the coal. Conventional wet or foam type dust suppressants add surface moisture and, to a certain extent, agglomerate fines. The control of dusting generally lasts until the added moisture evaporates from the surface. Binding agents, on the other hand, leave a coating on the coal surface. In some cases, a barrier is produced preventing moisture and oxygen from penetrating the surface of the coal. This phenomenon gives rise to the additional benefit of effectively minimizing coal oxidation.

Since coal materials are relatively good insulators, the heat dissipated to the environment from a stockpile is much less than the heat conducted internally as a result of the oxidation reaction. In a loosely packed pile where both moisture and air are abundant, oxidation can progress at a high rate. It is clear that monitoring the bulk or internal temperature of the stockpile gives a direct indication of the rate of coal oxidation.

Northern States Power's Sherburne County (Sherco) Station, located in Becker, Minnesota about 50 miles northwest of downtown Minneapolis, operates three coal-fired units with a combined generating capacity of 2,300 megawatts. Annually, 8-9 million tons of coal are burned at Sherco.

About half of the coal originates from Antelope, Rochelle, and Black Thunder mines in Cambell County, Wyoming. For the oxidation study, a train load of Black Thunder coal was treated and stockpiled.

Rail coal is unloaded at about 2,500-3,000 tons per hour. The current dust control program consists of foam applied to three track hopper (belt) feeders beneath the rotary unloader. Approximately 1/2 gallon of foam solution is added per ton of unloaded coal. Using high expansion foam technology, about 2 cubic feet of foam is applied to each ton of coal. Based on volume, the application ratio of foam to coal is 1:20 or 5%.

At Sherco, coal can be stored outdoors or in a covered coal barn. For the purpose of the study, five 1,000-ton test piles were stacked outdoors using a sticker/reclaimed. To distribute the binder as effectively as possible, foam was used to treat each test pile. Four foamable binders were applied to the four 'treated" piles. The "control" pile was treated with foam only. Four binding agents with distinct chemical properties were selected for this experimental evaluation. The binding agents are listed in the treatment table. The dust rating values listed are based on laboratory and field evaluation of the various binders on western subbituminous coal.

The binding agents were applied at relatively high treatment rates (about $0.060.10 per ton of coal) to ensure that the effects on coal oxidation could be sustained and easily observed. The duration of the study was limited to three weeks.

To measure the bulk temperature of the test piles, a thermocouple probe was inserted into the stockpiles. About 510 minutes were required for each temperature measurement.

Treatment of five 1,000-ton test piles

Test pile	Binder	Type	Dust rating
A	None	N/A	5
B	PL 2161	Polymer	1
C	PL 2151	Oil	2
D	PL 2174	Organic salt	4
E	DG 873	Polymer	3

Figure 1.—Control temperature profile

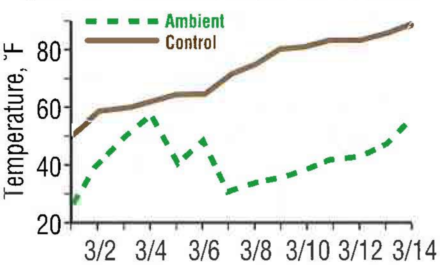


Figure 2.—Binder temperature profiles

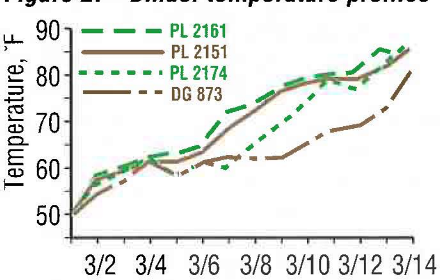


Figure 1 shows the temperature profile of the control pile. Ambient temperatures that were measured during monitoring of the piles are also shown. The control pile temperature increased by 35°F in two weeks. This corresponds to approximately 2.5°F/day. The rate of temperature increase was higher during the first week of the test (2.8°F/day) than the second week (2.4°F/day). Ambient temperatures ranged from 24-55°F over the duration of the test. Since all the test piles were located in the same vicinity, it was assumed that the effect of ambient temperature on the dissipation of heat from piles would be constant.

Figure 2 shows the temperature profiles of the treated piles. One of the polymer-based reagents, DG 873, had a temperature that was consistently lower than the control pile. Another binder, FL 2174, performed well during the first week, but rapidly approached the control pile temperature by the second week. Both DG 873 and FL 2174 pile temperatures increased at a rate of 1.7°F/day for the first week. This is a 40% reduction based on the control pile temperature increase. For the second week, DG 873 pile temperatures were still lower than those of the control pile but increasing at a similar rate of 2.6°F/day. The other binders appeared to have little or no measurable effect on the temperature increase of the coal piles.

The regression of the temperature profiles suggest that the binders did not permanently alter the course of the temperature increase but merely delayed the process. The fact that oxidation is affected by surface conditions suggests that changes take place on the coal surfaces. Although absorption of oil-based binders into the coal has been reported, this would be an unlikely occurrence for polymer-based binders. What has been generally observed in dust control applications is that the amount of binder applied to the coal is directly related to the longevity of its residual effects. Thus, an improved protective coating can be created by applying the binding agent to more surfaces or at a higher treatment rate. Moreover, this resilient barrier associated with a longer binding effect would likely result in an increased effect on oxidation as well.

Of the four dust control binders applied on western subbituminous (FRB) coal, the most effective was a polymer-based binder, DG 873. During the first week, the rate of temperature increase—and thus, the rate of oxidation—was reduced by as much as 40%. This significantly reduced the potential for coal pile fires or "hot spots." An additional benefit is the ability to avoid the loss of heating value during intermediate storage or to simply extend that time.

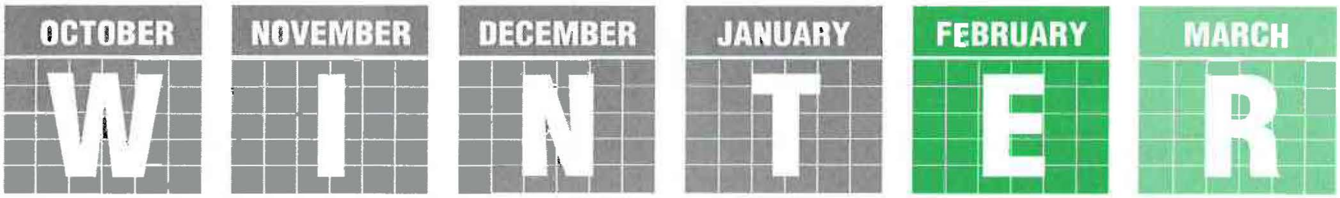
The temperature profiles of the treated stockpiles suggest that the oxidation inhibiting effects of binders postpone the eventual temperature increase. Similar to residual dust control effects, the loss of oxidation inhibiting effects over time may be attributed to the binding agent application rate.

The effectiveness of certain binders in controlling dust from western coal does not correlate with its ability to minimize oxidation. It is therefore possible to have excellent dust control and little or no (chemical) protection from oxidation or self-heating. However, when evaluating two binders that have comparable dust control abilities, it would be worth investigating their influence on oxidation of the coal.

Suppose a power plant burning about 1 million tons per year loses 1% of the coal's heating value over a one week intermediate storage period; at $20 a ton (delivered cost), this translates to $200,000 in lost heating value. If a dust control program using a binder reduces those losses by 40%, the power plant would save $80,000 annually or $0.08 per ton.

D.C. Roe and B.A. Uytiepo are with Betz Water Management Group, P.O. Box 3002, Trevose, PA 19053.

*Reprinted from the December 1994 issue of Acquire's **Coal Today.***



ALERT reminder: ● *Always maintain adequate mine ventilation and make frequent checks for methane and proper airflow.* ● *Know your mine's ventilation plan and escapeways. Properly maintain methane detection devices. Communicate changing mine conditions to one another during each shift and to the oncoming shift.* ● *Control coal dust with frequent applications of rock dust.* ● *Make frequent visual and sound checks of mine roof during each shift. NEVER travel under unsupported roof.* *Courtesy of Va. Dept. of Mines, Minerals, & Energy*

Emergency safety cable to reduce hazard and cost on dredges

Recently, a dredging operator called wanting to know if we have a list of scuba divers who would be immediately available. He needed a diver to locate and attach a cable to a jet venturi which was lost in the gravel pit, about 40 feet underwater. He stated that the suction pipe had worn thin and became weakened to the point that the pipe broke and the jet fell off. I was able to give him a couple of references.

However, I wondered why he hadn't considered installing a safety cable in anticipation of such an accident happening. After all, expensive dredging equipment such as rotary cutter heads, jet venturis, Hoffer valves and chain cutters can become lost or buried accidentally. Abandoning the piece of equipment is expensive as is recovering it and the hazards involved can be severe. In fact, one diver I recommended declined the job because of the depth and possibility of underwater banks of material caving. He felt the hazards were too great a risk for him.

A good safety precaution is to clamp a cable of at least 1/2 inch diameter to the underwater unit. Then, run the cable along the suction pipe or suction ladder and safety wire it in several places to hold it in place. The free end should be anchored somewhere on the barge deck. In the event of an accident, the cable will maintain the location of the equipment if it is buried, and can be pulled loose from the safety wire to pull or hoist the equipment from the pit. In the event the equipment is buried too deep to be pulled free, a temporary suction line can be rigged to clean material away in order to free the unit. The safety cable will serve as a location marker to dredge overhead material away.

Reprinted from the Fall 1994 issue of the ***Nebraska Mine Safety Training Newsletter.***

Bureau of Mines holds seminars on improving safety at small underground mines

By Robert H. Peters, Research Psychologist, M.S.H.E.

It has long been recognized that, in comparison to large mines, small mines experience a much higher rate of accidents causing fatalities. In an effort to help improve safety at small underground coal mines, the U.S. Bureau of Mines (USBM) presented a series of nine technology transfer seminars during the fall of 1994. These seminars were held at various locations in the four states where over 90% of all the small underground coal mines in the United States are located, i.e., Kentucky, West Virginia, Virginia, and Pennsylvania.

Presentations were given by mine safety experts from the USBM and West Virginia University, as well as a small mine owner from Pennsylvania—Mr. John Garcia. The seminars were co-sponsored by MSHA, mine operators associations, and state mining agencies in all four states. About 350 persons attended these seminars.

A 174-page proceedings containing the seminar papers has been published. This report is available from the National Technical Information Service. Call 1–800–553–NTIS and ask for document #PB 95-105466, "Improving Safety at Small Underground Mines" (Price: $27.00). Additional seminars are being planned for 1995. For information call Bob Peters at (412) 892–6895.

The last word...

"It doesn't pay to worry. Most things that happen are out of your control. If it's good, it won't last, and if it's bad, it's bound to get better."

"Give a man a fish, and you will feed him for a day. Teach him how to fish, and you will get rid of him on weekends."

"If youth be a defect, it is one that we outgrow only too soon." — James Russell Lowell

"Youth comes but once in a lifetime." — Henry Wadsworth Longfellow

"For God's sake, give me the young man who has brains enough to make a fool of himself." — Robert Louis Stevenson

"Through our great good fortune, in our youth our hearts were touched with fire. It was given to us to learn at the outset that life is a profound and passionate thing." — Oliver Wendell Holmes

"Youth, which is forgiven everything, forgives itself nothing: age, which forgives itself everything, is forgiven nothing." — George Bernard Shaw

"In all things it is better to hope than to despair." — Johann Wolfgang von Goethe

Every cloud has a silver lining, but it is sometimes difficult to get it to the mint." — Don Marquis

Hope for the best, but prepare for the worst." — English Proverb

NOTICE: We welcome **any** materials that you submit to the Holmes Safety Association Bulletin. We especially need color photographs (8" x 10" or larger) for our covers. We cannot guarantee that they will be published, but if they are, we will list the contributor(s). Please let us know what you would like to see more of, or less of, in the Bulletin.

REMINDER: The District Council Safety Competition for 1995 is underway—please remember that if you are participating this year, you need to mail your quarterly report to:

Mine Safety & Health Administration
Educational Policy and Development
Holmes Safety Association Bulletin
P.O. Box 4187
Falls Church, Virginia 22044-0187

Phone: (703) 235-1400

Joseph A. Holmes Safety Association
Awards Criteria

Type "A" Award – For Acts of Heroism
The award is a medal with a Medal of Honor Certificate.

Type "A" Award – For Acts of Heroic Assistance
The award is a Certificate of Honor.

Type B-l Award – For Individual Workers
(40 years continuous work experience without injury that resulted in lost workdays)
The award is a Certificate of Honor, a Gold Pin, and a Gold Decal.

Type B-2 Award – For Individual Officials
(For record of the group working under their supervision)
The award is a Certificate of Honor.

Type C Award – For Safety Records
(For all segments of the mineral extractive industries meeting adopted criteria)
The award is a Certificate of Honor.

Other Awards – For Individual Workers
(For 10, 20, or 30 years without injury resulting in lost workdays)
The awards are 30 years - Silver Pin and Decal, 20 years - Bronze Pin and Decal, 10 years - Decal bearing insignia.

Special Award – For Small Operators
(Mine operators with 25 employees or less with outstanding safety records)
The award is a Certificate of Honor.

For information contact: Secretary-Treasurer, Joseph A. Holmes Safety Association   (703) 235-8264

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