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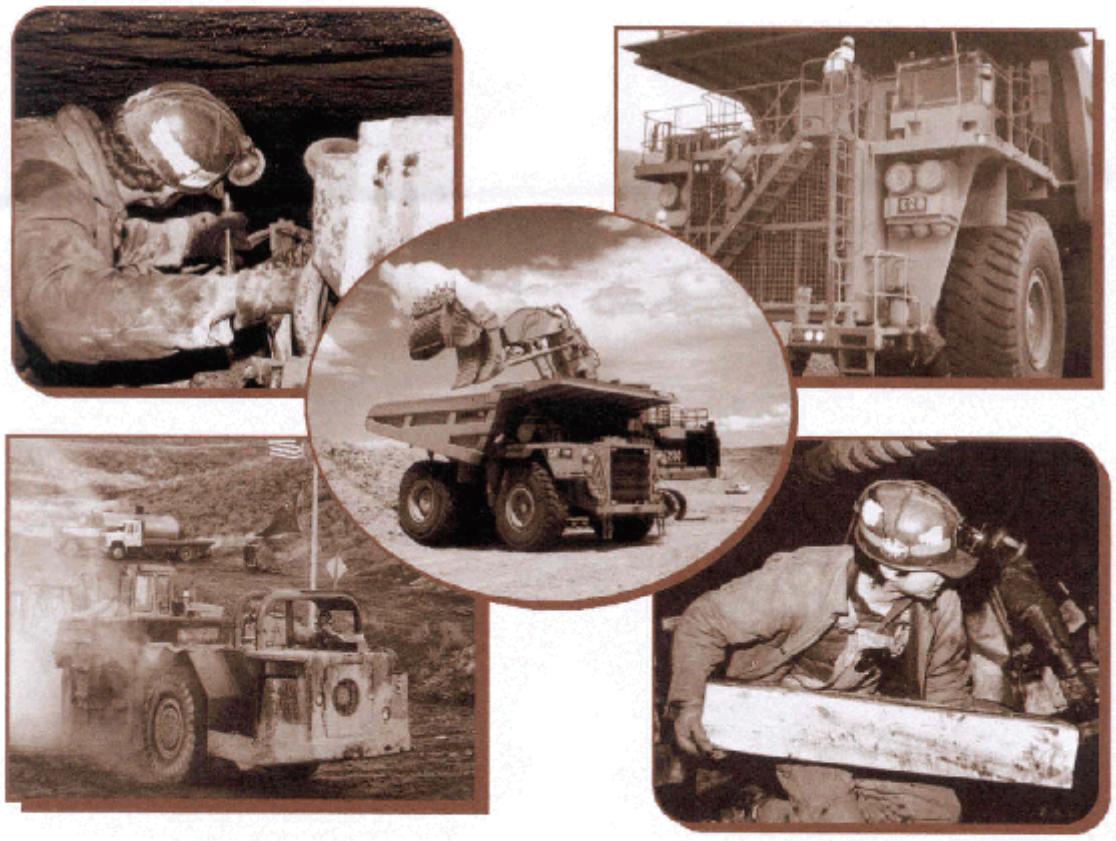

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

A COMPENDIUM
OF NIOSH MINING RESEARCH
2001

Spokane Research Laboratory and Pittsburgh Research Laboratory

U.S. Department of Health and Human Services
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Washington, DC

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FOREWORD

Ensuring the safety and health of America's mine workers continues to be a top priority for NIOSH. Our research highlights over the past year indicate a strong program for addressing these issues. Our program has been developed in close coordination with input from our stakeholders, and this input has been detailed in previous reports. Our surveillance efforts continue to identify the areas of greatest concern, and these areas serve as focal points for program development and review. The research highlights in this compendium cover all mining sectors and reflect the needs and concerns of the mining community as a whole.

On a more personal note, I am privileged and honored to join NIOSH as the Associate Director of the Office for Mine Safety and Health Research. During my brief tenure thus far, I have been most impressed by the strong stakeholder support for the research program and will continue to foster these relationships. The legacy left by Dr. Larry Grayson, the previous Associate Director, is one of research excellence, strong strategic planning, and exceptional involvement with the mining community. I will continue on the path established by Larry, and I am excited about being a part of the excellence and dedication of the NIOSH mining family.

This compendium communicates to our many partners the current research program of the Office for Mine Safety and Health Research. We are continually striving to enhance our communications and technology transfer efforts, and this publication has served those purposes well. I look forward to the many exciting and rewarding challenges of the mine safety and health research program and continued interactions and communications with our many partners.

Lewis V. Wade, Ph.D.
Associate Director, Office for
Mine Safety and Health Research
National Institute for Occupational
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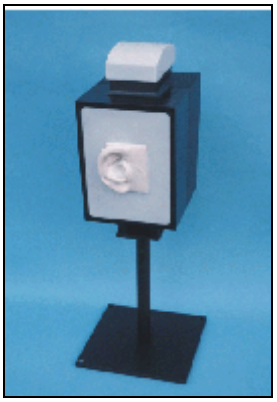

Artificial text fixture (simulated human ear) for hearing protector research.

HEARING LOSS PREVENTION

INVESTIGATION OF TECHNOLOGY FOR HEARING LOSS PREVENTION

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KEYWORDS: Noise, hearing loss, hearing protectors, earplugs, earmuffs, communication

PURPOSE: Evaluate practical technological advances in hearing protective devices for use in different mining environments.

RESEARCH SUMMARY: Previous NIOSH research shows that miners develop hearing loss much more quickly than nonoccupationally noise-exposed individuals. Also, miners experience a greater severity of hearing loss than would be expected for nonoccupational noise-exposed persons of the same age and sex. As described in the National Occupational Research Agenda, problems created by occupational hearing loss include (1) the reduced quality of life due to social isolation and unrelenting tinnitus, (2) impaired communication with family members, the public, and coworkers, (3) a diminished ability to monitor the work environment (e.g., warning signals, equipment sounds, etc.), (4) lost productivity and increased accidents resulting from impaired communication and isolation, and (5) expenses for workers' compensation and hearing aids.

Although the elimination of hazardous noise is the ideal long-term solution to the noise problem, miners will likely need to rely on personal hearing protection in certain situations for quite some time. However, it is well known that noise attenuation provided by hearing protectors as they are worn during everyday use in the workplace is usually worse than when tested under laboratory conditions. Additionally, workers may refuse to wear their hearing protection for any number of reasons. Therefore, this project was initiated to evaluate practical technological advances in hearing protectors, with an emphasis toward optimizing the balance between effectiveness, comfort, overprotection, and communication ability.

Currently, the necessary in-house laboratory facilities and research techniques are being finalized. Individual experiments are planned that involve analysis of new hearing protector technology under both laboratory and field conditions. The laboratory components are to consist of controlled studies using human subjects and/or an anthropometrically correct artificial test fixture to evaluate the adequacy/effectiveness of various hearing protective devices. Field studies are planned to determine the actual usefulness and practicality of the hearing protectors as used in different mining environments. Recommendations can then be offered to the mining community regarding correct earplug/earmuff usage that maximizes recognition of hazard/warning sounds while adequately protecting the miners' hearing.

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Noise profiling of underground mining equipment.

CROSS-SECTIONAL SURVEY: NOISE EXPOSURE PATTERNS/SOURCES

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PURPOSE: Establish representative noise exposure profiles of various mining occupations and equipment.

RESEARCH SUMMARY: In the mining industry, overexposure to noise remains a serious problem for U.S. workers. Every day, 80% of the Nation's miners go to work in an environment where time-weighted average (TWA) noise levels exceed 85 dBA. Moreover, 25% of the miners are exposed to a TWA noise level that exceeds 90 dBA. Research is needed to identify mine worker dosages and characterize the noisiest equipment and worker activities. This will help ensure that the hearing of miners is preserved, future hearing loss is prevented, and the quality of life of our Nation's miners will be enhanced.

The collection of baseline information provides a current and systematic characterization of worker noise exposure patterns and mining noise sources. This research is essential to develop effective intervention strategies targeting engineering controls for noisy equipment and hearing protection practices.

The approach of this research is to conduct a cross-sectional field study of the noise exposure of mine workers. The study is to include a variety of mine types, mining methods, equipment, geographic locations, and mine sizes. Representative noise exposure profiles for the various mine worker occupations will be established by undertaking comprehensive and extensive noise exposure measurements using time-resolved dosimeters to obtain full-shift noise exposures. In addition, a profile of the noise levels of the various mining machines is to be obtained using handheld sound level meters.

To date, noise measurements have been made at several underground coal mines, a surface coal mine, a coal preparation plant, and a stone mine. Numerous other mine surveys are planned in the near future.

KEYWORDS: Hearing loss, research, exposure assessment, noise exposure

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Researchers conduct hearing computerized audiometric evaluations.

A MODEL HEARING CONSERVATION PROGRAM FOR COAL MINERS

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PURPOSE: Design a model hearing conservation program for coal miners that includes both traditional and novel approaches toward hearing loss prevention.

RESEARCH SUMMARY: Hearing loss is one of the 21 priority research areas in the National Occupational Research Agenda and is a major occupational health problem for coal miners. The prevalence of noise-induced hearing loss (NIHL) has remained relatively unchanged for the last 20 years. A significant reason for this is the lack of a systematic plan of intervention proven to be effective for the mining community.

KEYWORDS: Noise, hearing conservation, hearing loss prevention

A cooperative agreement project was initiated with The Pennsylvania State University to develop and implement a "model" hearing conservation program (HCP) at a working underground coal mine. The objectives are to design a model HCP that incorporates the best practices of well-run programs from other industries, implement this program at a cooperating mine, evaluate the program over a 5-year period to demonstrate its efficacy in preventing hearing loss, and transfer findings to the coal mining industry (and others) as quickly and thoroughly as possible.

Other specific goals of the project are to evaluate, document, and statistically analyze hearing threshold shifts to quantify the program's effectiveness; determine individual worker and group data relative to self-reported perception of hearing handicap; identify the relationship between NIHL and hearing threshold shifts; determine the most effective hearing protection devices by measuring the amount of sound attenuation provided for each individual miner; and explore the practicality of using inexpensive personal noise monitors for alerting miners to the presence of excessive noise levels.

A detailed 5-year plan for each program element was completed during the previous year; databases were created to analyze audiometric test results, noise exposure measurements, and other information. Hearing tests are to be conducted every April and November for the duration of the project. As this project begins its third year, attention is focusing on the evaluation of personal hearing protection and the development and testing of effective health education training materials and delivery methods.

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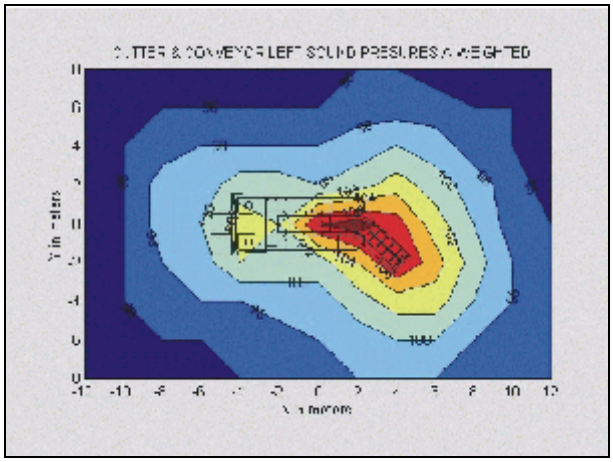

Noise profile for a continuous miner in free field, with the cutter and conveyor running.

ENGINEERING CONTROLS FOR HEARING LOSS PREVENTION

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PURPOSE: Develop a strategy and implementation plan for utilization of noise controls in mining to reduce noise-induced hearing loss (NIHL) among mine workers.

RESEARCH SUMMARY: Overexposure to noise remains a widespread, serious health hazard in U.S. mining and other industries despite 25 years of regulation. Most other categories of illnesses and injuries associated with mining have improved, except for hearing loss. The use of heavy equipment, the drilling of rock, and the confined work environment are just a few factors that contribute to high levels of noise exposure in mining. A recent NIOSH analysis of a large sample of audiograms showed that by age 51 about 90% of coal miners and 49% of metal/nonmetal miners had a hearing impairment. By contrast, only 10% of the nonoccupational noise-exposed population had a hearing impairment by age 51. Simply stated, most miners have a hearing loss by the time they retire. While NIHL is the most common occupational disease in this country, this problem is especially acute among miners. This project focuses on targeting engineering noise control for mining as the first line of defense.

KEYWORDS: Noise, control technology, mining, equipment

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Past research on engineering noise control has been reviewed to determine what has been done and which mining machines are the major sources of noise. Sound pressure profiles are being developed for these mining machines in free field conditions. These sound pressure profiles are being used to determine sound power sources of each machine. Theoretical models of sound pressure profiles are then to be derived for differing mining conditions, which will be validated by in-mine measurements.

Partnerships have been established with JOY, Kennametal, Fletcher, and Consol, which are assisting in evaluating the strengths and weaknesses of various implementation strategies. The strategies form the basis of a long-term implementation plan where appropriate engineering controls are to be selected and targeted to reduce excessive noise exposures to workers.

A Rock Buster is used to remove a roof fall.

INVESTIGATION OF IMPULSE NOISE IN MINING

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PURPOSE: Determine the extent of the hearing loss hazard from intense noise sources and develop the basic knowledge required to reduce the hazard through effective control technology and training.

RESEARCH SUMMARY: Impulse noise sources exist throughout the mining and construction industries and, to a lesser extent, in agriculture and manufacturing. These sources are varied and range from explosives to pile drivers. There are insufficient data to quantify the extent of the resultant health problem or even to support the development of damage risk criteria for impulse noises in confined areas. The most readily available information consists of military data on peak pressure levels associated with unconfined surface detonations as a function of distance and charge mass. There are very little data on blasting in underground complexes, e.g., tunnels and mines. The impulse noise from blasting in an underground mine differs from that on the surface and is strongly influenced by mine geometry, openings, and wall roughness. In a mine entry, the peak intensity is higher at a given distance than for the same explosive mass detonated on the surface, with the added complication that significant low-frequency acoustic oscillations remain for several seconds after the passage of the pioneer pressure pulse. The cumulative effect on workers associated with impulse noise exposure of low frequencies remains unclear, although considerable anecdotal evidence suggests that the effect is pronounced.

Research is underway at Lake Lynn Laboratory and the Safety Research Coal Mine to measure pressure histories from the unconfined detonation of the Mine Safety and Health Administration-approved permissible "Rock Buster." The initial focus of this new exploratory study is intended to address the following: (1) Is the current practice of keeping the blasting team at two right angles from the detonation sufficient to prevent hearing damage? (2) Do audiometric models, such as that developed by Dr. G. Richard Price, U.S. Army, Aberdeen Proving Ground, correctly predict the risk and damage criteria associated with impulse noise in the mining industry? Close collaboration with the U.S. Army Research Laboratory and the mining industry is to continue in FY01.

KEYWORDS: Mining, exposure, intense sounds, impulse

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Wearing hearing protection for 85- to 90-dBA noise levels is an element of the new noise rules promulgated by MSHA.

EVALUATING THE ROLE OF POSITIVE AND NEGATIVE EMOTION IN PROMOTING HEARING CONSERVATION BEHAVIORS AMONG COAL MINERS

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PURPOSE: To test the notion that positive emotions and humor are as effective at motivating behavior change (such as the wearing of hearing protection) as negative emotions, or "fear messages."

RESEARCH SUMMARY: Following a study of 17,260 audiograms from 2,871 coal miners, NIOSH concluded that 90% of coal miners have a hearing impairment by age 51 compared with only 10% of the general population. The present hearing conservation research will investigate two strategies designed to increase hearing loss prevention behaviors among coal miners. A communication framework for studying emotion in behavior change, the Extended Parallel Processing Model (EPPM), has been developed and validated in a number of occupational settings. It will be used to assess the comparative effectiveness of humor versus fear in motivating coal miners to adopt hearing loss prevention behaviors.

KEYWORDS: Mining, hearing loss, communication research

This research is timely because of new Mine Safety and Health Administration (MSHA) noise standards in effect as of September 2000. The new plan has a number of voluntary behaviors associated with it, including the wearing of hearing protection at noise levels between 85 and 90 dBA. Materials have been developed to explain key provisions of the new standards and to list steps that miners can take to lessen the effects of noise to which they may be exposed. The principles of message development, design, and implementation used in this study can also be applied to other occupational groups and risks.

Two versions of the person-wearable dust monitor. The left contains a lapel sampler and belt pack; the right has an integrated cap lamp and dust sampler.

DUST MEASUREMENT AND CONTROL

ASSESSMENT OF PERSONAL PARTICULATE EXPOSURE

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PURPOSE: Develop person-wearable monitors to measure respirable mine dusts and diesel particulate.

RESEARCH SUMMARY: Prolonged inhalation of respirable coal mine dust can cause coal worker's pneumoconiosis (CWP). Between 1968 and 1990, CWP caused the death of 55,467 U.S. coal miners. Accurate measurement of respirable dust is crucial to successfully reducing dust exposures and ending disease. In 1988, NIOSH recommended that diesel exhaust be regarded as a potential occupational carcinogen. Reducing workplace exposure to diesel exhaust would cut back cancer risks.

To reduce disease caused by particulate, improved measurement of respirable coal mine dust and airborne diesel particulate is needed. Real-time particulate monitoring can effectively locate areas where dust controls are needed and determine how well they are working. The Coal Mine Respirable Dust Task Group of the Mine Safety and Health Administration recommended development of both fixed-site and portable continuous respirable dust monitors. Specifically, there is a need to understand what mine dust fraction can be attributed to diesel exhaust. However, methods to measure the DPM levels in mining are still in development, and no real-time methods are available.

For a compliance accuracy device, NIOSH is developing under contract a person-wearable dust monitor using the tapered-element operating principle. The oscillating tapered element is the heart of a commercially available dust monitor used around the world to assess combustion particulate and ambient air quality levels. For a low-cost dust-measuring device, a differential pressure instrument is being used as a surrogate for mass. This device uses a disposable sample tube and a small pump to deposit mass onto a filter. The increase in pres-sure, caused by the dust loading, shows the dust level. In addition, new commercial instruments and new combinations of technologies are being tested. One is the combination of size-selective sampling with differential pressure measurement. This idea could form the basis for a near-real-time diesel particulate monitor for mine use. Another such combination is the integration of smoke detector technology with light-scattering technology. This could be a way to discriminate between coal mine dust and diesel particulate. The combined detector/light-scattering approach uses an ion trap technology and discrete forward light scattering to determine diesel and dust levels respectively. Bench-scale results are very favorable.

KEYWORDS: Dust, exposure assessment, coal mining, dust sampling, black lung

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Dust sampling in a full-scale longwall gallery.

DUST CONTROL IN LONGWALL MINING

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PURPOSE: Reduce the respirable dust exposure of mine workers at longwall mining operations of underground coal mines.

RESEARCH SUMMARY: Medical studies have shown that long-term exposure to excessive levels of respirable coal mine dust can lead to the development of coal workers' pneumoconiosis (CWP), a debilitating lung disease commonly known as "black lung." The most recent results of a voluntary x-ray screening program for underground coal mine workers indicates that about 8% of the workers with 25 or more years of mining experience were diagnosed with CWP. In 1999, shift production from longwall mining operations averaged 5,000 tons per shift; longwall mines accounted for over 50% of underground coal production. Nearly one of every five compliance dust samples from longwall operations exceeds the permissible exposure limit. Data from dust sampling, medical screening, and production trends indicate that controlling dust on longwalls remains a major health concern and challenge for longwall mining.

This multitasked research project addresses improvements in the application of primary control technologies: ventilating air and spray water. Laboratory testing is being conducted at a full-scale longwall gallery at the Pittsburgh Research Laboratory to evaluate the interactions between ventilating air, water flow, water pressure, spray system design, cutting direction, and mining height to measure the impact on dust levels on the longwall face. Tests at a mining height of 7 feet have been completed. The data from these tests are currently being analyzed to identify dust control trends that can be used by an individual longwall operator to optimize dust control for conditions specific to that mine. Additional laboratory testing has been completed within a wind tunnel designed to simulate dust liberation during shield advance and subsequent entrainment in high-velocity airstreams. Statistically significant increases in respirable dust levels were observed as air velocity was increased from 400 to 1,600 feet per minute.

KEYWORDS: Coal mine dust, underground mining, control technology

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Inlet hood prototype for improved dust capture on drilling operations.

DUST CONTROL IN SURFACE COAL MINING

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PURPOSE: Identify the effectiveness of existing dust control technologies used for highwall rock drills and bulldozers at surface coal mining operations and improve coal miners' health protection from silica dust exposure through the advancement of control technologies.

RESEARCH SUMMARY: Silicosis is a well-known occupational disease that kills more than 200 people annually and cuts across a wide variety of industrial settings. Surface mine rock drillers in particular are at high risk because of the potential of being exposed to extremely high levels of respirable silica dust when drilling through rock containing silica. NIOSH conducted a study of job categories to examine exposure data collected during a 2-year period at surface mine sites, preparation plants, and shop/maintenance facilities. The study concluded that the highwall drill operator and helper had the two highest silica exposures of all job categories examined.

The interactions between drilling parameters and overburden lithology are being characterized to determine how these interactions affect respirable silica dust generation. Once the drilling parameters and rock characteristics have been defined in terms of their impact on silica dust generation, appropriate control technologies can be developed to reduce silica emissions. Furthermore, many surface drills have dust containment problems at the shrouded drill table over the hole. Preliminary testing of an impaction inlet hood prototype of the drill's primary dust collection system was conducted and has shown that the new design successfully deflected larger size particles from being drawn into the collector. During surface mine dust surveys, sampling was also done to identify silica sources, exposures, and controls for bulldozer operators. Investigations into improving quality control methods to ensure the integrity of enclosed environmental cabs on bulldozers are being done through cooperative work with mining companies, equipment manufacturers, and the Mine Safety and Health Administration. A Cooperative Research and Development Agreement (CRADA) was drafted with Clean Air Filter to develop field test methods for evaluating the environmental integrity of enclosed operator cabs.

KEYWORDS: Surface mining, respirable dust, drilling, silica, dust control technology

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Cooperative research effort to lower surface drill operator silica dust exposure by improving cab filtration efficiency and pressurization.

SILICA DUST CONTROL IN METAL/ NONMETAL SURFACE MINING

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PURPOSE: Develop control technology to reduce worker exposure to silica and other harmful contaminants in metal/nonmetal mining operations.

KEYWORDS: Silicosis, silica dust, control technology, underground mining, surface mining, mineral processing

RESEARCH SUMMARY: Although all types of respirable dust are potentially harmful to a worker's lungs, overexposure to respirable silica is extremely hazardous. Chronic overexposure to respirable crystalline silica (particle diameter <10 microns) leads to progressive lung deterioration known as silicosis. In addition, in 1997, the International Agency for Research on Cancer stated that silica dust is also carcinogenic (lungs). More than 1 million workers across the United States are exposed to silica dust each year.

The Mine Safety and Health Administration's (MSHA) records indicate that there is a significant percentage of both underground and surface metal/nonmetal miners overexposed to silica each year. The following occupations have the highest exposures: truck drivers, crusher operators, front-end loader operators, rotary drill operators, bag operators, bag stackers, laborers, maintenance, cleanup, and utility workers.

One research effort is underway to determine the impact of different plant structural designs on respirable dust concentrations. This study has shown that, as expected, an open structure design provided the lowest dust levels of the various structures evaluated.

An extensive research effort is ongoing to lower equipment operators' dust exposure by improving filtration efficiency and pressurization in enclosed cabs in all types of mining equipment. This research is a multifaceted effort being performed in cooperative agreement with MSHA, several mining companies, and a number of dust filtration and pressurization manufacturers. Evaluations are currently being done at two surface mining operations. An enclosed cab study is also being investigated for a load-haul-dump application in an underground gold mine.

Research is also currently being conducted at both underground limestone and gold mines to determine primary silica dust sources and evaluate control technology. Improvements in mine-wide ventilation and localized ventilation systems are being investigated as a primary means for controlling various dust sources in underground operations.

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Roof bolter dust collectors require regular cleaning of the dust box and canister filter.

CONTROL OF SILICA DUST EXPOSURES IN UNDERGROUND COAL MINING

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PURPOSE: Develop means of reducing exposures to respirable silica dust at the continuous mining machine and roof bolter operator's location.

RESEARCH SUMMARY: The Federal respirable dust standard limits exposures to 2.0 mg/m^3 for an 8-hour working shift. If the silica content exceeds 5% by weight, the dust standard is reduced to 10/(% silica). The 2.0 mg/m^3 standard and a reduced standard limit silica exposures to 100 µg/m^3. However, recent data from the Mine Safety and Health Administration show that about one-fourth of continuous mining machine and roof bolter operator samples exceed 100 µg/m^3.

In-mine surveys indicate that overexposures to respirable silica dust can occur when the roof bolting machine works downwind of the continuous mining machine. A canopy air curtain, mounted on the underside of the roof bolter operator's canopy, can reduce these exposures by providing a constant flow of filtered air over the roof bolter operator. Laboratory tests were completed that show that the air curtain provides dust reductions for positions close to the canopy, although these reductions decrease as mean entry air velocity increases. In-mine evaluations of the canopy air curtain system are planned.

These mine surveys also show that the roof bolter can be a source of silica dust exposure for the continuous mining machine operator. Although existing dust collection systems on roof bolters can be very effective when operating properly, a lack of regular maintenance can reduce their effectiveness. Specifically, the dust canister filters can become clogged through lack of cleaning or torn through improper cleaning. Laboratory research is to be conducted to measure filter integrity and efficiency with regard to the impact of multiples cycles of filter loading and cleaning. Guidelines can be presented regarding proper use and maintenance of dust filters.

Water sprays and ventilation airflow are used to control dust exposures and methane gas levels. However, specific applications of water and ventilation to control respirable dust may not always control gas levels effectively. Using a full-scale test facility in conjunction with state-of-the art gas monitoring equipment, testing is to be done to evaluate different water spray and ventilation airflow designs for effective control of both respirable dust and methane gas.

KEYWORDS: Silica exposures, dust, coal mining, ventilation

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A water-powered scrubber simultaneously entrains air movement and captures dust.

DEVELOPMENT OF ENHANCED SPRAY DUST CAPTURE PRINCIPLES FOR IMPROVED SILICA DUST SUPPRESSION

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PURPOSE: Develop several novel spray nozzle technologies and apply fluid dynamic principles to improve water droplet collection efficiency of airborne respirable silica dust.

RESEARCH SUMMARY: Overexposure to airborne respirable crystalline silica dust can cause serious or fatal respiratory disease. Mining machine operators were the most frequent occupation (16.0%) recorded on silicosis-related death certificates during 1991-92; coal mining was the first (9.5%) and metal mining was the third (8.6%) most frequent associated industry. Compliance data from the Mine Safety and Health Administration (MSHA) for the permissible exposure limits (PELs) indicate that nearly 25% of the coal mine dust samples and over 20% of the metal mine dust samples exceed the MSHA-mandated PELs. About one-eighth of the nonmetal and stone mines also exceed their mandated respirable dust PELs. These data indicate that there continues to be a high likelihood of overexposure to silica dust in the mining industry, especially in coal and metal mines, which have a high incidence of silicosis deaths.

KEYWORDS: Respirable crystalline silica dust, mining, spray dust capture

The approach taken to combat the amount of respirable silica dust exposure present in the mining industry is to develop several enhanced spray dust capture principles into mine functional engineering control systems. This enhanced spray dust capture research will focus on increasing the probability of water droplet and respirable-dust particle interaction by (1) increasing the number of smaller sized spray droplets per unit volume of water used and (2) optimizing the energy transfer of spray droplets with the dust-laden air.

Spray atomization literature from other industries (automotive, aerospace, process engineering, agriculture, and medical) is being studied for application to experimental design and physical modeling of spray system optimization for dust capture.

Many miners are exposed to high levels of DPM.

DIESEL EMISSIONS AND TOXIC SUBSTANCES

REDUCING DIESEL PARTICULATE EXPOSURE IN WESTERN MINES

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PURPOSE: Reduce the exposure of workers in western mines to potentially dangerous levels of exhaust from diesel engines. Products of this research will be information and tools that the mining industry can use to reduce worker exposure levels.

KEYWORDS: Diesel exhaust, diesel particulate matter, worker exposure, mine health and safety, hydrogen

RESEARCH SUMMARY: Exposure to diesel exhaust, especially diesel particulate matter (DPM), has been recognized as a health concern for some time. The Mine Safety and Health Administration has identified DPM as a potential hazard and anticipates putting new regulations in place to help reduce worker exposure in underground mines. Several entities, including the U.S. Environmental Protection Agency, have produced studies that suggest diesel exhaust should be labeled as carcinogenic. As these events have unfolded, and despite uncertainties about current and past exposures of miners and health effects, key mining stakeholders have come together to pursue the reduction of diesel emissions in the mining workplace through partnerships. This project will support western mining partnerships through control technology research applied to existing diesel equipment and through feasibility studies of zero emissions technologies that could replace diesel engines.

A fully successful program has the potential to reduce exposure to diesel particulates by 90% or more. If implemented in underground mines, almost 100,000 workers would see significant reduction in DPM exposures. Research results could also be applied in other industrial sectors where diesel engines are used in close quarters, i.e., factories and warehouses. The transfer of technology to these sectors could reduce exposure for hundreds of thousands of employees in nonmining industries.

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Research scientists, using the thermo-optical method (NIOSH method 5040 for carbon) to determine the amount of DPM on filter samples collected in the workplace, are able to assess worker exposure and effectiveness of emission control systems.

DIESEL ENGINE EMISSIONS MEASUREMENT AND ANALYSIS

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PURPOSE: Advance technology for measurement of worker exposure to diesel exhaust contaminants in underground mines.

RESEARCH SUMMARY: Various State, Federal, and private health-watch organizations have declared diesel particulate matter (DPM), or carbon-based soot, to be a suspected or probable carcinogen. Recently, one nongovernment body, responsible for recommending occupational exposure guidelines, recommended a DPM concentration limit of 50 $\mu g/m^3$. DPM levels in U.S. mines expose about 30,000 workers to concentrations that approach 20 times this limit.

This project directly addresses the issue of accurately measuring DPM in the presence of carbon-containing mine aerosols (coal, limestone, and other ore dusts), oil mists, and cigarette smoke. In its proposed rule to regulate workplace concentrations of DPM in underground metal and nonmetal mines, the Mine Safety and Health Administration selected an analytical method that is susceptible to measuring the aforementioned carbon-containing mine dusts along with the diesel DPM. NIOSH performs laboratory and field experiments to define and mitigate the effects of nondiesel dusts on the measurement of DPM.

In underground mines with airborne ore dusts and elevated DPM levels, ore samples are being gathered. After technicians pulverize these ore samples to dust, they mix the dust with diesel exhaust and inject the mixture into a laboratory chamber. Dust samples are collected from within the chamber, and the results are analyzed. The goal is to quantify the effects of the carbon-based dusts on the compliance method and, ideally, to develop methods to stop these effects.

Accurate DPM measurement can reduce uncertainties concerning workplace concentrations of DPM, which enables better assessment of the effects of control technology on tailpipe emissions. It also provides a better measurement of worker exposures and workplace DPM concentrations.

KEYWORDS: Underground mining, diesel, exhaust, soot, elemental carbon, measurement

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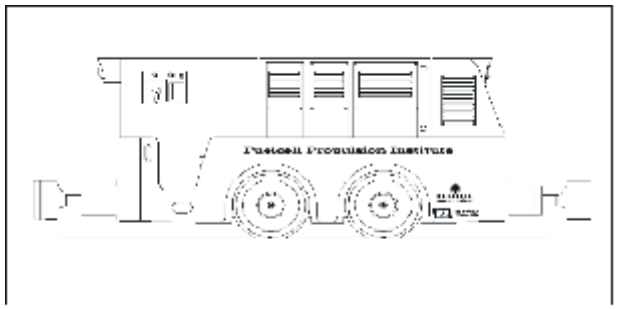

A small (4-ton) fuel cell-powered mine locomotive. ***(Courtesy of R. A. Warren Equipment, North Bay, Ontario, Canada).***

SAFETY AND HEALTH EVALUATION OF A FUEL CELL-POWERED FOUR-TON LOCOMOTIVE FOR UNDERGROUND MINING

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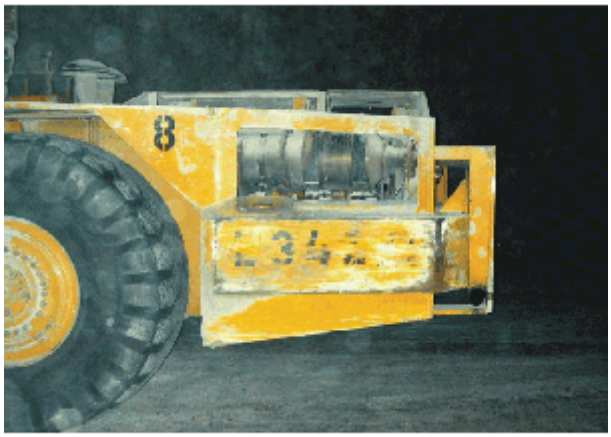
KEYWORDS: Mining, fuel cell, diesel, particulate, noise, locomotive

PURPOSE: Investigate the anticipated air-quality improvements and workplace noise level improvements expected when implementing fuel cell-powered mining vehicle technology to supplement diesel vehicle technology in underground mines.

RESEARCH SUMMARY: Due largely to the efforts of the Fuel Cell Propulsion Institute (FPI), fuel cell technology is anticipated to be demonstrated in the mining industry in the near future in the form of a 4-ton locomotive. Two areas are to be measured in field tests on a prototype vehicle: (1) air-quality improvements and (2) the improvements expected in workplace noise levels.

The Pittsburgh Research Laboratory has conducted a literature review to determine the performance to be reasonably expected of fuel cell technology in mining applications. The existing literature on diesel technology and a knowledge of proton exchange membrane fuel cell technology suggests that air-quality issues with a H_2-powered fuel cell vehicle will be nonexistent. Diesel exhaust contaminants will no longer contaminate workplace atmospheres. The emissions from the fuel cell powerplant will be water and oxygen-diminished air. Noise levels from fuel cell-powered vehicles should be comparable to those from electric vehicles. The greatest concern is H_2 safety, but contractual commitments by the FPI member companies have precluded a detailed NIOSH examination of this area of the technology.

The Mine Safety and Health Administration's (MSHA) Approval and Certification Center has sole authority and responsibility to grant or withhold an approval. NIOSH's role is to develop a protocol and conduct measurements to document the performance of each class of vehicles. Successful completion of this project will yield the first documented tests of the noise and air-quality performance of a fuel cell-powered mining vehicle.



Diesel exhaust filtration on mining equipment offers substantial reductions in workplace DPM concentrations.

DIESEL PARTNERSHIP RESEARCH

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PURPOSE: Investigate and evaluate performance of diesel exhaust control technology for application in underground coal and metal/nonmetal mines, with particular focus on technology for engines in outby areas of coal mines.

KEYWORDS: Underground mining, diesel, exhaust, soot, exhaust controls

RESEARCH SUMMARY: In many underground coal mines, mantrip and utility vehicles are diesel-powered. This machinery adds significantly to gaseous and particle contaminant levels in the ventilation air. Increasing the quantity of these contaminants can have a negative effect on miner health. As a result, the Bituminous Coal Operators Association, the United Mine Workers of America, and NIOSH have formed a partnership. The goal of this alliance is to find and test practical methods of reducing diesel exhaust contaminants. The partnership resulted in this project, which began in January 2000.

More stringent air-quality standards for highway and off-highway trucks are driving the rapid advances in diesel engine emission control technology. NIOSH researchers investigated these advancements and generated a summary of the many technology documents. Based on this assessment, in-mine evaluations of alternative emission control technologies are planned.

The Pittsburgh Research Laboratory is to soon receive a transportable engine dynamometer. This device will enable testing of emission control technologies at operating mines. At these locations, engine loads and mine ventilation dilution conditions can be realistically controlled. Plans also call for the long-term field testing of promising exhaust aftertreatment systems on mantrip vehicles at a partner's mine. Implementation of these control technologies can reduce emitted diesel particulate matter (DPM) by 95%. In addition, mines will have available cleaner engines and enhanced control systems. When miners apply these solutions and make use of better maintenance, they can effectively reduce worker DPM exposures.

Consult *www.deep.org* and *www.dieselnet.com* for up-to-date reports of research in the area of diesel emission control technology.

A sampling pump is being placed near the main rock crusher in a mill to collect a dust sample.

PORTABLE MONITORS FOR AIRBORNE METALS AT MINING SITES

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PURPOSE: Develop field-portable technologies and methods to (1) determine airborne metal concentrations in mines and refining operations rapidly so potential overexposures can be assessed quickly and (2) implement and evaluate intervention controls on a timely basis.

RESEARCH SUMMARY: Most workers at mining and construction sites encounter dust and fumes throughout the workday. In some cases, metals and trace amounts of other toxic substances in these dusts and fumes can cause significant health effects if exposures are great enough. Concern with metal exposures at construction and mining sites has been increasing as more connections between exposures and health effects are made. Identifying toxic substances in dust is a goal for all mining commodities. Previously, it was not possible to obtain timely on-site analyses of metal concentration and exposure data due to the lack of field-portable devices that were cost-effective and practical.

At present, the most common method of assessing workers' exposures to multiple airborne metals involves collecting filter samples and sending them to an analytical laboratory. There, wet chemistry methods are used to pretreat the sample, usually by digesting the filter medium. However, the time delay associated with this procedure has made it difficult to study real-time exposure. Therefore, in determining whether workplace metal exposures should be reduced and to evaluate subsequent control strategies, NIOSH researchers are utilizing cost-effective, on-site screening techniques for assessing multiple metal concentrations with near real-time (end-of-shift) speed.

On-site exposure assessment studies for lead are being conducted. Sampling consists of 2 days of collecting area air samples during milling and smelting operations in accordance with NIOSH standard methods. The samples are then analyzed for lead with field-portable x-ray fluorescence (XRF) spectrometry and anodic stripping voltametry (ASV) equipment. Preliminary results are given to the mining companies within a few days of sample collection. The samples are then sent to a laboratory for verification by standard analytical methods. Two to three months may pass before these results are received.

This new project will demonstrate the capability of the instrument and methods to measure and analyze the different forms of lead found in mining and smelting operations accurately. The benefit to the mining operation is near-real-time reporting of results.

KEYWORDS: Mining, exposure assessment, engineering controls

Following the processing of gold ore, a refinery worker in Bella Rica, Equador, burns the remaining impurities, which may lude small amounts of mercury.

CHEMICAL HAZARDS IN MINING AND PROCESSING

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PURPOSE: Investigate and evaluate potential chemical hazards in mining workplaces to enable development of control or mitigation methods. Characterize exposure to mercury vapor, silver dust and fumes, and hydrocarbons in underground coal mines.

RESEARCH SUMMARY: Exposure to metals and other chemicals in mining workplaces, particularly in milling and refining facilities, may adversely affect thousands of workers. Mercury occurs naturally in some ore deposits, and because of its similarity to gold and silver in chemical complexing and adsorption behavior, it is retained during processing. Because mercury has a high vapor pressure, whenever ore concentrates containing mercury are heated, the mercury is vaporized. While the use of mercury for processing gold is illegal in the United States, it is still used extensively in developing countries and continues to introduce both environmental and health risks worldwide. Minimizing exposure to mercury is crucial due to the serious health effects associated with overexposure. NIOSH researchers conducted surveys to determine if overexposure to mercury was occurring in Venezuela and Ecuador. Included in the surveys were industrial hygiene studies, biological monitoring, and an evaluation of mining processes.

Overexposure to the soluble form of silver also presents a potential hazard. The soluble compounds of silver are considered to be more toxic than silver metal dust and fumes; therefore, the American Conference of Governmental Industrial Hygienists (ACGIH) established separate threshold limit values (TLV) for metallic and soluble compounds of silver. However, the Mine Safety and Health Administration, NIOSH, and the Occupational Safety and Health Administration do not use separate standards. Research is being conducted to develop an analytical method that will differentiate between water-soluble silver compounds and metallic silver. This will enable mining companies to focus engineering control efforts on areas with higher concentrations of soluble silver compounds.

Some underground coal mines have encountered pockets of naturally occurring liquefied hydrocarbons. The purpose of this aspect of the project is to characterize the hydrocarbon material, determine the toxicity and the potential health hazard from dermal and inhalation exposures, compare the results to the established occupational exposure limits, and determine the flammability of the material and how the hydrocarbons will affect the lower explosive limit in the mine.

The engineering controls used by participating mines to minimize exposures will be evaluated. Additional workplace evaluations at precious metal mines will be conducted to collect information about mercury and silver exposure hazards.

KEYWORDS: Mercury, silver, mining, exposure assessment

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NO_2 fumes after a blast.

TOXIC FUMES FROM BLASTING

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PURPOSE: Reduce worker exposure to blasting fumes by determining the causes of excessive blasting fumes and the toxic fumes generation of various blasting agents under different blasting conditions. Develop strategies to minimize exposure to the fumes.

RESEARCH SUMMARY: All explosives generate toxic fumes when detonated. The composition of these fumes is typical of what might be expected from any combustion process and includes carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2), and ammonia (NH_3). Care must be taken to ensure that workers are protected from the fumes. As mines have switched from high explosives to ammonium nitrate/fuel oil (ANFO) over the past 30 years and blasts have increased in size, the problem of toxic fumes generation in blasting has increased.

To address the hazards of toxic fumes, a chamber has been constructed in which up to 10 pounds of blasting agent may be detonated and the toxic fumes confined. Following detonation, the fumes are sampled to determine the quantities of CO, NO, NO_2, NH_3, and other toxic gases. Blasting agent formulations typical of those employed in industry are evaluated to determine their relative fumes generation. The blasting agent is loaded in steel pipes of various wall thicknesses to simulate a variety of confinements. The blasting agent is soaked in water to simulate loading blasting agent in wet boreholes. Additionally, a variety of contaminants may be added to the blasting agent to determine their effect on fumes generation. Opportunities to extend this research into the field through cooperative agreements with mines are being explored.

This research is carried out in partnership with the Institute of Makers of Explosives, its member companies, and the members of the Wyoming Mining Association, all of which are aware of the hazard and are seeking solutions.

KEYWORDS: Explosives, blasting agents, fumes

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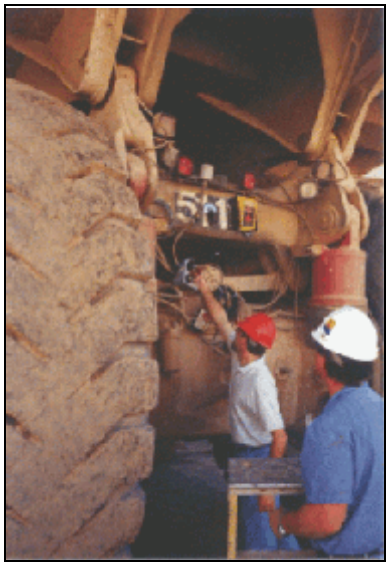

Mounting a collision warning device on the rear end of a haulage truck.

HAZARD DETECTION AND WARNING DEVICES

SAFETY ENHANCEMENTS FOR OFF-HIGHWAY HAULAGE TRUCKS

RESEARCHER: **Todd Ruff**

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KEYWORDS: Surface mining, powered haulage, dump truck, collision warning system, proximity detection

PURPOSE: Develop interventions that will decrease accidents involving off-road dump trucks in surface mining operations. Specific goals include reducing fatalities and injuries caused (1) when a truck operator cannot see all areas around the equipment from the cab and (2) by a lack of operator training or experience in adverse conditions.

RESEARCH SUMMARY: The following tasks are planned:

(1) *Visibility aids for dump truck operators*. This task will focus on developing and testing systems that provide information to a truck driver regarding the environment around the truck. The systems may consist of several technologies for providing reliable information to prevent collisions and other accidents, such as—

- Enhanced visual information from cameras on the truck that monitor blind area.
- Sensory information that warns an operator that the truck is near an obstacle, vehicle, person, or a change in terrain.
- Truck position and attitude data showing the distance to dumping points or other hazardous locations.

(2) *Improved truck driver training for adverse conditions*. This task will involve investigating available training methods and materials to determine if improvements can be made in training curricula for truck drivers. The focus will be on training a driver to react correctly in adverse situations, such as mechanical failure, excessive speeds on steep haul roads, adverse weather, and slippery roads. The future direction of this task will depend on findings during the first year, but may include developing improved training materials or methods and evaluating the latest training simulator technology as it becomes available. Recommendations will be made based on these evaluations.

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Static load/load rate monitoring system being tested on an MRS in a western U.S. coal mine.

MOBILE MINING EQUIPMENT WARNING SYSTEMS

RESEARCHERS: John Owens and Wayne Howie

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PURPOSE: Develop effective monitoring and warning systems for mobile mining equipment to reduce accidents resulting from dangerous operating conditions and practices.

KEYWORDS: Mining, mobile roof supports, pillar extraction, warning system, rollover, control technology

RESEARCH SUMMARY: A common danger in the mining industry occurs when mobile mining equipment is unknowingly operated in unstable configurations and dangerous conditions. Such instabilities can be initiated through both operator error and changing terrain and can result in equipment rollovers and deaths of workers. Unstable configurations and poor operating practices most frequently occur during the operation of front-end loaders, skid-steer loaders, highway trucks, and dozers. According to accident and fatality data for 1991-95 from the Mine Safety and Health Administration, the second largest category of causes of fatalities at underground mines was powered haulage (22%), while at surface mines, the categories were powered haulage (42%) and machinery (18%). A load rate monitoring device was developed by SRL researchers for mobile roof support (MRS) machines. The device monitors the loading rate on an MRS in real-time to alert miners of unstable ground conditions during pillar-pulling operations. Lights on the device indicate progressively higher load rates on the machine.

An integrated ground monitoring system is currently undergoing long-term testing at a coal mine in Utah. The system combines the simplicity of convergence measurements with monitoring the load rate on the hydraulic legs of an MRS to alert miners to unstable roof and pillar conditions so that miners and equipment can be removed before a roof fall occurs. Following successful completion of the field evaluation, the device will be adapted to monitoring critical operating parameters of other mobile mining equipment.

The research is being performed in four phases. The first phase involves completing the field tests and evaluations of the monitoring device on an MRS in a retreat mining section. The second phase will involve selecting mobile equipment to be studied according to criteria based on protecting the greatest number of workers. The third phase will involve identifying critical operating parameters that signify unsafe operating practices for the equipment selected and appropriate sensors to monitor these parameters. The fourth phase will involve redesigning the patented microprocessor-based MRS warning system to monitor these critical operating parameters and trigger an alarm whenever a critical combination of these factors occurs.

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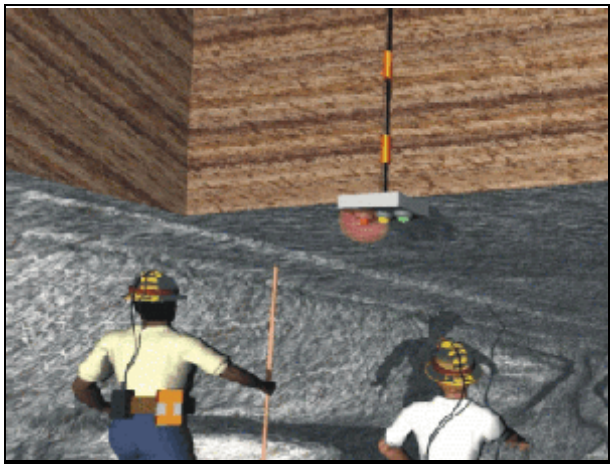

Warning device to alert miners to rock fall hazards.

ADVANCED WARNING OF GROUND STABILITY HAZARDS

RESEARCHERS: Steve Signer and Lewis Martin

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PURPOSE: Investigate ongoing developments in electronics, communications, and computer technologies; identify appropriate safety applications for these advances; and adapt and apply these improved technologies to monitoring ground stability hazards in underground mines. In conjunction with this research, develop practical warning devices to alert underground workers of hazardous locations and impending ground control failures.

KEYWORDS: Underground mining, ground stability, monitoring instruments

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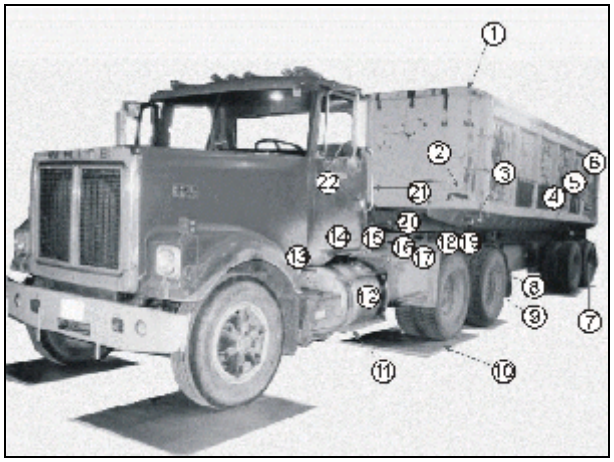
RESEARCH SUMMARY: Mine Safety and Health Administration statistics indicate that there is a dire need to warn underground miners of unexpected ground stability hazards. Although research studies conducted by the former U.S. Bureau of Mines and NIOSH have demonstrated that geotechnical instruments can be used effectively to identify and monitor ground control hazards, modern rock mechanics instruments are rarely used by the mining industry. Most mines, especially the smaller operations, do not have the expertise or resources available to design an effective instrumentation plan, properly install and monitor a variety of instruments, and analyze and interpret the electronic readings obtained from the instruments. As a result, ground control hazards are primarily monitored through visual observations, and injuries and fatalities continue to occur because of unexpected roof and rib falls.

To obtain ground stability information from locations that have traditionally been difficult to monitor, such as mined-out areas, active mining stopes, retreat mining faces, and tailgate entries, cableless techniques will be developed to monitor instruments remotely. A prototype miniaturized data acquisition system is being constructed that can measure and record strain readings remotely on 16 strain gauges for over 1 year without the need for long lead wires. This system will be used in conjunction with a new strain sensor and previously developed instrumented roof bolts. A sensor prototype has been developed that can measure rock movement up to 20% strain. This sensor can be configured for different rock types. Critical information includes determinations of when rock movement exceeds the strain limits of roof support systems; measurements of rock shear displacement, which causes failure of roof bolts; and monitoring changes in strain in three dimensions, which improves the design of an adequate level of support to prevent ground failures.

Both laboratory and field tests will be conducted on the miniature data acquisition system and the strain sensor. Hazardous levels of horizontal, vertical, and shear strain that can lead to rock failure will be detected using this technology so that a warning signal can be given and corrective action taken.



A 23-ton truck showing points used to measure voltage potentials that may be present on the exterior surface.

OVERHEAD POWER LINE CONTACT ALARM FOR MOBILE EQUIPMENT

RESEARCHER: **James C. Cawley**

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PURPOSE: Determine the electrical characteristics of mobile equipment that accidentally contacts an overhead power line. Design and test an effective alarm device to warn vehicle operators and nearby support personnel of vehicles energized due to accidental power line contact.

KEYWORDS: Mining, electrocution, power line, alarm, crane, truck

RESEARCH SUMMARY: Overhead electric power lines are a serious electrocution hazard to crane, truck, and drill rig operators in the mining industry. During 1980-97, at least 106 mobile equipment overhead-line contact incidents were reported in the U.S. mining industry. These caused 106 injuries, of which 30% were fatal. Most involved cranes (39%), dump-bed trucks (22%), and drills (13%). The widespread use of a reliable overhead power line contact alarm on mobile equipment could reduce the number of injuries and fatalities from equipment-line contacts. A practical contact alarm could also be applied in other industries where overhead power lines are a hazard, such as construction, agriculture, broadcast communications, and public utilities.

Initial research shows that electrical currents flowing through a vehicle in contact with a high-voltage source are of sufficient magnitude to be practically detected and trigger an alarm. An alarm device would warn the equipment operator and nearby coworkers that the vehicle is an electrocution hazard and should not be approached (or dismounted by the operator). Clearly, victims in contact with the crane or a conductor electrically connected to the crane (a control pendant or load line) at the instant of contact with the power line would not be protected.

Overhead power line contact by current and voltage-sensing methods were examined in the first year of this 2-year project. Both methods seem feasible at this point. Voltage differences between surfaces in the operator cab and along the operator's egress path have been measured on three vehicles and are being analyzed to determine under what circumstances lethal voltage differences may exist. Based on the preferred method of detection, a prototype device is to be constructed and subjected to laboratory tests to verify its performance. In addition, load links and remote controls may be studied as supplemental operator protective devices.

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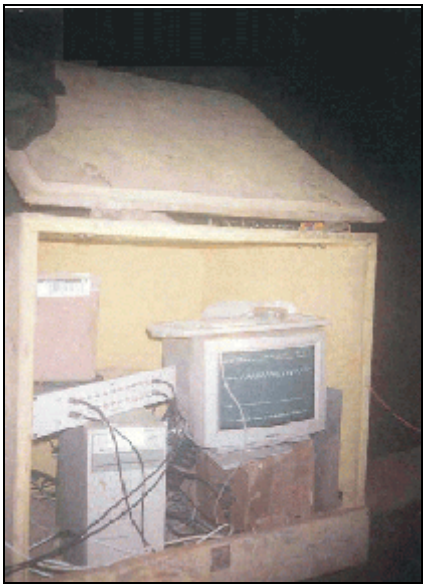

Electromagnetic data acquisition system.

INVESTIGATION OF ELECTROMAGNETIC PRECURSORS TO ROCK BURSTING

RESEARCHER: **Doug Scott**

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PURPOSE: Develop a method to monitor the rock surrounding miners and establish a baseline for measuring electromagnetic emissions during the mining cycle.

RESEARCH SUMMARY: Highly stressed rock in stopes continues to be a primary risk to the safety of miners in underground mines, and failure of the rock results in both injuries and deaths. Novel methods need to be developed that will alert miners to the possibility of imminent ground failure.

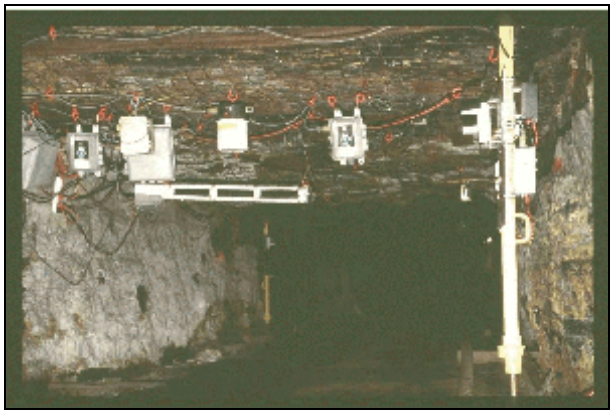
Acoustic and electromagnetic radiation emissions coincide when rock breaks. Acoustic monitoring of a rock mass to detect ground movement in deep underground mines has been done successfully for several years. Electromagnetic emissions associated with rock failure have been shown to occur in controlled laboratory situations; however, such emissions have not been used to detect imminent ground failure in deep underground mines. Monitoring electromagnetic emissions in a rock mass during the mining cycle could provide one method to warn miners of imminent ground failure.

KEYWORDS: Underground mining, electromagnetic emissions, monitoring instruments

An electromagnetic monitoring system has been in operation intermittently at the Galena Mine, Kellogg, ID, for several months. However, the data collected are suspect because of inherent mine electromagnetic noise, such as electrical interference from mine systems.

The project will proceed in two phases. Phase 1 involves comparing the original electromagnetic data with a controlled, independent electromagnetic system to prove whether or not the original data are reliable. Work will involve installation of an electromagnetic antenna system with an independent power source in the Galena Mine, as well as an accelerometer and a data acquisition system. Electromagnetic data from both the new system and the existing one will be compared and analyzed. A report will be prepared that characterizes the signals and provides recommendations for improving methods for recording electromagnetic signals from the rock mass.

Phase 2 will proceed if the data analysis from the Phase 1 research proves that this method is useful and reliable in detecting imminent ground failure in underground mines. Phase 2 will involve installation of several electromagnetic systems in mine stopes where miners may be in danger from ground failure resulting from rock stress.



Mine fire sensor array in the Safety Research Coal Mine.

SMART FIRE SENSORS

RESEARCHER: John C. Edwards, Ph.D.

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PURPOSE: Examine new and improved mine fire detection technologies for the protection of mine workers.

KEYWORDS: Fires, mining, detection

RESEARCH SUMMARY: The early and reliable detection of underground mine fires is important for the safety of miners in the workplace. Existing products of combustion (POC) mine fire sensors, as well as reliable POC sensors, are being developed as smart sensor technology with the capability to detect the fire, discriminate the fire combustible source in a gaseous and particulate background, and provide a mine fire location strategy in an underground mine. Diesel engines, welding, and cutting operations create the gaseous and particulate emissions background against which the sensors must discriminate. Gas sensor cross-interference effects from battery-charging operations and natural-occurring sources are being accounted for in the sensor selection strategy.

The two methods that are being used to develop smart fire sensor technology are (1) grouping fire sensors that are POC-specific and using a neural network to provide this decision capability and (2) developing or improving fire detector technology that will provide early-warning detection while functioning reliably in atmospheres containing diesel exhaust or welding and cutting emissions. Laboratory- and large-scale in-mine fire experiments are being conducted to evaluate the sensors and deployment strategy. The large-scale experiments are being conducted in the Pittsburgh Research Laboratory's Safety Research Coal Mine (SRCM). This in-mine research examines sensor response to signatures from smoldering and flaming coal, electrical cable, and conveyor belt fires, and flaming diesel fuel fires with and without nuisance background diesel emissions. The most efficient arrays of multiple fire sensors, which include chemical cell and metal oxide semiconductor gas sensors, and ionization and optical smoke sensors, are being evaluated for mine fire combustible source identification, discrimination of mine fire POC from diesel emissions, as a supplement to chemical cell CO sensors that are cross-sensitive to H_2 at a battery-charging operation, and for early detection of very low CO-emitting smoldering combustibles that produce visually obscuring smoke. This research is being supported by modeling applica-tions of a computational fluid dynamics computer program and a mine fire ventilation computer program. Predictive modeling can provide guidelines to the fire signature, its rate of change at a smart fire sensor location, and smoke reversal from a fire in a ventilated airway. A partnership with a coal mine is being established for an in-mine evaluation of new fire sensor technology. This research is to be conducted in cooperation with the Mine Safety and Health Administration, sensor manufacturers, and mine operators.

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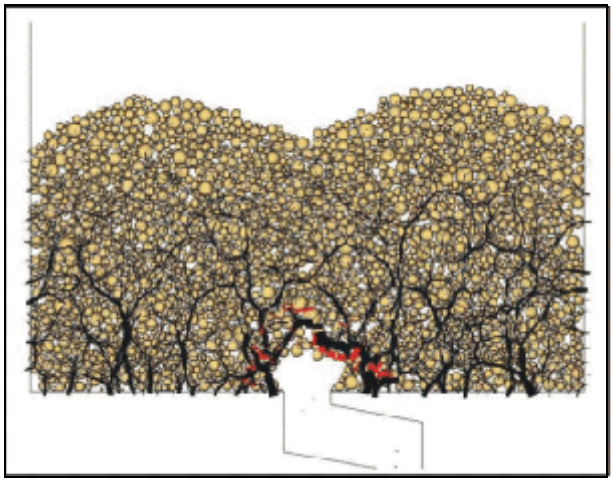

PFC model of a void forming above a feeder.

DETECTION OF BRIDGING IN SURGE PILES

RESEARCHER: Steve Iverson, Jeff Johnson, Mark Larson, and William H. Schiffbauer

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PURPOSE: Develop methods to detect and warn operators of voids in coal surge piles.

RESEARCH SUMMARY: Bulldozers are used to move coal on surge piles during pile expansion and when pushing coal to active feeders. These activities can be extremely hazardous if a void forms within the pile above a feeder. Because such voids are not visible from the surface, a bulldozer could be driven over or near a void, causing a collapse that could engulf the machine and injure or kill the operator. Eighteen fatalities have resulted from surge pile accidents between 1980 and the end of 1999. Most of these occurred because a void had formed in the pile and collapsed when the dozer was driven over it.

KEYWORDS: Surface mining, surge piles, bridging, voids, collapse

This project is focused on developing methods to detect voids in surge piles. Successful scaled tests using resistivity to detect voids have been completed. The use of infrared and ultrasound techniques that can be read in real time are being investigated. Ground-penetrating radar has been reviewed, but no tests of this technique are planned. Another method involves real-time comparisons of pile volume around drawpoints and the volume drawn. Relative deviations in the slopes of datapoints over time may be an indicator of void formation. This concept is being tested with a numerical modeling simulation using Particle Flow Code (PFC). Another investigation involves the development of an on-board global positioning system (GPS) for use in tracking dozers on a surge pile in real time.

Testing coal samples to determine strength properties is important to understanding flow conditions in a surge pile, especially when the coal is subjected to loads and vibration from a dozer. The data could also be useful for inputting into PFC models. Testing of coal samples from surge piles is planned following the construction of a shear test apparatus.

Pincher arm device for mechanically picking debris from a grizzly.

INJURY PREVENTION AND EQUIPMENT DESIGN

MATERIAL HANDLING ACCIDENT REDUCTION IN UNDERGROUND MINES

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KEYWORDS: Mining, materials handling, overexertion, injuries

PURPOSE: Improve methods and procedures to reduce or prevent injuries associated with materials handling in underground mines.

RESEARCH SUMMARY: Injuries while handling materials in underground mines continue to be a major safety problem. The approach taken in this project is to visit mines to identify (1) the kind of activities that result in injuries and (2) best practices and innovative solutions to common manual materials handling problems.

In 1999, 12 underground metal/nonmetal and 8 underground coal mines in 9 States were visited and/or materials handling accidents, needs, and innovative solutions to these problems were investigated. A total of 860 accidents, injuries, and illnesses at these mines were reported to the Mine Safety and Health Administration in 1999. Of these, 206 (24%) were classified as "handling of materials" accidents. Forty-six of these accidents resulted in restricted activities, 100 resulted in days away from work, 9 resulted in permanent disabilities, and the rest were injuries with no lost work time or restricted activity. Overexertion while manually moving (lifting, pulling, pushing, etc.) objects accounted for 53% of the materials handling accidents; of these, 64 were back injuries.

Activities in which the most overexertion injuries occur generally involve lifting. Manually cleaning debris, such as timbers, rock bolts, wire mesh, etc., from grizzlies covering ore passes also results in overexertion injuries. In this project, a grabber arm attached to an impact hammer head was designed to pick up the debris mechanically. This device can be operated from the control panel for the impact hammer. Another task is to modify and test an off-the-shelf manipulator. Making the manipulator mobile and finding or developing a grabber attachment that can pick up objects of different shapes and sizes are keys to the research. If these devices prove to be successful, many of the manual activities that cause overexertion injuries could be mechanized.

Work has begun on a best-practices handbook that will include current but innovative materials handling methods, new materials handling ideas and practices, and detailed analyses (fault tree analysis) of materials handling failures and events leading to back injuries.

Back injuries can result from shocks to an operator as loads of mine ore and waste rock are dumped onto a truck bed.

ENGINEERING CONTROLS FOR REDUCING JOLTING AND JARRING INJURIES IN SURFACE MINES

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PURPOSE: Devise and promote the use of engineering controls to minimize jolting and jarring injuries among haulage truck and other heavy equipment operators in metal/nonmetal surface mines.

KEYWORDS: Vibration, shocks, jolting, jarring, haulage trucks

RESEARCH SUMMARY: During the last several years, the number of surface mines in the West has increased. At the same time, larger haulage trucks, increased production demands, and more people in the workforce have led to more worker injuries and fatalities. During 1986-95, truck drivers accounted for approximately 63% (76 of 120) of the fatalities and 60% (3,551 of 5,569) of the lost-time injuries in surface mines.

Very little research has been done related specifically to shock trauma injuries—jolting and jarring injuries caused by haulage trucks—nor to the development of engineering controls to reduce such injuries.

Tasks in this project include—

- Development of software for linking information from global positioning systems (GPS) with jolting and jarring incidences.
- Bench-scale tests to characterize and isolate jolting and jarring elements so that shock loads on an operator can be identified.
- Definition of current engineering controls used to minimize exposure to health hazards and note their limitations.
- Field tests of a device called the "BackCycler" to evaluate its effectiveness as a method of conditioning a person's back to prevent injuries.
- Tests and evaluations of other engineering controls.

Using this process, we hope to lessen operator exposure to shock trauma and reduce lost-time injuries to haulage truck drivers.

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Jolts and jars while operating heavy construction equipment can contribute to lower back injuries.

REDUCING INJURY RISK FROM JOLTING AND JARRING ON MOBILE EQUIPMENT

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PURPOSE: To reduce back injuries resulting from jolting and jarring while operating mobile equipment used in mining, construction, and agriculture.

RESEARCH SUMMARY: Data from the Construction Chart Book and U.S. Bureau of Labor statistics show that, in 1994, 24.5% of the nonfatal injuries in the construction industry were back injuries. Back injuries are common in other industries as well, including agriculture; of the lost-time injuries to farm workers in 1993, 15% are estimated to have been back injuries. Data from the Washington State Department of Labor and Industries for 1992-97 show the average annual cost of back injuries to be $175.7 million, which is about twice the amount for any other category.

KEYWORDS: Vibration, shocks, jolting, jarring, back injuries

While a great deal of research has been done on whole-body vibration and its effects on the human body, very little has been done on the effects of single or multiple jolts. Little is known about how severe a jolt must be to result in an injury and what factors may contribute to an injury. It is important to understand the mechanism whereby an injury may be caused by a single jolt.

This new project is collaborative research among NIOSH's Spokane and Pittsburgh Research Laboratories and the Division of Applied Research and Technology.

Tasks in this project include—

- Characterization of the shocks drivers experience while operating selected types of construction and agricultural equipment.
- Identification and design of intervention techniques.
- Demonstration of the most promising techniques.
- Transfer of research results and technologies for implementation and reduction of jolting- and jarring-related injuries.

Examination of a flexible haulage truck ladder.

ERGONOMICS INTERVENTIONS IN MINING

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PURPOSE: Assess ergonomic risk factors in select mining environments. Develop, implement, and evaluate ergonomics interventions.

KEYWORDS: Mining, ergonomics, musculoskeletal disorders

RESEARCH SUMMARY: In 1998, the Mine Safety and Health Administration (MSHA) submitted a formal request to NIOSH to investigate musculoskeletal disorders (MSDs) in the mining industry. MSHA wanted a better understanding of the extent of MSD risk factors and evidence that ergonomics interventions are effective. An earlier analysis of National Occupational Health Survey of Mining (NOHSM) data showed that exposures to ergonomic hazards for mine workers were high compared to those in nonmining occupations. Another study that examined NOHSM data reported that the three most common musculoskeletal overload conditions in mining were neck and/or back, arm and shoulder, and heavy lifting. At least 35% of mine workers were potentially exposed to each of these conditions.

The research is planned as a two-phase effort. The first phase consists of risk factor assessments at four cooperating mine sites, with emphasis on MSDs. The second phase involves development, implementation, and evaluation of ergonomics interventions at one or two cooperating mine operations.

Risk factor assessments have been completed at an underground coal operation, surface copper operation, and surface phosphate operation. An evaluation is underway at an underground limestone operation. Results are being used to identify activities that provide significant risk for injury and to develop general risk reduction strategies. The primary benefit to cooperating mine sites is a better understanding of the types of ergonomic risk factors that exist at their operations and how to identify them. In particular, once risk factors have been identified, they can be prioritized and strategies for reducing them can be developed.

Specifics of the phase 2 work depend on phase 1 findings and identification of cooperating mine sites. The research team has met with representatives of two mine companies that have expressed a strong interest in participating in the second phase of this project, and partnerships are being pursued.

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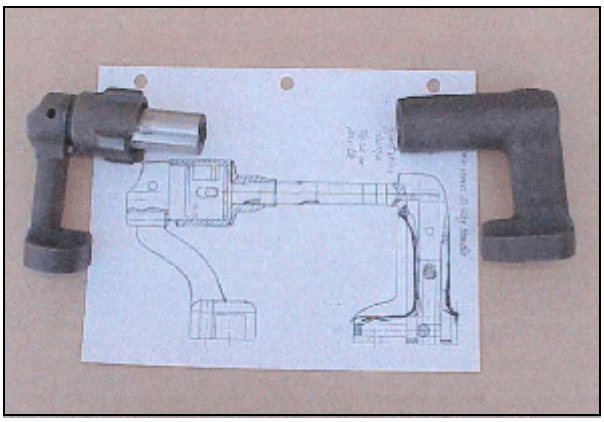

Newly designed ergonomic handles may reduce the fatigue experienced by jackleg drill operators.

INJURY PREVENTION FOR METAL/ NONMETAL DRILLING AND BOLTING

RESEARCHERS: Robert McKibbin and Curtis Clark

AFFILIATION: Spokane Research Laboratory
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PURPOSE: Identify the causes of injuries associated with drilling and bolting operations in metal/nonmetal mines and develop the technology to reduce or eliminate the risk of injury.

RESEARCH SUMMARY: Mine Safety and Health Administration (MSHA) statistics have shown that in an average year there are 2 fatalities and more than 200 injuries in drilling and bolting operations in metal/nonmetal mines. These account for 5% and 4% of all fatalities and injuries, respectively, in metal/nonmetal mines.

Project staff have highlighted a number of areas in which reductions in accidents might be realized. These include crushing injuries on carriage and jumbo drills; getting caught in rotating drill components; excessive weight, noise, and vibration of jackleg drills; slips and falls while getting on and off drills; rock falls while barring down or bolting; and handling steel or supplies. A significant finding was the number of injuries related to the weight (about 103 pounds) of jackleg drills. Such injuries result in about 35 lost-time injuries per year, or about 17% of all drilling and bolting injuries. Almost all of these are low-back injuries.

Project staff decided that one course of research offering a good probability of short-term success would be the fabrication and testing of an improved jackleg drill. The initial goal was to reduce the weight to 83 pounds without a reduction in the specific energy of drilling. A drill has been constructed in which several components are made of aluminum or titanium, resulting in a drill that is 20% lighter than a standard steel drill. Initial tests of this prototype in concrete blocks have shown that the drill is capable of drilling with no loss of penetration rate.

In addition to the weight reduction already achieved, project staff have designed and are in the process of fabricating several alternative jackleg drill handles. These designs address the concerns regarding vibration and fatigue experienced by the miners and include both vibration dampening and improved ergonomic shapes.

It remains to test these various improvements under actual mining conditions. Experienced hard-rock miners will serve as the final authority as to the efficacy of this research.

KEYWORDS: Mining, low back disorders, materials handling, jackleg, drilling safety, noise reduction, ergonomics, hard rock

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REDUCING SLIPPING AND FALLING INJURIES AT SURFACE MINES

RESEARCHERS: John K. Owens and Gregory G. Miller

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PURPOSE: (1) Identify the sources of slips and falls at surface mines among older workers, (2) design intervention techniques to prevent slip and fall injuries, (3) demonstrate the most promising interventions, focusing on mine equipment design and human factors, and (4) transfer research results and technologies to the mining industry.

RESEARCH SUMMARY: A significant fraction of accidents in the workplace is associated with tripping and slipping accidents. This is a particular problem in the mining industry where the average age of employees is 47 years. The severity of these accidents is often greater with older workers because of diminished flexibility with age. According to Mine Safety and Health Administration (MSHA) accident data for surface mines for 1992-94, the most common types of lost-time injuries were caused by handling materials (30%) and slips/falls (27%). The injuries resulting from slips and falls are sprains, bruises, and fractures of trunks or legs. Surface metal and nonmetal mine accident data for 1986-97 show that 11% of the back injuries to equipment operators were caused from slips and falls. Of these, 65% occurred while an operator was mounting or dismounting from a vehicle using the ladder portion of the steps.

KEYWORDS: Slipping, falling, and tripping injuries; surface mining; safety; accident prevention

The reduction of slipping and falling injuries would be of significant benefit not only in mining, but in the construction industry as well. Data from the U.S. Bureau of Labor Statistics for 1994 show that 22.8 % of the lost-time injuries in the construction industry were slip and fall injuries.

The investigative approach to reduce slipping and falling injuries will focus on mine equipment design and human factors. Equipment design research will include improved methods of mounting and dismounting equipment; location of handholds, steps, and ladders; ladder design; slip-resistant walking surfaces; and boot-cleaning devices. Human factor research will include analyses of older miners' risks for slipping and falling injuries using MSHA accident database and surveillance data; laboratory and field studies to identify risks among mine personnel for slipping and falling injuries; and development of effective behavioral, organizational, and/or educational interventions to address the leading causes of slip and fall injuries.

Computer modeling assists in seat research, and a full-scale mockup validates roof bolter models.

HUMAN FACTORS DESIGN FOR MACHINE SAFETY

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PURPOSE: Develop machine design guidelines and improved hardware to reduce injuries to personnel operating and working near mining equipment.

RESEARCH SUMMARY: Operational, functional, or structural design weaknesses of machinery continue to be associated with many fatalities and injuries. Analysis of accident data for 1993-96 shows that, for underground coal mining machinery injuries, the fatality rate is 0.0374 (incidences per 200,000 hours) and the injury rate is 6.833. In 1997, 32% of all injuries to underground coal miners working in the extraction area of the mine were attributed to roof bolting activities. Jolting/jarring and operator/machine interactions in mobile haulage equipment are a leading cause of injury.

The approach is to identify machine hazards through surveillance data and stakeholder input and to develop engineered interventions through the application of human factors design principles, computer-based design and analysis tools, and laboratory and field experimentation. Specific machine issues currently being investigated are safe roof bolter appendage speed and the jarring/jolting of mobile equipment operators. The bolter research involves the use of computer models in addition to laboratory and field experimentation to study the machine function and develop recommendations for safer boom speeds. Mockup tests with human subjects are being used to validate the bolter models. The operator jarring/jolting research involves computer modeling, the vibration testing facility, and laboratory and field research. Specific improvements to seating and alternative suspension systems are being evaluated for isolating the operator from excessive jolting. In FY2000, the jolting/jarring research was expanded beyond mining to construction and agriculture. A roof bolting manufacturer, a shuttle car manufacturer, and machine seat manufacturers are collaborating on this research. This project is producing design guidelines and improved hardware related to equipment hazards to improve machine safety in the mining, construction, and agriculture industries.

KEYWORDS: Mining, construction, and agriculture equipment; ergonomics; modeling; vibration; machine design and safety

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Sensitive ground fault relays can protect against electrocutions on underground mine circuits.

FUNDAMENTAL STUDIES IN ELECTRICAL HAZARDS

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PURPOSE: Identify, analyze, and classify electrocutions and electrical injuries across industries and determine appropriate strategies and technologies to reduce the occurrence of these events.

RESEARCH SUMMARY: Electrocutions account for more than 5% of all occupational fatalities, 14% of all deaths in the construction industry, and 5% of all deaths in the mining industry. Moreover, many of the systemic causes of electrocutions also result in flash and burn injuries, fires, and explosions. Mitigation of these hazards often involves similar practices and control technologies regardless of the industry. Some industries, such as underground coal, use more advanced technologies than others to prevent electrocutions. Accordingly, the practices may be more beneficial to the construction industry, among others. The underground coal industry may benefit from the technologies of other industries in realms such as lightning protection, an area in which there is concern because of lightning-initiated gas explosions in gob areas of the mine.

In ongoing work, surveillance groups within NIOSH have been consulted to identify occupational incident databases, appropriate severity measures, and methods to categorize incident criteria. Federal, State, and private data are being searched for information regarding fatal and nonfatal incidents involving electricity over the past decade. A questionnaire is being compiled to assist researchers in analyzing incident narratives. Queries are arranged in the following categories: environment, equipment, personnel, work practices, and medical.

Computer models have been used to evaluate the likelihood that a lightning strike above underground coal mines may be communicated through the overburden and cause an ignition of methane-air atmospheres in abandoned gob areas. Simulations have been done at various overburden depths and soil resistivities. Fast Fourier transform analyses show that the presence of a steel-cased borehole in the vicinity of the strike enhances the possibility of a lightning-induced ignition underground. Hardware is being procured to record voltages and currents that may be communicated underground. Underground findings will be time-correlated with lightning strike records on the surface.

KEYWORDS: Electrical shock, arcing, burns, mining, construction, safety, lightning

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Rear upset test with mannequin.

NEW TECHNOLOGY TO INCREASE ROPS USE ON TRACTORS

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PURPOSE: Design, develop, and evaluate rollover protection systems (ROPS) technology to equip significantly more tractors with ROPS.

KEYWORDS: Injury prevention, ROPS, tractors, rollovers

RESEARCH SUMMARY: Data show that over 60% of tractors in use in 1993 did not have ROPS installed; most were older tractors. ROPS have been proven as an effective safety device to prevent fatalities due to tractor rollovers. On average, 119 people died each year because of tractor rollovers during 1992-95. The use of ROPS is almost universally recommended as the key factor in reducing the fatality rate due to tractor rollovers. The long-term objective of this project addresses the Healthy People 2010 goal to increase the proportion of agricultural production tractors fitted with rollover protective systems to 100%. Cost-effective alternatives to original equipment manufacturer rollbars are needed for farmers to consider installing rollbars on older tractors. This project also supports the National Occupational Research Agenda (NORA) traumatic injuries research area. Information is to be shared with groups establishing ROPS certification standards, such as the American Society of Agricultural Engineers and the Society of Automotive Engineers.

This is a joint Pittsburgh Research Laboratory/Division of Safety Research safety engineering project that is working on a common problem: too many tractors still do not have ROPS. Innovative ROPS are being designed, developed, and evaluated. During 2000, 17 rollover tests were conducted using a remote-control Ford 4600 agricultural tractor outfitted with various ROPS. The tractor control system had no failures during the testing.

Fifteen to twenty rollover tests are planned during 2001. The roll sensors and different rollbar configurations are to be tested for reliability, integrity, and shock resistance.

Filming a video underground.

TRAINING AND EDUCATION

INTERACTIVE TRAINING AND EDUCATIONAL DEVELOPMENT

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KEYWORDS: Mining, safety training, virtual reality, computer visualization

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PURPOSE: Develop multimedia training tools that can be used to provide safety training to miners.

RESEARCH SUMMARY: A NIOSH study on occupational deaths during 1990-99 indicated that, in the mining industry, the average annual fatality rate is 26 per 100,000 workers. Mining is also the highest risk industry in 23 States and accounts for the largest number of occupational deaths in 3 States. Researchers believe that the use of enhanced computer visualization and multimedia training tools will help reduce these fatality and injury numbers.

The first objective of this work is to develop, evaluate, and refine a multimedia computer program that can be used by the mining industry to train miners in hazard recognition, accident avoidance, equipment use, and general mine safety. This multimedia program will enhance current training techniques by providing a real-time, visually appealing interactive training environment for mine workers. The program can record trainee scores and evaluate the effectiveness of the training techniques. The inherent flexibility of this type of program will allow easy and rapid updating and modification of training material.

The second objective is to develop video training modules. Mine safety professionals provide input to determining topics and issues, assist in ensuring that story boards and scripts are technically correct and relevant to trainees, and ensure that mine sites are available to show the topics under consideration effectively. They will also evaluate resulting products by assessing reaction to the videos during training sessions and by soliciting feedback from trainees on what was learned.

A PC screensaver that depicts the correct way to don a self-rescuer shows how effective training can be applied to new multimedia products.

EVALUATION OF INTERACTIVE MINE SAFETY AND HEALTH TRAINING METHODS

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PURPOSE: Determine the real-world effectiveness of a variety of low- and high-technology safety and health training approaches for miners.

RESEARCH SUMMARY: Mining occurs in unpredictable and dynamic environments where miners play an important role in preventing illnesses and injuries. Their skills at identifying and correcting or avoiding hazards are a critical supplement to engineering control approaches. Because these skills are unlikely to arise spontaneously, they must be imparted through effective training. Unfortunately, the effectiveness of the training delivered to the mining community is rarely measured. Interactive instructional technologies provide an opportunity for providing training content in a form that can be more readily measured. Also, the anticipated increased efficiencies available through these technologies offer better results from the scarce resources available.

Prototype interactive training systems have been developed and evaluated for mine safety and health training. These systems are based on a range of technologies, from low-cost latent-image methods to computerized authoring systems. The prototypes are being evaluated through field testing with miners, trainers, and safety personnel.

A training exercise completed for mining called “Hazard Recognition Training Program: Construction, Maintenance, and Repair Activities” was so well received that Pittsburgh Research Laboratory researchers are assisting another NIOSH laboratory in extending the training exercise to falls in the construction industry. Also, a computerized machine guarding exercise has been successfully beta-tested and is undergoing field trials to compare it with traditional training methods.

Another project goal is to improve the availability of high-quality training materials. A new distribution system was developed so that NIOSH miner training materials can be ordered by telephone, fax, or e-mail. This system has already distributed more than 27,000 training items since January 1999. Nineteen training products have been posted on the NIOSH Web site (www.cdc.gov/niosh) for more convenient access.

KEYWORDS: Mining, intervention, training, effectiveness

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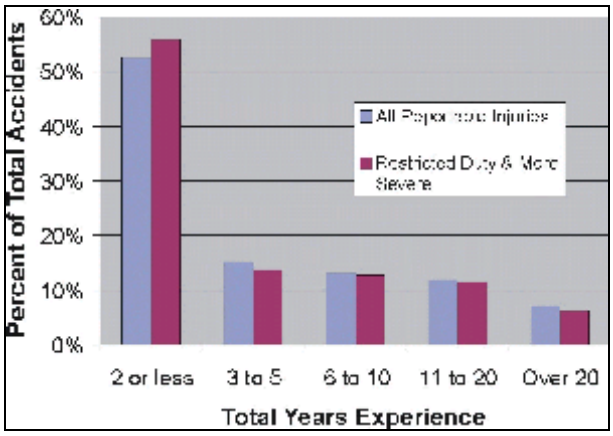

In 1999, over 50% of the injured sand and gravel miners in the United States had less than 2 years of total mining experience.

EVALUATING TOOLBOX TRAINING FOR CONSTRUCTION AND MINING

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PURPOSE: Develop toolbox training materials and evaluate their effectiveness for sand and gravel miners.

RESEARCH SUMMARY: "Toolbox" or "tailgate" training (weekly sessions usually about 10 to 15 minutes long) conducted on-site prior to work shifts and involving work crews are a primary mode of worker occupational safety and health training used in small construction companies. Toolbox training is also used in other sectors of industry, including mining and agriculture. However, the toolbox training approach has not been adequately evaluated. This project will (1) identify and review existing toolbox talks or series addressing construction, mining, or agriculture, (2) identify salient characteristics and different types of toolbox training materials, (3) prepare toolbox talks for one high-risk sector (sand and gravel) in mining and one high-risk sector (residential building) in construction, and (4) evaluate the effectiveness of representative examples of existing toolbox talks among small construction and mining companies. Each toolbox talk will contain a "story" about one or more serious or fatal injuries based on available injury and fatality investigative reports from NIOSH, the Mine Safety and Health Administration, the Occupational Safety and Health Administration, and other sources. Field evaluations in sand and gravel mines and during residential building construction will be conducted to determine whether the NIOSH toolbox talks produce the desired results, that is, increased knowledge, appropriate changes in attitudes, positive changes in behavior and work practices, and sustained positive changes. The effectiveness of the NIOSH toolbox talks based on didactic material will be evaluated and compared.

KEYWORDS: Mining, sand and gravel, training

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Scene from virtual mine training program.

ACCIDENT RECONSTRUCTION AND TRAINING FOR METAL/NONMETAL MINES

RESEARCHERS: Marc Filigenzi, Timothy Orr, and Todd Ruff

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KEYWORDS: Mining, hazard recognition, virtual reality, rescue and evacuation training

PURPOSE: Develop computer visualization techniques that can be used to reconstruct accident sites on the computer accurately. Use these techniques to develop computerized models of mines as part of a training program to teach hazard recognition and evacuation and rescue procedures to mine employees.

RESEARCH SUMMARY: Most current information dissemination and training methods are lacking in that they depend on training materials that are not specific to each mine. In addition, they are often outdated. Mine evacuation and rescue drills are expensive and time-consuming and cannot be practiced at regular intervals. New methods are needed to teach personnel about the hazards in mines, and about evacuation and rescue routes and procedures. By improving safety training in theses areas, researchers hope to increase worker safety and reduce accidents in the mines.

This project addresses two tasks.

(1) Accident reconstruction. In mining, as in most industries, injuries or death may result from equipment failure or human error. Accident investigators are often able to pinpoint the exact cause of the accident. However, the results of the accident investigations are published in a text format and are often difficult for a reader to absorb. The purpose of this task is to develop computer modeling and visualization techniques that will allow accident investigators to re-create an accident accurately on a computer. This computerized accident re-creation will be used to educate workers about the causes and results of the accident.

(2) Training methods for hazard recognition and mine evacuation and rescue. New methods of training mine personnel in hazard recognition and mine evacuation and rescue procedures are being investigated. Existing software technology is being applied to create realistic three-dimensional representations of specific mine sites. By running this software, mine employees are immersed in a "virtual mine" in which they are taught to recognize and avoid hazardous situations. In addition, the trainees use the virtual mines to follow rescue and escape routes and practice procedures particular to the mine they work in.

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Fighting a conveyor belt fire at Lake Lynn Laboratory.

MINE RESCUE AND RESPONSE

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PURPOSE: Develop realistic training simulations for responders to mine emergencies and evaluate technology that can be used during exploration and firefighting.

RESEARCH SUMMARY: Fires remain a common occurrence during mining operations. During 1990-99, the Mine Safety and Health Administration (MSHA) reported more than 153 fires at coal mines (fires lasting more than 30 minutes after discovery, or causing injury), or an average of 15 fires per year. These fires resulted in 1 fatality and 46 injuries. A significantly higher number of unreportable fires are believed to have actually occurred. Preparedness is an essential element of any underground mine's strategic plan in dealing with an unexpected event such as a fire. It is important that the fire be detected in the incipient stage and that well-trained and fully equipped miners respond during that crucial period. Any delay can mean serious injuries and the loss of the mine. A fully implemented fire preparedness and response plan is essential in reducing the probability and seriousness of a mine fire.

A study conducted by MSHA indicated that there are 274 State and company mine rescue teams in the United States (133 coal mine teams and 141 metal/nonmetal mine teams) composed of 2,000 rescue team members. These statistics show a drastic decline in the number of teams over the last decade as the number of mines decrease. Very often, rescue teams receive hands-on training during actual emergencies or in simulated mine environments with placards to identify objects and hazards. This dedicated group of miners often place their lives in jeopardy to save others.

Partnerships were established with two coal mines and a State agency to evaluate their mine rescue teams, and data have been collected from five mines in Colorado, Illinois, Pennsylvania, South Dakota, and Utah to determine their fire preparedness and response capabilities. Interviews with mine rescue teams and fire brigade members at Lake Lynn Laboratory and operating mines were conducted to determine current strengths and needs. These data were used to develop mine rescue training simulations and technologies for firefighting, exploration, and escape. A lighted lifeline for emergency responders was developed. The lifeline alleviated tripping and falling problems, and the different colored light wires allow the team members to easily find their usual position along the lifeline when ex-ploring in darkness and smoke-filled passageways. An underground coal mine fire preparedness and response checklist was completed and is intended to enhance the safety of mine workers by improving the state of fire preparedness at underground mines. A similar checklist is being developed for metal/nonmetal mines.

KEYWORDS: Fires, mining, preparedness, emergency responders, mine rescue training

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A miner is tested in the mobile audiometric test unit.

INTERVENTION THROUGH EDUCATION AND TRAINING TO PREVENT HEARING LOSS AMONG MINERS

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PURPOSE: Educate miners regarding hearing conservation measures and train them to recognize ways that they may assist in the reduction of occupational hearing loss.

RESEARCH SUMMARY: Noise is one of the most pervasive health hazards in mining. Exposure to high-intensity sound levels results in the development of noise-induced hearing loss (NIHL). One consequence of NIHL is a reduced quality of life due to the inability to communicate with family, friends, and the general public. However, this normally occurs after the hearing loss has progressed too far, and the damage is irreversible. Although excessive noise exposure can cause a permanent disability, NIHL is nearly always preventable.

The goal of this project is to educate miners regarding hearing conservation procedures and train them to recognize ways that they may assist with the hearing loss prevention process. Site visits are conducted nationwide with the Pittsburgh Research Laboratory's state-of-the-art mobile audiometric test unit. Hearing tests and individual fit-testing of personal hearing protection (i.e., earplugs) are performed on noise-exposed miners. By explaining the results to each individual, the problem becomes a "personal" one that a miner has a vested interest in. Results of the earplug fit-testing are analyzed and compared to the amount of hearing loss observed to determine whether individuals with a hearing loss are more inclined to achieve a better fit with their earplugs. Additionally, the mobile unit has the capability to show a hearing loss training video or computerized hearing loss demonstration to each participant.

This intervention project is intended to educate and empower miners by encouraging each miner to become more proactive in efforts to preserve his or her hearing. The best use of available educational activities will be assessed as the project progresses. Successful intervention methods will be further tested and disseminated more widely among the different mining sectors. This has recently become even more important since a more stringent noise regulation was promulgated for the mining community. Therefore, compliance with the new regulation and increased awareness on the part of all miners will likely provide the necessary incentives for future prevention of NIHL.

KEYWORDS: Noise, hearing loss, prevention, intervention, training, education

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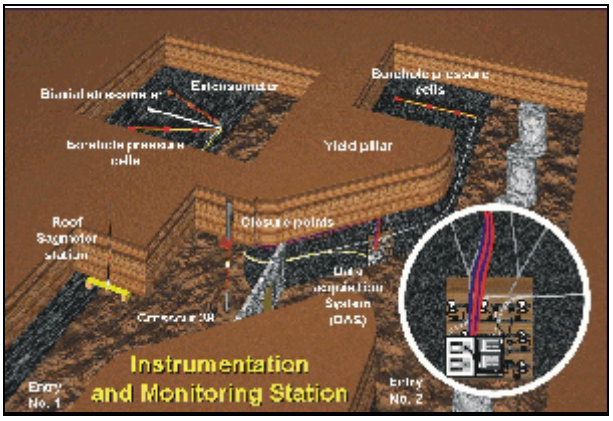

Stress monitoring system field tested for assessing coal bumps.

GROUND CONTROL

SAFETY DESIGN FOR UNDERGROUND MINE STABILITY

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KEYWORDS: Underground mining, ground stability, ground fall, horizontal stress, numerical modeling, coal bump, rock joint

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PURPOSE: Develop and integrate new computer modeling and field measurement techniques to assess rock mass properties and the stability of underground workings more accurately over time. Develop indicators to allow miners to assess the immediate stability of their working environment.

RESEARCH SUMMARY: Mine Safety and Health Administration statistics for 1994-98 show that 47% of the mine fatalities and 16% of the mine injuries in underground mines were attributable to ground falls. Loss of ground stability, either locally or across large sections of a mine, is a serious problem for the mining industry. This project seeks to develop better geotechnical, monitoring, and modeling tools so mining companies and consultants may design and operate more stable underground mines, thereby reducing the fatality and injury rates of underground miners.

Research efforts involve field studies and evaluations, laboratory investigations, property measurements, and computer modeling studies. In the field, a stress monitoring system is being developed to monitor stress changes during mining. This system is being evaluated for its potential to predict imminent coal bumps. Methods of conveying measurement information to engineers, foreman, and miners and gathering feedback are being developed and improved. The stress monitoring system is being adapted to solve other stability concerns.

In another research task, the role of rock joints in the stability of drifts and stopes is being studied. In the laboratory, a series of direct shear tests have been completed on jointed mudstone from a coal mine to determine friction and creep properties to be used to look at various failure mechanisms. This same series of tests will be done on core obtained from a platinum-palladium mine. Computer models are being used to understand the effects of high topographical relief on ground stability at a coal mine, as well as how joints affect rock mass stability.

By taking this approach through state-of-the-art field, laboratory, and computer modeling studies, ground failure mechanisms will be better understood so that accidents resulting from ground falls may be prevented or reduced in number.

RMSS cable and read-out box.

REDUCING GROUND FALLS IN UNDER-GROUND STONE AND NONMETAL MINES

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PURPOSE: Improve mine worker safety in underground stone and nonmetal mines by using a combination of communication/ surveillance, safety research engineering , and technology transfer activities.

RESEARCH SUMMARY: Roof and rib falls are a constant potential hazard to underground mine workers. Falls of ground can cause fatalities and typically result in severe injuries. Measuring and detecting roof rock movements provide a starting point in understanding roof behavior and can be indicators of mine conditions.

The stresses on a mine roof can be from vertical or horizontal forces. Horizontal stresses affect large spans of mine roof rock and often cause large roof falls. An estimated 25% to 35% of the underground stone industry is subjected to horizontal stresses. To address the unstable roof conditions resulting from high horizontal stresses, an experiment is underway to determine if changing the direction of mining and the size and spacing of the pillars can lessen the adverse affects of horizontal stress.

At a mine in southwestern Pennsylvania, an array of microseismic instruments is recording the "noise" levels of rock as mining proceeds in two different directions. A broad simplification of the concept behind this work is that if the direction of the horizontal stress is perpendicular to the direction of mining, less "noise" will be measured from the rock at and above the roof line. It is believed that the amount and intensity of the rock noise is related to the amount and intensity of rock failure; therefore, the mine layout that produces the least noise will be the safest. In addition, because most underground stone is mined using rooms and pillars of approximately the same dimensions, elongated and staggered pillars may also lessen damage to the roof.

Another instrument used in an attempts to determine roof behavior is the NIOSH-developed Roof Monitoring Safety System (RMSS). The RMSS provides the capability to measure roof movements through insertion into a borehole in the mine roof. Since its inception in 1998, more than a dozen operations have used this instrument. The RMSS is intended for use in a comprehensive ground control program. Visual inspections of geologic conditions, along with recording of other physical conditions and tracking roof movement, help to maintain a safer mine environment.

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Rib failure at an underground gold mine in Nevada.

REDUCING GROUND FALL HAZARDS IN NEVADA UNDERGROUND MINES

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PURPOSE: Identify, describe, and quantify ground and backfill response to mining, conditions that contribute to ground falls, and practices that reduce ground fall risks.

RESEARCH SUMMARY: The discovery of extensive, high-grade gold deposits at depth in Nevada has led to an increase in new underground operations that is likely to continue for decades to come. The large size and irregular shapes of the ore zones and the pervasive alteration and extensive fracturing that characterize these gold deposits makes the ground weak and vulnerable to unplanned collapses. Ground failures on all scales are major hazards, with at least one mine reporting five major cave-ins within ore zones and another indicating numerous falls of ground involving rock failure beyond rock bolt anchorages. During 1990-99, injuries from falls of ground exceeded injuries in all other categories in all years except one. Seven ground-fall-related fatalities occurred during this period, six of them since 1995. As mines become deeper and mining more extensive, the potential for small- and large-scale catastrophic failures is likely to increase greatly.

This new project is an interdisciplinary investigation involving experts in the fields of geology, backfill, load and strain instruments and measurements, physical property investigations, and modeling. Field measurements will be analyzed within a geologic perspective that incorporates local lithology, structure, and rock alteration. Modeling of stress and strain in host rock, ore, and backfill will incorporate localized and large-scale geologic and physical property data obtained in the lab and in the field.

Interaction between filled and unfilled mine openings and ore and wall rock will be investigated on various scales. Such studies will include elastic, brittle, and time-dependent displacements; their effects on mine openings; and the response of backfill and other ground support to loading. Experience gained from ongoing cooperative research with underground mines in other States will be used to supplement backfill and ground support investigations for the weak ground conditions in Nevada.

KEYWORDS: Ground fall hazards, Nevada underground gold mines, mining in weak rock

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Rock burst damage in a hard-rock mine.

IDENTIFICATION AND CONTROL OF ROCK BURST HAZARDS

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KEYWORDS: Ground control, rock bursts, in situ stress, geology

PURPOSE: Increase miner safety by identifying geologic features that contribute to the risk of rock bursts and linking these features to specific rock burst mechanisms.

RESEARCH SUMMARY: Rock bursts pose a serious hazard to miners throughout the world even after a century of research. In places where rock bursts of a similar type recur, countermeasures have been developed and employed that improve miner safety. However, these countermeasures must be appropriate to local geologic conditions and rock burst mechanisms to be effective.

The geologic environment of many ore deposits is very complex. An unexpected change in geology can trigger a rock burst where it would not be expected and result in injuries or fatalities. Researchers are seeking to identify those few features most likely to contribute to rock bursting and link them to specific rock burst mechanisms and relative levels of rock burst risk. Topics of particular interest include natural stress concentrations developed through tectonic processes and the association of particular types of altered rock with residual stress. Appropriate protection measures are also being studied. Currently, project studies are focused on mines in the Coeur d'Alene Mining District of northern Idaho, but will also address rock burst hazards in other deep metal mines in the United States.

The discovery that silicification, which is the alteration of rock by silica-bearing faults emanating from quartz veins, appears to be a marker of significantly increased levels of rock strength, rock brittleness, and in situ stress levels. A method for modeling concentrations of gravitational, tectonic, and residual stresses in various geologic features is being developed and used to study variation in rock burst hazards in the Coeur d'Alene district.

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Catastrophic slope failure in a surface mine.

SLOPE STABILITY HAZARD RECOGNITION FOR METAL/NONMETAL MINES

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PURPOSE: Minimize hazards associated with unstable mine slopes through an aggressive research approach involving engineering controls, advanced monitoring equipment, geotechnical design, and computer models.

KEYWORDS: Highwall, slope stability, open pit, remote sensing, monitoring, rock mechanics, bench, software

RESEARCH SUMMARY: Whether underground or on the surface, unanticipated rock movements create the potential for a mine catastrophe. A review of Mine Safety and Health Administration statistics from 1995 through the second quarter of 2000 revealed that 33 workers were killed in slope-failure-related accidents.

Open-pit mines are deeper than ever before, and the mechanics of rock mass strength and rock mass movement at large scales is poorly understood. However, even shallow strip mines and quarries can experience devastating consequences from slope failure.

This project addresses three major areas.

(1) *Slope monitoring systems*. The effectiveness and limitations of current slope monitoring and warning systems are being evaluated. A handbook for the mining industry is being developed to teach mine personnel about the proper use and placement of instruments and the limitations of various warning systems. Field tests of state-of-the-art equipment are also scheduled.

(2) *Geotechnical design.* Beta version software has been developed to estimate probable failure volumes on catch benches. Geotechnical engineers will be able to use this software to determine whether benches are designed wide enough to keep rock from falling to the working surface below. Several training courses related to software use and release of the final version are scheduled.

(3) *Engineering forensics and risk analysis.* Research analysis of documented failures will be used to identify root causes. New methods for computer modeling of rock mass behavior, pore pressure effects, and other tools will be studied. Input into a preliminary risk analysis model will also be collected.

Better design and control of slopes will reduce the number of fatalities and injuries. Results of this research can be transferred to a number of other civil and geotechnical engineering problems, including landslide control, design of roadcuts, railroads, canals, refuse disposal sites, and earth dams.

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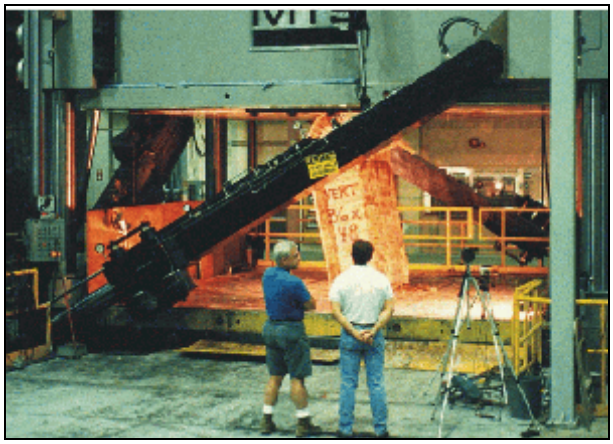

Safety performance testing of an innovative timber support in the Mine Roof Simulator.

DEVELOPMENT AND EVALUATION OF INNOVATIVE ROOF SUPPORT TECHNOLOGIES

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KEYWORDS: Coal mining, roof support, underground mining, emerging technologies

PURPOSE: Facilitate the development of new roof support technologies through industry partnerships with various support manufacturers and ensure that these new support technologies meet basic safety standards before they are commercialized for use in underground mines.

RESEARCH SUMMARY: This project began in FY2000 and is planned to continue for at least the next 5 years as new support technologies are developed for improving ground control in underground mines.

Ground control is a fundamental aspect of all underground mining. Historically, 30% to 40% of the fatalities in underground mines are caused by unstable roof rock falling in on the miner, and this percentage has been increasing in recent years. Roof support systems are routinely installed in all mines in an effort to prevent these catastrophic roof falls from occurring. While these supports are necessary to prevent roof falls from occurring, the material handling requirements for the construction of these supports is another major source of injury to mine workers. Surveillance data show that there are approximately 4,500 lost workdays per year in coal mines alone due to material handling injuries associated with roof support construction. Because of the importance of ground control, roof support manufacturers continually strive to develop new roof support technologies that provide superior ground control at less cost.

Our goal is to ensure that new support technologies are properly designed to ensure the safety of mine workers. Through a cooperative program with various support manufacturers, each new support technology is rigorously tested in NIOSH's unique Mine Roof Simulator. During the development of a new support system, this testing identifies design deficiencies so that they can be corrected early. Once the support system satisfactorily passes this testing protocol, the performance characteristics and its limitations are determined in order to optimize the safe use of this support in the mine.

Sixteen new support technologies have been successfully developed and implemented into mines throughout the world during the past 5 years. Using the database of support safety performance testing, a software program (Support Technology Optimization Program (STOP)) was recently developed to optimize the design and use of these new support technologies.

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Monitoring the operation of an underground microseismic network.

COAL BUMP REDUCTION THROUGH ADVANCED MINE DESIGN

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PURPOSE: Reduce the injuries and fatalities caused by coal bumps through the development of improved coal mine design concepts.

RESEARCH SUMMARY: Coal bumps are the sudden, violent expulsion of coal from a pillar or rib into an adjacent entry and related strain-energy release. On average, in the United States two coal miners are seriously injured every year and a miner is killed every other year because of coal bumps. In general, the exact mechanics of coal bumps are still not completely understood. It is believed that this lack of fundamental knowledge is the primary hindrance to further bump mitigation.

The basic research approach of this project is to instrument a deep, bump-prone longwall mine and determine the main roof, gob (broken rock), and floor behavior using a real-time microseismic system. This microseismic system "listens" to the rock and determines the timing and location of the failure of the rock strata surrounding the longwall. By analyzing the observed rock failure, researchers can better understand the caving of the massive main roof, the compaction and load acquisition of the gob, the failure of the floor, and the stress redistribution in the coalbed and surrounding strata. With this additional knowledge, mines can be better designed to reduce dangerous bump occurrences.

Throughout the first 3 years of this project, a microseismic system was installed at a deep coal mine in Utah (in cooperation with the coal mine, the University of Utah, the Virginia Polytechnic Institute and State University, and several contractors), and one entire panel was monitored. The system consists of 24 geophones (microphones for listening to the rock) surrounding the coal mine on the surface and underground. At the mine office, a data analysis workstation receives, processes, and stores the data from the geophones. Future data analysis will determine the exact nature of the massive overburden failure. An appropriate mechanistic model (beam theory, plate theory, discrete-element, finite-element, boundary-element, etc.) will then be used to simulate and approximate the observed behavior for pursuing improved bump-proof mine designs.

KEYWORDS: Bumps, bounces, coal mine, ground control, rock mechanics

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Cables connect sensitive seismometers to an underground networked data acquisition computer.

GROUND STABILITY ASSESSMENT WITH SEISMIC MONITORING

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KEYWORDS: Rock bursts, coal bumps, mine collapse, mining-induced seismicity, rock mechanics

PURPOSE: Develop and apply seismic monitoring tools to aid in estimating and forecasting ground control hazards resulting from uncontrolled or unplanned deformation of the local ground surrounding underground openings.

RESEARCH SUMMARY: Rock bursts, coal bumps, roof falls, and large-scale collapses represent serious ground control problems facing miners in certain industry sectors. These low-probability, high-consequence events often result in severe injuries or death and can affect an entire underground workforce. An inability to address these problems effectively can result in resource abandonment and/or mine closure and cause a significant economic impact on entire communities.

Project objectives are to (1) develop inexpensive automated seismic monitoring technology for use in reducing mine worker exposure to catastrophic ground hazards and emergency response time, (2) transfer the technology to mine operators, mining organizations, and consultancy groups, and (3) apply this technology in NIOSH studies seeking to reduce or eliminate these hazards.

A user-friendly, PC-network-based, automated seismicity monitoring system is under development. The first prototype system was initiated in a joint project with Silver Valley Resources, Inc., at the Galena Mine in Wallace, ID. By developing the technology at a low cost, NIOSH can employ several systems in different mine safety research studies and, at the same time, encourage industry adoption as a safety tool in daily operations. Hardware and software development continue with an emphasis on shifting the placement of instruments from the harsh underground environment to the more readily accessible surface. NIOSH seismic monitoring networks are currently in operation with industry partners in deep metal, coal, trona, and limestone mines to address problems of rock bursts, coal bumps, mine collapses, and roof falls.

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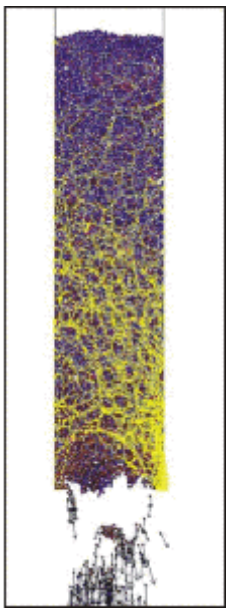

Cohesive forces and particle velocity vectors in a simulated ore pass.

DESIGN OF MINE ORE PASSES

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PURPOSE: Improve ore pass safety and design criteria to prevent hangups and structural failures.

RESEARCH SUMMARY: Recent accidents have underlined the lack of ore pass designs and standards available to both mine engineers and Mine Safety and Health Administration (MSHA) enforcement staff. This project will focus on ore pass design, ore and waste hangup prevention, and safe procedures for removing hangups.

Based on accident investigations, review of MSHA data, and hazard and fault tree analyses, several areas of research were identified that could lead to reducing ore pass hazards. These topics are—

- Static and dynamic loading of ore pass chutes and gates.
- Prevention of hangups of material in ore passes.
- Development of a field-ready, ore pass load measurement system.

Both physical and computer models are being used to validate computer codes. Design and construction of a reduced-scale test facility of an actual ore pass and chute and gate assembly have been completed for static and dynamic load tests. These tests will validate strategies for obtaining static and dynamic response to varying loads in an actual ore pass. Work is underway to determine the role of moisture content, the fine grain-size fraction, and stop-and-go ore movement on cohesive-type hangups. Computer models using two- and three-dimensional particle flow programs will be continued to predict particle flow and hangups. Special tests will be conducted to determine stiffness characteristics and damping coefficients of mine material. These data will be used as input to the models for more accurate predictions of particle flow. Various designs of ore pass structures will be simulated in the models.

Improved ore pass safety and design criteria will prevent hangups and structural failures. Newly developed particle flow computer programs might also be applied to analyzing construction code design standards.

KEYWORDS: Ore pass, particle flow, dynamic loads, hangups

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Haulage vehicle fire.

FIRES, EXPLOSIONS, AND VENTILATION

CONTROL AND SUPPRESSION OF MINE FIRES

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PURPOSE: Enhance the safety of mine workers by increasing the mining industry's ability to control and extinguish fires through the development of new and improved fire suppression systems.

RESEARCH SUMMARY: Although the number of fires and fire injuries is relatively low for underground mining, fires that occur in confined spaces have potentially catastrophic consequences. Federal regulations require mine operators to take measures to prevent fires in underground mines. However, fires still occur because of the misuse of materials, spontaneous combustion, conveyor belt equipment malfunction, electrical arcing, overheating of equipment, and other causes. Fires on large surface vehicles can erupt rapidly via ignition of fuel, lubricating fluids, or hydraulic fluids. The fires can spread rapidly to other parts of the vehicle, such as the large rubber tires, endangering the lives of the operators. Egress from such vehicles is often awkward and time-consuming, thereby necessitating the need for fire protection systems.

This project focuses on three tasks. The first evaluates the application of new and improved fire suppression systems to protect underground mine haulageways and stationary equipment. Full-scale experiments are being conducted in the Lake Lynn Laboratory fire suppression facility to determine the effectiveness of water mist systems for extinguishing air compressor fires. The second task assesses the flammability hazards of selected noise control materials that are being introduced into the mining environment under realistic, end-use conditions. The results may be applicable to the development of new or modified laboratory-scale fire tests for fire-resistant noise control materials used in mines. The third task determines the intrinsic causes of large surface vehicle and surface equipment fires. The results are used to recommend new or improved types of fire detection and/or suppression systems for these vehicles and equipment. These tasks are being done in collaboration with the Mine Safety and Health Administration and the mining industry.

KEYWORDS: Mine fires, suppression, extinguishment, flammability, water mist

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Testing of sealant strength across concrete block joint.

IMPROVING CFR SAFETY EVALUATIONS FOR MINE VENTILATION SEALS AND STOPPINGS

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KEYWORDS: Coal mining, Code of Federal Regulations, mine ventilation stoppings, mine seals, ASTM E-72

PURPOSE: Provide a safer environment and reduce material handling injuries for mine workers by developing alternative safety evaluation requirements for mine ventilation stoppings and seals that more realistically simulate actual mine conditions. Examine emerging lightweight material technologies that currently fail existing regulatory statutes.

RESEARCH SUMMARY: This project is in its second year. The initial phase of full-scale testing to determine the impact of restraint and preload on dry-stacked block constructions has verified that the transverse loading capability of these structures is greatly improved by the restraint provided by the mine roof and floor and the addition of preload at the completion of the wall construction. The systematic series of full-scale laboratory tests in NIOSH's unique Mine Roof Simulator is to continue during the next year with various block designs to determine a quantitative relationship between these parameters. Failure mechanisms show that the shear strength and compressive strength of the block are important parameters that determine the loading capability of these structures, but these parameters are ignored in the current Code of Federal Regulations. Part of this effort is to define new criteria to account for these deficiencies and, by doing so, provide more insurance against premature failure of these critical structures.

Several lightweight block technologies have been identified for examination as replacement to conventional mortar blocks used for stopping construction. Five different lightweight block units weighing up to 50% less than the conventional block have been chosen for analysis. Using the NIOSH-revised lifting equation, these lightweight blocks are within the recommended lifting thresholds for this type of activity. As such, they are expected to significantly reduce musculoskeletal repetitive trauma disorders and other material handling injuries associated with stopping wall construction in underground mines.

An underground study of one of the lightweight block technologies is underway at a Consol Energy mine. Two walls constructed from these lightweight blocks are being instrumented to measure the loading and convergence and are being compared to two instrumented walls constructed from conventional mortar block. The goal of this study is to provide baseline loading data and compare the response of the two materials, as well as provide information on the loading conditions that can be incorporated into the laboratory testing protocols used in the Mine Roof Simulator.

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Remains of standard seal destroyed by methane-air-oxygen explosion.

HYDROSTATIC EVALUATION OF MINE SEALS

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KEYWORDS: Mine ventilation seals, water inundation, explosions

PURPOSE: Develop improved apparatus and methodologies to better characterize strength properties of mine seals; evaluate equivalence of hydrostatic, pneumatic, and explosion testing of seals; and identify models for possible use by the Mine Safety and Health Administration (MSHA) in approval actions regarding seals.

RESEARCH SUMMARY: Seals are used extensively in mining to isolate worked-out areas of a mine, contain active fire zones, and control water inundations, thereby protecting miners from these life-threatening hazards. Seals, along with generalized rock dusting, are the last line of defense against underground explosions in U.S. coal mines. MSHA has a compelling need to evaluate geometric scaling criteria for seals, alternative designs for high-convergence conditions, and adverse geologic conditions such as friable adjacent strata. No single seal design is suitable for all possible scenarios. Some seals must withstand excessive convergence, some require quick curing, some require special anchoring because of the adjacent strata conditions, some need to resist attack by acid mine water, some are needed for very wide or high roadways, some need to hold back water, some need steel reinforcement and high-strength cement, some need fire traps, some need a low gas leakage rate, and some must perform for years. In the past, seals were evaluated in full-scale mine explosion tests, an expensive and time-consuming task, or were not evaluated at all because there was no practical, reliable testing methodology available.

Constant volume explosion studies continue in both the standard (2,500-ft^3) and large (6,800-ft^3) explosion test chambers at Lake Lynn laboratory. The seals are subjected to various explosion pressure histories produced by the combustion of mixtures of methane, nitrogen, and oxygen. Seal flexure and ultimate failure conditions are measured as a function of pressure loading. A major effort in FY01 is to evaluate seals of different cross-sectional areas. Cost-sharing research is to continue in FY01 with important collaboration between NIOSH, the mining industry, and seal manufacturers. Results from such tests provide valuable information applicable to the on-site evaluation of new mine seals and the development of size-scaling relationships and design safety factors.

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A researcher checks the cellular telephone data transmission components of the Remote Gob Gas Venthole Data Acquisition and Transmission System.

CHARACTERIZATION AND MITIGATION OF MINE GAS EMISSIONS

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PURPOSE: Develop optimized longwall methane control systems and strategies to reduce the risk of catastrophic explosions and fires in the underground workplace.

KEYWORDS: Coal mining, mine safety, methane explosions, control technology, methane drainage

RESEARCH SUMMARY: An increased risk of explosions in underground mines can be the direct result of excessive methane emissions. Methane emission rates are often unpredictable because the interactions between geology, mining, ventilation, and methane control systems vary considerably due to site-specific conditions and mining practices. The focus of this research has been increased methane emissions associated with longwall gobs resulting from emerging technologies that facilitate the mining of increasingly larger dimension longwall panels in U.S. coal mines. This project is nearing completion of its investigation of the factors controlling gas emissions from longwall gobs and the development and/or optimization of control technologies.

Due to the variability of the multiple factors controlling gas emissions associated with longwall mining, both mine-site field characterization studies and theoretical modeling studies are necessary to address the research problem. The longwall gob gas flow characterization field studies use controlled releases of a tracer gas into the mine ventilation and methane control systems to identify methane gas flow paths and associated flow characteristics. These studies are being conducted at a RAG American Coal Co. mine in close coordination with organized labor (United Mine Workers of America) and State and Federal regulatory authorities (the Pennsylvania Bureau of Deep Mine Safety and the Mine Safety and Health Administration). Selected optimized methane control strategies developed from the preliminary results of the field studies are being implemented at the study mine and at an adjoining mine. The results of this final phase of the field studies and the gob gas flow theoretical modeling are to be used to refine the best practices for longwall gob gas control. These best practices include information on optimized placement of gob gas ventholes and operational efficiencies, including a state-of-the-art monitoring and data transmission system based on cellular telephone technology to provide real-time performance data from remote gob gas venthole locations.

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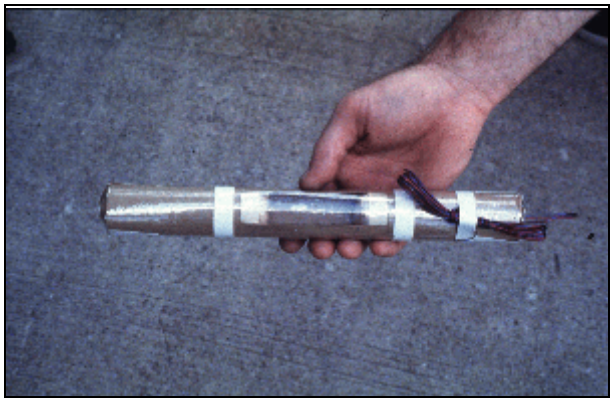

Explosive charge set up for the air gap test. This test evaluates the ability of the detonation of a permissible explosive to jump a gap in the explosive column.

EXPLOSIVES HAZARD SURVEILLANCE AND EVALUATION FOR THE MINE SAFETY AND HEALTH ADMINISTRATION

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PURPOSE: Provide technical assistance to the Mine Safety and Health Administration (MSHA) in the testing of new candidate permissible explosives, explosive accident investigations, and in conducting research on other explosive hazards.

KEYWORDS: Permissible, explosive, blasting

BIBLIOGRAPHY

30 CFR 15, Requirements for Approval of Explosives and Sheathed Explosive Units.

RESEARCH SUMMARY: The tasks of this project are to (1) test new candidate permissible explosives for use in underground mining for MSHA based on requirements detailed in 30 CFR 15, (2) assist MSHA in explosives accident investigations, including the testing of explosives involved in the accidents, and (3) conduct research on explosive hazards revealed during the course of accident investigations. The goal is to develop engineering solutions to help prevent future injuries and fatalities.

Research was completed on a detonator/booster assembly that was involved in a recent fatal incident. Indications were that a detonator/booster assembly fell into a borehole and exploded prematurely when it hit another booster already in the hole. This particular type of explosive had been involved in two other incidents (one fatal) in recent years. Cooperative research with the manufacturer and MSHA is continuing in an effort to find reliable, practical ways to prevent such incidents in the future.

Frictional test apparatus showing ignition of methane-air.

EXPLOSION HAZARDS REDUCTION

RESEARCHERS: Kenneth L. Cashdollar, Michael J. Sapko, and Issac A. Zlochower, Ph.D.

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PURPOSE: Reduce explosion hazards in mining through basic and applied research on the prevention and suppression of gas and/or dust explosions.

RESEARCH SUMMARY: Explosions in coal mines are due to accumulations of coal dust and/or methane gas. The ignition of such flammable materials can develop into a major disaster, such as the recent explosion at a Utah mine, which resulted in two fatalities. Explosions can be prevented or mitigated by minimizing methane concentrations through ventilation and drainage, by adding sufficient rock dust to inert the coal dust, by eliminating ignition sources, by using passive and active barriers to suppress propagating explosions, and by using high-strength seals to prevent gob explosions from propagating into working areas of the mine. Research into the causes and mechanisms of gas and dust explosions is needed to develop techniques and strategies for explosion prevention and suppression in underground mines and in aboveground processing plants. Assistance is also provided to the Mine Safety and Health Administration (MSHA) in the forensic investigation of mine accidents. Research on frictional ignitions includes experimental studies and surveillance in commercial mines. Intermediate-scale experimental research is being conducted on the relative incendivity of sandstone, metal, etc., for igniting methane gas and hydrocarbon oils from mines. Additional research on frictional ignitions is being conducted in the 20-liter explosibility chamber through measurements of the hot-spot temperature and surface area necessary to ignite flammable gases, vapors from oil, and dust mixtures with air. Close cooperation with the mining industry, MSHA, and the United Mine Workers of America is expected.

Continuing basic experimental research includes large-scale coal dust explosion studies conducted at the Lake Lynn Experimental Mine and explosion studies conducted in the 20-liter chamber. These experiments are conducted to better understand coal dust combustion mechanisms to aid in the development of explosion prevention and suppression techniques. This basic explosion research is conducted in conjunction with laboratory research at universities and private laboratories.

KEYWORDS: Explosions, prevention, mining

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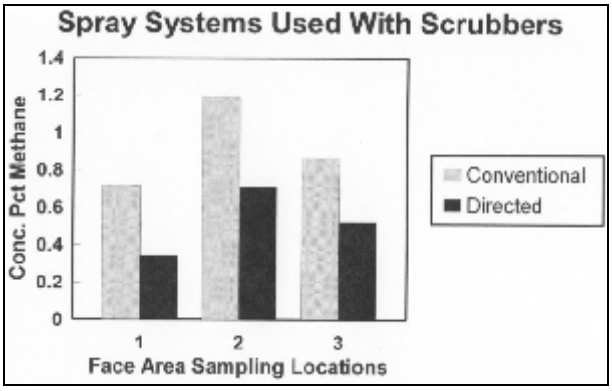

Modified spray system used with scrubber.

EXTENDED-CUT AIR DELIVERY SYSTEMS

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KEYWORDS: Hazard identification, prevention, exposure assessment, underground mining, methane

PURPOSE: Develop better ventilation techniques for delivering air to the mining face and improved methane sampling strategies for estimating face concentrations during extended-cut mining.

RESEARCH SUMMARY: Normal distances between the end of the ventilation curtain or tubing and the face often increase when extended-cut mining methods are used. Increased setback distances can result in reduced face airflow and increased methane concentrations. When methane levels increase, there is a greater risk of frictional ignitions and worker injury.

Improved techniques are being developed to maintain sufficient face airflow and prevent methane ignitions during extended-cut mining. Testing is conducted in a full-scale gallery where ventilation conditions for extended-cut mining are simulated.

Using either a machine-mounted scrubber or water sprays helps to reduce face methane levels during extended-cut mining. Tests show that modifying the spray system by directing individual sprays toward the return side of the entry further reduces face methane levels. Continuing research is evaluating how the direction of the scrubber exhaust affects the airflow patterns created by the scrubber and water sprays.

During underground mining, prevention of frictional ignitions can be ensured only if there is accurate monitoring of methane concentrations, particularly at the face where higher accumulations of the gas are most likely to occur. Methane monitoring at the face is more difficult during extended-cut mining because workers making the measurements must remain under supported roof. Regulations require continuous methane monitoring using a monitor permanently mounted on the mining machine and usually located 5 to 10 feet from the face. In the test gallery, methane levels are monitored concurrently at the face and at multiple locations on the mining machine. Recommendations are provided for selecting the best sampling locations on the mining and roof bolting machines for a range of operating conditions.

It is not possible to check the accuracy of a machine-mounted methanometer whenever it is under unsupported roof. In general, the longer the extended cut, the less frequently instrument performance can be checked. Techniques for evaluating instrument performance, using response time as a criterion, are being evaluated and will be used to provide a test protocol. Guidelines for determining methanometer reliability, based on response time measurements, will be written.

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Collecting SCSRs for a long-term field evaluation study.

LIFE SUPPORT FOR SURVIVAL AND RESCUE

RESEARCHER: **John G. Kovac**

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PURPOSE: Ensure that deployed self-contained self-rescuers (SCSRs) that pass their inspection criteria function properly.

RESEARCH SUMMARY: On June 21, 1981, coal mine operators in the United States were required to make available to each underground coal miner an SCSR as an aid to escape in the event of a mine emergency. Federal regulations require that each person in an underground coal mine wear, carry, or have immediate access to a device that provides respiratory protection with an oxygen source for at least 1 hour, as rated by the certifying agencies: NIOSH and the Mine Safety and Health Administration (MSHA).

NIOSH is conducting a long-term evaluation of SCSRs deployed in underground coal mines. Mine operators are located that are willing to participate in the study, deployed SCSRs are exchanged for new ones, and then the deployed SCSRs are tested. The objective of this long-term program is to evaluate the in-mine, operational durability of deployed SCSRs. Of utmost concern is the successful performance of any SCSR that passes its manu-facturer's approved periodic inspection criteria. Only apparatus that pass their inspection criteria are included in the study. Such apparatus are relied upon to function successfully in an emergency. Apparatus that fail inspection criteria are expected to be removed from service.

Seventeen mines were visited in MSHA Districts 2, 3, 4, 5, 6, 7 and 8 in the most recent phase of this program. One hundred SCSRs were collected for testing both on human subjects and on a breathing and metabolic simulator. Past findings have resulted in modifications to quality assurance procedures and inspection criteria, apparatus design changes, and recall and decertification of SCSRs. In the most recent phase, it was found that accelerated aging caused the breathing hose in an apparatus to deteriorate and fail. This resulted in an industry-wide recall and inspection of nearly 40,000 apparatus. Another apparatus was discovered to have leaked chemical from the canister into the breathing circuit, which was undetectable by visual inspection criteria. To detect this internal damage, an additional inspection criterion (a noise test) was added. This resulted in an industry-wide field inspection of nearly 2,500 apparatus and replacement of damaged units.

KEYWORDS: Self-contained self-rescuer, respiratory protection, mine emergency escape

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One of three brattice cloth ventilation stoppings installed in the Lake Lynn mine for this project.

VENTILATION OF LARGE-OPENING MINES

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KEYWORDS: Mine ventilation, metal/nonmetal mines, large openings, anemometry, ultrasonic, laser distance measuring

PURPOSE: Extend the body of knowledge on airflow within large underground mine workings.

RESEARCH SUMMARY: Hundreds of metal/nonmetal underground mines operate throughout the United States. These operations extract commercial products from deposits, such as limestone, salt, and gypsum. The mining process generates a wide variety of gases and dusts, such as silica, diesel exhaust, radon, blasting byproducts, and perhaps even methane. If these substances are airborne, they can adversely affect the health and safety of individuals working underground. Many metal/nonmetal mines have large cross-sectional airways. The largest airways feature areas that are over 60 times larger than an average underground coal mine entry. These airways require adequate volumes of fresh air to dilute, make harmless, and exhaust the toxic and, at times, explosive byproducts.

For mines with enlarged airways, it is a challenge to provide an adequate quantity of fresh air. Often this air must travel a considerable distance to reach the working area. The quantity of air entering a typical enlarged airway is such that the resulting air velocity is quite low. Low air velocity can make large entries prone to air stagnation and recirculation. In some entries, the air flow may be in opposite directions at different elevations. The adverse health and safety impacts of inadequate fresh air delivery in these mines can be serious. Mine operators, Mine Safety and Health Administration inspectors, and Pennsylvania Bureau of Deep Mine Safety officials have expressed concerns about the problem.

This project, which began in FY2000, is testing methods to measure very low air flows in large-opening mines. First, a way to quantify air volumes in large entries must be determined. The research is presently determining how to divide the entry area to provide the most accurate estimate of actual entry air volume. Here the use of conventional air flow measurement techniques can be suspect. Traditional tools for measuring air movement are vane anemometers, smoke tubes, tracer gas, and differential pressures. The application or adaptation of other technologies, e.g., ultrasonic anemometry, is being ex-amined. An important goal of this research is to publish a handbook of recommended practices for measuring low air velocities, monitoring low air flows, and ultimately improving the ventilation patterns in large-opening mines.

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In a December 1999 accident, a baseball-sized piece of flyrock went through the window of this truck and killed the miner inside.

INVESTIGATION OF FLYROCK INJURIES AND FATALITIES

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KEYWORDS: Blasting, explosives, flyrock, mining

PURPOSE: Reduce fatalities and injuries caused by flyrock and lack of blast area security in surface mining operations involving coal, metal, and nonmetal mining.

RESEARCH SUMMARY: Annually, billions of pounds of explosives are used in the United States by the mining and construction industry. In all blasting operations, it is expected that broken rock will move within the "blast area" identified by the blaster. It is standard procedure for the blaster to ensure that no one is in the blast area during a blast and that no rock leaves the blast area. When a person is struck by rock within the blast area, it is called a blast area security accident; when a person is struck outside the blast area, it is called a flyrock, or "wild" flyrock, accident. Each year these accidents result in fatalities and serious injuries. In some cases, the victims are persons who are not connected with the mine.

Flyrock and lack of blast area security are the major causes of blasting injuries and fatalities in surface mining. During 1978-98, flyrock and lack of blast area security contributed to 74% of all fatal and nonfatal injuries involving the use of explosives in surface coal mining operations. Data also indicate that during the same period, flyrock and lack of blast area security contributed to 65% of all fatal and nonfatal injuries involving the use of explosives in surface metal and nonmetal mining operations.

A report reviewing accident reports from the Mine Safety and Health Administration (MSHA) and other Government agencies has been completed. Selected blasting sites are being visited, and procedures are being examined to gain an in-depth understanding of the factors contributing to blasting incidents. Statistical analysis of parameters and causative factors of wild flyrock and blast area security accidents is being done. Through education, training, and improved procedures during blasting operations, a reduction in the frequency of injuries from flyrock in blasting operations is anticipated.

Partners/collaborators in the project are MSHA, the Institute of Makers of Explosives, and the United Mine Workers of America.

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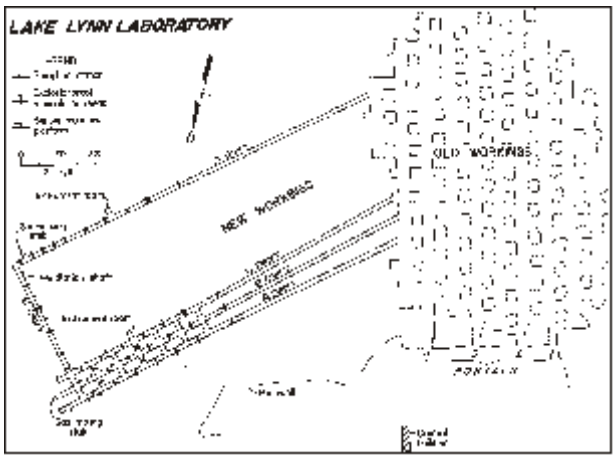

Experimental mine at Lake Lynn Laboratory.

LAKE LYNN LABORATORY

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PURPOSE: Provide a modern, full-scale realistic laboratory for underground and surface research that significantly contributes to the enhancement of workplace safety and health for miners and other workers.

RESEARCH SUMMARY: Lake Lynn Laboratory near Fairchance, PA, provides an isolated surface facility and a full-scale underground mine to conduct large-scale research in mine disaster prevention and response, as well as numerous other research areas of national interest requiring the study of large-scale surface and underground safety and health problems. The ability of Lake Lynn to simulate virtually any underground coal mine geometry provides a practical, realistic research laboratory for mining research under various controlled conditions of ventilation, humidity, pressure, and temperature. To facilitate the underground research, electrical power, compressed air, water, communications, video lines, natural gas lines, and a unique high-speed data-gathering instrumentation system with a state-of-the-art computer system have been incorporated into the design at the site. The surface facilities provide an isolated environment in which large-scale research and testing can be conducted in a realistic, yet environmentally controlled manner.

Ongoing research at Lake Lynn includes the development and evaluation of fire suppression systems and early-warning technologies, development and evaluation of mine seals and other ventilation structures, evaluation of prototype mining equipment and sensors, noise control studies, ventilation studies, roof support technologies, evaluation of explosive incendivity and toxic gases, determination of explosion limits for combustible dusts and ignitability of mists and vapors, mine rescue team training evaluations in smoke-filled entries, and respirable dust deposition and diesel particulate studies. The information generated as a result of the research at Lake Lynn is vital to the members of the mining industry in the development of improved technology and practices to protect mining personnel from the many hazards associated with their jobs. Although the primary mission of Lake Lynn is in support of mine safety and health programs, the unique characteristics of the facility make it attractive for research in support of other industrial problems. Cooperative research within these areas is often conducted on a resource availability, cost-reimbursement basis. This project supports and coordinates all of the Lake Lynn research efforts; enhances the research capabilities of Lake Lynn; and maintains safety, health, and environmental controls at Lake Lynn.

KEYWORDS: Lake Lynn Laboratory, health and safety, explosions, fires, explosives

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Toxic fumes from blasts and explosions are one of the many hazards faced by miners.

SURVEILLANCE

HAZARD SURVEILLANCE IN THE MINING INDUSTRY

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PURPOSE: Develop and implement a targeted hazard survey for the mining industry.

RESEARCH SUMMARY: NIOSH plans to conduct, on a periodic or ongoing basis, a nationally representative survey(s) to evaluate the prevalence and distribution of potentially hazardous working conditions among the U.S. workforce. The surveillance of occupational hazards (e.g., chemical, biological, physical, and psychosocial) will provide a rational basis for guiding public health policy and research. Hazard surveys targeted by industry, occupation, or hazard are also planned in addition to a comprehensive, national hazard survey. Focused supplemental surveys provide the opportunities to explore and confirm trends detected by the national survey, as well as investigate newly hazardous conditions that result from emerging technology. Mining has been selected as one of the initial industries to be studied. It has the highest worker fatality rate of all industries nationally, as well as in 26 States. A priori identification of potential hazards permit safety and health threats to be successfully mitigated before harm is done.

This is a new project developed in FY2000. An ad hoc advisory committee composed of NIOSH researchers involved in mining safety and health has developed a methodology to nominate and rank candidate hazard conditions as to their relevance, feasibility, and value to mine safety and health research. A working list of hazard survey candidates has been selected. The next step is to develop survey methodology and protocols in partnership with the national hazard survey team and other NIOSH divisions for the first survey.

KEYWORDS: Hazard surveillance, mining

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Integration of GPS and GIS to map the distribution of air-borne and ground dust and particulate matter.

IMPROVING SURVEILLANCE DATA UTILIZATION THROUGH GEOGRAPHICAL INFORMATION SYSTEMS

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PURPOSE: Develop and demonstrate geographical information system (GIS) methodologies for spatially mapping and analyzing accident and occupational disease information.

RESEARCH SUMMARY: Combinations of mapping and analytical techniques offer great potential for discovering regional differences in the occurrence of accidents and health risks. Geographical information system (GIS) and global positioning system (GPS) technologies will allow surveillance data to be examined in relation to the geographic locations of accidents or exposure sites. This information will enhance surveillance efforts by allowing spatial analyses that are likely to reveal causal relationships between injury variables not heretofore seen. A second goal is to demonstrate and use GIS technology to disseminate mining industry disease and injury data through computer networks such as CDC's Intranet.

KEYWORDS: Surveillance, GIS, GPS

The first step was to produce basic GIS maps that show locations associated with selected mining health and injury information by topic (accident classification by State or commodity, for example). The project is now exploring the usefulness of producing and publishing interactive maps on the Intranet. A site is being developed and will be evaluated. Such maps will allow NIOSH users to perform specialized queries by selecting different combinations of themes from available options. Other GIS products, such as Intranet facility management modeling, will be investigated. Of special interest is a model that depicts the spatial distribution of local accident sites, hazardous work areas, and/or chemical storage, for example, with respect to safety equipment, exits, and office space. Eventually, we hope to study the technology and feasibility of linking GIS and document management technologies that would allow users to access health and safety data simply by clicking on specific features of a map showing the U.S. mining industry.

Knowledge gained in this research in GIS and GPS has allowed the tools to be used to assist other research projects in gathering and analyzing data. One such example is a "proximity warning system" that has the potential of reducing haulage truck accidents.

Miner at a longwall face in an underground coal mine.

RISK FACTORS FOR ATHEROSCLEROSIS AMONG COAL MINERS

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PURPOSE: Determine the prevalence of preclinical atherosclerosis and risk factors for atherosclerosis among a sample of coal miners.

KEYWORDS: Cardiovascular disease, stress, coal mine dust

RESEARCH SUMMARY: Based on death certificate data from NIOSH's National Occupational Mortality Database, coal miners seem to have an elevated risk of death from heart attacks (myocardial infarction). Factors involved in the risk of atherosclerotic heart disease include genetics and lifestyle issues, such as diet and smoking. Heart disease has also been shown to be related to work in certain types of jobs, particularly jobs involving high demands with low levels of control over work. The relationship between workplace organizational factors and cardiovascular disease is being investigated under the National Occupational Research Agenda (NORA).

Recent developments in cardiovascular research allow for the detection of preclinical atherosclerotic disease with a noninvasive technique involving ultrasound measurement of the intimal lining of the carotid arteries. This study is determining the prevalence of subclinical atherosclerotic disease, as assessed by b-mode ultrasound of the carotid arteries, among a sample of coal miners. Measurements of established risk factors for coronary heart disease are to be obtained in this population, as well as measurements of possible risk factors related to the work environment, including work-related stress and inhalation of coal dust. The effect of these risk factors on atherosclerosis is to be examined. This project is being conducted in cooperation with the United Mine Workers of America.

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Sand and gravel mines are being studies to evaluate the ecoomic and social consequences of an injury to a miner.

HAZARD REDUCTION IN SURFACE MINING OF SAND AND GRAVEL

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PURPOSE: Provide data on the economic and social costs of workplace injuries and fatalities at sand and gravel operations based on the use of actual accident cases.

KEYWORDS: Mining, sand and gravel, economics

RESEARCH SUMMARY: The true costs of a mining injury or fatality involve more than just the direct costs to the mining company or its insurer, but presently there is little or no good information on such costs. Direct costs may include such things as medical and insurance administration costs. Indirect costs include lost earnings, lost home production, lost fringe benefits, employer costs of retraining and restaffing, coworker costs of lost productivity, and time delays. Indirect costs can often exceed direct costs.

This task will involve collecting available information on direct costs with the assistance of various collaborators. In addition, a protocol will be developed to measure indirect costs associated with a worker injury or fatality. This protocol will include a literature search, enhancement of the existing system of obtaining direct and indirect costs, and collection of associated social and economic impacts through personal and professional interviews. This task will be completed during the first year of the project when a pilot study will be done of a benchmark group. The benchmark group is envisioned to be a small sand and gravel operation with six or fewer workers that has not necessarily experienced an accident. This group will be used to establish the methodology and test the economic model. The benchmark model will determine direct and indirect cost sources of data relevant to a serious accident.

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Dust emissions at a surface drilling site.

A HEALTH HAZARDS STUDY OF SURFACE DRILLING OPERATIONS

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PURPOSE: Develop databases on silica and noise exposures for surface drilling operations. Provide the basis for hierarchical recommendations on engineering controls, work practices, use of personal protection, and training exercises for workers engaged in surface drilling operations.

KEYWORDS: Noise, silica, control technology, mining, drilling, construction

RESEARCH SUMMARY: Long-term exposure to excessive levels of respirable silica dust can lead to silicosis, a debilitating and potentially fatal lung disease. Excessive levels of noise can result in noise-induced hearing loss (NIHL), which is permanent and irreversible. Mine Safety and Health Administration data from dust sampling conducted on drillers at surface mines have shown that over 75% of silica samples exceeded the permissible exposure level. A recent medical screening survey of surface mine workers in Pennsylvania showed that about 13% of the workers with drilling experience were diagnosed with silicosis. In addition, NIOSH data indicate that at least 70% of mine workers (also engaged in drilling activities) suffer NIHL severe enough to be classified as a hearing disability. Similar equipment and working conditions exist at surface drilling sites (water well, construction) that suggest that operators at these locations may also be overexposed.

In this new project, noise and dust assessments on various types of surface drills (air-rotary, tabletop rotary (motor), cable tool, auger, impact) are being done in Minnesota, Pennsylvania, Wisconsin, and Ohio. Airborne respirable dust (ARD) sampling, along with noise dosimetry, time-motion analysis, and characterization of noise profiles, are being done at all drilling sites. ARD sampling is being conducted to examine the effectiveness of dust control practices and to assess dust exposures to the workers. Noise dosimetry, time motion studies, sound pressure profiles, and narrow-band sound level data are being collected to characterize (1) worker noise exposure related to location and job activity, (2) the noise environment surrounding different types of drilling rigs, and (3) prevailing frequencies associated with dominant noise sources for assistance in determining appropriate engineering controls. Training exercises are to be presented at workshops nationwide that target operators, workers, and equipment manufacturers.

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Haul trucks are expected to increase in size, and trolley power is one possibility to improve efficiency. Such innovations can impact the safety and health of mine workers. ***(Photo courtesy of Siemens AG.)***

EMERGING TECHNOLOGIES

EMERGING TECHNOLOGIES AND OTHER ISSUES IN MINING

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PURPOSE: Identify anticipated major changes that are expected to impact the safety and health of mine workers in the next 5-10 years.

KEYWORDS: Emerging mining technology

RESEARCH SUMMARY: The mining industry is dynamic. It has made significant gains in safety, health, productivity, production, and environmental impact. In achieving these accomplishments, it has adopted new technologies, accommodated encroachment of a world market, and addressed new environmental regulations. All of these changes can influence the safety and health of all mine workers. It is important to anticipate future trends in technology, public policy, and demographics to enable the NIOSH research program to take advantage of changes that could improve miner's safety and health and prepare interventions to neutralize emerging threats.

This project is identifying major changes that are anticipated to impact, for better or worse, the safety and health of mine workers in the next 5-10 years. The study is combining an analysis of expected commodity production in the United States, anticipated social and public policy, and emerging technologies to produce a series of recommendations for research.

The demand for a commodity can influence miner safety and health. Trend analysis in coal production and employment has been completed, and analyses for the other mined commodities are currently underway. A study by RAND Corp. to identify critical technologies in the mining industry has been completed. Public policy that impacts when and how mining is done is also being reviewed.

The combined results of the analysis described above will result in the identification of likely, new technologies and trends that are expected to impact miner safety and health, along with recommendations for targeted etiological and intervention research efforts.

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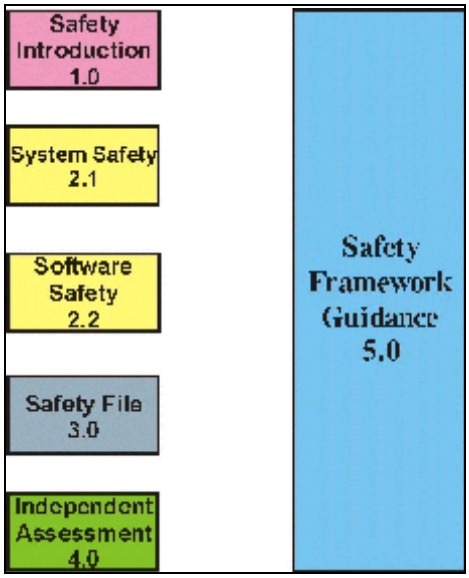

The safety framework and associated guidance documents.

SYSTEM SAFETY: PROCESSOR CONTROL APPLICATIONS

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KEYWORDS: Emerging technology, control technology, mining

PURPOSE: Develop a series of recommendations detailing safety processes for programmable electronic-based mining systems.

RESEARCH SUMMARY: Mining does not have a formalized process for addressing programmable electronics safety as do other industries. This project documents such a process that encompasses hardware, software, humans, and the operating environment for functional safety of equipment with programmable electronics over the equipment's entire life cycle. A risk-based, systems safety process, along with lessons learned by other industries, is used. The project's recommended safety process will benefit the U.S. mining industry and the global mining community since no such system safety process specific to this technology in mining formally exists.

Researchers reviewed various world standards addressing system safety in different industries and used this information to draft recommendation documents addressing the functional safety of processor-controlled mining equipment applicable to the full life cycle of the equipment. The Mine Safety and Health Administration (MSHA) is currently cooperating in this project to achieve voluntary adoption of the system safety recommendations by the mining industry. MSHA does not intend to pursue a regulatory approach to system safety. A work group has been formed that is composed of representatives from MSHA, NIOSH, and the mining industry to develop a best practices guide to help implement the system safety recommendations.

Key members of industry realize the need to address processor control safety as shown by their continued participation in an Industry Safety Workgroup. To investigate hazards and concerns identified by the panel, NIOSH established extramural activity with The Pennsylvania State University and the University of Alabama. Their studies substantiated the claims of the panel. The same safety concerns have been voiced in Australia during our meetings with Standards Australia and its Approval and Certification group.

The outcome of this project is a set of safety framework documents specifically tailored for mining applications (best practices and guidance) for the emerging technology of programmable electronics and its associated software. It also will furnish functional safety processes for design, testing, approval/certification, operation, and maintenance of mining systems using programmable electronics. The “Introduction” and “System Safety” documents have been completed; a draft of the “Software Safety” document is being reviewed by MSHA and the mining industry workshop.

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