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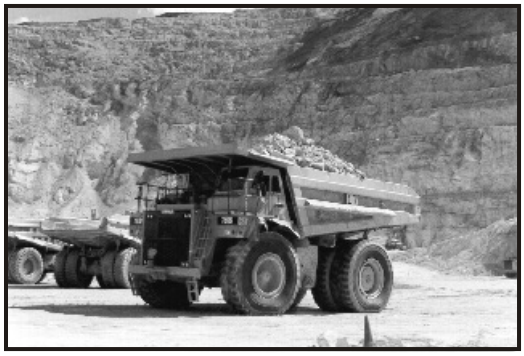
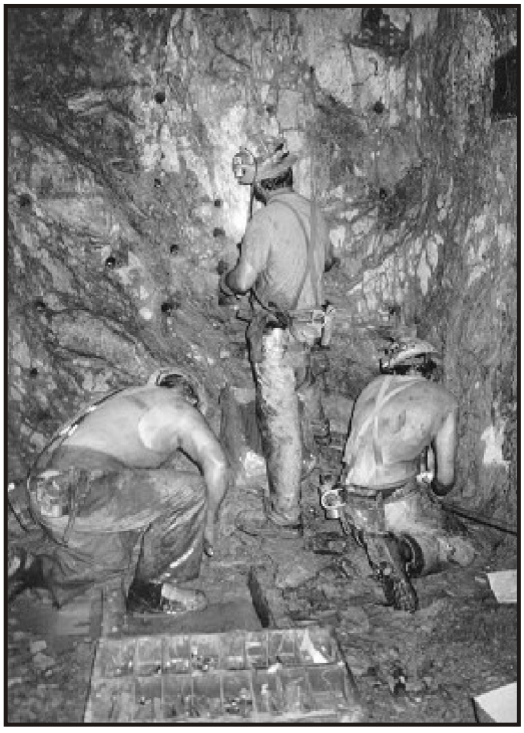
A Compendium of NIOSH Mining Research 2000





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Cover photos: *(Left) NIOSH is investigating ways to reduce the respirable dust exposure of mine workers at longwall mining operations. (Upper right) NIOSH is studying technologies that will reduce haulage truck collisions at surface mines. (Lower right) NIOSH has developed training tools for miners, including a video on how to safely handle explosives underground.*

A COMPENDIUM OF NIOSH MINING RESEARCH 2000

Spokane Research Laboratory and Pittsburgh Research Laboratory

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

February 2000

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DHHS (NIOSH) Publication Number 2000-109

FOREWORD

To continue serving the safety and health needs of the Nation's miners, NIOSH is coordinating extensively with stakeholders across the country to obtain valuable insight into their priorities. This input, together with results from comprehensive analyses of safety and health data, has allowed us to begin balancing the mining research program to address the prioritized needs of miners in various industry sectors.

This publication provides brief descriptions of the NIOSH projects dedicated to the primary mission of reducing miners' occupational injury and illness. The breadth and quality of research represented here is a true testament to the dedicated NIOSH researchers working in this field. As problems and issues emerge, or are effectively addressed over time, the research program will change accordingly, but it will continue to be based on a solid, scientific rationale and anchored in reality.

NIOSH is always looking for better ways to communicate our research and results. This publication is just one way we are reaching out to inform our mining partners and other interested individuals and organizations about our current mining research projects. I look forward to continued interaction with NIOSH's many mining partners.

Linda Rosenstock, M.D., M.P.H.
Director, National Institute for
Occupational Safety and Health

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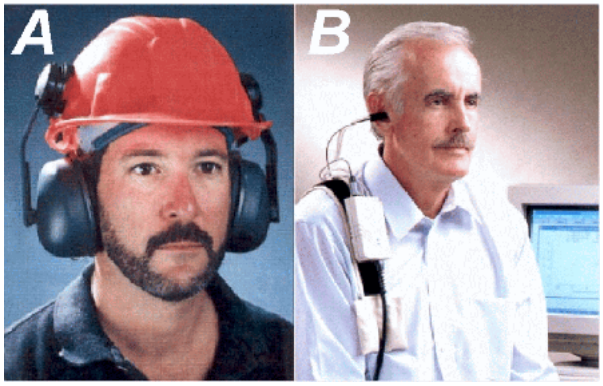

***A*, Human subject testing of hardhat-mounted earmuffs; *B*, Typical auditory assessment being conducted prior to earplug testing.**

HEARING LOSS PREVENTION

INVESTIGATION OF TECHNOLOGY FOR HEARING LOSS PREVENTION

RESEARCHER: David C. Byrne

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National Institute for
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1-800-35-NIOSH

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

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PURPOSE: Evaluate practical technological advances in level-dependent hearing protectors and inexpensive personal acoustic monitors.

RESEARCH SUMMARY: The results of previous NIOSH research show that miners develop hearing loss much more quickly than nonoccupationally noise-exposed individuals and that miners experience a greater severity of hearing loss than would be expected for nonoccupational noise-exposed persons of the same age and gender. Using hearing thresholds at 4,000 Hz as an indicator, coal miners experience hearing loss 2.5 to 3 times greater than would be expected for persons not exposed to occupational noise. At age 50, 90% of coal miners and 49% of metal/nonmetal miners were found to have a hearing impairment. In comparison, only 9% of a nonoccupationally exposed control group had a hearing impairment at age 50.

There are numerous barriers to the prevention of hearing loss among miners. In an effort to overcome some of these obstacles, this work was initiated to evaluate practical technological advances in level-dependent hearing protectors and inexpensive personal acoustic monitors. Experiments will involve analysis of this new technology under both laboratory and field conditions. Laboratory components will consist of controlled studies using an anthropometrically correct test fixture as well as human subjects to evaluate the adequacy/effectiveness of various hearing protective devices. Electroacoustical performance testing of new noise monitors will also be conducted in a laboratory setting. Subsequent field studies will determine the actual usefulness and practicality of the personal protective/monitoring equipment as used in different mining situations.

It is anticipated that increased on-the-spot awareness of hazardous noise levels and the availability of better-suited hearing protectors will provide a degree of protection beyond what is currently attained in different mining environments. Therefore, the intent of this project is to identify and adapt new acoustical technologies and products that have a direct application to individual mine workers. With increased knowledge of these technological advances, a greater demand for similar devices will likely occur, which, in turn, will lead to a better understanding and awareness of hearing loss prevention methods throughout the mining community. The ultimate goal is for widespread integration of useful hearing loss prevention products and devices into the daily routines of miners.

Noise measurements being made on a continuous mining machine.

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

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CROSS-SECTIONAL SURVEY: NOISE EXPOSURE PATTERNS/SOURCES

RESEARCHERS: **Eric R. Bauer and Roy C. Bartholomae**

AFFILIATION: **Pittsburgh Research Laboratory National Institute for Occupational Safety and Health 1-800-35-NIOSH**

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

RESEARCH SUMMARY: Noise-induced hearing loss has been recognized as the most common occupational disease in the United States. Despite the progress achieved over the last 2 decades, overexposure to noise in the mining workplace 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. Even worse, 25% of the miners are exposed to a TWA noise level that exceeds 90 dBA. Research is needed to identify and characterize the noisiest equipment and mine worker activities. This will ensure that the hearing of miners will be preserved, that future hearing loss is prevented, and the quality of life of our Nation's miners will be enhanced.

The collection of baseline information will provide a current and systematic characterization of worker noise exposure patterns and mining noise sources. This research is essential to the development of 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 will 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 TWA full-shift noise exposures. In addition, a profile of the noise levels of the various mining machines will be obtained using a handheld sound level meter.

To date, noise measurements have been made at Harrison Mining Co., NIOSH's Safety Research Coal Mine at the Pittsburgh Research Laboratory (underground coal); and Commercial Stone Co. (underground limestone). Cooperation is also expected from Consolidation Coal Co. The results of these measurements will be used to design future noise exposure measurements, in particular, which occupations need to be monitored and which machines and which components and/or operating functions contribute the most noise.

Data collection in an underground coal mine.

A MODEL HEARING CONSERVATION PROGRAM FOR COAL MINERS

RESEARCHER: David C. Byrne

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
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1-800-35-NIOSH

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

RESEARCH SUMMARY: Noise-induced hearing loss (NIHL) is a major occupational health problem for coal miners. The prevalence of NIHL has remained relatively unchanged for the last 20 years. A significant reason for this is the lack of a systematic effective plan of intervention for the mining community.

With researchers from The Pennsylvania State University, a cooperative agreement project was initiated 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, to implement this program at a cooperating mine, to evaluate the program over a 5-year period, to demonstrate its efficacy in preventing hearing loss, to transfer the findings of this study to the coal mining industry (and others) as quickly and thoroughly as possible, and to make the model HCP as "portable" as practicable.

Other specific goals of the project are to fully 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.

The program design phase of the project is nearly complete. This included a significant amount of information collection regarding the current state of hearing conservation measures at the cooperating mine, as well as baseline hearing tests and noise measurements. The second main task is to develop the detailed 5-year plan for each program element, including noise exposure monitoring, engineering and administrative controls, audiometric evaluations, use of hearing protection devices, education and motivation, record-keeping, and program evaluation.

KEYWORDS: Noise, hearing conservation, hearing loss prevention

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The operation of mining equipment, (e.g., the drilling of rock) can contribute to high noise levels.

ENGINEERING CONTROLS FOR HEARING LOSS PREVENTION

RESEARCHER: R. J. Matetic

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National Institute for
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1-800-35-NIOSH

KEYWORDS: Noise, control technology, mining, equipment

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 the U.S. mining industries despite 25 years of regulation. Lower elements in the hierarchy of controls for reduction of noise exposure, including administrative practices (e.g., job rotation), and use of personal protective gear have been main sources of noise control, relying on workers to properly wear and maintain their hearing protection. Analysis of longitudinal data (audiograms) from miners in underground coal mines suggests that this approach has not been effective and has resulted in a serious NIHL problem among miners.

A balanced approach to the prevention of NIHL that includes not only education, surveillance, and intervention, but also a research emphasis on low cost or economically feasible engineering controls for noise is necessary. Engineering controls represent a permanent solution, whereas the use of personal hearing protection is seen as an interim one. The new Mine Safety and Health Administration rule for Health Standards for Occupational Noise Exposure is to be effective on September 13, 2000. It requires the use of all feasible engineering and administrative controls to reduce a miner's noise exposure to the permissible exposure limit. This project focuses on targeting engineering noise control for mining as the first line of defense.

The approach is to review past mining research on noise control to determine what has been done and what remains relevant and to investigate best practices of noise control currently available in the mining industry and in other industries. A workshop will be held to bring together mine operators, union officials, manufacturers of mining equipment, trade organizations, and Government researchers and regulators to discuss and develop a strategy for adopting economically viable engineering controls for noise control in mining. By bringing together all of the relevant parties in the workshop, strengths and weaknesses of various implementation strategies can be refined. This strategy is the basis of an implementation plan where appropriate engineering controls are selected and targeted to reduce excessive exposure to noise on the job. The quiet-by-design approach for noise control is being emphasized, but low-cost retrofit of equipment with noise control measures is also a component.

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An eight-filter sample wheel speeds analysis by automated sample handling and alignment.

DUST MEASUREMENT AND CONTROL

ANALYTICAL TECHNIQUES FOR SILICA

RESEARCHER: Donald P. Tuchman

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National Institute for
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1-800-35-NIOSH

KEYWORDS: Silica, dust, exposure assessment, analytical methods

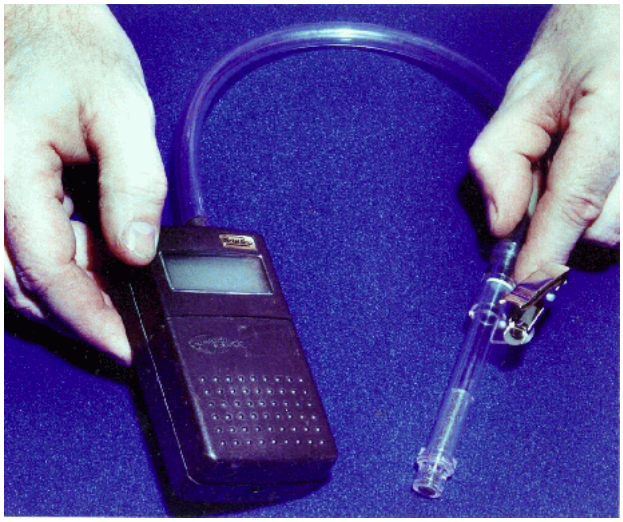
PURPOSE: Develop technology to measure crystalline silica in respirable coal mine dust samples by a rapid on-filter technique.

RESEARCH SUMMARY: Respirable crystalline silica has long been known as a toxic agent that causes silicosis and has also been found to aggravate coal workers' pneumoconiosis. The National Coal Workers Autopsy Study records that 12% of miners have silicosis lesions. Other studies show that more than 5% of surface mine workers have silicosis. Better ways to measure crystalline silica will enable the health and enforcement community to pursue improved epidemiology, detail dose-response relationships, verify effectiveness of control technology, and reduce exposure by enabling a rapid response to overexposure situations.

The analytical technique currently used to determine crystalline silica content of coal mine respirable dusts is a lengthy and labor-intensive approach. It involves ashing filter samples and redepositing the ash onto other filters. This research seeks to develop a new method in which filters are placed directly in an infrared spectrometer, without pretreatment, and silica content results are made available in a few minutes. This research also seeks to automate the analyses. Automation will help reduce human errors, minimize time and effort spent per sample, and maximize the benefits of the new method.

To date, customized software and hardware for the new type of analysis, including an automated eight-filter sample wheel, have been developed and are almost fully debugged. Comparison analyses are in progress, checking results with an established reference method, to evaluate the new method's accuracy. Extensive work is continuing to integrate advanced features into the customized automation system.

Besides the development of a new, rapid analytical method, the specialized software being developed is also a valuable product in its own right. A variation of the software, usable by a large number of laboratories, can be employed without the need for any automation hardware at all. Its use will reduce interlaboratory variations in the analysis of silica, thereby improving measurement accuracy for the analytical community as a whole.



The dust dosimeter has two components: a small pump and a dust detector tube.

PERSONAL DUST MONITORING

RESEARCHER: Steven J. Page

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
Occupational Safety and Health
1-800-35-NIOSH

PURPOSE: Investigate a disposable and inexpensive dust exposure assessment device known as the dust dosimeter and the fundamentals of the measurement technology used in its design. In addition, this program will be responsible for the certification of coal mine dust personal sampling units.

RESEARCH SUMMARY: Assessment of personal respirable dust exposure is a critical step in eliminating dust-related occupational illness and disease. Currently, dust levels are measured by weighing dust collected on filters or with instantaneous electronic dust monitors. The filter method is used for compliance purposes, and results can take several weeks to process. The delay in receiving filter results prevents timely correction of excessive dust levels. Electronic devices are complex, expensive, and cumbersome. The approach is to develop an end-of-shift, inexpensive dust measuring device that resembles a gas detector tube and measures the differential pressure across a filter as a function of dust loading. It is intended to be used as a screening tool to decide if additional, more rigorous, dust evaluation is warranted. It will also quickly alert miners and mine operators when miners are overexposed to dust. The relationship between differential pressure across various types of filter media and the mass of respirable dust collected on the filters, as well as the effect of diesel exhaust particulate on the differential pressure, is being studied.

The development of the dosimeter has been done in partnership with the United Mine Workers of America, the U.K.'s Health and Safety Executive, the Mine Safety and Health Administration, Consolidation Coal Co., Jim Walter Resources, Inc., The Pennsylvania State University, and the University of Minnesota. A Cooperative Research and Development Agreement (CRADA) partner has been added to the work for subsequent commercialization of the dosimeter. Prototype versions of the dosimeter have been received and tested, and manufacturing problems are currently being resolved. A new sampling pump for the dosimeter has been developed under the CRADA. This pump provides higher pressure resolution, displays output directly in respirable dust concentration, and provides midshift and end-of-shift readouts. The successful outcome of the work will be a new tool and a new approach to dust monitoring in mining.

This program has also absorbed the responsibility for certifying each new coal mine dust personal sampling unit that will be used for personal compliance sampling in all underground and surface mining operations.

KEYWORDS: Mining, dust, monitoring

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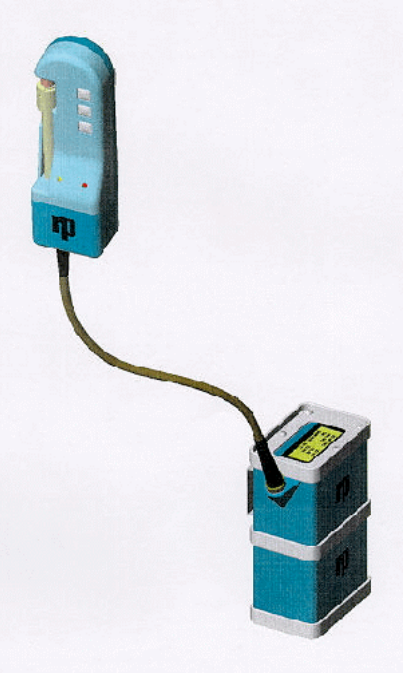

Person-wearable dust monitor.

TAPERED-ELEMENT OSCILLATING MICROBALANCE (TEOM) DUST MONITORS

RESEARCHER: Fred N. Kissell

AFFILIATION: Pittsburgh Research Laboratory
National Institute for
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1-800-35-NIOSH

PURPOSE: Develop a person-wearable dust monitor using the tapered-element operating principle.

RESEARCH SUMMARY: Prolonged inhalation of respirable coal mine dust can cause coal workers' pneumoconiosis. Accurate measurement of respirable dust is crucial to successfully reducing dust exposures and eliminating disease. However, the sampling of coal mine dust has remained virtually unchanged in the last 30 years since the Federal Coal Mine Health and Safety Act of 1969 mandated a dust exposure limit of 2 mg/m^3. The need for a new type of coal mine dust sampling device is evident. The Mine Safety and Health Administration (MSHA), the mining industry (the Bituminous Coal Operators Association), and the United Mine Workers of America have requested that NIOSH develop a personal respirable dust monitor that can provide a rapid readout of a full-shift exposure and real-time respirable dust concentration readings during a shift.

To fill this need, NIOSH has awarded a contract to Rupprecht and Patashnick Co., Inc. (R&P) in Albany, NY, to develop a person-wearable dust monitor using the tapered-element operating principle. The operating principle uses a replaceable filter cartridge mounted on the narrow end of a hollow tapered tube. The wide end of the tube is fixed. Air passes through the filter and down through the tube to a pump. The tapered tube with the filter on the end is maintained in oscillation. The oscillation frequency depends on the characteristics of the tube and the filter mass at its end. As dust collects on the filter, the mass change is sensed as a frequency change in the oscillation of the tube. The mass of dust collecting on the filter is then determined directly. Since frequency can be measured accurately, the method can measure very small mass changes. The required accuracy is ±25% of the current sampling method, and the size and weight are expected to be reasonable for a miner to wear.

These units will be evaluated jointly by NIOSH and MSHA for performance and reliability in underground mine tests. Upon acceptance of the production prototypes, five more units will be constructed and delivered to NIOSH.

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

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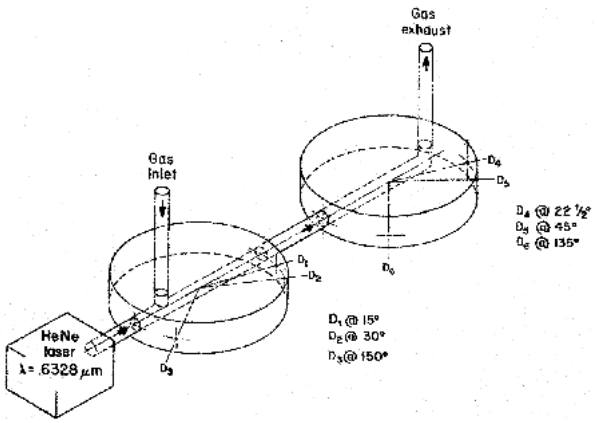

Light-scattering test apparatus schematic.

FUNDAMENTAL SCATTERING PROPERTIES OF RESPIRABLE DUSTS AND SUSPENDED PARTICULATE MATTER

RESEARCHER: C. D. Litton

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1-800-35-NIOSH

KEYWORDS: Respirable dust, diesel particulate matter, combustion aerosols, light scattering, pneumoconiosis, silicosis

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PURPOSE: Explore the light-scattering properties of respirable mine dusts and combustion-generated submicrometer particulate matter. Use the results of these investigations to develop improved instrumentation for measurement and characterization of respirable dusts and suspended particulate matter.

RESEARCH SUMMARY: Pneumoconiosis and silicosis are two major health hazards resulting from prolonged exposure to respirable coal dust and silica dust, respectively. In addition, suspended particulate matter from combustion sources, such as diesel engines or other combustion processes, lie entirely within the respirable range, and prolonged exposure results in adverse health effects. Devices for the measurement and characterization of respirable mine dusts and suspended particulate matter are needed to assess worker exposure to these health hazards and to evaluate control technologies.

When airborne dusts or suspended particulates are irradiated with light, the light is scattered in all directions. The intensity of light scattered at any particular angle depends on the wavelength of the light and the size, volatility, and mass concentration of the dust or suspended particles. Both theory and experiment indicate that at a scattering angle of around 20° to 30°, the size and volatility of respirable coal dusts have a negligible impact on the measured intensity so that this intensity is directly proportional to the mass concentration of the dust. At an angle of 15°, equal concentrations of either respirable coal dust or diesel particulate matter (DPM) yield equal intensities of scattered light. At larger angles, the intensities from DPM are significantly greater.

These results, while tentative, imply that devices that measure light-scattering signatures at one or more specific angles in the range of 15° to 30° offer significant promise for respirable dust or DPM measurement and, possibly, for determination of mass fractions of dust/DPM mixtures. As this basic research project progresses, these implications will be explored in greater detail. We will also evaluate light-scattering signatures from silica dust and other suspended particulate matter.

Dust generation and water spray application at an operating longwall face.

DUST CONTROL FOR LONGWALL MINING

RESEARCHER: **Jay F. Colinet**

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1-800-35-NIOSH

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

KEYWORDS: Coal mine dust, underground mining, control technology

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 approximately 9% of the workers with 25 or more years of mining experience were diagnosed with CWP. Longwall mining operations now account for over 50% of underground coal production, and average shift production levels on longwalls has increased over fourfold since 1980. As more coal is mined, greater quantities of respirable dust are generated and the potential for worker overexposure increases. In response to increased production levels, longwall operators have increased the level at which ventilating air and spray water are applied in an effort to provide greater dust control.

This multitasked research project is addressing improvements in control technology for longwall mining operations. Laboratory testing is being conducted at a full-scale test gallery at the NIOSH 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. These data will allow longwall operators to optimize dust controls for conditions at their respective mines. Additional laboratory testing is being conducted within a specially designed wind tunnel to evaluate the entrainment of respirable dust in high-velocity airstreams, which will represent dust liberated during the advance of shield supports. Mine site testing will be used to evaluate the effectiveness of novel dust control technologies after implementation by industry.

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Dust sampling array for assessment of respirable dust concentrations.

DUST CONTROL IN SURFACE COAL MINING

RESEARCHER: **Jeffrey M. Listak**

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National Institute for
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1-800-35-NIOSH

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

PURPOSE: Identify the effectiveness of existing dust control technologies used for rock drills and bulldozers at surface coal mining operations and improve coal miners' health protection from silica dust exposure through the advancement of existing 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 are at particularly high risk because of the potential of being exposed to extremely high levels of respirable silica dust when drilling through rock containing silica. A study of job categories was conducted to examine exposure data collected during a 2-year period at surface mine sites, preparation plants, and shop/maintenance facilities. This study concluded that occupations associated with highwall drilling (operator and helper) had the highest silica exposures of all job categories examined.

Research efforts will focus on the interactions between drilling parameters, overburden lithology, and bit design and how these interactions affect respirable silica dust generation. Once the drilling parameters, bit designs, and rock characteristics have been defined in terms of their impact on silica generation, appropriate control technologies can be developed to reduce silica emissions. Furthermore, many surface drills have dust containment and capture problems at the shrouded drill table above the hole. Laboratory and mine site development work for improving the highwall drill's primary dust collection system is planned. Mine Safety and Health Administration (MSHA) dust exposure data show that, in addition to drilling personnel, bulldozer operators represent the next occupation at surface coal mines that most frequently exceed the permissible exposure limit for respirable dust. Consequently, during surface mine surveys, dust sampling will also be conducted to identify silica sources, exposures, and controls for bulldozer operators. Additionally, investigations into improving quality control methods to ensure the integrity of enclosed environmental cabs will be done through cooperative work with mining companies, equipment manufacturers, and MSHA.

This research will improve dust control technology alternatives provided for surface coal mining operations.

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Drilling operations in the stone industry are a potentially high source of silica dust liberation.

SILICA DUST CONTROL FOR UNDERGROUND METAL/NONMETAL MINES

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1-800-35-NIOSH

KEYWORDS: Underground mining, silica dust, dust control technology

PURPOSE: Reduce silica exposure among workers in underground metal/nonmetal mines. Assess the effectiveness of current dust control technologies and develop or modify existing technologies where needed.

RESEARCH SUMMARY: The health hazards associated with overexposure to respirable silica dust in the mining industry have been well documented. Chronic overexposure to respirable silica (particle diameter < 10 microns) leads to progressive lung deterioration known as silicosis. An analysis of the Mine Safety and Health Administration (MSHA) compliance dust sampling data has shown that a high percentage of samples from underground stone, metal, and nonmetal mines exceeded the permissible exposure limit (PEL) for silica. From 1993 to 1997, on average between 20% and 25% of underground respirable dust samples from these three mining sectors exceeded the PEL for respirable quartz. In the stone industry, most silica overexposures have historically occurred in limestone mines. The occupations most at risk include truck drivers, crusher operators, front-end loader operators, and rotary drill operators. In the metal industry, gold mining has the most silica problems. Several occupations have been identified as being chronically overexposed. In the case of scoop-tram operators, almost 50% of the samples exceeded the PEL. Silica exposure needs to be addressed through improved dust sampling methodologies and the development of practical dust control technologies.

Metal/nonmetal mining encompasses many types of commodities, each with different mining types and methods. For instance, limestone generally uses room-and-pillar mining methods. Gold operations may use long-hole open stoping or underhand drift-and-fill methods. These mining methods present unique dust control problems for the occupations specific to these operations.

In this new project, the evaluation of current technologies and the development of new ones will focus on four primary areas: (1) dust control at the generating sources such as that produced during drilling, blasting, or loading operations, (2) dust capture after generation involving the application of ventilation and water sprays, (3) dust control in contained working areas such as enclosed cabs on loading and haulage equipment, and (4) dust avoidance by implementing control technology that directs dust away from workers. This research will provide metal/nonmetal mine operators with data identifying major sources of silica dust liberation and potential controls for reducing worker exposure.

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 and nonmetal surface mining operations.

RESEARCH SUMMARY: Although all types of respirable dust are potentially harmful to a worker's lungs, crystalline silica is even more hazardous because it causes progressive deterioration to the lungs once it has become embedded in the tissue. More than 1 million workers across the United States are exposed to silica dust. Mine Safety and Health Administration (MSHA) records show that since 1974, more than 82,000 of the 134,000 full-shift air samples collected by inspectors in the metal/nonmetal mining industry contained at least 1% silica. In a similar report, MSHA stated that the occupations with the greatest exposure to silica are bag operators, bag stackers, and laborers. Maintenance, cleanup, and utility workers are also often overexposed because their mobility makes it hard to provide them with engineering controls.

In a cooperative effort between Malvern Minerals Co., MSHA, and NIOSH, a study was recently completed to reduce a bag stacker's exposure at a ground silica sand packaging station using a semiautomated palletizing machine. A number of NIOSH modifications made to the palletizing setup were successful in significantly lowering the bag stacker's respirable dust exposure.

Work is continuing at mineral processing operations to determine the impact of silica sand plant structural designs on ambient dust and noise levels within each operation. Three structural designs–a masonry pebble mill and screening tower, an open structure screening facility, and a metal-sided pebble mill–have been evaluated to date.

A cooperative effort is underway between NIOSH, Clean Air Filter Co., and U.S. Silica to lower respirable silica dust exposures to surface mine drill operators by improving filtration efficiency and pressurization in enclosed cabs on rotary percussive drills. Baseline testing has been completed, and an improved filtration and pressurization system has been installed. This research will lead to a cleaner work environment for workers in the metal/nonmetal mining industry by reducing respirable dust exposures, especially silica dust. This will decrease the potential for life-threatening lung diseases.

KEYWORDS: Silicosis, control technology, surface mining, mineral processing

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Field description of coal compositional banding in the Lower Kittanning Coalbed prior to collecting a channel sample at a surface coal mine.

INVESTIGATION OF SILICATE DUST GENERATION AND RARE EARTH ELEMENT BEHAVIOR IN COALS

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PURPOSE: Explore the origins of the silicate mineral fraction in coal dust produced during mining. Investigate the behavior of rare earth elements (REEs) in coal and characterize their geological/biological interactions.

RESEARCH SUMMARY: This new project will conduct basic research into two elements, silica and rare earth elements (REEs), that can be liberated during the mining of coal and can cause adverse health impacts to exposed workers. Miner exposure to silica dust has been well documented, as have the debilitating effects of silicosis. The toxicity of certain REE compounds has raised concerns about respiratory illnesses such as pneumoconiosis and genetic aberrations. About 20 cases of REE pulmonary diseases caused by the inhalation of metal dusts have been documented.

The relationship between the silicate mineral composition of whole coal samples and the mineral composition of dusts produced by the mining of U.S. coalbeds is not clearly understood. The concentrations of rare earth elements (REEs) produced in occupational settings are not reported. The nature of REE exposures is very broad and includes a wide variety of worker exposures. In 1996, a U.S. mine was the second highest producing rare earths mine in the world. The goal of this project is to (1) compare the silicate fraction of coal dust produced during mining to that of whole coal, (2) investigate the fundamental behavior of REEs in nature, and (3) develop new in-house analysis capabilities for determining the origins of potentially toxic materials.

NIOSH is currently collaborating with the University of Pittsburgh on the REE research task. A technical review of the draft REE work plan, the methodology for coal and rock sample preparation, and sample analysis procedures were completed. A sample collection protocol has been developed, and five mines have been visited to collect coal and rock samples. The silicate composition of the host material will be determined and then related to the silica content of the airborne dust levels associated with mining the host material. Further definition of the relationship between silica and REEs in host material and worker exposure during mining will allow for improved controls to be developed to reduce worker exposures.

KEYWORDS: Mining, mixed exposures, silica, chemistry

Field assessments are measuring the roof bolter operator's exposure to respirable silica dust.

CONTROL OF SILICA DUST EXPOSURES IN UNDERGROUND COAL MINING

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1-800-35-NIOSH

PURPOSE: Develop means of reducing exposures to respirable silica dust at the continuous mining machine and roof bolter operators' 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%, the dust standard is reduced to 10/(% silica), which limits silica exposures to 100 µg/m^3. Recent sampling data show that roughly 40% of continuous mining machine operator samples exceeded 5% silica, and 25% of these samples exceeded 100 µg/m^3. For the roof bolter operator, nearly 60% of these samples exceeded 5% silica and one-third exceeded 100 µg/m^3.

Information identifying dust control and ventilation practices, geologic characteristics, and occupational dust exposures was collected for 80 continuous mining operations with silica levels above 5%. Forty of these operations maintained silica concentrations less than or equal to 100 µg/m^3 in the majority of their dust samples; the remaining 40 operations had difficulty in maintaining silica below 100 µg/m^3. Comparing data from these two groups indicated that those operations having difficulty controlling silica levels had the greatest overexposures for roof bolter operators when the roof bolting machine was operating downwind of the continuous mining machine.

Field assessments are underway to document roof bolter exposures, while laboratory testing is planned to assess improved dust control technology for roof bolter operators. Canopy air curtain technology offers the potential to reduce roof bolter exposures to respirable coal dust and silica dust when working downwind of the mining machine. This air curtain device mounts on the underside of the roof bolter operator's canopy and provides a flow of filtered air over the roof bolter operator. Lab testing will be conducted to optimize performance of this control technology, followed by an in-mine evaluation.

Water sprays and ventilation airflow are used for control of 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 will be conducted to evaluate different water spray and ventilation airflow designs for effectively controlling both respirable dust exposures and methane gas.

KEYWORDS: Silica exposures, dust, coal mining, ventilation

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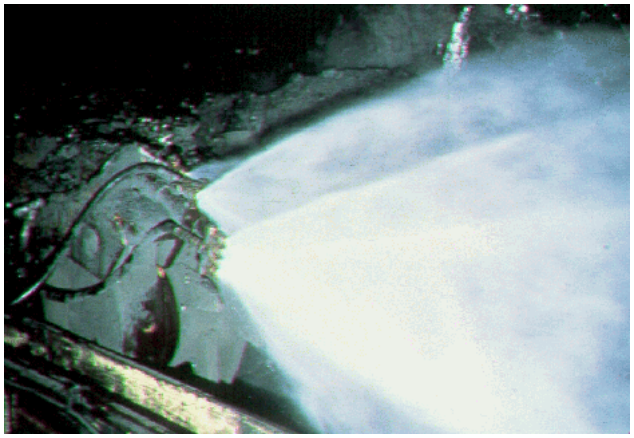

Water spray application on an underground coal mining machine.

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

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PURPOSE: Develop novel spray nozzle technologies and 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. Coal mining has the highest industrial silica-related deaths (9.5%); metal mining has the third highest (8.6%). Coal mining machine operators were the most frequent occupation (16.0%) recorded on silicosis-related death certificates during 1991-92. MSHA's compliance data indicate that a significant portion of the airborne respirable dust samples collected in mines exceed the mandated permissible exposure limits (PELs). Nearly 25% of the coal mine dust samples and over 20% of the metal mine dust samples exceed the MSHA-mandated PELs. About 13% of the dust samples from nonmetal and stone mines also exceed their mandated respirable dust PELs. These data indicate that there is a high likelihood of overexposure to silica dust in the mining industry, especially in coal and metal mines.

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

One approach to combat the amount of respirable silica dust exposure present in the mining industry is to develop 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 contact by (1) increasing the number of smaller sized spray droplets per unit volume of water utilized and (2) optimizing the energy transfer of spray droplets with the dust-laden air.

The first phase of this new project will involve laboratory investigation and development of several novel spray nozzle technologies and fluid dynamic principles for improving water droplet and dust particle interaction. The second phase of this research will involve the integration and demonstration of these enhanced spray technologies as viable engineering controls for improving respirable silica dust suppression from mining, crushing, screening, and milling processes.

Diesel fumes generated by mining machines.

DIESEL EMISSIONS AND TOXIC SUBSTANCES

REDUCING DIESEL PARTICULATE EXPOSURE IN WESTERN MINES

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National Institute for
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1-800-35-NIOSH

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.

RESEARCH SUMMARY: Exposure to diesel exhaust, especially diesel particulate matter (DPM), has been recognized as a health concern for some time. MSHA has recognized 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 mine workplace through partnerships. This project will support the western mining partnerships through control technology research applications on existing diesel equipment.

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 diesels are used in close quarters, i.e., factories and warehouses. The transfer of technology to these sectors could easily reduce exposure for hundreds of thousands of employees in nonmining industries.

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

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Diesel exhaust filtration on mining equipment offers substantial reductions in workplace concentrations of diesel particulate matter.

DIESEL ENGINE EMISSIONS MEASUREMENT AND ANALYSIS

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PURPOSE: Advance technology for measurement and control 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 (soot) to be a suspected or probable carcinogen. Recently one nongovernment body, responsible for recommending occupational exposure guidelines, recommended a maximum average level of 50 micrograms of diesel particulate matter (DPM) per cubic meter of air. About 30,000 U.S. underground mine workers are exposed to DPM levels that are up to 20 times this level.

This project directly addresses the issue of accurate measurement of DPM (which is mostly carbon) in the presence of mine dusts (such as coal, limestone, and other ores), oil mists, and cigarette smoke, which also contain carbon. Both analytical methods for filter samples and direct- indicating instrument methods are being investigated. Laboratory and field experiments are being performed to define and mitigate the effects of nondiesel dusts on the measurement of DPM.

The rapid advances in diesel engine emission control technology, which are driven by more stringent air quality standards for highway and off-highway trucks, are being followed. This knowledge is being used to provide technical and scientific support to a partnership among the Bituminous Coal Operators Association, the United Mine Workers of America, and NIOSH. The objective of this partnership is the application of technologically feasible controls to curtail worker exposure to DPM.

This project will reduce uncertainties in the measurement of workplace concentrations of DPM. This will enable better measurement of worker exposures and better assessment of the effects of control technology on tailpipe emissions and workplace concentrations and thus better day-to-day control over engine emissions. Control technologies, which have the potential of reducing emitted DPM by 80% to 95%, will be studied and feasible ones selected for demonstration. As a result, mines will use cleaner engines, apply better maintenance, and use control systems that will reduce worker exposures to DPM by factors of 10 to 20, thereby reducing exposure levels to that of other occupations.

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

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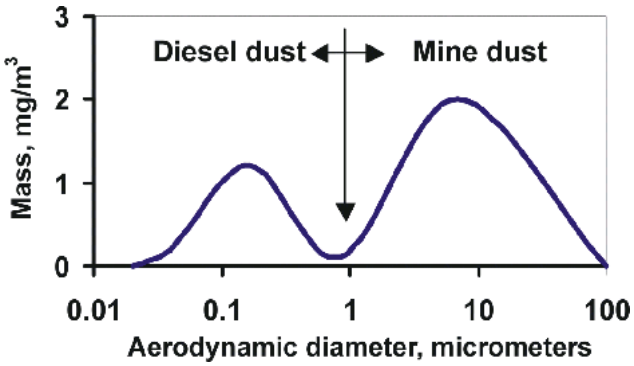

Typical mine diesel and dust sizes form the basis of a measurement technique to determine DPM in mining.

DIESEL PARTICULATE DOSIMETER

RESEARCHER: Jon C. Volkwein

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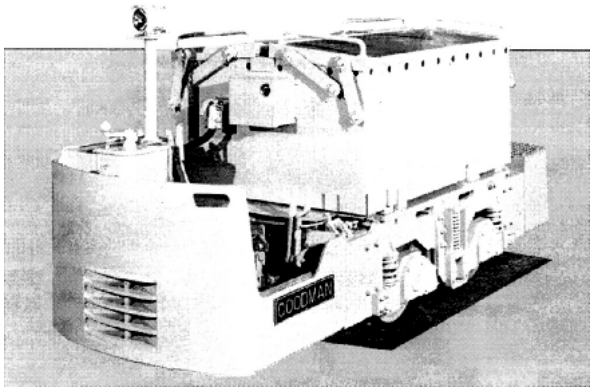
PURPOSE: Investigate the correlation of differential pressure increase with diesel particulate mass loading of filters as a potential real-time method of monitoring work environmental diesel particulate levels.

KEYWORDS: Mining, diesel particulate matter, monitoring

RESEARCH SUMMARY: Levels of diesel particulate matter (DPM) in mining and other industrial settings represent an increasing health concern because of the presence of carcinogens associated with the particulate. Diesel-powered mining equipment is the main power source in metal and nonmetal mining and is being used more frequently in U.S. coal mines. Recent legislative rulemaking by the Mine Safety and Health Administration has increased the need to understand what fraction of the mine dust is attributable to diesel exhaust. However, methods to monitor the levels of DPM in mining have, until recently, been unavailable. Studies indicate that adverse health impacts result from overexposures to DPM, and the American Conference of Governmental Industrial Hygienists has proposed an exposure limit of 150 micrograms per cubic meter. DPM monitoring is near the top of the health and safety priority list of the United Mine Workers of America. Current methods to monitor DPM do not permit timely results that would enable immediate action to be taken to prevent overexposures.

This project builds on the existing dust dosimeter project that monitors exposure to coal mine dust based on differential pressure across a filter. During the course of that project, it was found that diesel particulate in mines greatly increased the response of filter differential pressure to the mass relationship of the dust dosimeter. The intent of this project is to take the filter clogging disadvantages of DPM with the dust dosimeter and use the increased response as a way to monitor DPM.

Development of technology to quickly assess mine DPM levels in near-real-time would allow for immediate corrective action to occur if these concentrations are found to be excessive. This technology would be of use to all mines operating diesel-powered equipment. Furthermore, such a tool would enable workers and management alike to monitor DPM levels and increase their personal awareness of the quality of their work environments. The technology may also be of use to other industries, such as bus and rail maintenance shops, as well as the environmental monitoring of submicrometer particulate.



Small (4-ton) mine locomotive (courtesy Goodman).

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

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PURPOSE: Investigate the safe storage, distribution, and use of hydrogen as a vehicle fuel; the air quality improvements anticipated when diesel technology can be replaced by fuel cell technology; and the improvements expected in workplace noise levels by implementing fuel cell technology in mining.

RESEARCH SUMMARY: Due largely to the efforts by the Fuel Cell Propulsion Institute, fuel cell technology is anticipated to be demonstrated in the mining industry in the near future in the form of a 4-ton locomotive. Three areas were identified as particular safety and health concerns when existing diesel or electric technology is compared to emerging fuel cell technology: (1) the safe storage, distribution, and use of H_2 as a fuel, (2) air quality improvements, and (3) 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. The literature review produced general and specific information on H_2 production, storage, and use in existing environments, but only limited information on specific underground applications and use.

MSHA's Approval and Certification Center has sole authority and responsibility to grant or withhold an approval. NIOSH's role is to develop a protocol for the conduct of sound safety and health science. Successful completion of this project will produce a joint MSHA/NIOSH protocol document for testing the locomotive to acceptable mining standards and will yield the first documented tests of the noise and air quality performance of a fuel cell-powered mining vehicle. Hydrogen safety will also be thoroughly investigated.

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

Young miner using mercury to separate gold in Venezuela.

CHEMICAL HAZARDS IN MINING AND PROCESSING

RESEARCHER: Pamela L. Drake

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PURPOSE: Investigate and evaluate potential chemical hazards in mining workplaces to enable development of control or mitigation methods.

RESEARCH SUMMARY: Exposure to metals and other chemicals in mining workplaces, particularly in milling and refining facilities, may adversely affect thousands of workers. Mercury and silver are examples of potentially hazardous metals found in ore deposits in the Western United States.

Occupational exposure to silver and mercury can occur during numerous refining processes. Dust containing mercury or silver can be stirred up while handling dry concentrates and while cleaning silver bars (doré bars) after smelting. Also, metal fumes can be released when concentrates are heated during retorting and during smelting. Mercury or silver from the refinery can be spread to other areas on shoes or clothing. In addition, because mercury has a high vapor pressure, whenever ore concentrates containing mercury are heated, the mercury is vaporized.

Characterization of exposure to mercury vapor and silver dust and fumes during refining is the focus of this project. Workplace evaluations at precious metal mines will be conducted to collect information about the mercury and silver exposure hazards associated with refinery operations. The protocol for evaluating the refinery operations at each mine will consist of (but not be limited to) initial and followup site visits. The initial site visit will be designed to assess mercury and silver exposures at a given refinery; to collect information about the process, engineering controls, and other interventions; and to evaluate qualitatively the presence of other hazards. The followup site visit will consist of further mercury and silver exposure assessments, an evaluation of the engineering controls and interventions, and exposure assessments for other hazards present in the refinery areas. The results of this project will include implementation of engineering controls that minimize chemical exposures within the refinery to protect the health of the miners.

KEYWORDS: Mining, dust, airborne contaminants

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Transport of talc by tramlines generates dust.

EXPOSURE TO TOXIC SUBSTANCES IN DUST AT NONMETAL MINES

RESEARCHERS: Patrick Hintz and Pamela L. Drake

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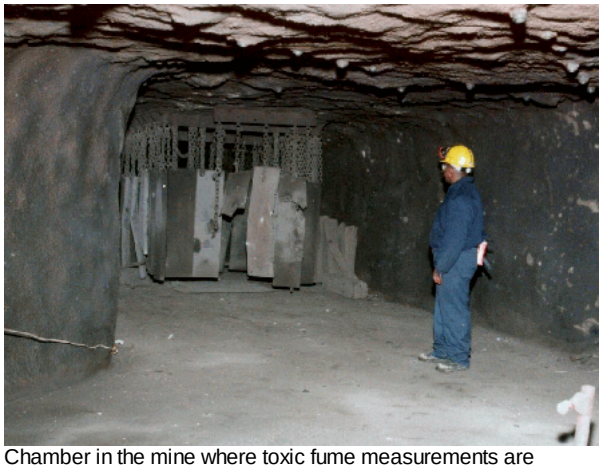
KEYWORDS: Trona, nonmetal dust, ore dust, dust monitoring

PURPOSE: Assess exposures to toxic substances in ore dusts and recommend engineering controls to limit worker exposures to these substances.

RESEARCH SUMMARY: There are approximately 25,000 workers employed in nonmetal mines. The largest sources of dust at nonmetal mines are drilling and blasting operations in underground mines and crushing operations in surface mines and mills. Haulage traffic is a source of dust at all locations. Although metals and other trace toxic substances can be present in nonmetallic ores, the extent to which they occur in dust and whether exposure levels constitute a hazard have not been studied extensively. Neither are the health effects of exposure to dusts in these mines addressed under the current NIOSH mining safety and health research program except where significant amounts of silica are present. Stakeholder input from a talc mine in Montana and anecdotal accounts from workers in trona mines in Wyoming indicate there are concerns about exposure to dust in nonmetal mines.

Existing literature on nonmetal mines pertaining to the occurrence of toxic substances, exposure monitoring, and adverse health effects will be reviewed. An inventory of the potential occurrence of toxic substances in nonmetal ore bodies will be developed from assays of ore samples obtained from previous studies or available mining company records. Dust monitoring will be conducted at selected sites to estimate exposures. A protocol for dust monitoring will be developed to evaluate the effects of exposure to toxic substances in ore, mining method used, engineering controls used, personal protection practices, and management and worker attitudes. Consideration will be given to variability among commodities and among individual deposits of a given commodity when estimating exposures. Practices that generate dust will be identified and recommendations will be made for engineering controls to reduce dust production or ventilation to reduce dust exposures.



Chamber in the mine where toxic fume measurements are conducted. The steel plates protect the chamber from shrapnel produced by the detonation of the pipe bomb.

TOXIC FUMES FROM BLASTING

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1-800-35-NIOSH

PURPOSE: Reduce worker exposure to blasting fumes by determining the causes of excessive blasting fumes and the rate of 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 they detonate. 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. Over the past 30 years, blasters have switched from the use of high explosives to less expensive blasting agents such as ammonium nitrate/fuel oil (ANFO) mixtures. ANFO generates more toxic fumes than high explosives, and there is no standard test to determine the quantities of toxic fumes generated by blasting agents. Additionally, surface mines have moved toward shooting larger blasts, which has caused new problems from blasting fumes. These large blasts produce proportionately larger quantities of fumes that take longer to dissipate.

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 bore holes. Additionally, a variety of contaminants may be added to the blasting agent to determine their effect on fumes generation.

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 working to find solutions. Information generated by this research, combined with the experience of industry, will allow blasters to design blasts that minimize toxic fumes generation.

KEYWORDS: Explosives, blasting agents, fumes

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Haulage truck

HAZARD DETECTION AND WARNING DEVICES

HAZARD REDUCTION FOR SURFACE MINING HAULAGE EQUIPMENT

RESEARCHER: Todd Ruff

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1-800-35-NIOSH

PURPOSE: Investigate, evaluate, and develop tools to reduce haulage-related accidents and injuries in surface coal and metal/nonmetal mines. The project addresses three issues: hazard recognition, economics of safety, and operator training.

RESEARCH SUMMARY: In the past 5 years, powered haulage accounted for 43% of all fatalities in mining and was one of the top five sources of injuries in surface mines. Inadequate training and inadequate information regarding the work environment contributed to the majority of these accidents. Through partnerships with industry and MSHA, solutions to these problems will be investigated and introduced to the mining industry.

This project consists of three main tasks. The first addresses accidents caused when haulage equipment operators were unaware of obstacles in the blind spots of their machines and other sources of limited visibility. This task will investigate existing technologies for collision avoidance and develop improved technologies if needed. Currently, radar, radio-frequency identification, and intelligent video camera technologies are being developed and tested. The goal of the second task is to provide mine operators with data to make informed decisions on choosing one work practice over another on the basis of economics and safety. For example, a cost analysis of end-dumping versus short-dumping has been completed. The third task will investigate new methods of training haulage equipment operators in safe driving practices and safe reactions to emergency conditions. Computer-based simulation and training methods are being studied.

KEYWORDS: Surface mining, hazard recognition, haulage

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Load rate warning device being tested on mobileroof support.

MOBILE MINING EQUIPMENT WARNING SYSTEMS

RESEARCHERS: John Owens and Wayne Howie

AFFILIATION: Spokane Research Laboratory
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Occupational Safety and Health
1-800-35-NIOSH

PURPOSE: Develop effective monitoring and control systems to reduce mining equipment accidents and their associated death and injuries resulting from poor operating practices. The recently patented load-rate monitoring device will be adapted for this purpose. The approach focuses on accident prevention over that of accident survivability.

KEYWORDS: Coal mining, load monitoring, mobile roof supports

RESEARCH SUMMARY: A device for monitoring and displaying loading rate on the legs of mobile roof supports (MRSs) in real time has been developed and patented by NIOSH's Spokane Research Laboratory. The purpose of this device is to alert miners to dangerous ground conditions during pillar extraction operations in coal mines. In this project, the device will be adapted to monitor critical operating parameters of mobile mining equipment. Both dynamic measurements and instantaneous rates of change of critical parameters will be used to provide an early warning to operators so they can take corrective actions to prevent selected accidents involving equipment. Later phases of the research will include identification of control devices that could be activated automatically if the operator did not take corrective action immediately or if such action were insufficient.

The research will be performed in four phases. The first will involve completing field tests and evaluating the load-rate monitoring device on an MRS in a retreat mining section. The second phase will be to select mobile equipment types to be studied according to criteria based on the probability of protecting the greatest number of workers within resource limitations. 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 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. Research will be conducted to define a delay period between the time an alarm is triggered and the actual critical point that will allow sufficient time for the operator to react and take corrective action.

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PATENT

Method and Apparatus for Load Rate Monitoring, patent application

Miner operating a continuous mining machine using a remote control.

INVESTIGATE PROXIMITY DETECTION AND COLLISION AVOIDANCE

RESEARCHER: Gary L. Mowrey

AFFILIATION: Pittsburgh Research Laboratory
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1-800-35-NIOSH

PURPOSE: Develop an electromagnetic-based proximity warning system for miners operating remote-controlled continuous mining machines.

RESEARCH SUMMARY: A major safety problem in underground coal mining is that of personnel becoming permanently disabled or being killed by machinery (average 40 per year) and powered haulage (44 per year). From 1992 to 1997, 24 fatalities were associated with continuous mining machines. Mining machine operators and helpers, preoccupied with operating their equipment to mine coal, may unintentionally put themselves into potentially hazardous locations. Based on such statistics, the Mine Safety and Health Administration (MSHA) requested that the Pittsburgh Research Laboratory develop a proximity warning system (called "HASARD" - Hazardous Area Signaling and Ranging Device). This system warns miners if they are unknowingly putting themselves into a possible pinning or crushing scenario, thereby helping to reduce the occurrence of such incidents.

KEYWORDS: Proximity warning, mining, collision avoidance, injury prevention, hazard

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The HASARD system consists of two main components: a transmitter that is mounted on a continuous miner (CM) and a receiver worn on the belt of each worker. The transmitter injects a 60-kHz sinusoidal wave into one or more wire loops fastened around the perimeter of the CM. Each worker's receiver has a set of six orthogonally mounted ferrite core antennas that measure the resultant magnetic field and compare this measurement against two present levels, calibrated to identify levels of risk to the workers near the CM.

To determine the practicality of this device in an active mining environment, a series of technical and human factors field experiments using the HASARD system are being conducted at an underground coal mine. Such in-mine testing will provide valuable information for optimizing this system in the mine environment. This system is expected to significantly reduce injuries and fatalities related to pinning and crushing incidents. It could also be modified for protecting workers in other industries, such as agriculture, construction, and forestry.

Roof bolter

KEYWORDS: Underground mining, ground stability, monitoring instruments

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ADVANCED WARNING OF GROUND STABILITY HAZARDS

RESEARCHERS: Steve Signer and Lewis Martin

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1-800-35-NIOSH

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.

RESEARCH SUMMARY: MSHA statistics indicate that there is a dire need to warn underground miners of unexpected ground stability hazards. Although previous research studies conducted through NIOSH and the former U.S. Bureau of Mines have demonstrated that geotechnical instruments can be effectively used to identify and monitor ground control hazards in underground mines, 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. Innovative methods will be investigated for supplying power for electronic measurements through a remote cableless input signal. A prototype miniaturized data acquisition system will be developed that can measure strain gauges remotely without long lead wires.

Gauge design will be reviewed to develop a more practical instrument for monitoring rock strains. This sensor will measure plane strain and detect shear movement along the length of the sensor. Hazardous levels of horizontal, vertical, and shear strain that lead to rock failure will be detected so that a warning signal can be given and corrective action taken.

Data from more than 100 instrumented roof bolts and cable bolts installed at more than 10 mine test sites will be analyzed. Effects of geology, geometry, and in situ stress fields will be studied, and conditions that cause rock support failures will be identified. Standards for hazardous strain levels that indicate excessive loading of rock supports will be established.

Ford F800 single axle dump truck undergoing tests at Lake Lynn Laboratory.

OVERHEAD POWER LINE CONTACT ALARM FOR MOBILE EQUIPMENT

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1-800-35-NIOSH

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

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PURPOSE: Reduce the incidence of electrical injuries that occur when mobile equipment accidentally comes into contact with overhead power lines by devising a means to warn vehicle operators and nearby support personnel of line contact.

RESEARCH SUMMARY: Overhead electric power lines are a serious electrocution hazard to crane, truck, and drill rig operators in the mining industry. From 1980 to 1997, at least 106 mobile equipment overhead line contact incidents were reported in the U.S. mining industry, causing 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 would reduce the number of injuries and fatalities from equipment-line contacts. A practical contact alarm would also have a significant impact in other industries where overhead power lines are a hazard, such as construction, agriculture, communications, and public utilities.

The question to be addressed is whether electrical currents flowing through a vehicle in contact with a high-voltage source can be practically detected and trigger an alarm. The alarm would then warn the operator and bystanders 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 may be detected by either current or voltage-sensing methods; both will be explored. Operator safety during an overhead power line contact accident requires all surfaces in the operator compartment and in the path used to exit the vehicle to be at the same electrical potential. Voltage differences between surfaces in the operator cab and along the egress path will be measured to determine whether lethal voltage differences exist. Depending on the preferred method of detection and the results of the other test phases, a prototype device will be constructed and subjected to laboratory tests to verify its performance.

Accelerometers

INVESTIGATION OF ELECTROMAGNETIC PRECURSORS TO ROCK BURSTING

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

Coal fire detection experiment in the Safety Research Coal Mine.

SMART FIRE SENSORS

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PURPOSE: Examine new and improved mine fire detection technologies and develop strategies for ensuring the safety of underground mine workers.

RESEARCH SUMMARY: The early and reliable detection of underground mine fires is important for the safety of miners in their workplace. Existing products of combustion (POC) mine fire sensors, as well as reliable POC sensors currently not used in underground mines, 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 stations 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 within 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. The in-mine research examines smoldering and flaming coal, electrical cable, and conveyor belt fires, and flaming diesel fuel fires. Chemical cell and metal oxide semiconductor gas sensors, and ionization and optical smoke sensors provide the matrix of sensors for sampling the POC downwind from the fire. This research is being supported by modeling applications of a computational fluid dynamics computer program and a mine fire ventilation computer program. Predictive modeling can provide guidelines to the fire signature and its rate of change at a smart fire sensor location. A partnership with a coal mine is being established for an in-mine evaluation of new fire sensor technology. This research will be conducted in cooperation with the Mine Safety and Health Administration, sensor manufacturers, and mine operators.

KEYWORDS: Fires, mining, detection, sensor systems

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Solar panel generates energy for monitoring seismic activity in the mountains.

GROUND STABILITY ASSESSMENT WITH SEISMIC MONITORING

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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, and massive pillar failures 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 have the potential to affect an entire underground workforce. An inability to address these problems effectively can result in resource abandonment and/or mine closure and 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. Field efforts are underway with industry partners in hard-rock, coal, and trona mines.

Development of a user-friendly, PC-based, automated seismicity monitoring 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. At the Galena Mine, a specific goal is to detect and locate sites of sudden mining-induced failure (rock bursts) in the widely distributed working areas and to provide this information in real time to supervisory and safety personnel stationed underground and on the surface. As development of this technology continues, it will be applied in other mines to address different types of ground control problems.

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

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Void created in surge pile.

DETECTION OF BRIDGING IN SURGE PILES

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PURPOSE: Investigate technologies to detect voids in coal surge piles.

RESEARCH SUMMARY: Bulldozers are used to move coal toward drawpoints in surge piles at coal mines, which can be extremely hazardous if a void forms within the pile because of bridging. Because voids are not visible from the surface, a bulldozer or other piece of machinery could be driven over or near a void, causing a collapse that could engulf the machine and injure or kill the operator. Seventeen 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 machinery was driven over it.

This project is focused on developing methods to detect voids in surge piles. One possible method is to combine real-time volume profiling near feeders and measurements of the amount of volume drawn. Deviations between the amount of load measured in a chute and the amount of load expected would confirm that a void is forming.

Studies will also be conducted using particle flow code to model void formation in surge piles. Coal samples will be collected to determine the physical properties to be used in the models. Initial work has included visits to surge pile sites, investigations of the use of global positioning systems to track dozers and locate drawpoints, studies of surge pile design, and evaluations of current mitigation measures used by the Mine Safety and Health Administration and mining companies.

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

Demonstration of improved scaling bar.

INJURY PREVENTION AND EQUIPMENT DESIGN

SAFETY ENHANCEMENTS FOR ROCK SCALING PERSONNEL

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1-800-35-NIOSH

PURPOSE: Study present methods of scaling and their associated safety risks and develop interventions that will reduce the number of injuries caused by scaling-related accidents.

RESEARCH SUMMARY: Scaling, which is the removal of loose rock from the walls and roof in an underground mine, may be necessary during any stage of mining. Manual scaling is very labor-intensive, and mechanical methods may actually produce less stable roof because the techniques used are too intensive. MSHA data for the past 10 years indicate that 30% of the fatalities in underground metal/nonmetal mines were related to failures of ground. In addition, researchers noted that many otherwise classified accidents could be linked to scaling processes, such as prying or barring down, or to loose material falling. These injuries were often classified as "hit by rock" or "strain/back injuries." Thus, the process of scaling was identified as a major source of injury to miners and was targeted for investigation.

The approach taken will be to assess current scaling methods and their associated safety risks. This work will include first-hand observations, discussions with mine workers and supervisors, and investigation of mine accident data to identify specific problem areas. Then alternative scaling methods, training materials, and equipment will be developed that allow miners to free loose rock from a safe distance and reduce the use of brute force, which is the source of many sprains, strains, and back injuries.

KEYWORDS: Materials-handling accidents, mining equipment, rock falls, scaling

VIDEO: *Rock Falls: Preventing Rock Fall Injuries in Modern Mines*

Removing conveyor belt in an underground mine.

MATERIALS HANDLING ACCIDENT REDUCTION IN UNDERGROUND MINES

RESEARCHERS: Bill Stewart and Ted Williams

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1-800-35-NIOSH

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

RESEARCH SUMMARY: Repetitive trauma and materials-handling accidents continue to be a problem in underground mines because of limited space, poor footing, inadequate materials-handling equipment, and the weight and bulk of the materials themselves. For example, a search of the MSHA database for the period between 1987 and 1996 identified 78 accidents out of 392 (20%) in underground metal/nonmetal mines as being due to breaking or cleaning rock manually from the top of a grizzly. Another major cause of accidents involved removing the belt conveyor frame and rollers during longwall operations in western underground coal mines. The rock and coal dust under and around the belt is often wet, creating a very poor surface for maintaining one's footing while removing heavy conveyor parts. Identifying state-of-the-art procedures for removing the structure and developing improved engineering designs for the workplace may reduce the repetitive trauma and accidents associated with this common job.

KEYWORDS: Repetitive trauma, materials handling, manual rock breaking

The approach taken in this project is to identify best practices in underground mines having low injury rates and then to transfer this information to the rest of the industry. Engineering solutions to some common problems may also be developed. MSHA accident statistics will be reviewed to identify underground mines with both very good and bad materials handling records. A series of mine visits will be conducted to acquire an understanding of the general materials-handling approaches used in the various underground industries. The information gathered during the initial visits will then be used to focus the project for the remaining 3 years. Possible focus areas might be creating a best practice report after examining procedures at a large number of mines or developing engineering design solutions to one or two problem areas found to be common throughout the industry, such as removing heavy conveyor parts and manually breaking oversize rock on grizzlies.

In underground metal, nonmetal, and stone mines, it may be more difficult to identify a single focus area because materials-handling equipment and procedures vary greatly from mine to mine. However, nonmanual or reduced-manual materials-handling methods will be the primary research consideration at all mines. For some mines, a best practices handbook may have the greatest impact for reducing injuries.

Dropping load into haulage truck creates impact shock for the truck operator.

ENGINEERING CONTROLS FOR REDUCING JARRING AND JOLTING INJURIES IN SURFACE MINES

RESEARCHERS: Fred Biggs and Rusty Miller

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

RESEARCH SUMMARY: During the last several years, the number of surface mines in the West has increased. This increase has resulted in larger haulage trucks, increased production demands, and more people in the work force, which in turn has led to more worker fatalities and injuries. Between 1986 and 1995, truck drivers accounted for 35 approximately 63% (76 of 120) of the fatalities in surface mining truck haulage and 60% (3,551 of 5,569) of the lost-time injuries. Very little research has been done related specifically to shock trauma injuries, that is, jolting and jarring injuries caused by surface mine haulage trucks, nor to the development of engineering controls to reduce such injuries.

Tasks in this project include —

- Developing software for tying global positioning systems and jolting and jarring incidences together.

- Conducting bench-scale tests to characterize and isolate jolting and jarring elements that could lessen shock loads on an operator.

- Defining current engineering controls used to minimize exposure to health hazards and note their limitations.

- Testing various engineering control alternatives under laboratory conditions. Alternatives showing the greatest promise will be developed to the point where they can be tested in the field. Current developments will be evaluated to select technologies applicable to the surface mining environment.

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

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

Field interview with underground miners.

ERGONOMICS INTERVENTIONS IN MINING

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1-800-35-NIOSH

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

KEYWORDS: Mining, ergonomics, musculoskeletal disorders, slips and falls

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Zhuang Z, Groce D [1995]. The national occupational survey of mining: magnitude of potential exposures to musculoskeletal overload conditions. In: Bittner AC, Champney PC, eds. Advances in Industrial Ergonomics and Safety VII. London: Taylor and Francis, pp. 273-280.

RESEARCH SUMMARY: In early 1998, the Mine Safety and Health Administration (MSHA) submitted a formal request to NIOSH to investigate musculoskeletal disorders (MSDs) in the mining industry. MSHA representatives wanted a better understanding of the extent of MSD risk factors and evidence that ergonomics interventions are effective. An analysis of results from the National Occupational Health Survey of Mining (NOHSM) indicated that both coal miners and metal/nonmetal miners are exposed to a higher number of ergonomic risk factors than workers in nonmining occupations. Miners experience more disability from knee and back pain, more absenteeism, more osteoarthritis, and more disk degeneration than comparison industrial populations.

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

Four mine sites are participating in risk factor assessments. They consist of an underground coal operation, a surface copper operation, a surface phosphate operation, and an underground limestone operation. Assessment results are being used to identify activities that provide significant risk for injury and to develop general risk reduction strategies. The primary benefit to a cooperating mine operator is 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.

A separate, but related investigation under this project involves the high incidence of slips, trips, and falls in mining. From 1990 to 1997, 26,703 slips, trips, and falls were reported, making this one of the largest categories of lost-time injuries. The research involves a comprehensive literature review, analysis of surveillance data, and field investigations to assess injury risk. Intervention strategies are being developed and evaluated in the field.

A lighter jackleg drill could reduce injuries among drill operators.

INJURY PREVENTION FOR METAL/ NONMETAL DRILLING AND BOLTING OPERATIONS

RESEARCHERS: Robert McKibbin and Curtis Clark

AFFILIATION: Spokane Research Laboratory
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1-800-35-NIOSH

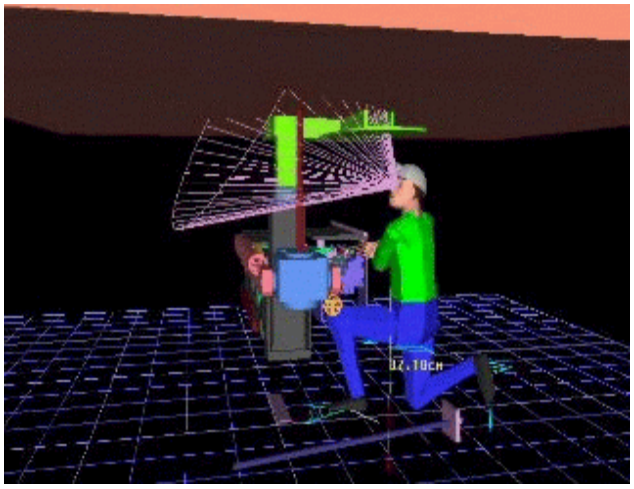
PURPOSE: Identify the causes of injuries associated with drilling and bolting operations in metal/nonmetal mines and develop the technology to reduce or eliminate the risk of injury.

RESEARCH SUMMARY: MSHA-based statistics show that during the 5-year period of 1992-96, there were 10 fatalities and more than 1,000 injuries in drilling and bolting operations in metal/nonmetal mines, accounting for 5% and 4% of all fatalities (233) and injuries (25,693), respectively, in those years. During the first year of this project, investigators highlighted a number of areas in which reductions in accidents might be realized. These included crushing injuries on carriage and jumbo drills, getting caught in rotating drill components, excessive weight of jacklegs, slips and falls while getting on/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 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 a lightweight jackleg. The goal is to reduce the weight to 77 pounds without a reduction in the specific energy of drilling. A drill was constructed in which several components were made of aluminum and titanium, resulting in a drill that is 25% lighter than a standard steel drill. Laboratory testing of the drill was started in late FY99 and will continue in FY2000, followed by in-mine testing.

Background research will be ongoing and will be augmented by discussions with various segments of the mining community, including miners, mine managers, engineers, safety officers, equipment manufacturers, and union representatives. Additional work in the future could include further weight reduction of the jackleg, a reduced-vibration jackleg handle, design modifications to prevent being caught in rotating components, a modular add-on to an existing piece of machinery, design recommendations to equipment manufacturers, or procedural changes based on results of human factor evaluations.

KEYWORDS: Mining, low back disorders, materials handling, jackleg, drilling safety



Computer simulation assists in the investigation of safe boom speeds for roof bolter operators.

HUMAN FACTORS DESIGN FOR MACHINE AND HAULAGE SAFETY

RESEARCHER: August J. Kwitowski

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

RESEARCH SUMMARY: Mining machinery continues to be linked with numerous fatalities and injuries. From 1993 to 1996, analysis of underground coal mining machinery injury data shows that the fatality rate was 0.0374 (rates are incidences per 200,000 hours); the nonfatal injury rate was 6.833. During 1997, 32% of all injuries to underground coal miners working in the extraction area of the mine were attributed to roof bolting activities. Nineteen percent of these injuries were from equipment design problems. In addition, the broad injury categories of mining machinery and powered haulage are prevalent across all commodities in surface and underground mining.

The overall approach is to identify specific mining 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. Two specific machine problems are currently being investigated: safe roof bolter boom speed, and the jarring and jolting of mobile equipment operators. The roof bolter research involves the use of computer modeling/simulation in addition to laboratory and field experimentation to study the problem and develop recommendations for safe boom speeds. A major roof bolting manufacturer is collaborating on this research. The operator vibration/seating research involves computer modeling, the Pittsburgh Research Laboratory's vibration testing facility, and laboratory and field research. Both improved seating and alternative suspension systems are being evaluated for isolating the operator from excessive jolting. A major shuttle car manufacturer and a mining seat manufacturer are cooperating on the jarring and jolting research. This project is producing design guidelines and better hardware for mining equipment hazards through cooperation with equipment manufacturers and mining companies to improve equipment safety.

KEYWORDS: Mining equipment, ergonomics, intervention, vibration, machine design, safety

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Underground coal mine workers may be electrically shocked when handling portable power cables with defective insulation.

FUNDAMENTAL STUDIES IN ELECTRICAL HAZARDS

RESEARCHER: Michael R. Yenchek

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National Institute for
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1-800-35-NIOSH

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 the 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 areas such as lightning protection, an area in which there is concern because of lightning-initiated gas explosions in gob areas of the mine.

This research is identifying, analyzing, and classifying the causes of electrocutions across industries according to established categories, e.g., voltage class, source, exposure, etc. This information is being used to determine the type of interventions that could prevent future occurrences, such as training, personal protective equipment, and design. Available intervention technologies are being reviewed to identify any gap areas. Finally, recommendations for specific actions to reduce fatalities are being formulated.

In addition, specific technologies to mitigate electrical hazards are being examined. For example, analyses of hazards on high-voltage longwall power systems, lightning-initiated gas ignition hazards, and temporary wiring hazards at construction sites are being conducted to quantify the hazard and assess the appropriateness of certain control strategies.

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

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Improved sensors to monitor hoist conditions could lead to safer operating conditions.

MINE HOIST AND ELEVATOR SAFETY

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1-800-35-NIOSH

KEYWORDS: Mine hoisting, wire rope tension, conveyance monitoring, wireless data transmission

PURPOSE: Improve the safety of hoist and elevator operations by using sensor and computer technology to increase the amount of information and efficiency of flow to hoist operators and inspectors.

RESEARCH SUMMARY: This project was initiated at the request of MSHA because of increasing concern about hoist and elevator safety. According to accident statistics, mine hoist maintenance workers and hoist operators are exposed to many hazards in hoisting environments. MSHA, mine hoist operators, and maintenance personnel have expressed an interest in better technology to monitor these hoist conditions.

A state-of-the-art hoisting and ore pass research facility has been constructed. This facility allows assessment of mine hoisting and elevator safety and control systems, including hoisting machinery (hoist room controls, motors and gear boxes, and winders) and shaft infrastructure (support frameworks, guides, wire ropes, and skips and cages). Sensors and real-time data acquisition interfaces to monitor hoisting operations have been developed. These systems allow personnel to assess critical hoist operating parameters, such as hoist position, speed, and acceleration; conveyance loads; rope tension; and shaft guide alignments. A load cell has been developed to measure rope tension and has been patented. Field work to evaluate the performance of these systems is underway in cooperation with mine hoist equipment suppliers and mining companies.

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PATENT

No. 5,728,953. Flex-Beam Load Cell.

Loosening blockages in ore passes can be extremely hazardous.

DESIGN OF MINE ORE PASSES

RESEARCHERS: **Michael J. Beus and Bill Stewart**

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National Institute for
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1-800-35-NIOSH

PURPOSE: Improve ore pass design criteria to prevent hangups and structural failures and investigate safe procedures for removing hangups. Develop enabling technology for detecting and remediating blockages in ore passes in hard-rock mines.

RESEARCH SUMMARY: Research on ore pass designs will include measurements of static and dynamic loads, predictions of loads using particle flow models, studies of the influence of ore pass inclination on loading, tests of innovative methods to determine fill levels and hangup locations, and development of safer hangup removal methods.

Because of the relationship between hangups and the physical properties of ore and rock, physical models will be tested at SRL's shaft and ore pass test facility. Special emphasis will be placed on investigating the role of moisture content, the fine grain-size fraction, and stop-and-go ore movement on cohesion-type hangups. Hangup removal methods will also be tested, and the effects of ore hangups on the structural integrity of the test facility will be examined. Various designs of ore pass structures will be simulated in computer models. Such information will aid mine engineers in designing safer ore passes and increase miner awareness of proper hangup removal procedures.

KEYWORDS: Ore pass, field measurements, computer analysis, materials handling, ground control

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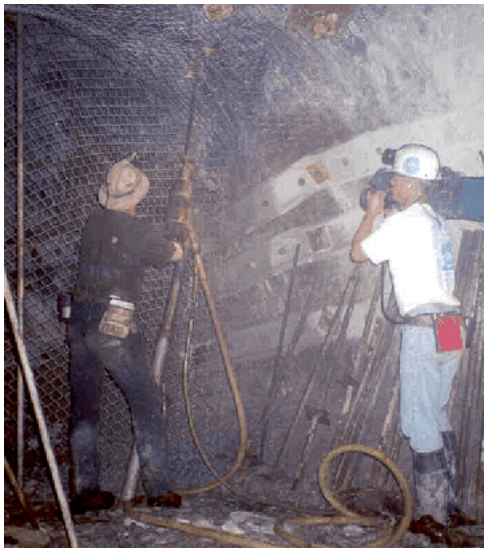

Filming a video to show safe mining practices.

TRAINING AND EDUCATION

INTERACTIVE TRAINING AND EDUCATIONAL DEVELOPMENT

RESEARCHERS: Elaine Cullen, Marc Filigenzi, and Timothy Orr

AFFILIATION: Spokane Research Laboratory
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1-800-35-NIOSH

KEYWORDS: Mining, safety training, computer visualization

VIDEO

Handling Explosives in Underground Mines

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

RESEARCH SUMMARY: A NIOSH study on occupational deaths between 1980 and 1989 indicate that, in the mining industry, the average annual fatality rate is 31.9 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 will serve as an advisory board to assist in determining topics and issues, assist in assuring that story boards and scripts are technically correct and relevant to trainees, and assure that mine sites are available to show the topics under consideration effectively. This advisory board will also be used to evaluate resulting products by assessing reaction to the videos during training sessions and by soliciting feedback from trainees on what was learned.

Pilot test of new computer-based training module on proper use of machine guards.

EVALUATION OF INTERACTIVE MINE SAFETY AND HEALTH TRAINING METHODS

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1-800-35-NIOSH

KEYWORDS: Mining, intervention, training, effectiveness

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 increased efficiencies available through these technologies offer better results from the scarce resources available.

Prototype interactive training systems are being 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 successful field evaluation of an interactive construction, maintenance, and repair exercise was recently completed through mining industry cooperation. The project team is also conducting a cooperative project with a mine in Colorado to evaluate the special needs of an anticipated influx of younger, inexperienced workers and to develop cost-effective training tailored to specific worksites. Building upon the latent-image hazard recognition effort, content has been selected for prototype computerized applications, and an initial working version has been completed.

Another project goal is improving 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 13,000 training items since January 1999.

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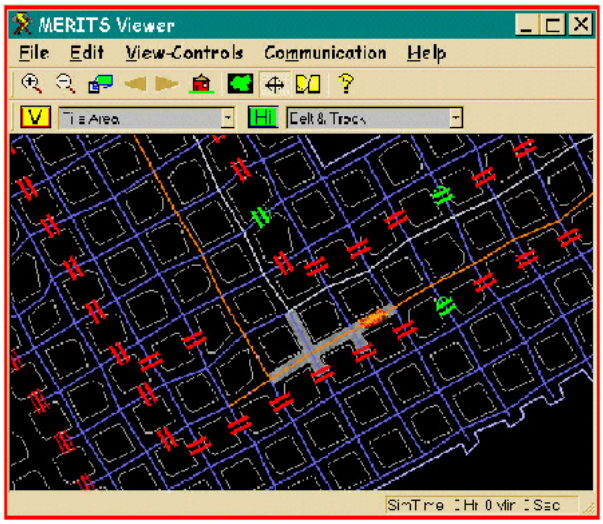

Screen shot of fire and smoke in simulated underground coal mine.

EDUCATION FOR EFFECTIVE MINE EMERGENCY RESPONSE

RESEARCHER: Launa G. Mallett

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1-800-35-NIOSH

PURPOSE: Reduce the risks associated with infrequent, but potentially catastrophic, mine emergencies by developing training materials for first responders and command center personnel.

RESEARCH SUMMARY: As mines become safer and disasters fewer, the number of individuals that have hands-on experience with mine emergencies is decreasing. A gap in expertise is being created that could have serious consequences at future major emergency events. Because potentially catastrophic hazards are not faced routinely, emergency prevention and response is sometimes given a low priority in training plans. Training for command center leaders is not mandated, and most managers have little or no experience with mine emergencies. Although some training is available to the mining industry, it can be expensive to conduct and/or not easily accessible to all mining operations.

The goal of this project is to reduce the risks associated with infrequent, but potentially catastrophic incidents by improving prevention and emergency response training (and access to that training) for miners, incident responders, and command center personnel. Methodologies and training packages are being developed to teach prevention and first-response strategies. These materials and strategies will meet the need for training in limited timeframes. Software is being developed to teach command center leaders to coordinate and manage response efforts via computer simulation. This customizable software will allow emergency response experts (including State and Federal agencies) to develop new and varied training scenarios. Delivered via the Internet, this training will be accessible to all U.S. mining operations. The products of this project will be applicable, with some modification, to all mining worksites. Some of the results will also be useful for emergency training in other types of work settings.

Project activities are being conducted in cooperation with staff at two underground coal mines (one in Colorado and one in Pennsylvania), the Mine Safety and Health Administration, and the State mining agency in Pennsylvania.

KEYWORDS: Training, simulation, emergency response, command center, fire prevention

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Use of virtual reality is being studied to improve mine safety training.

ACCIDENT RECONSTRUCTION AND TRAINING FOR METAL/NONMETAL MINES

RESEARCHERS: **Marc Filigenzi, Timothy Orr, and Todd Ruff**

AFFILIATION: **Spokane Research Laboratory**
National Institute for Occupational Safety and Health
1-800-35-NIOSH

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

RESEARCH SUMMARY: Current information dissemination and training methods are lacking in that they depend on training videos and/or printed materials that are not specific to each mine and that are often outdated. Mine evacuation drills are expensive and time-consuming and cannot be practiced at regular intervals. New ways are needed to train personnel about hazards in mining workplaces and about evacuation procedures. By improving safety training, researchers hope to increase worker safety and reduce work-related accidents. Two tasks are being addressed.

KEYWORDS: Mining, hazard recognition, rescue and evacuation training

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Accident Reconstruction. In mining, injuries or death may result from equipment failure or worker 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 to absorb. As a result, mining personnel may not learn exactly which hazardous situation to be on guard against. The purpose of this task is to develop computer modeling and visualization techniques that will allow accident investigators to re-create an accident on a computer accurately. This re-creation can then be used as an educational tool. Employees will view a computer-generated animation showing the cause and results of the accident. They will then be shown the proper way to avoid such accidents in the future.

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 in deep multilevel mines will be investigated. Existing software technology will be applied to create realistic three-dimensional representations of a mine environment. Mine trainees will then be immersed in this "virtual mine" in which emergencies are simulated. The trainees will then practice escape and rescue procedures. This same virtual mine will be used to train employees in hazard recognition and avoidance.

Fighting a conveyor belt fire at Lake Lynn Laboratory.

MINE RESCUE AND RESPONSE

RESEARCHER: Ronald S. Conti

AFFILIATION: Pittsburgh Research Laboratory
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1-800-35-NIOSH

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

RESEARCH SUMMARY: Unfortunately, fires remain a common occurrence during mining operations. During 1990-99, the Mine Safety and Health Administration (MSHA) reported more than 130 fires at underground coal mines (fires lasting more than 30 minutes after discovery or causing injury). These fires resulted in 1 fatality and 43 injuries. A significantly higher number of unreported fires are believed to have 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 may 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 survey conducted by MSHA indicated that there are 281 State and company mine rescue teams in the United States (124 coal mine teams and 157 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 has decreased. 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.

During the last year, partnerships were established with one coal company, the Pennsylvania Bureau of Deep Mine Safety, and the West Virginia Office of Miners' Health, Safety, and Training to evaluate their mine rescue teams. Data have been collected from five mines in Colorado, Illinois, Montana, Pennsylvania, and Utah to determine their fire preparedness and response capabilities. Interviews with mine rescue teams and fire brigade members during training simulations at Lake Lynn Laboratory and at operating mine sites 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. An underground mine fire preparedness and response checklist, which is currently being developed for coal and metal/nonmetal mines, is intended to enhance the safety of mine workers by improving the state of fire preparedness at underground mines.

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

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Operator's station inside 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 hearing loss among miners nationwide.

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, which can be a serious physical, psychological, and social problem. The overall goal of this project is to educate miners regarding hearing conservation measures and train them to recognize ways that they may assist in hearing loss prevention. Initial emphasis has been placed on techniques that can be quickly implemented while reaching as many miners as possible. A pilot study involving mine inspectors from the Mine Safety and Health Administration (MSHA) and students was conducted at MSHA's National Mine Health and Safety Academy, Beaver, WV, from March to June 1999. Different combinations of intervention techniques and strategies were examined for their usefulness, efficiency, and practicality.

Successful intervention methods will be further tested and disseminated more widely, perhaps instituting a "train the trainer" approach that will perpetuate itself throughout all mining sectors. With this approach, one or more persons from each mine site could be trained to become the on-site "expert" or source of information for fellow miners. In this manner, the need for proactive hearing conservation measures will be continuously reinforced.

The education and training of selected mining populations relies on site visits by a fully functional mobile audiometric test unit. An important element of the project is to conduct hearing tests on noise-exposed miners, which personalizes the problem and forms the basis for the educational aspects of the intervention. Similarly, individual fit-testing of personal hearing protection (e.g., earplugs or earmuffs) is done on each miner. Each participant is shown a hearing loss demonstration via a multimedia computer program. The best use of these different elements will be refined and updated as the project progresses. To this end, questionnaires, individual interviews, and posttraining surveys are used to collect data on miners' attitudes, behaviors, and knowledge toward hearing conservation.

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

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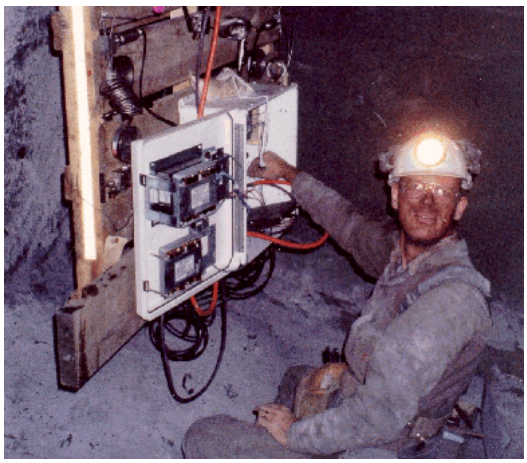

Collecting data on mine stability for entering into computer model.

GROUND CONTROL

SAFETY DESIGN FOR UNDERGROUND MINE STABILITY

RESEARCHERS: **Mark Larson, Jeff Johnson, and Eric Zahl**

AFFILIATION: **Spokane Research Laboratory**
National Institute for Occupational Safety and Health
1-800-35-NIOSH

KEYWORDS: Underground mining, ground stability, modeling

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: Over the last 10 years, 30% of the mine fatalities in underground metal/nonmetal mines and 44% of the fatalities in underground coal mines were caused by failures of ground. Thus, 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 engineering tools for the design and analysis of stability in underground mines through the use of personal computers.

Cooperative arrangements to investigate the stability of underground mines and develop new instruments and techniques to measure and monitor stability have been developed with several industry partners. The Stillwater Mining Co., Montana Tech, and the Spokane Research Laboratory have entered into an agreement to investigate how a stability analysis can best be integrated into the design of an expansion at the Stillwater Mine and address a number of safety concerns. At the Homestake Mine, the Ross shaft pillar is being analyzed for stability. Cooperative work with RAG (formerly Cyprus Plateau Mining Co.) is directed to methods of installing and monitoring instruments and analyzing the resulting data to determine the potential for ground falls, coal bumps, and other types of rock mass failures.

The results of this research will help predict the potential for ground falls and coal bumps and allow miners to select appropriate secondary support systems or restrict access to a particularly hazardous area, thereby reducing accidents, injuries, and fatalities.

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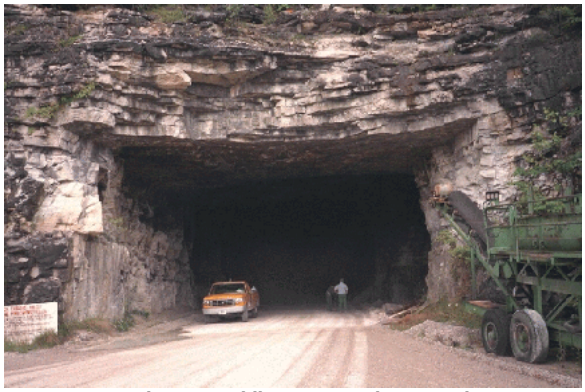

Underground limestone mine portal.

REDUCING GROUND FALLS IN UNDERGROUND STONE AND NONMETAL MINES

RESEARCHERS: L. J. Prosser, Jr., and Roy H. Grau III

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1-800-35-NIOSH

KEYWORDS: Mine worker, underground stone, falls of ground, safety, monitors, horizontal stress, mine planning

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: Injury statistics from the Mine Safety and Health Administration (MSHA) show that about 80% of the lost days and 20% of the accidents in the underground stone sector were attributed to falls of ground. In the nonmetal underground mining sector, falls of ground also represent a significant portion of injuries. More than 10% of the accidents and 25% of the total lost days were attributed to falls of ground in the nonmetal underground mining sector. The underground stone/nonmetal sector employs approximately 6,000 miners. Although the need to initiate research to reduce ground falls in underground stone and nonmetal mines is surveillance-based, this effort is also strongly supported by stakeholders, including MSHA, State and national mining organizations, (e.g., Kentucky Crushed Stone Association, Ohio Aggregates and Industrial Minerals Association, and National Stone Association).

It must also be noted that stone and other industrial minerals (i.e., nonmetals) are the basic raw materials used in construction that drives economic development nationwide. These sectors are expected to continue to expand in line with the thriving U.S. economy. Constraints to surface mining and the availability of resources are increasing the development of underground stone mines. Thus, the likelihood and severity of incidents involving mine workers in this sector may also increase without preventive measures. As such, expanded research efforts in this area will help to improve safety conditions of mine workers employed in these sectors today and in the future.

The intervention strategy used in this project is rooted in the fostering of communication among the principals. The focal point is an annual safety seminar, the only national meeting directed entirely toward this segment of mining. This seminar provides a forum for the exchange and discussion of issues related to the safety and health of the mine worker. In addition, roof behavior awareness has been enhanced through the development of the Roof Monitoring Safety System (RMSS) that is, in varying degrees, used at mines in Pennsylvania, Kentucky, Indiana, and Illinois. Lastly, a safe mine layout for minimizing roof rock damage from elevated horizontal stress levels is being evaluated at a cooperating underground stone mine.

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Area extensively damaged by rock burst in hard-rock mine.

IDENTIFICATION AND CONTROL OF ROCK BURST HAZARDS

RESEARCHERS: **Jeffrey K. Whyatt, Brian G. White, and Ted Williams**

AFFILIATION: **Spokane Research Laboratory
National Institute for
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1-800-35-NIOSH**

KEYWORDS: Ground control, rock bursts

PURPOSE: Identify geologic features that contribute to the risk of rock bursts and link 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 reoccur on a regular basis, countermeasures have been developed and employed that reduce the level of risk. However, these countermeasures must be appropriate to local geologic conditions and rock burst mechanisms.

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.

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Slope failure

SLOPE STABILITY HAZARD RECOGNITION FOR METAL/NONMETAL MINES

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KEYWORDS: Surface mining, slope stability

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

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 (MSHA) statistics from 1992 to 1998 revealed that 9% of the surface mine fatalities were directly attributable to slope failures. Twenty workers were killed in slope-failure-related accidents in the 5 years between 1994 and 1998. In 1999, at least seven surface mine workers (or 15% of the surface mine fatalities as reported through October) have died in slope-failure-related accidents.

Open-pit mines are deeper than ever before, but the mechanics of rock mass strength and rock mass movement at large scales is poorly understood. Four types of slopes may fail at open-pit mines: highwalls, dumps, stockpiles, and tailings embankments. An understanding of slope failures related to mining activity and the technology available to prevent these types of failures is the focus of this project.

The project addresses three major areas. (1) 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 the proper use and placement of instruments and the limitations of various warning systems. (2) The efficiency and effectiveness of current preventive measures are being evaluated, including physical supports (i.e., bolts, mesh, shotcrete, cable lacing, etc.), controlled blasting methods, rockfall catchment systems, effects of unloading/unweighting, buttresses, and dewatering techniques. (3) 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.

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 applications, including landslide control, design of roadcuts, railroads, canals, refuse disposal sites, and earth dams.

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Site of fatality caused by massive sandstone roof failure in a mine in Mingo County, WV.

REDUCING INJURIES FROM THE FAILURE OF COAL MINE ROOF SUPPORT SYSTEMS

RESEARCHERS: Dennis R. Dolinar, Gregory M. Molinda, and Christopher Mark

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KEYWORDS: Roof bolts, ground control, geology, support system design, intersections, roof falls

PURPOSE: Develop methodologies and/or guidelines for the selection of roof bolt support for coal mines. Better roof support design will lead to fewer unplanned roof falls and reduce the number of associated injuries and fatalities.

RESEARCH SUMMARY: More than 100 million roof bolts are installed each year in underground coal mines to prevent falls of ground. Nevertheless, during a typical year, about 55% of operating mines will experience at least one roof fall. For example, in 1996, more than 2,600 roof falls were reported to the Mine Safety and Health Administration, resulting in 711 injuries and 8 fatalities. Approximately 80% of these roof falls were caused by failure of the primary roof bolt support system. The number of roof falls and fatalities indicates that the current methods for designing support systems, based on trial and error and local experience, are inadequate. There is a clear need for a scientific support selection methodology that can be applied in a broad variety of geologic conditions.

The project's approach is to use multivariate statistical techniques to evaluate roof bolt performance and to determine the most important factors affecting the stability of coal mine roof. A nationwide database has been created through visits to 35 mines in Alabama, Colorado, Kentucky, Illinois, Indiana, Ohio, Pennsylvania, Virginia, West Virginia, and Wyoming. Underground studies were conducted at each mine to characterize the roof geology with the Coal Mine Roof Rating (CMRR), measure roof spans, and verify roof bolt data. Extensive interviews were also conducted with mine staff to gather details on roof fall history and roof bolt performance.

Preliminary statistical analyses indicate that there is a strong correlation between the CMRR, the roof span, and the frequency of roof falls. Based on the final results, new guidelines will be developed for the selection and design of roof bolt systems.

The new methodology will be presented to the mining community at Open Industry Briefings (OIBs) on New Technology for Coal Mine Roof Support. The OIBs will be held during the summer of 2000 in a variety of U.S. coalfields. The OIB will also showcase a variety of roof support technologies that have been developed or evaluated in recent years by the Pittsburgh and Spokane Research Laboratories, including skin control techniques, intersection support, and horizontal stress control techniques.

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Truck depositing backfill in mine.

SAFE MONITORING OF ENGINEERED BACKFILL

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PURPOSE: Develop practical methods and field techniques for assessing the stability of underground backfill, innovative instruments for monitoring mining-induced stresses and displacements in backfill and host rock, and more accurate methods of evaluating and forecasting the stability of cemented fill.

RESEARCH SUMMARY: MSHA statistics show that ground failure accounted for 44% of all fatalities in underground coal mines and 30% of the fatalities in underground metal/nonmetal mines over the past 10 years. Many of the traumatic injuries and fatalities resulting from these ground control problems could be avoided through the use of backfill mining techniques. Backfilling openings with an engineered fill material provides excellent long-term ground support that improves the safety and stability of underground workings. By reducing the number of abandoned openings, backfilling also eliminates workings that pose dangers to mine workers and diminish the efficiency of mine ventilation systems.

Cooperative research will be conducted with several underground mines currently using cemented backfill to address the lack of information regarding the ground support characteristics of placed fill and the unknown safety and health hazards associated with new backfilling applications. Practical field techniques will be investigated for assessing the competency and in situ properties of placed cemented fill.

Innovative rock and backfill instruments will be developed to provide a better means of monitoring the behavior of placed fill and its interaction with the host rock. These instruments will be installed to address safety issues associated with unique backfilling applications and to demonstrate the importance of using instruments and numerical modeling techniques to monitor and evaluate the stability of underground openings.

By providing a more thorough understanding of backfill material properties and mix designs, this research will lead to the development of more competent and cost-effective backfill mixes and better quality control measures for batching and placing fill. These advances will reduce the safety and health hazards associated with backfilling operations, improve the safety and stability of backfill mining methods, and provide a more comprehensive engineering approach to the use of cemented fill.

KEYWORDS: Underground mining, ground control, backfill

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Installing a geophone in a borehole in the mine roof.

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.

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

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 2 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). This system consists of 21 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.

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Fire suppression facility at Lake Lynn Laboratory.

FIRES, EXPLOSIONS, AND VENTILATION

CONTROL AND SUPPRESSION OF MINE FIRES

RESEARCHERS: Alex C. Smith and Charles P. Lazzara

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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 will evaluate 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 mine and fire suppression facility to compare the effectiveness of these systems to those currently used in underground mines. The second task assesses the flammability hazards of selected 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 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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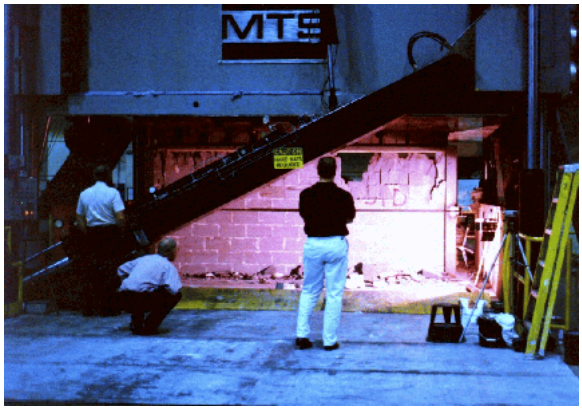

Failure of a mine ventilation stopping in the mine roof simulator.

IMPROVING CFR SAFETY EVALUATIONS FOR MINE VENTILATION SEALS AND STOPPINGS

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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.

RESEARCH SUMMARY: Nearly all underground mines in bedded deposit formations use stoppings and seals (cement block walls) to control ventilation. Failure of these structures can lead to disastrous mine explosions and fires. The current Code of Federal Regulations (CFR) requires underground coal mine stoppings to pass rigorous testing for transverse loading capability. This criterion is for a freestanding wall. In the mine, the ventilation structures are restrained on all four sides by the mine roof, floor, and coal pillar ribs. The transverse loading capability is significantly enhanced in this confined condition.

Most mine ventilation stoppings are currently constructed from concrete blocks weighing between 50 and 60 pounds per block. About 40% of the underground coal miners lift such blocks and could be at high risk for musculoskeletal repetitive trauma disorders. Several emerging materials that provide a 50% weight reduction in the building blocks for mine ventilation stoppings have been developed. However, these lightweight material constructions have failed to meet the transverse loading requirements. A theoretical analysis indicates that they all would have passed the transverse load requirements had they been tested in a realistic restrained configuration.

Tests are being conducted in the unique mine roof simulator load frame at the Pittsburgh Research Laboratory. These tests will more accurately simulate the underground mine environment by confining the stopping at the roof and floor interface and applying transverse loads to determine the structural integrity of the walls. From these tests, more realistic design criteria for ventilation structures are being developed. With these criteria, alternative constructions using various lightweight material technologies will be examined as a means of reducing material handling injuries.

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

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Construction of standard seal.

HYDROSTATIC EVALUATION OF MINE SEALS

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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.

KEYWORDS: Mine seals, explosion-resistant stoppings, water inundation

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 hazards and preventing the loss of lives. MSHA has a compelling need to evaluate geometric scaling criteria for seals, alternative designs for high-convergence conditions, and seals for erection in 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 way to do it.

This research is aimed at developing pneumatic and hydrostatic testing procedures to characterize new mine seal designs for explosion resistance, atmosphere control, and water retention. It will help address problems of concern to the United Mine Workers of America (UMWA), MSHA, the mining industry, and seal manufacturers. Results will provide information applicable to the on-site evaluation of new mine seals and on the development of size scaling relationships and strength safety factors for seals. Various seal manufacturers, MSHA, and the UMWA have shown interest in partnerships for developing size scaling relationships and understanding failure mechanism associated with their seals under various conditions. The pneumatic and hydrostatic approaches would lend themselves for use in evaluation of seals in operating mines.

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A NIOSH researcher prepares to inject sulfur hexafluoride tracer gas into a gob gas venthole to determine gas flow paths in the longwall gob.

CHARACTERIZATION AND MITIGATION OF MINE GAS EMISSIONS

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1-800-35-NIOSH

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 geologic characteristics, mining and ventilation practices, and methane control systems vary considerably due to site-specific conditions and the relative influence of each is unknown. The current focus of this research is the increased methane emissions associated with the emerging technology of mining increasingly larger dimension longwall panels in U.S. coal mines. This project is investigating the factors controlling gas emissions associated with longwall mining, in particular, gas emissions from the gob, to develop and/or optimize control technologies to improve safety in the underground workplace.

Due to the great 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. The field studies are currently being conducted in cooperation with a mine operating in the Pittsburgh Coalbed in southwestern Pennsylvania. These field studies are being conducted in close coordination with organized labor (United Mine Workers of America) and with State and Federal regulatory authorities (Pennsylvania Bureau of Deep Mine Safety and Mine Safety and Health Administration). Future field studies are expected to be conducted in the Western United States to determine the variability of results between mining regions. In addition to the methane control system improvements already developed from the preliminary results of the field studies, the tracer gas data are being used to develop a gob gas flow theoretical model. In addition to facilitating an understanding of the intricacies of longwall gas flow, the theoretical modeling effort is being used to simulate and evaluate potential optimized methane control strategies before they are proposed to the cooperating mine for field testing.

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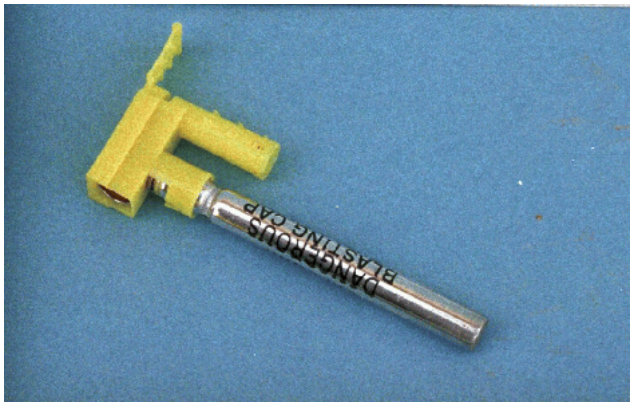

A nonelectric blasting cap.

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

RESEARCHER: Thomas C. Ruhe

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1-800-35-NIOSH

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

RESEARCH SUMMARY: The three 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.

Currently, an investigation is being conducted on a detonator/booster assembly that was involved in a recent fatal incident. Indications are 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 has been involved in two other incidents (one fatal) in recent years. The Pittsburgh Research Laboratory is drop-testing the explosive components in a borehole according to a test plan developed in cooperation with MSHA to identify the most critical impact conditions. The results should lead to the dissemination of appropriate warning information to explosives users or suggest modified explosive handling procedures. Longer term research will be conducted to determine the impact sensitivity of booster/detonator assemblies to more precisely define the nature of these explosive components.

KEYWORDS: Permissible, explosive, blasting

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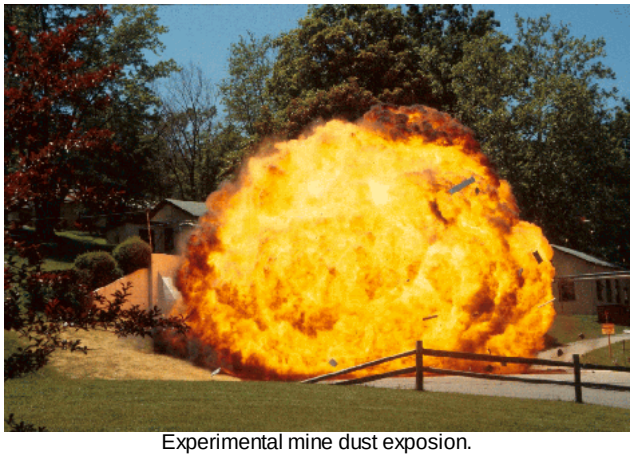

Experimental mine dust exposion.

EXPLOSION HAZARDS REDUCTION

RESEARCHERS: Kenneth L. Cashdollar and Isaac A. Zlochower

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National Institute for
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1-800-35-NIOSH

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

KEYWORDS: Explosions, prevention, mining

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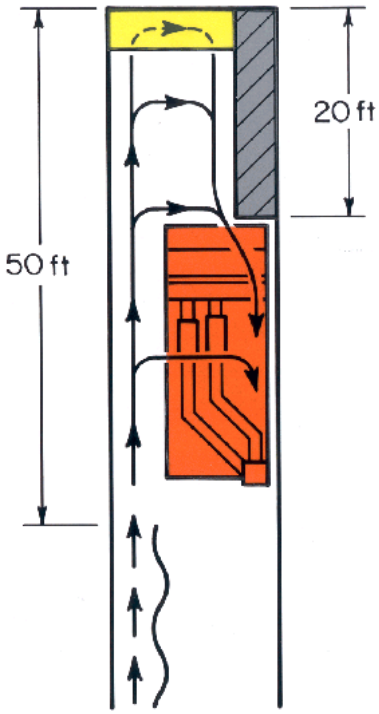
RESEARCH SUMMARY: Explosions in coal mines are due to accumulations of coal dust and/or methane gas. The ignition of such flammable materials can develop into a major disaster with multiple fatalities. Explosions can be prevented or mitigated by minimizing methane concentrations through ventilation, 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 provided to the Mining Safety and Health Administration (MSHA) in the forensic investigation of explosions.

The current experimental research includes large-scale coal dust explosion studies conducted at the Lake Lynn Experimental Mine to study coal dust particle size effects on limestone rock dust inerting requirements. This explosion research is also closely coordinated with the project on the South African Stone Dust Barrier Evaluation at Lake Lynn. As part of these mine tests, gas and dust samples are collected during and after the explosions. These samples are analyzed in an attempt to better understand the combustion mechanisms. The large-scale mine research is conducted in conjunction with laboratory testing in PRL's 20-liter explosibility chamber.

Research on frictional ignitions includes surveillance in commercial mines and experimental studies. Surveillance of lightning-induced gob gas explosions includes the evaluation of a pressure-balancing technique to reduce the volume of flammable methane within the gob at a mine in Alabama. Experimental research is being conducted on the relative incendivity of sandstone, metal, etc., for igniting methane and hydrocarbon oils from mines. Close cooperation with the mining industry, the United Mine Workers of America, and MSHA is expected. Industry briefings and direct technical assistance are used to communicate the findings. Additional research on frictional ignitions is being conducted in the 20-liter chamber by measurements of the hot-spot temperature and surface area necessary to ignite flammable gases, vapors from oil, and dust mixtures with air.



Evaluating face airflow during extended-cut mining.

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

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EXTENDED-CUT AIR DELIVERY SYSTEMS

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1-800-35-NIOSH

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

RESEARCH SUMMARY: More than one-half of all mechanized mining units have variances to use extended-cut mining methods. Usually the effective use of extended-cut mining methods requires that normal curtain or tubing setback distances be increased. This makes efficient face ventilation more difficult. Increasing the setback distance often reduces the amount of intake air reaching the face, which can result in accumulations of methane. Worker safety is at risk if this methane is ignited by hot cutting bits. Extended cutting should be employed only if it can be demonstrated that methane levels can be maintained at safe levels.

This research is evaluating techniques that can be used to maintain face airflow high enough to keep methane concentrations at safe levels while employing extended-cut mining. During an underground mining operation it is difficult to obtain data needed to determine the quantity of air reaching the face. A full-scale ventilation gallery is used to simulate ventilation conditions during extended-cut mining. Methane is released at the face of the gallery, and concentrations of the gas are monitored at multiple locations near the face. With this information airflow quantity and distribution can be estimated. Face airflow quantities are estimated for different machine locations, curtain and tubing setback distances, intake and scrubber airflow quantities, and water spray configurations. Simulation tests are conducted for roof bolting and continuous mining operations.

During underground mining, face methane measurements are the primary means for determining if face ventilation is adequate. With extended-cut mining, it can be difficult to periodically obtain methane measurements at the face. Gallery studies enable methane concentrations to be measured at the face and multiple locations outby the face. Face and outby concentrations are compared to determine if reliable alternative methane sampling strategies can be used to estimate face concentrations.

These gallery studies provide a quick and reliable method for evaluating extended-cut face ventilation systems and methane monitoring strategies in a controlled environment. Constantly changing conditions make this impossible to do in an underground mine. However, the findings from the gallery studies can be employed in mines to provide a higher level of worker safety.

Collecting SCSRs for long-term field evaluation study.

LIFE SUPPORT FOR SURVIVAL AND RESCUE

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1-800-35-NIOSH

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 in Morgantown, WV, and the Mine Safety and Health Administration (MSHA).

The NIOSH Pittsburgh Research Laboratory (PRL) is conducting a long-term evaluation of SCSRs deployed in underground coal mines. PRL locates mine operators that are willing to participate in the study, trades deployed SCSRs for new ones, and then tests the deployed SCSRs. 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 manufacturer'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.

Eighteen mines were visited in MSHA Districts 2, 4, 5, 9, and 11 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, an additional inspection criterion (a noise test) was added for one model of apparatus (approximately 40,000 in the field) by the manufacturer to detect apparatus with degraded chemical canisters. In addition, another apparatus was found to have leaked chemical from the canister to the breathing circuit, undetectable by its inspection criteria. This unit (approximately 7,000 in the field) was recalled and decertified.

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

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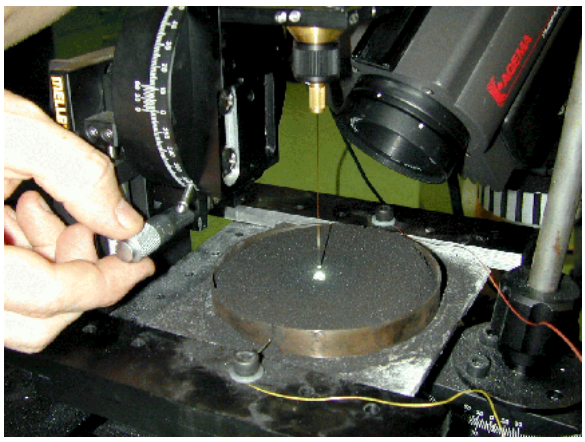

Researchers vary laser powers to determine laser ignition thresholds for a coal dust layer.

LASER SAFETY FOR HAZARDOUS LOCATIONS

RESEARCHER: **Thomas H. Dubaniewicz, Jr.**

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1-800-35-NIOSH

PURPOSE: Develop recommendations for safe power and power density limits for lasers used in underground coal mines, specifically, in atmospheres containing flammable methane-air and/or coal dust.

KEYWORDS: Hazardous locations, laser, methane

RESEARCH SUMMARY: Laser technology is being pursued as a way to measure methane concentrations at the face of underground coal mines in response to safety concerns with conventional measurement techniques. However, above certain power levels, lasers pose a risk of ignition of flammable gas or coal dust.

Previous research demonstrated the explosion hazard of a new commercial fiber-optic powered instrument thought to be safe in explosive atmospheres. Australian researchers reported that relatively modest levels of laser power, when properly focused, may heat dust particles and cause ignition of the surrounding methane air atmosphere. These developments generated international interest in developing safety recommendations for these emerging optical technologies.

Researchers are conducting ignition experiments to determine laser power thresholds for igniting methane-air and/or coal dust. A theoretical model of the ignition process has been derived. Correlation between theory and experimental evidence would provide a solid justification for safety recommendations. Maximum safe beam powers and power densities for lasers will be recommended. Collaborators on the project include the International Society for Measurement and Control, the International Electrotechnical Commission, and the Laser Institute of America. This research is expected to support regulatory and consensus standards formulation.

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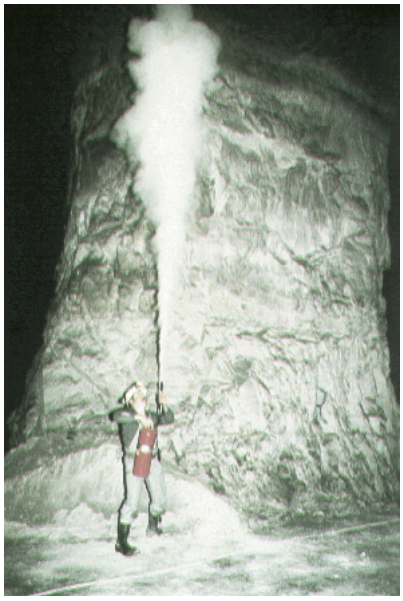

Vertical exhaust trajectory from a fire extinguisher is unaffected by the underground mine ventilation air flow.

VENTILATION OF LARGE-OPENING MINES

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1-800-35-NIOSH

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 producing commercial product from in situ deposits such as limestone, salt, and gypsum. A wide range of airborne substances within the mine air that may adversely affect miners' health and safety include methane, diesel exhaust, radon, and blasting byproducts. Many of these mines have large airways, with the largest featuring cross-sectional areas that are over 60 times larger than typical underground coal mines. Providing adequate quantities of fresh air into the advancing face areas and long dead headings in these large room-and-pillar operations is challenging. Adequate fresh air volumes are needed to dilute, render harmless, and carry away toxic and explosive gases.

It is difficult and expensive to maintain adequate air velocities in these large-opening mines. As air from the surface enters these underground openings, the air velocity is quickly diminished due to the increase in cross-sectional entry area and the number of entries being ventilated. This air is often required to travel great distances to reach the working areas. Because of the low air velocities, the large entries and associated face areas are prone to air stagnation and recirculation. Air flow in a cross-section of a large opening can actually be moving in opposite directions at different elevations. The adverse health and safety impacts of inadequate fresh air delivery in these mines are potentially serious. Inspectors from the Mine Safety and Health Administration and the Pennsylvania Bureau of Deep Mine Safety have expressed serious concerns over this problem, as have many mine operators.

This new project will evaluate methods of increasing and monitoring air flow in these large-opening mines. Because the use of traditional air flow measurement techniques can be problematic in large-opening mines, a primary goal of this project is to establish practical measurement techniques and methodologies for these mines. In addition to using traditional tools, e.g., vane anemometers, smoke tubes, tracer gas, and pressure differentials, the application or adaptation of other relevant technologies will be considered. Additionally, current face ventilation practices will be evaluated to determine if methods exist to increase air flow to the immediate face. An important goal of the project is to publish a handbook of recommended practices for improving and monitoring the ventilation of large-opening underground mines.

KEYWORDS: Mine ventilation, metal/nonmetal mines, large openings

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Flyrock being thrown by a surface blast.

INVESTIGATION OF FLYROCK INJURIES AND FATALITIES

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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. Blasting, although hazardous, is considered a very essential component of surface mining operations. Each blast is associated with fragmentation. In many instances, the projection of rocks from the blast site (flyrock) extends to a great distance.

Each year, rocks thrown beyond expected bounds result in fatalities or serious injuries. Several of the reported incidents involved innocent bystanders, some of whom were not even employed at the mine. Flyrock and lack of blast area security are the major factors relating to blasting incidents 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.

In this new project, the approach is to critically review accident reports from the Mine Safety and Health Administration and other Government agencies to determine those key factors that have contributed to "wild" flyrock (i.e., flyrock thrown much farther than expected) and to determine why persons are sometimes too close to a blast site. Selected blasting sites will be visited and procedures examined to derive an in-depth understanding of paramount factors contributing to blasting incidents. Statistical analysis of parameters and causative factors of wild flyrock and blast area security accidents will be done. Through education/training and improving procedures during blasting operations, it is anticipated that there will be a reduction in the frequency of injuries from flyrock in blasting operations.

Partners/collaborators in the project are the Mine Safety and Health Administration, Institute of Makers of Explosives (IME), and United Mine Workers of America (UMWA).

KEYWORDS: Blasting, explosives, flyrock, mining

Underground view of the multiple-entry section of the Lake Lynn Experimental Mine.

LAKE LYNN LABORATORY

RESEARCHER: Eric S. Weiss

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1-800-35-NIOSH

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 research conducted at Lake Lynn includes areas such as the development and evaluation of fire suppression systems and early warning technologies; development and evaluation of mine seals, stoppings, and bulkheads; 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 conducted at Lake Lynn is vital to agencies such as the Mine Safety and Health Administration (MSHA) in the development of regulations 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 Government agencies, such as the U.S. Department of Transportation and the U.S. Department of Defense, and other national and international research organizations. Cooperative research with these agencies is conducted on a resource availability, cost-reimbursement basis.

The unique ability of Lake Lynn to simulate virtually any underground coal mine geometry provides a practical, realistic research laboratory to study mine fires, explosions, respirable dust deposition, diesel fumes, noise reduction, environmental remediation, etc., 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. Two recently completed underground chambers are now being used to evaluate the failure modes and size-scaling relationships for mine seals and bulkheads. The surface facilities provide an isolated environment in which large-scale research and

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

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testing on diesel fuels, explosives, chemicals, and similar materials can be conducted in a realistic, yet environmentally controlled manner. The availability of the large, open areas permits the setup of experimental facilities to evaluate equipment and test novel concepts for the physical handling and use of materials.

Technology transfer of Lake Lynn capabilities and research outcomes are routinely conducted through open industry briefings, tours, and on-site presentations and discussions with representatives from national and international research agencies and governmental and private mining organizations. Realistic mine rescue training evaluation programs are conducted in the smoke-filled entries of the underground mine and at the surface fire facilities with State and private teams from the West Virginia Office of Miners' Health, Safety, and Training; the Pennsylvania Bureau of Deep Mine Safety; and a variety of mine operators. Research programs are continuing to be conducted in cooperation with international mining research organizations and industry, such as the Council of Scientific and Industrial Research (CSIR) of the Republic of South Africa, Barclay Mowlem Construction Limited of New South Wales, Australia, and Tecrete Industries Pty. Ltd. of Queensland, Australia. Programs are ongoing with several NIOSH researchers from Morgantown, WV. One study entails collecting dust generated from cutting saw operations on various concrete block and brick samples. Another program is using the mine's single entry as a low-velocity wind tunnel for an ergonomics study to determine the accuracy of collecting respirable dust based on the location of the sampler unit on a miner relative to the miner's position to the air flow. West Virginia University uses the surface and underground workings of Lake Lynn as a field location for its mine surveying classes each year.

The Lake Lynn project team members (1) support and coordinate Lake Lynn research efforts for the Pittsburgh Research Laboratory research groups, other NIOSH centers, MSHA, and other governmental and industrial organizations, and colleges and universities, (2) enhance the research capabilities of Lake Lynn and establish plans to meet expected needs, and (3) maintain safety, health, and environmental controls at Lake Lynn and provide cost-effective maintenance at the laboratory for roads, grounds, buildings, the Experimental Mine, surface test facilities, heavy equipment, utilities, and computer facilities through close association with the Administrative Services Branch of the Pittsburgh Research Laboratory.

Equipment at sand and gravel mine.

SURVEILLANCE

HAZARD REDUCTION IN SURFACE MINING OF SAND AND GRAVEL

RESEARCHER: C. M. K. Boldt

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1-800-35-NIOSH

PURPOSE: Collect information on the economic and social costs of workplace injuries and fatalities at sand and gravel operations using data from actual accident cases.

KEYWORDS: Mining, sand and gravel, economics

RESEARCH SUMMARY: According to the MSHA *Metal-Nonmetal Monitor* of July 1, 1996, there were 34,379 employees working 59 million hours in 6,162 sand and gravel mines in 1994. These mines had an average of less than 6 employees each. The nonfatal days lost (NFDL) incident rate was 4.05. Stone mills employed 66,196 workers at 703 operations. A cursory look at the MSHA accident data shows that sand and gravel operations had 28 fatalities in 1995 and 34 fatalities in 1996. This is nearly one-third of mining industry fatalities for each year.

At present, there is little or no good information on the true costs of a mining injury or fatality. Costs involve more than just the direct costs to the mining company or its insurer. Direct costs include such things as medical and insurance administration. Indirect costs, which include lost earnings, lost home production, lost fringe benefits, retraining and restaffing expenses, and lost productivity caused by time delays, can often exceed direct costs. This project will be directed to collecting information on direct costs and will involve the assistance of various collaborators. In addition, a protocol will be developed to measure indirect costs associated with a worker injury or fatality.

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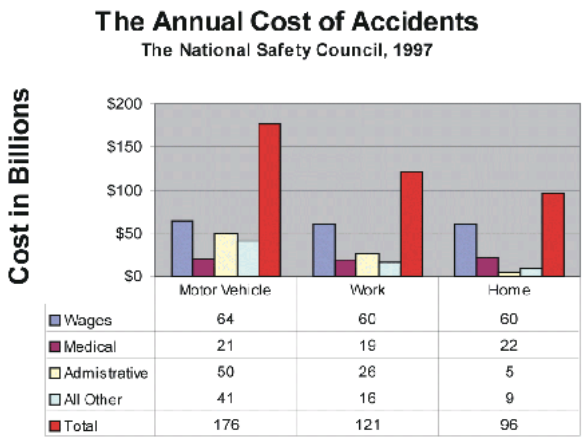

The total cost of all injuries was $393 billion in 1997. Workplace injuries accounted for almost one-third of those costs.

ECONOMIC COST MODEL FOR TRAUMATIC INJURIES

RESEARCHER: H. Kenneth Sacks

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1-800-35-NIOSH

PURPOSE: Redesign the outdated Accident Cost Indicator Model (ACIM) so that it can generate cost estimates for mining injuries.

RESEARCH SUMMARY: The original model (referred to as ACIM), which was developed by the former U.S. Bureau of Mines (USBM), is a computer-based model that estimates the tangible costs of work-related injuries and illnesses in the U.S. coal mining industry. It was developed in the late 1970s to express the annual statistics of injury and death in terms of costs (medical, worker's compensation and union benefits, lost production and wages, investigation costs, etc.) and to allocate these costs to the characteristics of the work environments that cause the accidents and to the sectors of society (public, private, and family) that bear these costs. This model was used internally by the USBM to generate estimated costs for mine accidents recorded in the Mine Safety and Health Administration (MSHA) Accident/Injury/Illness Database. However, it was limited in its abilities, as it could compute costs only for fatalities and permanent disabilities reported by coal mine operators. Less severe incidents, incidents reported by metal/nonmetal operators, and incidents reported by independent contractors were not covered. Further, the model was purely theoretical and depended on numerous assumptions about the demographics of the mining workforce. Today, the model is out-of-date and no longer produces accurate estimates, even for coal operator incidents.

The new model will use the same basic method used by other NIOSH researchers, i.e., society costs based on the human capital approach. The model will include medical and lost production—both market and nonmarket components. Values will be based on actual costs of worker's compensation claims and on current wage and salary data for the mining industry.

The model will compute costs for all incidents that result in injury and will generate output in a common, PC-based database format (such as MSAccess and SPSS for Windows).

KEYWORDS: Economic consequences, injuries, mining, human capital

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Testing GIS as a surveillance tool.

IMPROVING SURVEILLANCE DATA UTILIZATION THROUGH GEOGRAPHICAL INFORMATION SYSTEMS

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National Institute for
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1-800-35-NIOSH

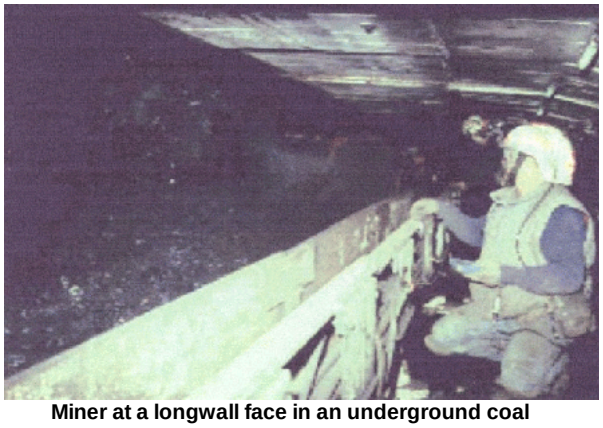
PURPOSE: Develop and demonstrate geographical information system (GIS) methodologies for spatially mapping and analyzing accident and occupational disease information.

RESEARCH SUMMARY: This research will begin by producing basic GIS maps that show locations associated with selected mining health and injury information by topic (accident classification by State or commodity, for example). Combinations of those mapping and analytical techniques that offer the greatest potential for discovering regional differences in the occurrence of accidents and health risks will be determined.

Utilizing recently available GIS technology, the project will then explore the usefulness of producing and publishing interactive maps on the Intranet/Internet. Such maps could allow users to perform specialized queries by selecting different combinations of themes from available options. Other GIS products will be investigated, such as linking GIS and Document Management System technology that would allow users to access health and safety data simply by clicking on specific features of a map of the U.S. mining industry.

These technologies will allow surveillance data to be examined in relation to geographic locations associated with accidents or exposure sites. This information will enhance our surveillance efforts by allowing spatial analyses that are likely to reveal causal relationships between injury variables not heretofore seen or realized. A secondary objective is to demonstrate and use GIS technology to disseminate mining industry disease and injury data through the Intranet and Internet.

KEYWORDS: Mining, surveillance, geographical information systems



Miner at a longwall face in an underground coal mine.

RISK FACTORS FOR ATHEROSCLEROSIS AMONG COAL MINERS

RESEARCHER: Deborah Landen

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1-800-35-NIOSH

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

RESEARCH SUMMARY: Based on death certificate data from NIOSH's National Occupational Mortality Database, coal miners appear to have an elevated risk of death from heart attacks (myocardial infarction) (MI). Factors involved in the risk of atherosclerotic heart disease include genetics and lifestyle factors, 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.

KEYWORDS: Cardiovascular disease, stress, coal mine dust

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 will determine 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 will 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 will be examined.

Injuries to face workers are being analyzed to determine areas for research.

ANALYSIS OF RISK TO FACE WORKERS IN CONTINUOUS COAL MINING

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National Institute for
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1-800-35-NIOSH

PURPOSE: Perform an in-depth injury/risk analysis of face workers in underground coal mine continuous mining sections.

RESEARCH SUMMARY: Approximately 50,000 miners work in U.S. underground coal mines. About 16,000 of these miners operate equipment full-time at the mine face, where they are exposed to a wide range of safety and health hazards. Another 17,000 miners routinely enter the face area during their shift for supervisory, maintenance, and other activities. From 1993 to1997, U.S. coal mine operators reported 44,376 underground accidents, 114 fatalities, 333 disabling injuries, and 952,275 lost workdays.

Many hazards at the coal mine working face greatly increase the safety and health risks to equipment operators and other support personnel in this area. Emerging equipment control technologies offer potential for reducing accidents and injuries at the face area.

Presently, accident data from the Mine Safety and Health Administration (MSHA) are categorized by type of incident rather than causes of the incident. This study will review MSHA accident data and narratives and will attempt to classify accidents by root causes. At the same time, a detailed analysis is being performed to determine which hazardous tasks need further study and research.

The combination of these two approaches will lead to a greater insight into the accident/injury picture and the formulation of future areas of research for reduction of accidents and injuries. The specific overall objectives of this project are to (1) provide an in-depth overview of the incident and injury data in underground coal mine face areas, (2) assess the impact of emerging technologies involving the control of mining equipment on the accidents and injuries, (3) make recommendations for future areas of research to reduce injuries at the face area, and (4) prepare a model surveillance report and database for injuries at underground continuous coal mine face areas.

KEYWORDS: Mining, mine face workers, injuries, analysis

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Installation of novel roof support system with hydraulically powered lifting device.

EMERGING TECHNOLOGIES

EMERGING TECHNOLOGIES AND OTHER ISSUES IN MINING

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National Institute for
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1-800-35-NIOSH

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

RESEARCH SUMMARY: The mining industry has made significant gains in safety, health, productivity, production, and environmental impact. In achieving these impressive accomplishments, it has adopted new technologies, accommodated encroachment of a world market, and addressed new environmental regulations. It has also increased production in response to continued growth in consumption of many commodities. 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. This will enable NIOSH's mine safety and health research program to take advantage of changes that could improve miner's safety and health and prepare interventions to neutralize emerging threats. The study of emerging technologies is also a National Occupational Research Agenda (NORA) priority area.

KEYWORDS: Emerging technology, mining

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This new project is identifying anticipated major changes that are expected to impact the safety and health of mine workers in the next 5 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 certain commodity can influence miner safety and health. For example, the recent passage of the Transportation Equity Act for the 21st Century (TEA-21) has resulted in a sharp increase in the consumption and mining of crushed stone. This has caused new quarries to open and existing quarries to work longer hours. Potential safety and health concerns include the impact of extended shifts, consecutive days worked, and an influx of new and inexperienced workers. A sudden increase in production in any commodity is also expected to increase the likelihood that new equipment and processes will be developed and implemented. Therefore, identification of commodities that are expected to experience substantial increases in demand will identify those mining

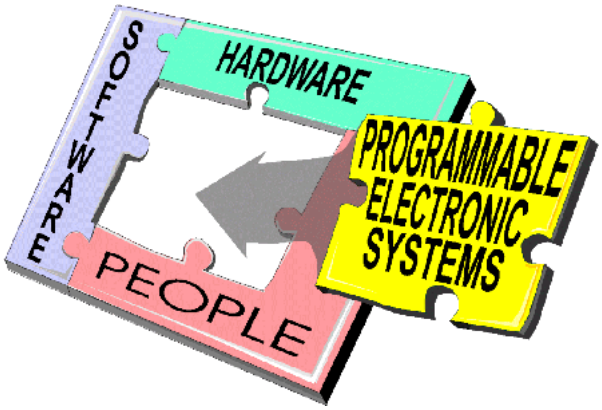
industry segments most likely to embrace new technology.

Social pressures and public policy also impact mining. For example, the Clean Air Act has resulted in a shift in coal production to low-sulfur seams, causing mines in the Midwest to close and production in the western and southern Appalachian regions to increase. This shift has caused an increase in surface mining and a change in underground mining conditions. Stone mines need to be located near their markets, but few towns want them nearby because of the dust, noise, and environmental and safety issues. Public opinion is causing these mines to move underground, which is a potentially more hazardous mining location.

Demographic trends are also impacting mining. Scarce hiring during the last 2 decades has resulted in the average age of a miner to be 50 years in some segments of the mining industry. Finally, legislative action such as TEA-21, the Clean Air Act, and anticipated mountaintop mining legislation in West Virginia will impact who is mining and where mining will take place.

Since 1991, the U.S. Congress has sponsored reports about the status of critical technologies in the United States. The latest such effort, *New Forces at Work* by the Rand Corp., describes a methodology that will serve as a model for an effort to determine those technologies in mining that are critical to its continued performance. For example, rock cutting methods might be one such critical technology. It is expected that limiting factors will be the subject of continued research and, as such, will be the areas where new technology is likely to emerge. Once these critical technologies are defined, patent and literature searches, along with interviews and possibly focus group meetings, will be completed to determine likely candidate advancements.

Finally, by combining the results of the analysis described above, new technology and likely trends that are expected to impact miner safety and health will be identified, along with recommendations for targeted etiological and intervention research efforts.



The safety of programmable electronics requires a system-atic, integrated approach for the software, hardware, and people.

SYSTEM SAFETY: PROCESSOR CONTROL APPLICATIONS

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1-800-35-NIOSH

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

KEYWORDS: Emerging technology, control technology, mining

RESEARCH SUMMARY: This research addresses the emerging technology of programmable electronics, including microprocessors, personal computers, programmable logic controllers, and the associated software, in mining. Programmable electronics brings new hazards due to added complexities and the ambiguous nature of software. The Mine Safety and Health Administration (MSHA) addresses only the permissibility of equipment. Thus, equipment can be permissible but not safe to operate, as evidenced by accidents involving programmable electronics.

The trend is for increasing use of programmable electronics in diverse applications that include longwall systems, atmospheric monitoring systems, mine hoists, and mine load-haul-dump vehicles. MSHA has recognized the need to address the safety of programmable electronics before it proliferates in mining. The mining industry's experience with safely applying the technology is small, and no guidelines or standards exist for its safe use in mining.

Other industries (military, rail transportation, medical devices, and aviation) have been confronted with the safety challenges and needs of programmable electronics. They employ system/software safety standards and guidelines. The process encompasses hardware, software, humans, and the operating environment for the equipment's life cycle.

Researchers are using the same approach that other industries have taken to focus on a risk-based, system safety process for programmable electronics in mining. Functional safety processes are being developed for design, testing, approval/certification, operation, and maintenance of mining systems employing programmable electronics. The project's recommended safety processes will benefit the U.S. mining industry and the global mining community. MSHA is a partner on this project, and several mine equipment manufacturers and mine operators are cooperators.

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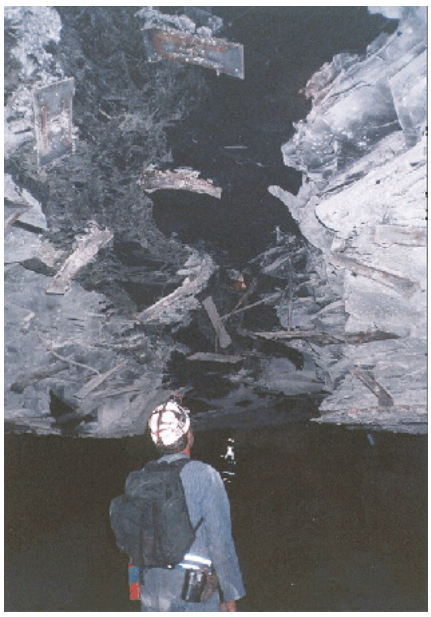

A researcher collects information at an underground mine site.

OUTCOME MEASURES FOR MINING SAFETY AND HEALTH RESEARCH

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PURPOSE: Identify the type of performance measures appropriate for research conducted by NIOSH's Office for Mine Safety and Health Research (OMSHR).

RESEARCH SUMMARY: The Government Performance and Results Act (GPRA) requires Federal agencies to establish standards measuring performance and effectiveness. The law requires the development of strategic plans describing overall goals and objectives, annual performance plans containing quantifiable measures of progress, and performance reports describing success in meeting those standards and measures.

Measuring the impact of research is particularly challenging for several reasons. First, by its very nature, the results of research are often uncertain. A negative result (e.g., the discovery that a particular process will not work in certain applications) should not be viewed as a failure, but rather an important contribution to the body of scientific knowledge.

Secondly, for a variety of reasons, the results of successful research are often not adopted until years after the discovery or development of a process or product. For example, a product that is too expensive today may become acceptable after manufacturing processes or the discovery of substitute materials make the product affordable. An impact assessment process that ends with the research project will most often not reflect the eventual benefit of the research. Finally, NIOSH is usually not the only party that can influence the solution of the problem. Any performance measurement must assess the success of that portion of the solution process that NIOSH can influence.

KEYWORDS: GPRA, mining, performance measures

This new project begins by examining the detailed requirements of the GPRA and the performance measures used by other Government research agencies. Those measures are being examined to see if they can be tailored to our research situation. Various congressional supporters and architects of the GPRA have offered commentary and ratings of the performance plans of various research agencies. Those comments are being examined as guidance for what type of measures meet their expectations. Finally, the history of successful research projects or programs is being studied to learn about appropriate performance measures.

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DHHS (NIOSH) Publication No. 2000-109